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A model study of sediment transport across the shelf break

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A variety of dynamical processes can contribute to the transport of material (e.g., particulate matter) across the shelf break – the region separating the continental shelf from the continental slope. Among these processes are (i) the reflection of internal waves on the outer shelf and upper slope, and (ii) the instability of hydrographic fronts, roughly aligned with isobaths, that are often present at the shelf break. On the one hand, internal waves reflecting on a sloping boundary can produce bottom shear stresses that are large enough to resuspend non-cohesive sediments into the water column. On the other hand, eddies shed from unstable shelf break fronts can incorporate into their core particle-rich waters from the outer shelf and upper slope, and transport these waters offshore.

Here we present numerical experiments with a three-dimensional numerical model of ocean circulation and sediment transport, which illustrate the joint effect of internal waves and eddies on sediment transport across the shelf break. The model is based on the primitive equations and terrain-following coordinates. The model domain is square and idealized, comprising a flat continental shelf, a constant continental slope, and a flat abyssal basin. The model grid has O(1 km) horizontal resolution, so that (sub)mesoscale eddies observed in the vicinity of shelf breaks, such as south of New England, can be represented in detail. Internal waves are excited through the specification of a periodic variation in the across-slope component of velocity at the offshore boundary of the domain, and eddies are generated from the baroclinic instability of a shelf break jet that is initially in strict thermal wind balance. Numerical experiments are conducted that are characterized by (i) different slopes of internal wave characteristics relative to the continental slope, representing sub-critical, critical, and super-critical regimes, and (ii) different values for the dimensionless ratios that emerge from the linear stability analysis of shelf break fronts. Emphasis is placed on the physical conditions that are conducive to the formation and maintenance of bottom and intermediate nepheloid layers – the particle-rich layers that are often observed near oceanic margins in the traces of optical instruments.