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The Eddy Correlation Technique

A method for making in-situ measurements of vertical property fluxes

Measurement of vertical transport of properties, such as dissolved substances and fresh water, across the sediment-water boundary in marine environments is a prerequisite for biogeochemists, benthic ecologists, physical oceanographers, and resource managers who need precise quantitative data for modeling systems or developing regulatory guidelines. Traditionally, enclosed core and box chambers were the tools of choice to obtain flux data. These methods were heavily biased from true in-situ flux because turbulent mixing was either simulated (via propellers inside the enclosure) or removed altogether due to the enclosure structures. A relatively new method for marine studies, the Eddy Correlation Technique (ECT), also known as Eddy Covariance, is highly accurate at determining the average vertical flux of dissolved substances (i.e. O_2), and fresh water through the sediment-water interface. The ECT, is representative of a known sediment surface area (Figure 1) and calculated from both the measured vertical velocity and property concentration at a specific point above the area of interest. The averaged property flux is calculated as:

$$\overline{flux} = \overline{u_z' P'}$$

Where the bars symbolize the averaging over the time series, and u_z' and P' are the turbulent fluctuating components of the vertical velocity and the property concentration. These two variables must be measured within an appropriate resolution of time (reflective of the scale of turbulent mixing), and extended over a sufficient period. Most importantly, ECT utilizes new technologies and instrumentation to allow for in-situ measurements that do not interfere with natural hydrodynamics or sediment characteristics.

Nortek has collaborated with Dr. Peter Berg (Department of Environmental Sciences, University of Virginia), Volker Meyer and Hans Røy (Max Planck Institute for Marine Microbiology, Germany) and Dr. John Crusius (USGS) to develop integrated “plug-and-play” systems to measure fluxes of dissolved oxygen and fresh water seepage using ECT. The two integrated systems consist of the Nortek Vector Acoustic Doppler Velocimeter and a rapid response Clark-type O_2 microelectrode for O_2 studies, and a rapid response conductivity-temperature (CT) sensor for fresh water studies. The Nortek Vector can provide power to, and log data from any two analog sensors. In the ECT application, the O_2 or CT sensor is coupled to the Vector (Figure 2). This integration allows for simultaneous measurements of the property concentration and the three-dimensional velocity flow field. This ensures perfect alignment of the variables; a must for accurate turbulence calculations. Measurements are typically made at 64 Hz.

Through the use of the Nortek integrated Vector-O_2 platform, Dr. Berg has conducted several experiments measuring the O_2 flux at the sediment-water interface during various conditions. In a recent project, his results reflect significant diurnal changes in the O_2 flux; the sediment ecosystem switches from an O_2 producing environment during the day, to an O_2 sink during the night (Figures 3 & 4). Time series data such as this, collected in-situ continuously or in rapid bursts, can shed new light on biogeochemical processes that could not be achieved by previous sampling methods such as box chambers or periodic whole water sampling.

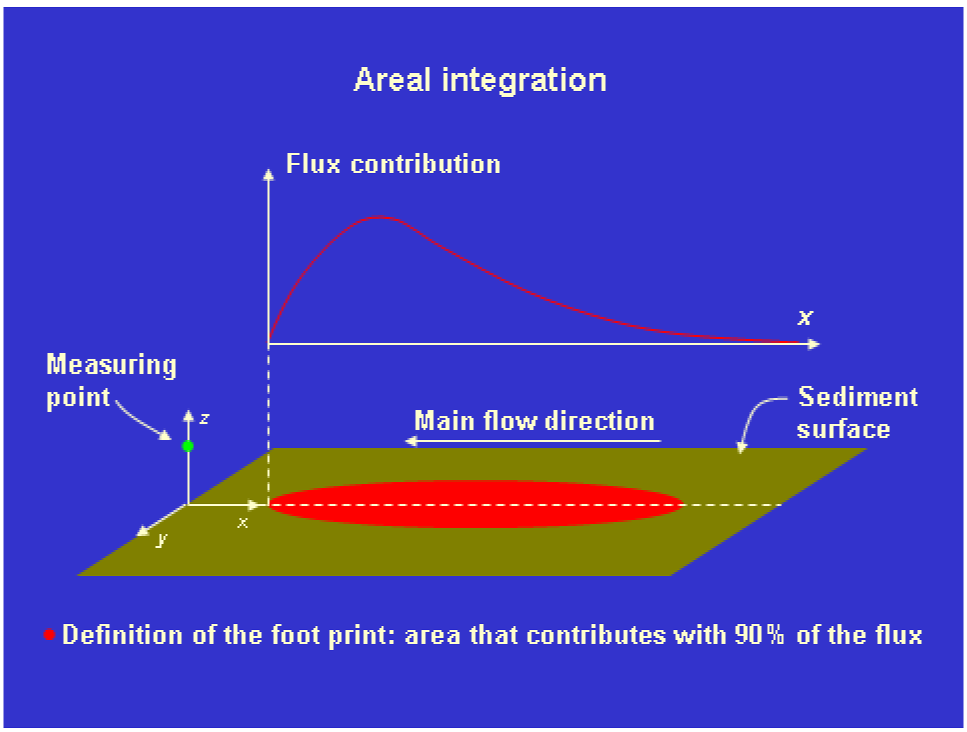

Figure 1. Definition of the foot print area that contributes 90% of the property flux. The foot print area is controlled by bottom roughness and height of the measurement point. It is independent of current speed.

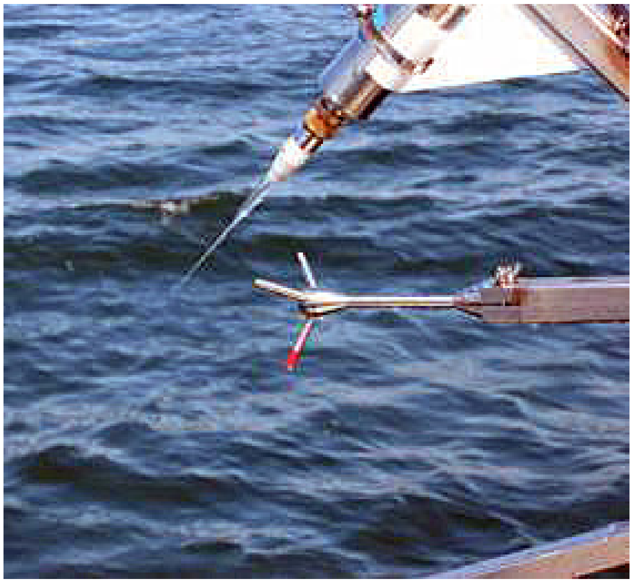

Figure 2. Detail photo showing Vector probe and fast-response O_2 sensor. The O_2 sensor is positioned to measure directly adjacent to the Vector sampling volume, 15 cm from the Vector probe.

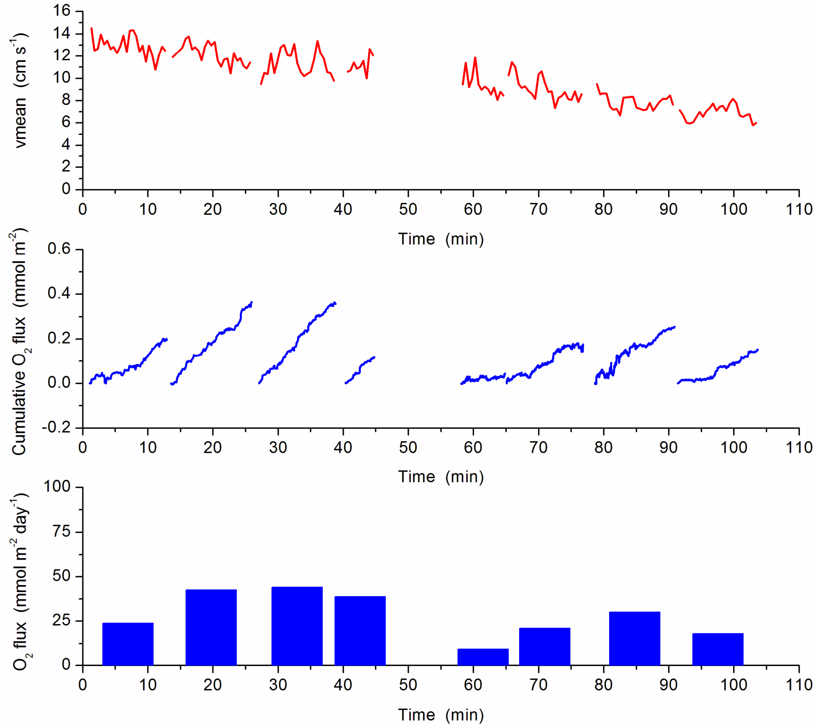

Figure 3. Mean vertical current velocity, cumulative O_2 exchange, and a positive O_2 flux (release). In this deployment there was a net release of O_2 from the sediment due to photosynthesis. The variation in the flux is again likely caused by variation in light. The clear decrease in current velocity does not appear to influence the O_2 exchange. Mean value of the O2 exchange is a release of 28.5 ± 4.4 (SE) mmol m^{-2} day^{-1}.

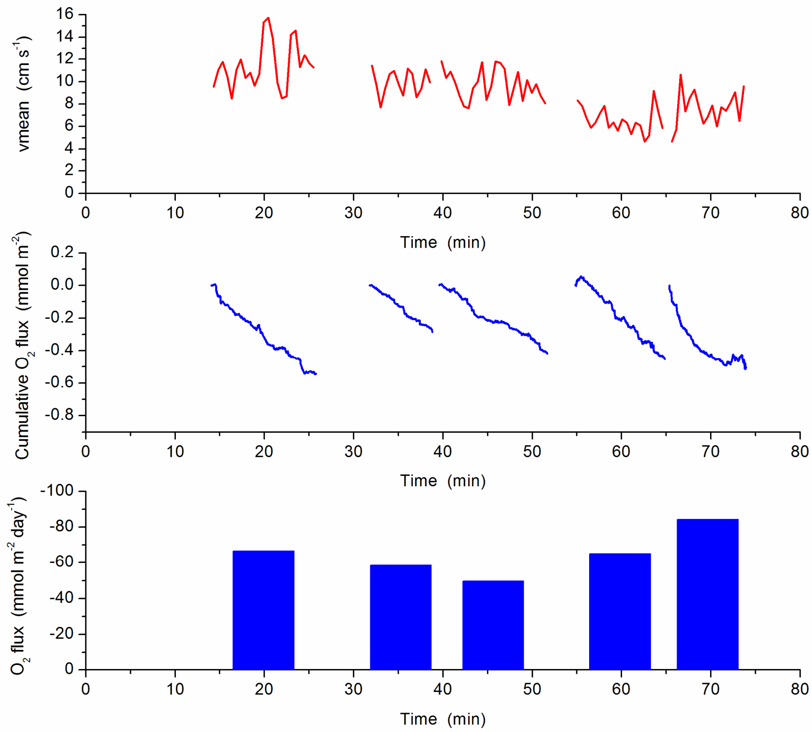

Figure 4. Mean vertical current velocity, cumulative O_2 exchange, and a negative O_2 flux (uptake). This deployment, which occurred in the dark, suggests respiration caused the O_2 exchange to change from an net release to a net uptake. The mean value of the O_2 uptake of 64.9 ± 5.7 (SE) mmol m^{-2} day^{-1}.

All figures are courtesy of Dr. Peter Berg & Andrew Hume, University of Virginia.

Suggested readings on applications of the Eddy Correlation Techniques applied to marine studies:

Berg P, Roy H, Janssen F, Meyer V, Jorgensen B, Huettel M, de Beer D (2003). Oxygen uptake by aquatic sediments measured with a novel non-invasive eddy-correlation technique. Mar Ecol Prog Ser. 261:75-83.

http://www.nortekusa.com/PDF/EddyCorrelationBergEtAl2003MEPS.pdf

Kuwae T, Kamio K, Inoue T, Miyoshi E, Uchiyama Y (2006). Oxygen Exchange flux between sediment and water in an intertidal sandflat, measured in situ by the eddy-correlation method. Mar Ecol Prog Ser. 307:59-68.

http://www.nortekusa.com/PDF/EddyCorrelationKuwaeEtAl2006.pdf