A probabilistic approach for the analysis and prevision of Black Sea ecosystems

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1 Objectives

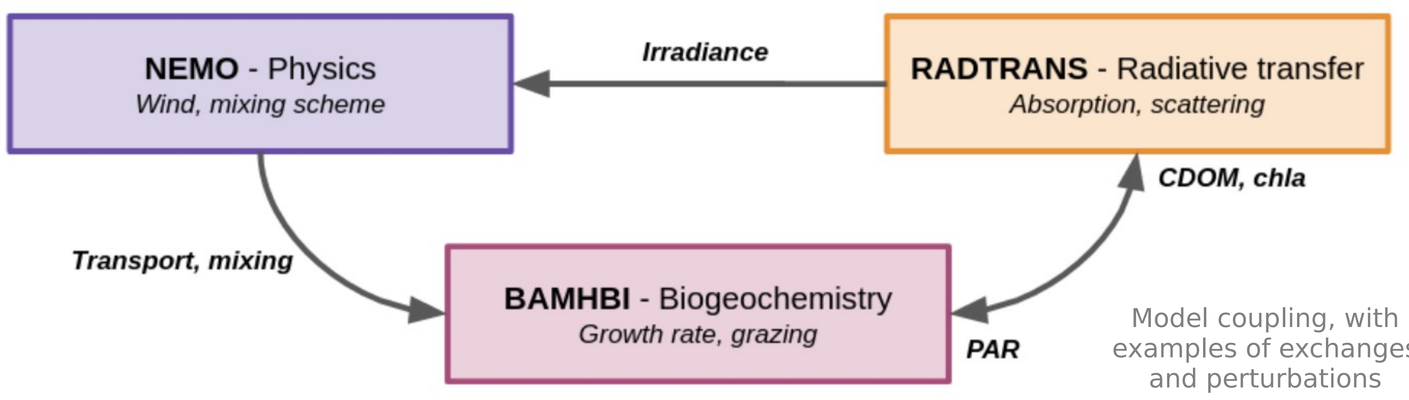
The main objective of my thesis is to develop an **ensemble system for the coupled physical-biogeochemical model** NEMO-BAMHBI, applied to the Black Sea, to which a **radiative transfer module** is added. This systems aims at evaluating the **major sources of uncertainty of the model**, whether of physical or biogeochemical (BGC) origin, that have a significant influence on climate and health indicators. This will be achieved by applying perturbations either to the external physical forcings or to biogeochemical and optical parameters.

From then on, the aim is to perform ensemble projections of the Black Sea physical and biogeochemical state over the next 10 years. A last line of research will be the evaluation of a reflectance assimilation scheme in hindcast simulations, meant to reduce uncertainties arising from light propagation in sea water.

2 Methodology

The complete model system will consist of a coupled physical-biogeochemical-radiative model, with parameters that can be perturbed in each of the components.

The first step is the addition of the radiative transfer model, that will allow a better modeling of light propagation through sea water, which influences directly primary production.



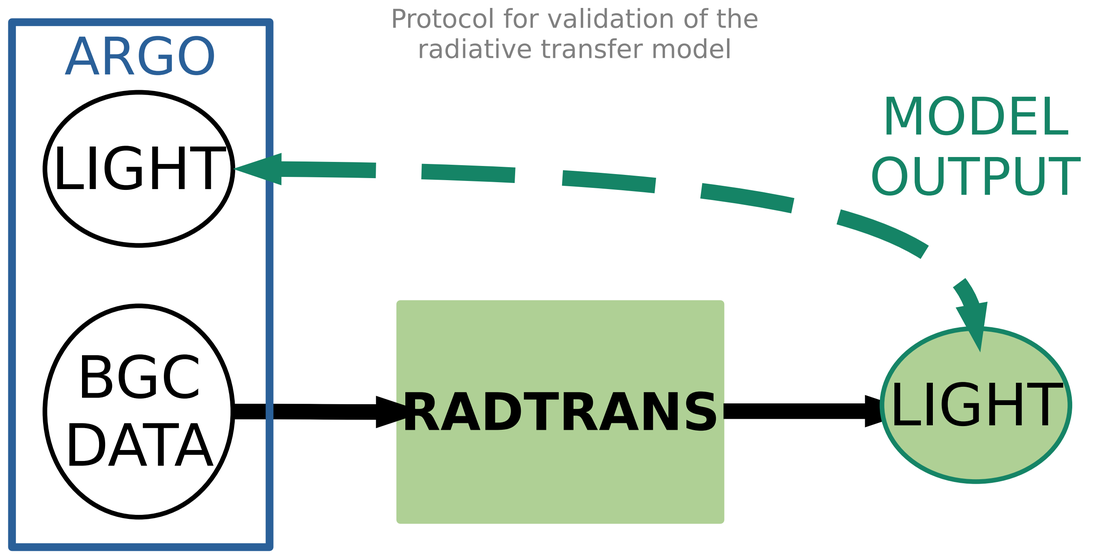
Model coupling, with examples of exchanges and perturbations

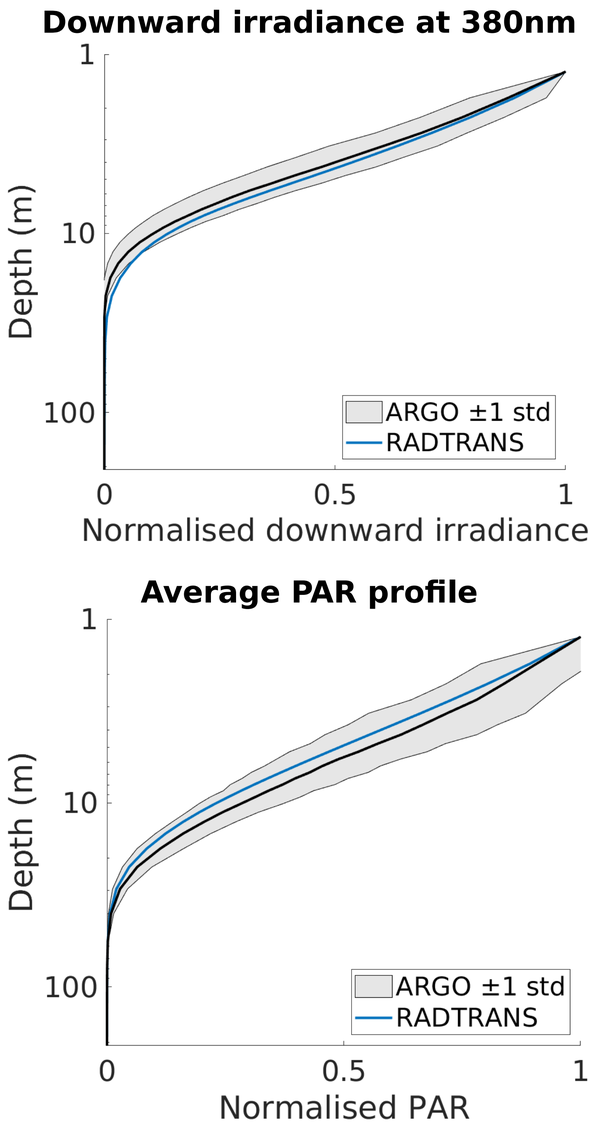
3 Radiative transfer model

Based on Dutkiewicz et al.[1], RADTRANS is a **radiative transfer model that simulates irradiance** in 33 wavelengths. Light extinction is modelled as the sum of 4 main contributors: water, phytoplankton, particles/detritus and colored dissolved organic matter (CDOM).

ARGO data in the Black Sea includes measurements of both inputs (e.g., chlorophyll) and outputs of RADTRANS (irradiance, Photosynthetic Active Radiation - PAR)[2]. Therefore, a well formulated model should provide results that agree with light measurements when forced by BGC ARGO data.

By adjusting extinction parameters, the aim is to validate RADTRANS before adding it to the coupled system and moving on to ensemble simulations.





Average data from ARGO float 6901866 (Black Sea, June 2015 – July 2019)

Extinction contributions from water, detritus and phytoplankton are well known in the literature. However, that from CDOM is more difficult to model, as its inherent optical properties highly vary seasonally and spatially.

Assuming other contributions are known, the method is to derive the CDOM contribution by fitting 380 nm irradiance profiles with those measured by ARGO floats[3].

Then, CDOM absoprtion in other wavebands is derived using an exponential formulation.

PAR is computed as the integral of irradiances between 400 and 700 nm. It is also measured by ARGO floats, which provides a dataset to validate the radiative transfer model.

These results are used to derive **a formulation for CDOM absorption** independant from ARGO profiles. The analysis of the fitting process shall also give insights on CDOM variability in the Black Sea.

4 Ensemble simulations

Coupled with the existing physical-biogeochemical model framework, the radiative transfer model will be part of **ensemble simulations** with the objective of determining the main sources of **uncertainty on biogeochemical variables**.

Perturbations will be applied on either forcings or model parameters. Methods considered for generating perturbations are 2D autoregressive methods, and EOF or Fourier modes perturbations[4].

Component	Examples of processes	Goal
Radiative transfer	Inherent optical properties	Validate the formulation of RADTRANS
Forcing	Wind, surface irradiance	Model uncertainties on biogeochemical variables
Physics	Mixing	
Biogeochemistry	Growth rate, photosynthetic efficiency	

Finally, the ensemble will be used to perform **hindcast simuations and projections** at a decadal scale, focusing on features such as carbon export, oxygen inventory and the oxycline position.

References: ***1 -*** *Dutkiewicz, S., Hickman, A. E., Jahn, O., Gregg, W. W., Mouw, C. B., and Follows, M. J.: Capturing optically important constituents and properties in a marine biogeochemical and ecosystem model, Biogeosciences, 12, 4447–4481, https://doi.org/10.5194/bg-12-4447-2015, 2015.* ***2*** *- Argo. Argo float data and metadata from Global Data Assembly Centre (Argo GDAC). SEANOE. https://doi.org/10.17882/42182, 2000* ***3 –*** *Terzić, E., Miró, A., Organelli, E., Kowalczuk, P., D'ortenzio, P., et al.. Radiative Transfer Modeling With Biogeochemical-Argo Float Data in the Mediterranean Sea. Journal of Geophysical Research. Oceans, Wiley-Blackwell, 126 (10), 10.1029/2021jc017690. hal-03430344, 2021.* ***4 -*** *Garnier, F.. Paramétrisations stochastiques de processus biogéochimiques non résolus dans un modèle couplé NEMO/PISCES de l'Atlantique Nord. Applications pour l'assimilation de données de la couleur de l'océan. Thèse de doctorat, Université de Grenoble Alpes, 202 p., 2016*

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