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Investigating suspended particulate matters from multi-wavelength optical and multi-frequency acoustic measurements

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Long term and high-frequency monitoring of water quality, particularly the suspended particulate matter (SPM) concentration are crucial to decipher the health and sustainable development of marine ecosystems. However, in-situ measurements based on indirect optical or acoustic techniques are often associated with large uncertainties due to the dynamics of natural SPM, especially throughout the land-sea continuum. Therefore, this study aims to improve the accuracy of long term in-situ measurements by quantitatively elucidating the physical mechanisms by which sand and fine sediment respond to multi-wavelength optical and multi-frequency acoustic signals. We **hypothesize** that whilst fine sediment is very sensitive to optical signals, the coarser particles are more sensitive to acoustic signals, and vice versa. We further **hypothesize** that the SPM compositions and variability can be differentiated and derived based on such sensitivities and differences in behaviors of sand and fine sediment under different types of signals, i.e., optical and acoustic.

Before testing the hypotheses, a novel laboratory device that is capable of 1) generating homogeneous suspended concentration and 2) providing sufficient space for multiple sensors to operate simultaneously must be developed. The new device, DEXMES (dispositive experimental de quantification des matières en suspension), primarily consists of two main components. The upper part is a cylindrical tank with an inner diameter of 0.96 m and 1.4 m high. To break up the large vortexes and mitigate the vortex-induced bubbles (e.g., generated by the impeller), four baffles with dimensions of 0.09 x 1.31 m are evenly attached to the inner side of the tank. The bottom part of the DEXMES device is a convex, elliptical Plexiglas bed. Turbulent flow is generated by an impeller with a diameter of 0.36 m placed approximately 1 m below the water surface. The speed of the impeller, ranging from 0 to 235 rpm, is regulated by a controller box.

To test the hypotheses, 30 experiments, consisting of 6 concentrations and 5 mixture ratios (by mass) of Bentonite and fine sand (d_{50} = 100 µm), i.e., 100/0, 75/25, 50/50, 25/75, and 0/100, were thoroughly investigated using three acoustic sensors (ADV, AQUAscat, LISST-ABS) and three optical sensors (Wetlabs, HydroScat, LISST-100X). On average, each data point is the averaged value of 10 min of recording at 1 or 32 Hz. First, results show logarithmic/linear relationships between concentration and acoustic/optical signals respectively for a given bentonite/sand. Second, the

slope of this relation is a function of the Bentonite/sand ratio. Third, the results confirm the hypotheses that coarser particles are more sensitive to acoustic signals and fine sediment is more sensitive to optical signals. Simple regression models were developed for different pairs of acoustic and optical sensors based on their relative sensitivity to SPM characteristics. The correlation coefficient, bias, and RMSE between observed and predicted concentrations then were examined. The results also show that it is possible to use a combination of one acoustic and one optical sensor to infer the concentration and the ratio of fine/coarse sediment in suspension with minimum use of water samples calibration.