Sedimentation Event Sensor: Early insights into variability of sinking particulate matter at hourly resolution, and future event detection

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Introduction

Measuring the quantity and composition of sinking particulate matter reaching the deep sea is critical to understanding the biogeochemistry of the ocean. Typically, sinking particles are measured from samples collected and preserved in situ by sequencing sediment traps, which are limited by a small number of sample bottles. The Sedimentation Event Sensor (SES, Fig. 1) is a new sediment trap that analyzes up to 6200 samples in situ, and can operate autonomously for a year between servicing. The SES captures macro images of each sample to provide detailed views of detritus, exuviae and fecal pellets (Fig. 2). Fluorometric measurements taken at 590 nm and 690 nm bands provide estimates of the presence of chlorophyll *a* and accessory pigments. After processing, the sample is discarded, the sample plate is cleaned, and collection of the next sample begins. A detailed technical description of the SES is in McGill, et al. 2016.

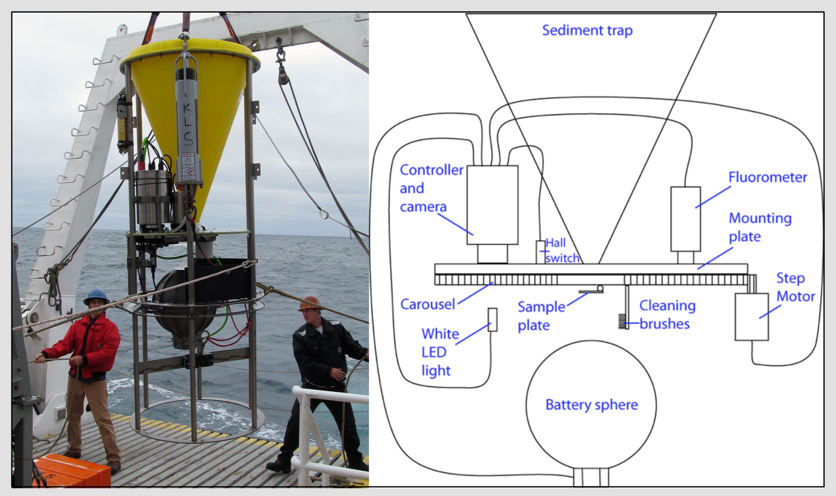

Figure 1. The SES on deck during deployment (left), and a schematic of major system components (right).

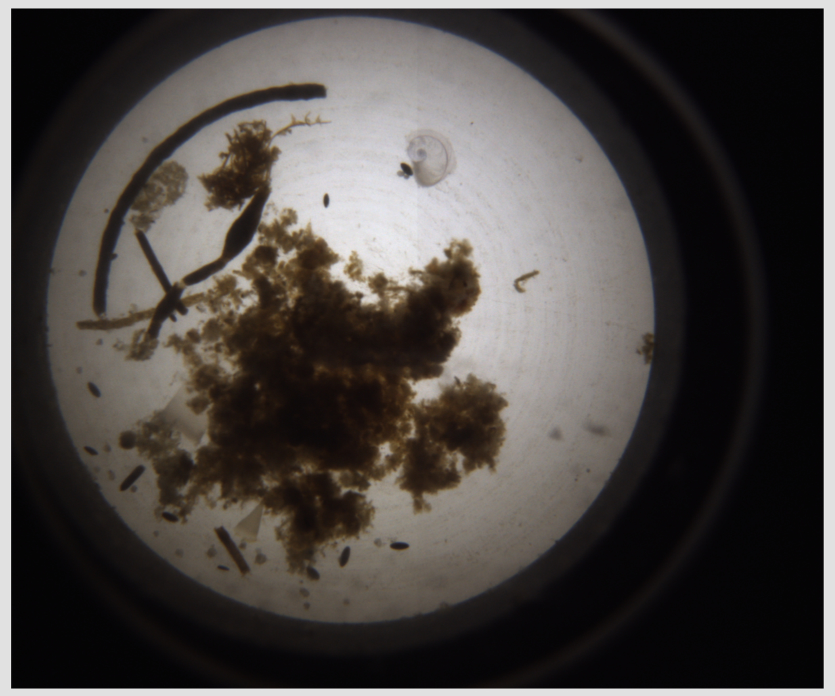

Figure 2. A backlit macro image recorded by the SES's 5-megapixel camera. Each pixel in the image represents a distance of 13.9 μm on the 25-mm-diameter sample plate.The SES camera can also light the sample plate from the front, revealing more information about the color of the sample.

Long-term variability

Images from the SES macro camera contain a lot of detail and can be used to quantify the size distribution and composition of collected sediment. However, in lieu of a detailed analysis of every image, we are able to obtain a rough estimate of the quantity of collected material by measuring the brightness of each backlit image compared to an empty sample plate. This technique effectively uses the SES as an integrating transmissometer. These sediment quantity data, along with the measurements of fluorescence at 690 nm, are plotted in Fig. 3. The 6,730 samples shown were collected between June of 2012 and November of 2016 at 3910 m depth at Station M (34° 50' N, 123° 00' W), a long-term study site located 220 km offshore of the central California coast (Smith et al. 2013).

The plots show the seasonal variation in the quantity of material reaching abyssal depths, with most of it arriving during the summer months. There is typically a big pulse in spring, followed by elevated activity and then a second pulse later in the summer. Sedimentation rates measured by the SES compare favorably with POC flux measured by carbon analysis of traditional sequencing sediment traps, but with the SES providing much higher time resolution.

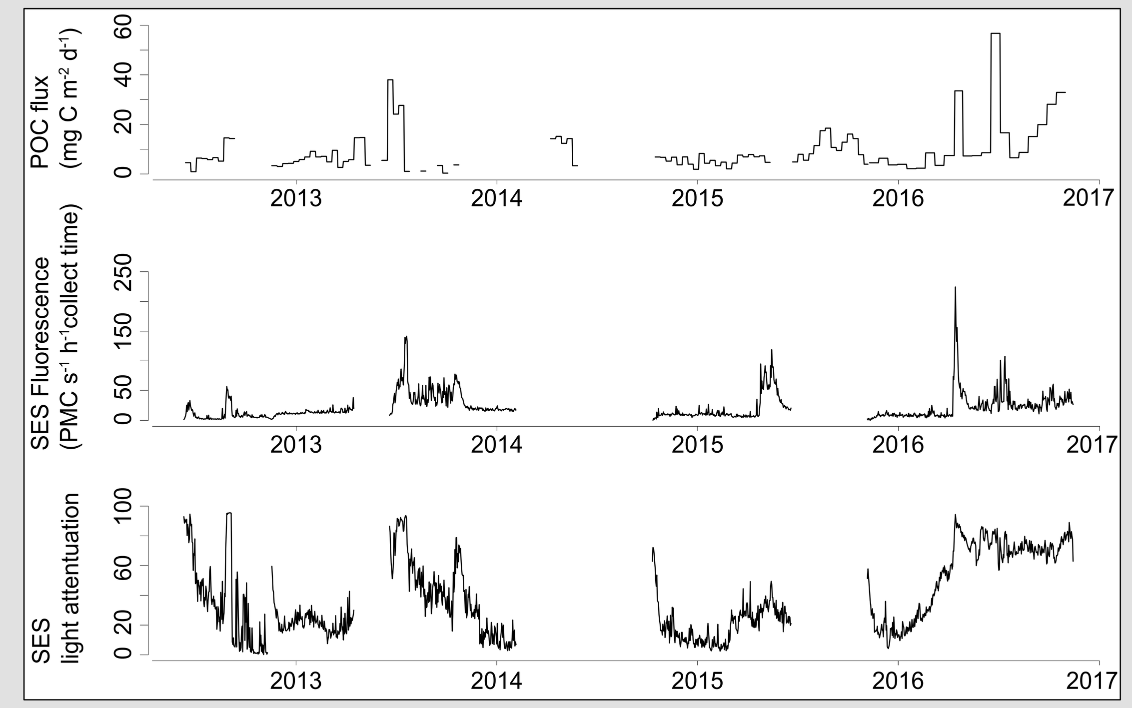

Figure 3. A 4.5 year record of sediment quantity and quality at Station M. Top panel: POC flux measured by carbon analysis of samples collected by traditional sequencing sediment traps. Middle panel: 690 nm fluorescence of sediment samples collected by the SES. Bottom panel: estimates of sediment quantity derived from SES back-lit images.

Short-term variability

Sedimentation rates vary greatly even over short times periods of days and hours, as seen in Figs. 4 and 5. Sinking particulate matter arrives at the bottom in waves or aggregations despite having fallen almost 4 km. We can't resolve the extent of these aggregations at the SES's current 4 hour sampling interval, although the SES is capable of much higher sampling rates.

Until we develop more sophisticated image processing algorithms, the fluorescence signal seems to be a more reliable indicator of the arrival of quality food to the seafloor. Better image processing, however, could automatically quantify the abundance of fecal pellets or other constituents of the sediment samples.

Figure 4. A sequence of macro images for ten days starting March 1, 2015, with each row containing one day of images. The sequence illustrates the highly variable nature of the sedimentation rate with changes occurring on an hourly basis.

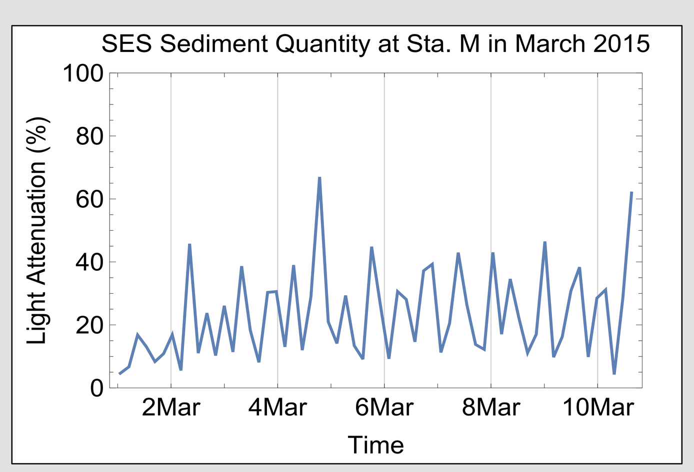

Figure 5. Estimates of sediment quantity as measured by the brightness of the images in Fig. 4.

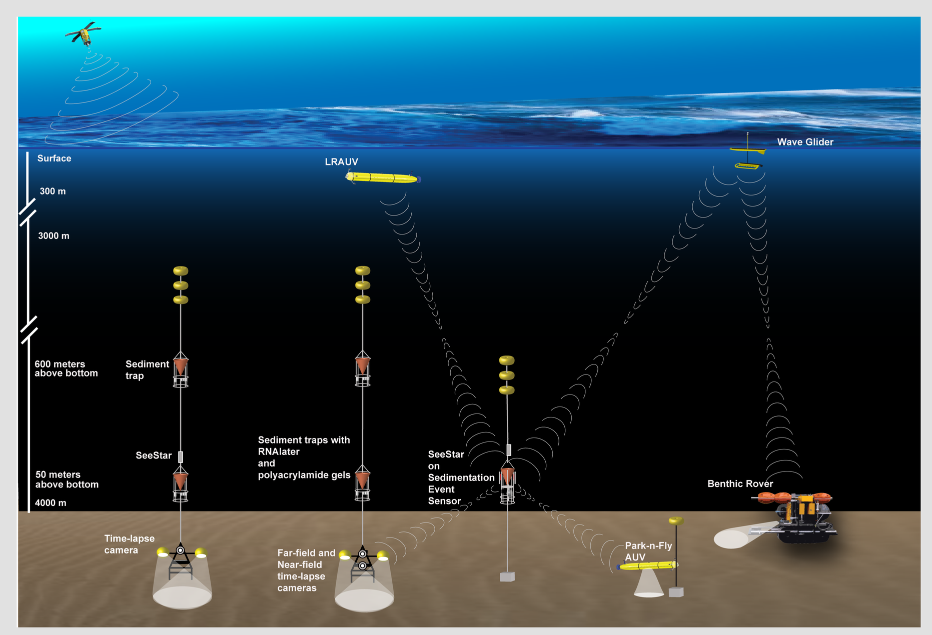

Figure 6. The array of stationary and mobile platforms at Station M. Increased sedimentation rates detected by the SES could be used to initiate sampling or alter the sampling frequency of the other instruments to better understand the sediment community's response to sudden increases in available particulate organic carbon.

Event-triggered sampling

Our goal is to use the SES's high resolution and in situ analysis capabilities to trigger the sampling of other instruments at Station M, shown in Fig. 6. These include two Time-lapse Cameras, which will increase the rate at which they take images of the seafloor, and multiple AUVs, which will perform phototransects of the bottom and measure chemical and biological conditions near the sea surface. Estimates of food supply from these sources will be compared to a time series of food consumption measured by the Benthic Rover, a bottom-crawling vehicle that measures sediment community oxygen consumption along with visible and fluorescence transect images. By catching the start of a large sedimentation event, we can better measure the full cycle of the sediment community's response to food falls.

Literature cited

McGill P.R., R.G. Henthorn, L.E. Bird, C.L. Huffard, D.V. Klimov, K.L. Smith, Jr. (2016) Sedimentation Event Sensor: new ocean instrument for in-situ imaging and fluorometry of sinking particulate matter. Limnology and Oceanography Methods, doi:10.1002/lom3.10131.

Smith Jr, K. L., H. A. Ruhl, M. Kahru, C. L. Huffard, and A. D. Sherman. (2013) Deep ocean communities impacted by changing climate over 24 y in the abyssal northeast Pacific Ocean. Proc. Nat. Acad. Sci. 110: 19838-19841.

Further information

For more information about the Station M time series, see http://www.mbari.org/station-m-time-series/

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