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Fast and accurate multi-spectral optics in an ocean model

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Solar radiation and penetrative heating processes play a key role in the thermal and ecological evolution of the upper ocean and are in turn sensitive to the vertical distribution of chlorophyll. In order to accurately model this complex interaction between physical and biochemical processes an accurate hydro-optics model is required, which also accounts for the spectral nature of sunlight. In this paper we present the results from a coupled implementation of the Hyperlight hydro-optics model with Fluidity-ICOM, a non-hydrostatic state-of-the-art ocean model that presently uses a simple exponential decay model to estimate the vertical light field. Hyperlight is an extremely efficient multi-spectral solar irradiance model that uses pre-computed lookup tables to provide an accurate approximation solution to the Radiative Transfer Equation (RTE) across 36 individually modelled wavebands. The objective is to assess the computational overheads of incorporating a sophisticated solar radiance model into a full-scale ocean model such as Fluidity-ICOM and to evaluate any changes in the model predictions that accrue. The light field computed by Hyperlight is validated against that obtained by running a full-scale RTE algorithm (HYDROLIGHT) as well as observational data gathered by the Bermuda Bio-Optics Project. The model is shown to match both well. Performance results show that RTE-based scalar irradiance can be computed with computational overheads of less than 20% for coupled models of ocean, optics and biology. We evaluate the effect that the multi-spectral radiance model (which includes an additional temperature source term due to solar heating) has on the behaviour of both an integrated turbulence model within Fluidity-ICOM and an embedded model of plankton biology. In both cases the results for the enhanced optics model are compared to those obtained using Fluidity-ICOM's existing exponential decay function for the light field, which is computed in conjunction with 6-hourly surface irradiance data from the ECMWF ERA-40 dataset. These experiments show a considerable change in sea-surface temperature due to the added temperature source term, and a corresponding impact on the biology. The latter is mainly the result of resolving the surface irradiance with increased temporal resolution, since the optics model computes the azimuthal angle internally, resulting in a more fine grained diurnal cycle of incident sunlight.