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Analysis, quantification and identification of in situ bioluminescence signals by an innovative sensor (CEMSOR2)

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Bioluminescence, the light emitted naturally by marine organisms, is the main light source in the mesopelagic zone. Nearly 75% of marine organisms, from the surface to the deep sea, use this capability for communication with diverse ecological goals (predation, repulsion...). Bioluminescence detection thus offers an indirect way of tracking the presence, distribution and migrations of organisms (ranging from zooplankton, dinoflagellates to fishes). Such detection can lead for example to a better understanding of vertical migrations of organisms and consequently of a better quantification of the active carbon export in the mesopelagic ocean. However, current technologies still limit large deployments, and high frequency observations of in situ bioluminescence.

To overcome these limitations, the CEMSOR2 project aims to develop an innovative, low cost, compact, multi-instrumented sensor capable of measuring bioluminescence in situ. The CEMSOR2 is designed to be easily deployable on a wide range of vectors (such as underwater gliders, CTDs, buoys, trawls, living organisms). The sensor being easy to deploy will enable us to collect a wide range of bioluminescent data with high spatiotemporal resolution, while recording environmental and behavioral variables related to the organisms.

A series of controlled tests is essential to validate the sensor's robustness under diverse marine conditions (pressure, salinity, light, etc.) and to characterize its performance in capturing subtle bioluminescent events. This process includes specification and calibration steps to ensure the sensor’s sensitivity to required wavelengths, sampling frequencies, and intensity levels, while accounting for operational limits, such as the maximum detectable intensity and baseline noise level.

The analysis of bioluminescence data involves several key steps to enhance data quality. First, background noise (sensor dark noise and other artifacts) is filtered out, through measurements taken in a dark chamber. Next, ambient light interference is minimized to prevent contamination

of bioluminescent signals. Bioluminescent flashes are identified using a peak-detection algorithm based on frequency and threshold filters, distinguishing true bioluminescent signals from background light.

Once detected, each flash undergoes detailed analysis, with characteristics such as Flash Duration (FD), Peak Intensity (PI), Rise Time (RT), Decay Time (DT), and Integrated Flash Energy (IFE) evaluated. Deconvolution techniques further separate overlapping flashes, allowing for a clearer understanding of multi-peak events. This analysis helps classify bioluminescent events by their spatio-temporal dynamics, intensity, and form, which are crucial for linking bioluminescence patterns with specific species' behaviors and environmental variables, especially in relation to migratory and behavioral patterns of marine organisms.

By advancing bioluminescence detection and interpretation, the CEMSOR2 project contributes essential tools and insights for marine biology, enhancing our understanding of the role bioluminescent organisms play in oceanic ecosystems.