Zooplankton diel vertical migration and the biological pump

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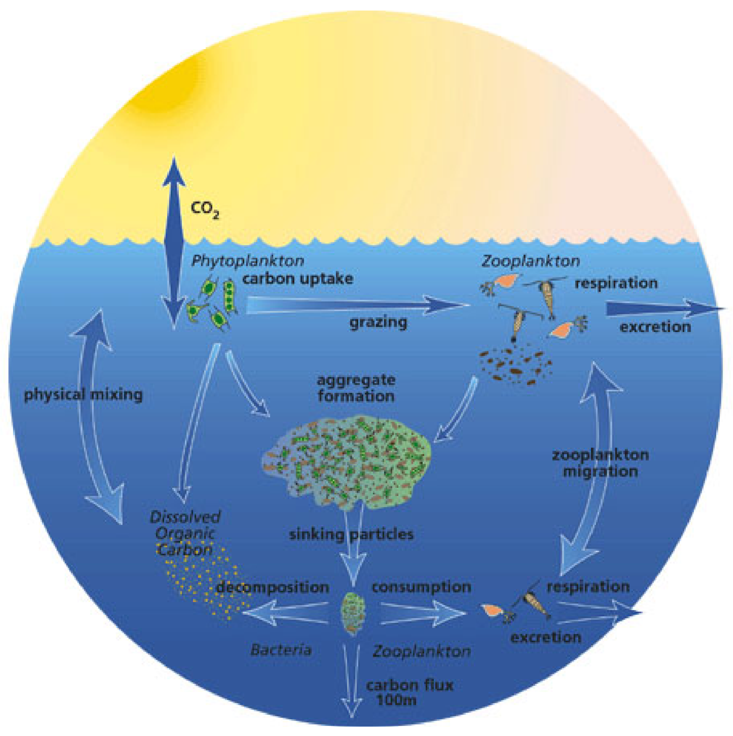
ABSTRACT



One pathway of the biological pump that remains largely unquantified in many export models is the active transport of carbon from the surface ocean to the mesopelagic by zooplankton diel vertical migration (DVM). Here, we investigate the effect of DVM on export and mesopelagic biogeochemistry with a global model of the biological pump. The model describes export out of the euphotic zone and the fate of exported carbon in the twilight zone using a surface food web model driven by diagnostic satellite measurements of net primary production, algal biomass, and size structure. The modeled global export flux from the base of the euphotic zone was 6.7 PgC/yr, which represents an 18% increase over the export flux in model runs without DVM. The annual mean (± standard deviation) export ratio, calculated over space and time, was 0.12 ± 0.05. DVM activity accounted for about one-fifth of both total carbon export and total respiration within the twilight zone. DVM also pushes dissolved inorganic carbon production and oxygen utilization deeper into the thermocline and creates a deep local maximum in the oxygen utilization profile. The effect of DVM on export was most sensitive to the assumptions for the fraction of fecal pellets produced in the euphotic zone, the fraction of individuals participating in DVM, and the fraction of grazed carbon that is metabolized. The model indicates that DVM is an important export pathway in the biological pump that also significantly influences mesopelagic biogeochemistry.

BUILDING THE MODEL

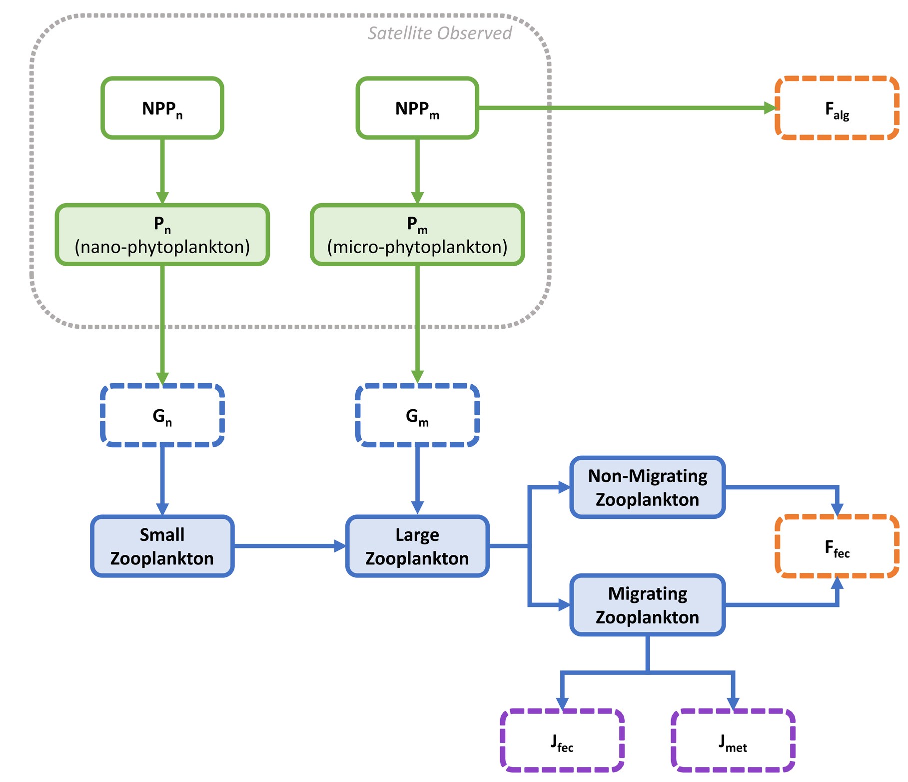


Figure 1. The food web model is driven by satellite observations of NPP and phytoplankton community size structure. The model estimates passive sinking export fluxes (orange) including sinking phytoplankton cell aggregates (F_{alg}) and sinking fecal pellets (F_{fec}), as well as DVM-mediated fluxes (purple), including fecal pellets produced in the twilight zone (J_{fec}) and zooplankton metabolism in the twilight zone (J_{met}).

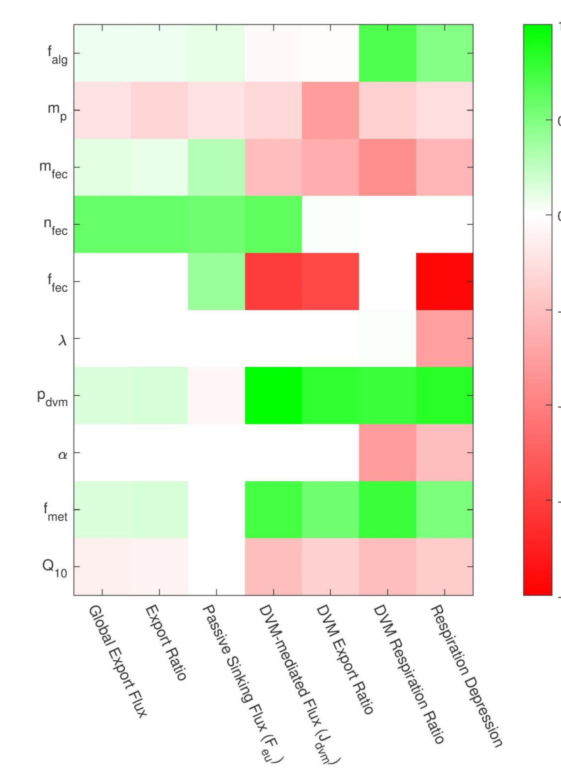


Figure 2. The model is most sensitive to changes in the assumptions for the fraction of the zooplankton community participating in DVM (p_{dvm}), the fraction of fecal pellets produced in the twilight zone (f_{fec}), and the fraction of zooplankton metabolism that occurs in the twilight zone (f_{met}).

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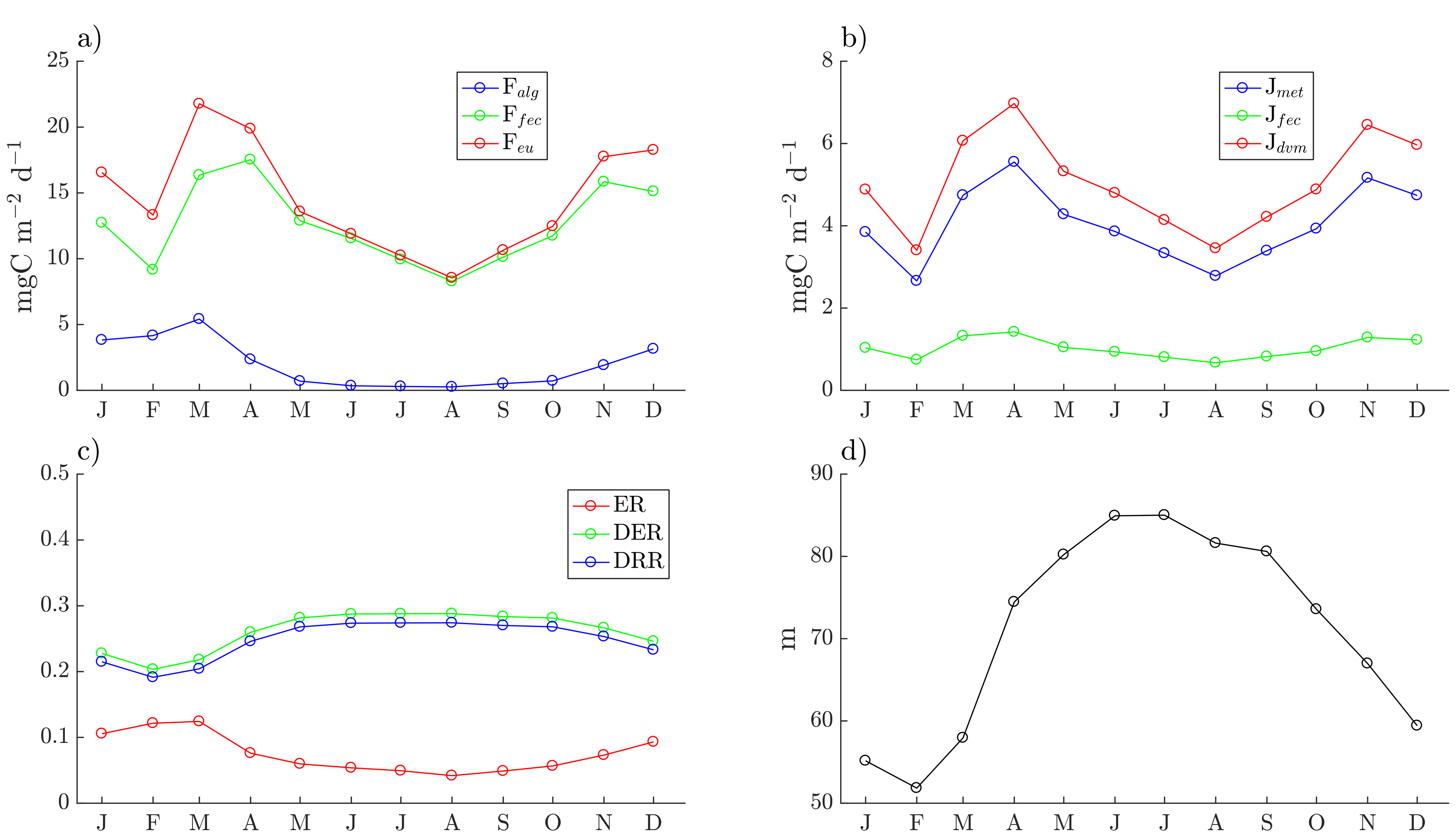

Figure 3. Modeled export fluxes at the BATS location (31° 40' N, 64° 10' W). The passive sinking export flux (a) was approximately three times larger than the DVM-mediated flux (b). We also calculated the export ratio (ER), the fraction of total exported carbon transported by DVM (DER), and the fraction of total twilight zone respiration accounted for by DVM (DRR). DVM activity also pushed the weighted mean depth of DIC production and oxygen utilization about 70 m deeper compared to simulations that we ran without any DVM (d). This effect is termed the respiration depression (RD).

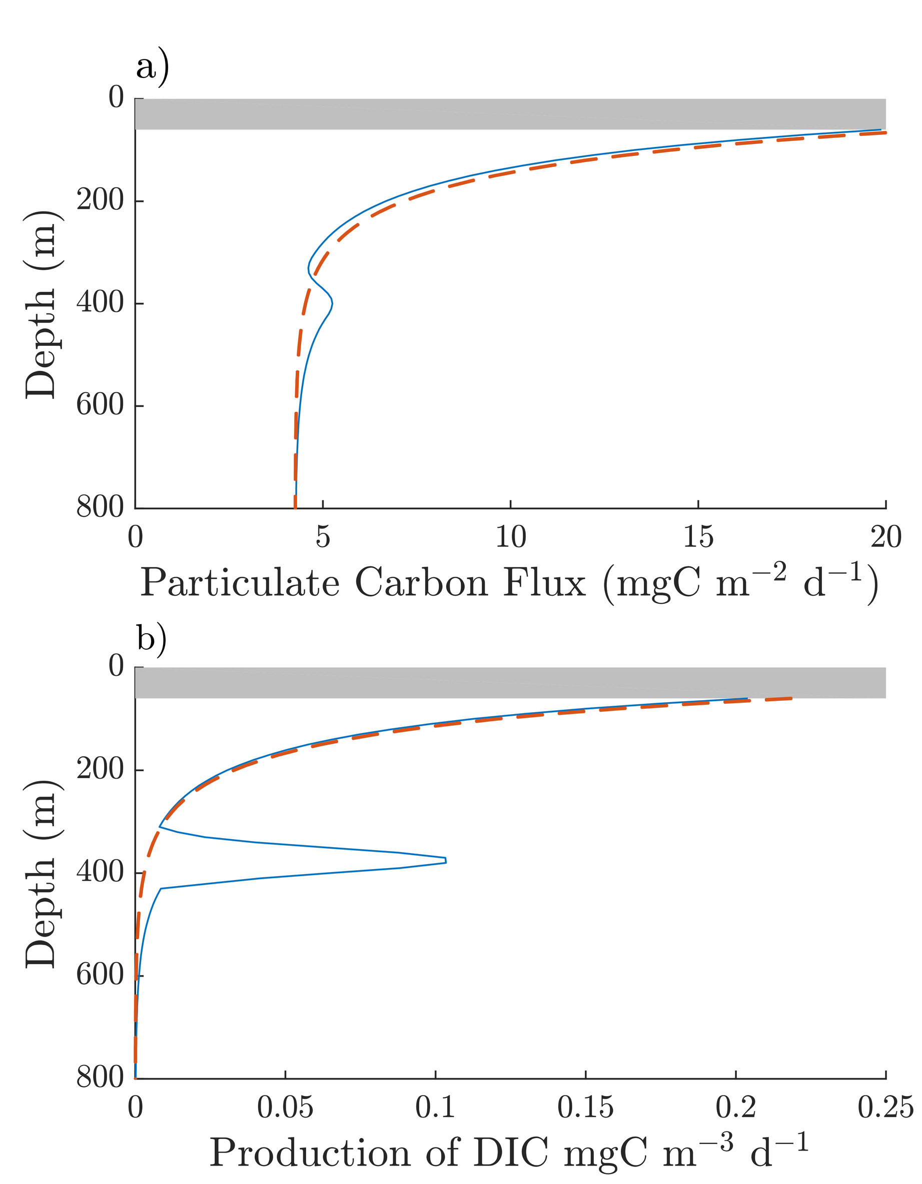

Figure 4. DVM effects in the twilight zone, showing simulations without DVM (red dashed line) vs. those where DVM activity was included (blue line). DVM had only a small impact on the vertical POC flux in the twilight zone (a), but had a very significant impact on DIC production and oxygen utilization (b). DVM may result in oxygen utilization profiles that are non-monotonically decreasing through the water column. The respiration of migrating zooplankton dominates oxygen utilization at the depth where the migrating layer is present.

GLOBAL ANALYSIS

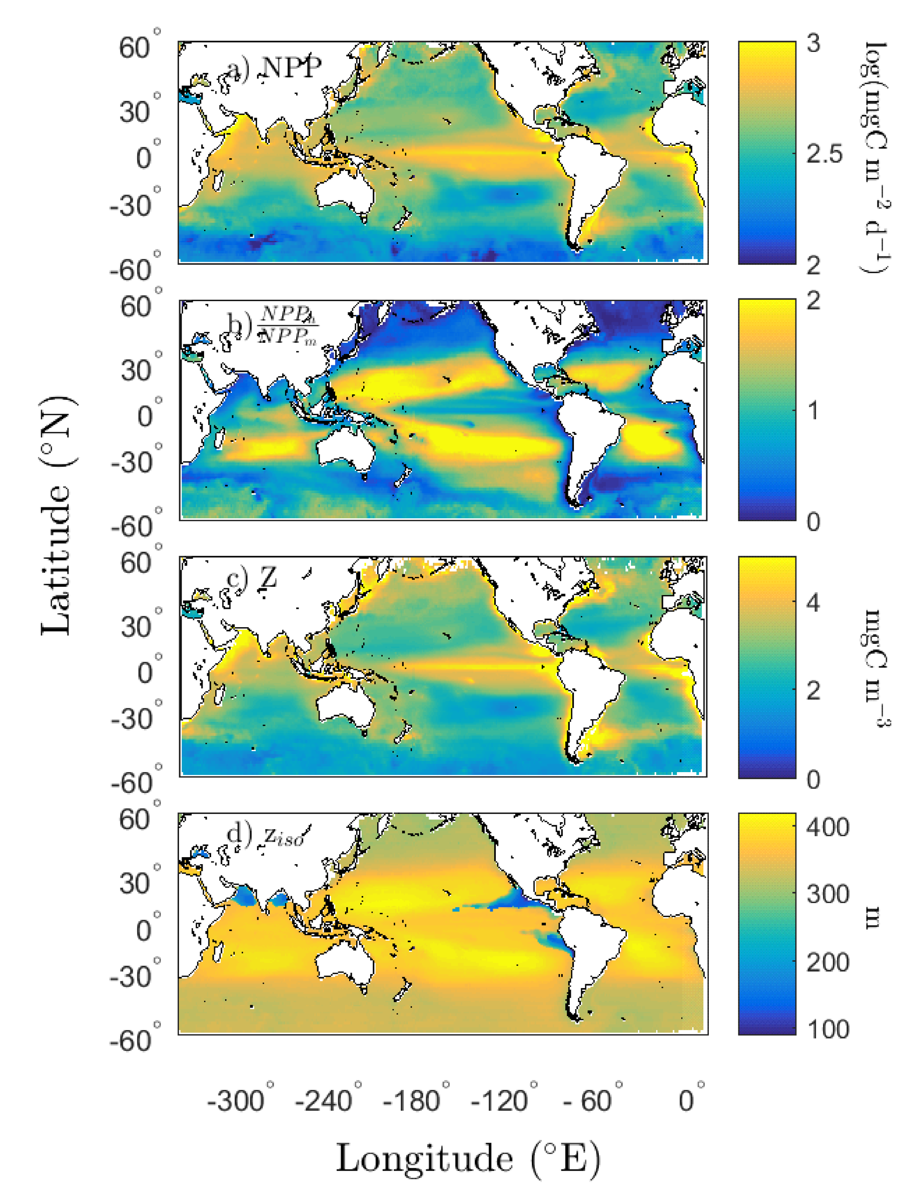

Figure 5. Global model simulations showing (a) NPP, (b) the NPP size fraction, (c) zooplankton biomass, and (d) the depth of migration. In the subtropical latitudes, NPP and zooplankton biomass are reduced, but the phytoplankton community is dominated by nano-plankton.

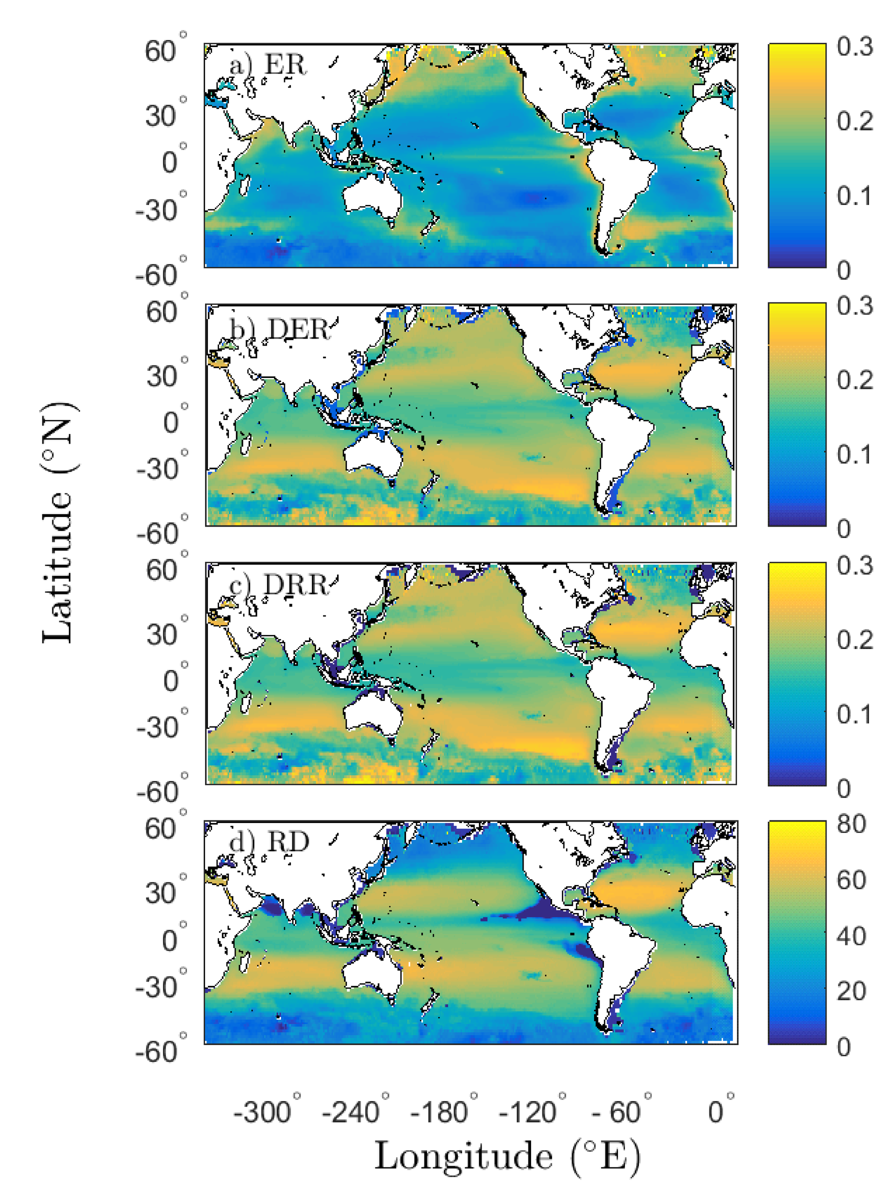

Figure 6. Metrics of the effect of DVM activity on carbon export and twilight zone respiration. DVM had an increased impact on biogeochemistry in the subtropical latitudes.

CONCLUSIONS

- The generalized model framework provides a simple blueprint for future studies of zooplankton diel vertical migration at a global scale.
- We evaluated the sensitivity of the model and identified important parameters that need to be accurately defined to improve the utility of the model.
- Diel vertical migration is a significant contributor to carbon export out of the euphotic zone, especially in the subtropics.
- The export flux mediated by diel vertical migration significantly impacts mesopelagic DIC production and oxygen utilization.

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