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High-spatial resolution numerical simulations of in-water radiative transfer processes

D. D'Alimonte (1), T. Kajiyama (2), and G. Zibordi (3)

(1) CENTRIA, DI/FCT, Universidade Nova de Lisboa, Caparica, Portugal, (2) CITI, DI/FCT, Universidade Nova de Lisboa, Caparica, Portugal, (3) Global Environment Monitoring Unit, Joint Research Centre, European Commission, Ispra, Italy

Monte Carlo (MC) simulations of radiative processes allow for addressing optical radiometric problems strictly linked to complex geometries. Within such a context, MC simulations have been used to investigate uncertainties affecting in-water radiometric measurements performed with free-fall optical profilers commonly utilized for the vicarious calibration of space sensors or the validation of satellite ocean color primary products (e.g, the normalized water leaving radiance). Specifically, a MC code (henceforth called MOX) has been developed to simulate in-water and above-water radiometric fields with high spatial-resolution (up to 1 cm) over a 2-dimensional (2D) domain of tens of meters. This has been achieved by exploiting high performance computing (HPC) solutions (e.g., parallel programs and job-scheduling based on novel performance prediction and optimization schemes) to trace up to 10˘12 photons. A dedicated study, focused on the simulation of in-water radiometric fields, has led to the generation of virtual optical profiles accounting for perturbations due to light focusing effect by sea-surface gravity and capillary waves at a spatial resolution comparable to that of actual measurements. Different from field experiments, which are often constrained by environmental factors like illumination conditions and sea-water optical properties, numerical simulations permits analyzing realistic cases whereas allowing for a free input parameter selection. MOX simulations have shown that uncertainties induced by focusing effects upon radiometric data products can be reduced by slowing the deployment speed of free-fall optical profilers, rather than increasing the sampling frequency (i.e. while keeping the same number of samples per depth unit). This result has confirmed the appropriateness of profiling techniques (i.e. multicasting) so far solely supported by a limited number of field measurements and has additionally suggested the possibility of investigating further sources of uncertainties strictly linked to the sensor technology (e.g., integration time). New MOX functionalities, such as 3D simulations supported by advanced sky-radiance modeling, have now been implemented to investigate uncertainties challenging above-water radiometric measurements more and more used to support satellite ocean color investigations. The general conclusion of this study is that the exploitation of MC numerical simulations supported by HPC solutions, keeping the support of field measurements (even though restricted to specific environmental conditions) provides valuable information on measurement uncertainties and insight for the optimization of measurements protocols.