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An assessment of upper ocean carbon and nitrogen export fluxes on the boreal continental shelf: A 3-year study in the open Baltic Sea using sediment traps, ^{234}Th proxy, nutrient and oxygen budgets

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The paradigms of what controls upper ocean carbon export have changed over the past decade. One aspect that has received renewed interest is the quantitative role of inshore and continental shelf regimes in the temperate-to-high latitudes, which are now suggested to host 30-50% of the carbon export from the global surface ocean owing to a combination of their generally higher primary production and higher ratios of export production to primary production. It behooves us to perform equally biogeochemically comprehensive time-series studies of the carbon export on temperate continental shelves, as is performed in subtropical gyres (e.g., BATS and HOT sites), in order to both better understand any regime-specific driving mechanisms of POC settling and to quantify the long-term fluxes in these globally significant carbon export regimes.

However, accurately measuring this carbon export flux, in any regime, has remained an elusive and troublesome task. Historically, the surface ocean carbon export fluxes to deeper strata have been estimated using upper ocean sediment traps. Such shallow trap deployments are complicated due to a combination of swimmer-related and hydrodynamic artifacts. Partially as a result of these upper ocean trap challenges, the ^{234}Th proxy method has increasingly been used to estimate upper ocean carbon export fluxes. While having the added advantage of greater spatial coverage compared to sediment traps, the accuracy of the ^{234}Th-derived POC fluxes are challenged by issues such as difficulties in obtaining the POC:^{234}Th ratio on truly settling particles, non-steady state effects, and uncertainties regarding over which depth the method should be integrated. Other indirect geochemical methods to estimate the upper ocean carbon export, such as through constraining the nitrogen and oxygen budgets, are faced with the difficulty of estimating the rate of exchange across either the air-water interface or across the thermocline. The inherent uncertainty with any given estimation method suggests that we should not rely on any one single technique but rather apply all available methods and scrutinize results for biogeochemical system consistency.

Emulating the type of comprehensive biogeochemical frameworks established at BATS and HOT, the objective of this report is to assess how accurately the biological organic carbon pump can be determined at a long-term time series station on the vast and highly productive northern European continental shelf (BY31 station, Landsort Deep, open Baltic Sea) and to provide constrained estimates of the average year-round carbon fluxes that may be used for regional parameterization of global biogeochemical carbon models. To this end, we evaluated a comprehensive three-year record with at least monthly resolution from the 40 km offshore BY31 station where simultaneous data were obtained on primary production, phytoplankton community composition, nutrient and oxygen budgets, particulate organic carbon (POC) and nitrogen (PON) inventories, ^{238}U-^{234}Th disequilibria, and upper ocean sediment trap fluxes. The six independent estimates of year-round average POC export fluxes ranged from 22 – 145 g OC m^{-2} yr^{-1}. Normalized to the primary production, direct estimates of POC export obtained in cylindrical traps (0.14) is suggested to be an underestimate as it is well below the long-term averages of the new production (0.30; estimated from comprehensive N budget) and the net production (0.24; estimated from comprehensive O budget). Similarly dubious is the long-term estimate of POC export from the ^{234}Th proxy, based on POC:^{234}Th ratios on filters (0.89). In better agreement with the biogeochemical budgets are the estimates from the collection-efficiency corrected trap POC fluxes (0.31) and the ^{234}Th proxy, using the POC:^{234}Th ratios on trap-collected particles (0.22). The different estimates are interpreted by collectively considering the interacting effects of methodological aspects and seasonally-varying composition of settling particles.