A new approach to spectral ocean color satellite data assimilation and its effect on ocean physics, biogeochemistry and optics prediction in the Black Sea

The modeling of ocean physics has progressed considerably in recent decades, achieving a prediction quality similar to that of weather prediction. The increase in computing resources and significant advances in our capacity to observe ocean physics from autonomous platforms at sea and from satellites contribute to the improved quality of ocean predictions. However, the modeling of ocean biogeochemistry is less advanced, as there is no equivalent to the Navier-Stokes equations for biological and biochemical components, and there are far fewer observations to support the parameterization and validation process. Biogeochemical model variables are mostly not directly observable, and their connection to observations requires the use of empirical models. This is the case for chlorophyll, which is mostly derived either from satellite-observed reflectance using an imperfect inversion algorithm or from in-situ fluorescence measurements of the sea. Our limited capabilities to simulate optically active components in the ocean (e.g., chlorophyll) can degrade the prediction of physical variables since temperature profiles (and thus density and ocean dynamics) depend on heat penetration. In recent years, ocean models have been extended with spectral radiative transfer models to link their model variables more directly with satellite observations. In this study, we use a stochastic ocean physical-biogeochemical model of the Black Sea coupled with a spectral radiative transfer model to assess the impact of assimilating satellite reflectance observations on the quality of ocean predictions. This study focuses on developing a new data assimilation approach that involves incorporating the radiative transfer model into the assimilation flow. The RADTRANS spectral radiative transfer model is optimized against model state variables through a loss function built upon the MAE (mean absolute error) between modeled and observed satellite radiative reflectance. Using this approach, we provide an analyzed estimate of three-dimensional Chl-a, carbon in phytoplankton, and particulate organic matter concentrations, as well as phytoplankton growth rates. A comprehensive validation of data assimilation results yields a reliability and effectiveness assessment of the suggested DA (data assimilation) approach. The methodology is tested in the Black Sea, where the research group runs a biogeochemical model in forecasting and reanalysis within the framework of the European Copernicus Marine Service.

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