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Temporally-resolved mechanisms of deep-ocean particle flux and impact on the seafloor carbon cycle in the northeast Pacific

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A B S T R A C T

High-temporal-resolution views of particle flux to the abyssal benthic boundary layer are provided for an eight-month period (October 2014–June 2015) at the long-term monitoring site Station M within the California Current ecosystem. Contributions of fecal pellets and aggregates to particulate organic carbon (POC) flux at 3900 m depth were estimated based on optical sediment trap (Sedimentation Event Sensor) images captured as a time-series of 2 h collections. POC flux estimated from Sedimentation Event Sensor (SES) images explained variation in carbon consumption and the carbon budget balance (supply − demand) with finer resolution than POC flux measurements from bulk collections by a concurrently deployed conventional sediment trap. Indicators of particle transport by benthic boundary layer currents and active transport by zooplankton were evaluated by comparing SES-estimated POC flux to measured current speed and direction, hours since solar noon, and modeled lunar illumination at the surface. Influence of particles (fecal pellets and aggregates) on the carbon budget was evaluated by comparing particle-specific contributions to POC flux with sediment community oxygen consumption (SCOC) measured by the Benthic Rover at 4000 m depth. During the eight-month sampling period, salp fecal pellets delivered an estimated 45% of the total POC flux to the benthic boundary layer and were responsible for an estimated 74% of a temporary carbon surplus in May and June 2015. Salp fecal pellets also appeared to be the primary source of chlorophyll peaks at the site. By contrast, most aggregates appeared to be lower-quality particles possibly sourced from lateral advection and local rebound of recently-settled detritus, which settled according to spring-neap tidal oscillations. Some aggregates may have been fresher, as suggested by non-linear relationships with SCOC and the carbon budget balance. Results suggest sinking particles packaged in surface waters and reaching abyssal depths in fresh condition (e.g. salp fecal pellets) had a greater influence on carbon consumption (e.g. SCOC) and the carbon budget balance than more refractory particles.

1. Introduction

Improving carbon budgets through full-ocean depths requires a better understanding of the mechanisms driving particle production, vertical transport, and consumption (Christina and Passow, 2007; Estapa et al., 2017; Boyd et al., 2019; Stukel et al., 2017). Ecological processes transform surface-derived carbon into particles, such as fecal pellets and aggregates, which have different sinking speeds and trophic qualities (Cavan et al., 2015; Turner, 2015; Wilson et al., 2008). They are transported downward through the water column by a variety of physical and biological mechanisms, which strongly influence the depth and rates at which carbon is consumed (Boyd et al., 2019). A highly variable amount of carbon in these particles reaches the deep sea, where it may be sequestered from the atmosphere for hundreds to thousands of years (Boyd et al., 2019). Most of this carbon is consumed by food-limited seafloor communities (Ruhl, 2008; Smith et al., 2014); the small fraction that evades this consumption may be sequestered in sediments for millennia (Dickens et al., 2004). Improving biogeochemical models will require identifying the particles responsible for carbon flux to the deep sea, understanding their vertical transport mechanisms (Le Moigne, 2019), and measuring their impact on the seafloor carbon budget at high temporal resolution.

A particle's origin and processing strongly influence its impact on deep-sea carbon budgets. Particles that package surface production and transport it rapidly below the mixed layer, such as larvacean houses (Robison et al., 2005), and krill fecal pellets (Gleiber et al., 2012; Belcher et al., 2019), deliver a significant quantity of carbon to the deep sea (Guidi et al., 2009; Riley et al., 2012). This material provides a high-quality food resource to seafloor communities, which begin consuming it almost immediately after it settles (Witte et al., 2003; Smith et al., 2014). By contrast, particles formed deeper in the water column, from more refractory material, are less carbon-rich (Ransom et al., 1998) but they hasten the downward flux of particles that might have remained suspended otherwise (e.g. Wilson et al., 2008). Vertical

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