Charaterisation of uncertainties in an ocean radiative transfer model for the Black Sea

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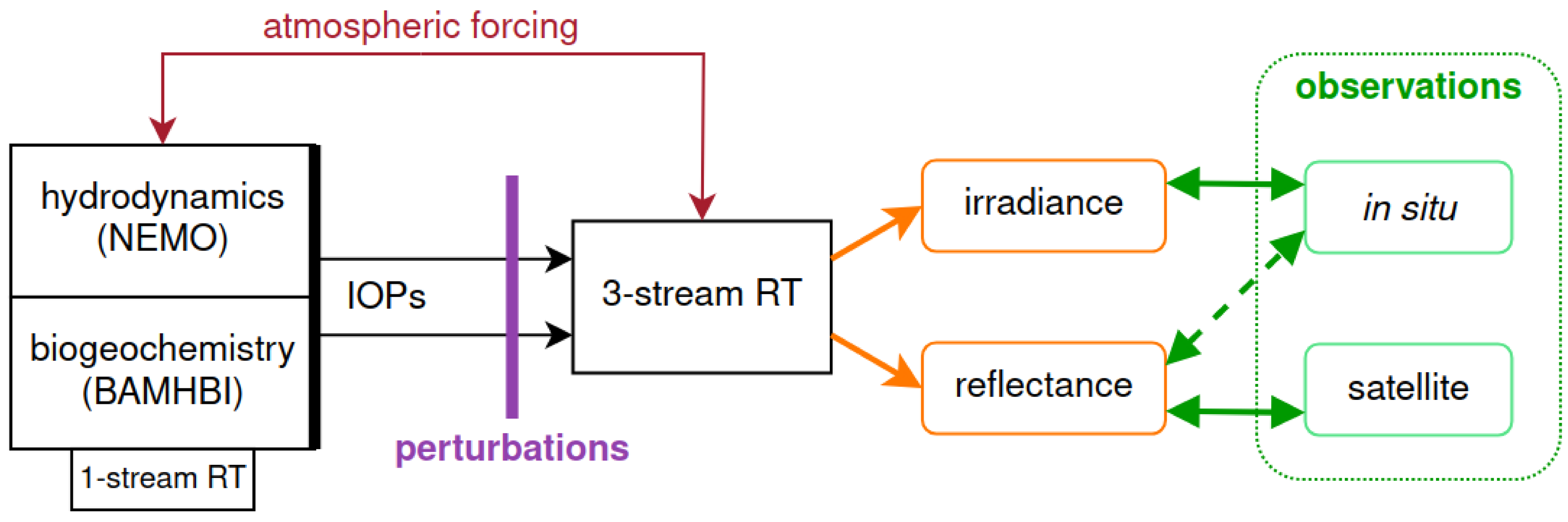
Context and strategy

A **3-stream radiative transfer** (RT) model[1] is added to a coupled physical-biogeochemical framework for the Black Sea as an **observation operator**. We aim at characterising the **influence of uncertainties in the inherent optical properties** (IOPs) of water constituents on the outputs of this RT operator..

We perturb the IOPs of **phytoplankton, non-algal particles and CDOM** using first order autoregressive random processes η of unit mean, correlated in time and space. For each vertical profile:

$$IOP_{pert}(x,y,z,t,\lambda) = IOP(x,y,z,t,\lambda) \times \eta(x,y,t)$$

Additionally, the absorption spectrum of CDOM is also perturbed using the same process.

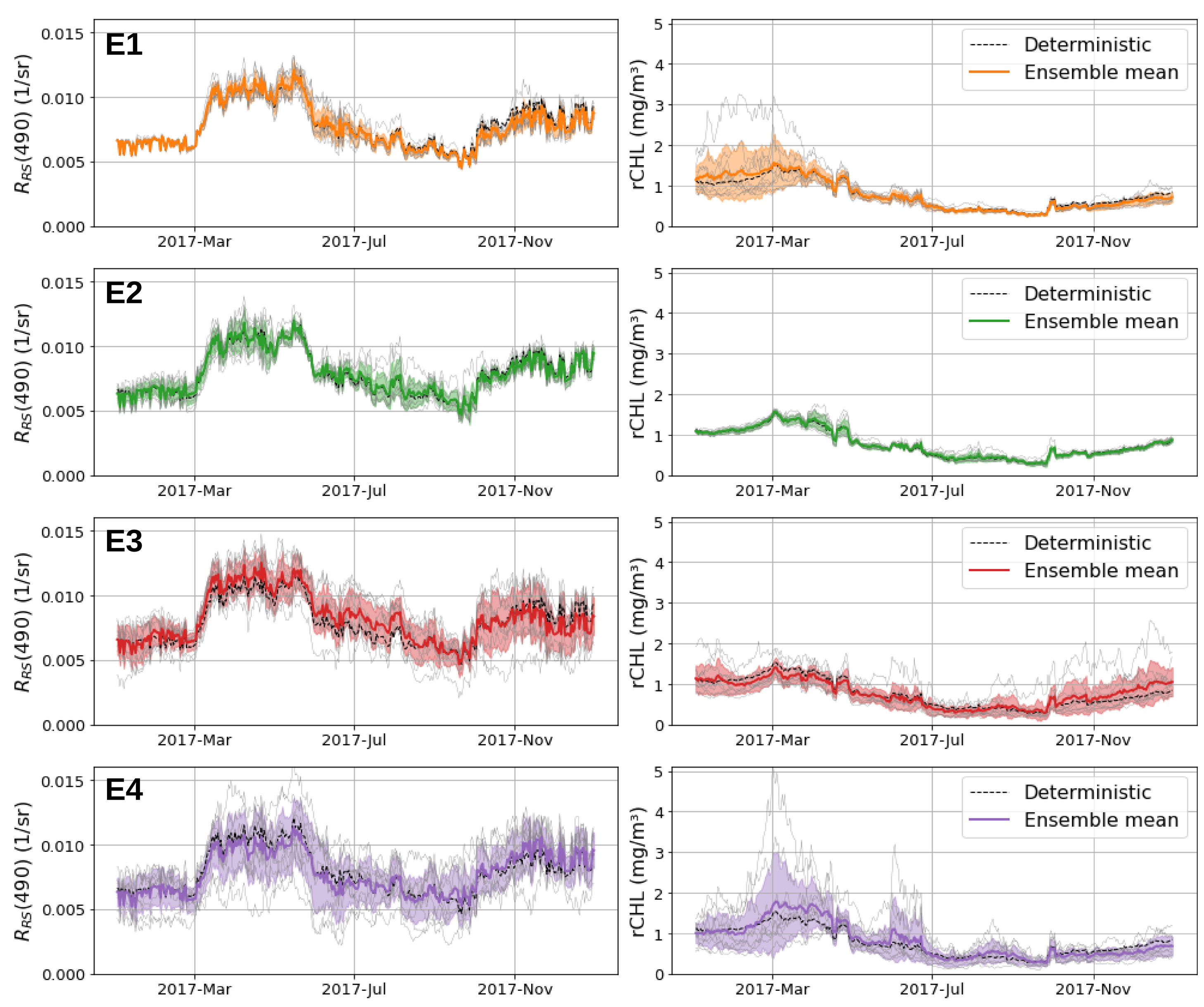


Coupled physical-biogeochemical-optical model framework.

We run 3 experiments with individual uncertainties::
- **E1**: perturbation of phytoplankton IOPs
- **E2**: perturbation of non-algal particles IOPs
- **E3**: perturbation of CDOM IOPs

And a 4[th] ensemble combining uncertainties:
- **E4**: combined perturbations of E1, E2 and E3

1) What is the effect of perturbations on the RT model outputs ?



Time series of sea surface reflectance at 490nm and rCHL in the Eastern Gyre over 2017.

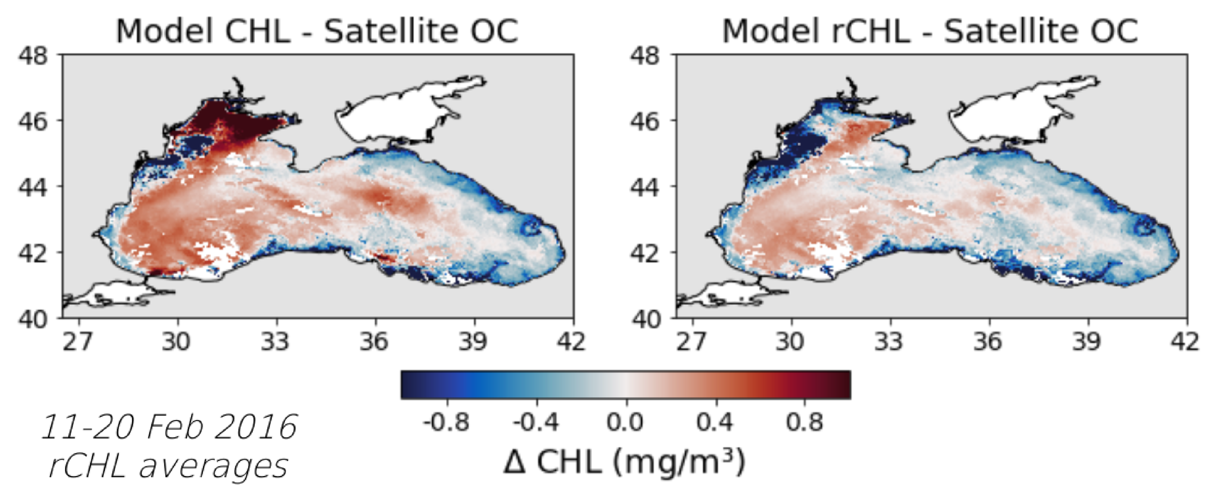
Phytoplankton and CDOM have the most influence on reflectance and rCHL following seasonal variability. The **non-linear** combination of perturbations exhibits the influence of each constituent and the **deviation between the ensemble mean and the deterministic run.**

rCHL ?

Inspired by the blue/green band-ratio algorithm used for ocean colour (OC) products, we introduce reflectance-derived chlorophyll rCHL:

$$log(rCHL) = \sum_{k=0}^{3} c_k \times \left[log\left(\frac{R_{RS}(490)}{R_{RS}(555)}\right)\right]^k$$

with c_k coefficients specific to the Black Sea area[2].

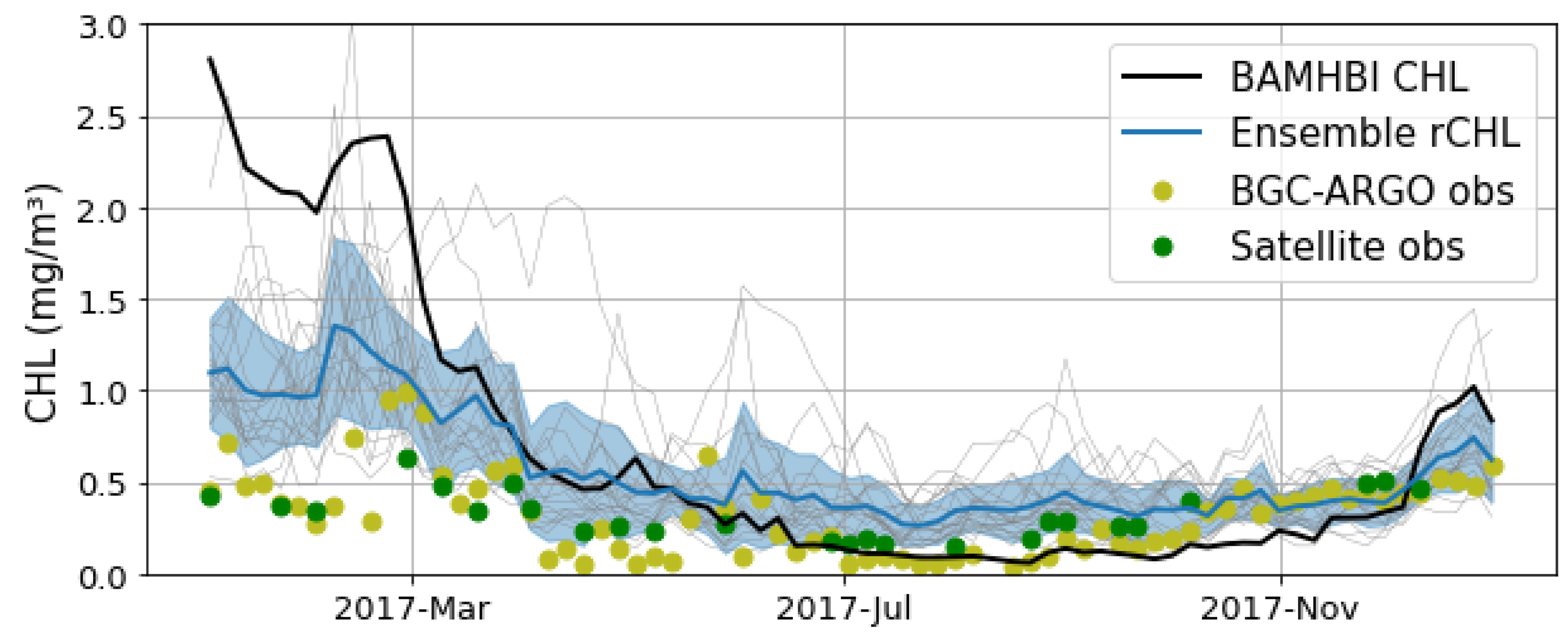


11-20 Feb 2016 rCHL averages

We find that rCHL is closer to OC products than chlorophyll (CHL) from BAMHBI, especially during blooms.

Advantage of rCHL: using a ratio removes some of the uncertainty on sea surface reflectance.

2) Can this stochastic RT model generate distributions of rCHL that are consistent with observations ?

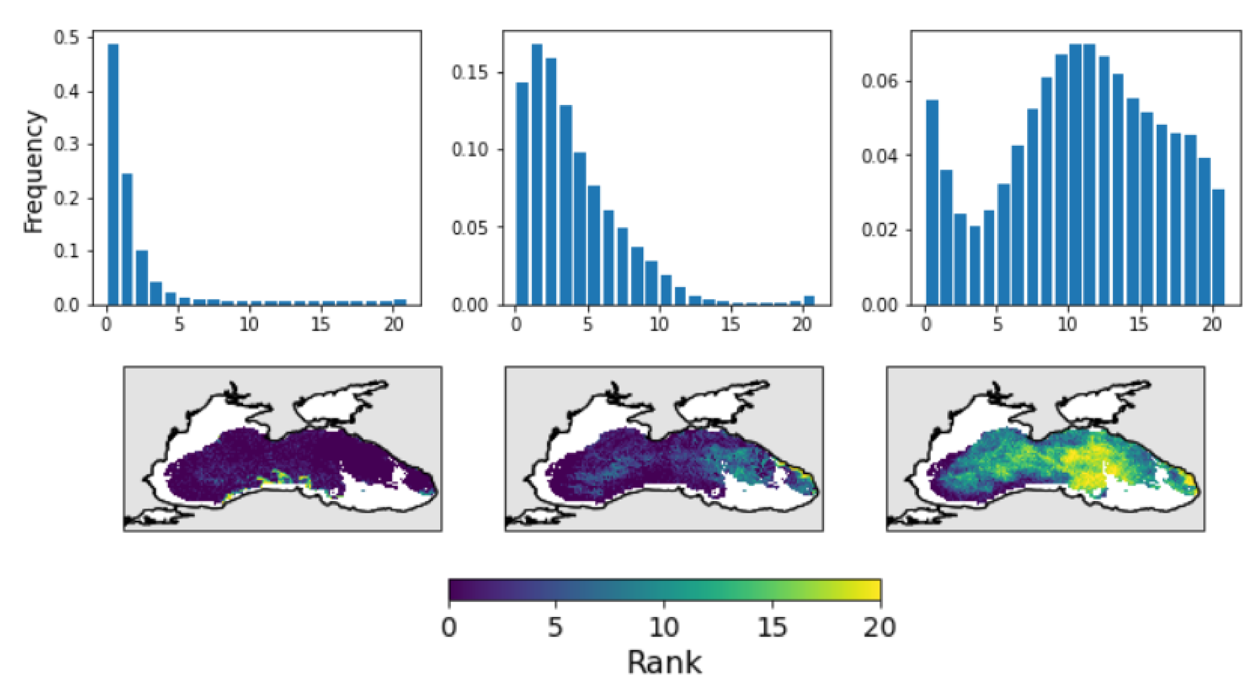


Time series of chlorophyll from modelled and observed in the Eastern Gyre over 2017 (ensemble E4). Each thin grey line corresponds to a member.

Spring - the model tends to **overestimate chlorophyll concentration** (diatoms bloom). Uncertainties in IOPs do not fully explain the bias between model and observations.
Summer - distributions of rCHL get closer to observations, in particular in the central parts of the Black Sea.
Autumn/winter - the model is able to **capture observations** of chlorophyll with rCHL, performing even better than BAMHBI chlorophyll.

Rank histogram: representation of the ability of an ensemble to reproduce a distribution of observations by sorting observations among the ensemble members[3].

Observations are more likely to fall within the ensemble spread in autumn than in spring. Rank maps show that biases remain concentrated to shallower areas.



Rank histograms and rank maps for rCHL in the E4 ensemble (20 members) on 5[th] March 2017 (left), 8[th] June 2017 (centre), 13[th] September 2017 (right).

Distributions of rCHL produced by the model are not always consistent with observations, but results are promising in central regions during autumn and winter.

Perspectives

In this study, the RT model is only used as an observation operator. Performances of a **2-way coupled model** will be studied in the future, with feedback from the RT to the hydrodynamics and biogeochemistry.

This work is also preparatory towards **assimilation of sea surface reflectance** data in this coupled framework for the Black Sea.

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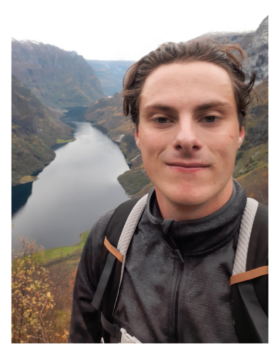

__References__: 1 - Dutkiewicz, S., Hickman, A., Jahn, O., Gregg, W., Mouw, C. & Follows, M. (2015), 'Capturing optically important constituents and properties in a marine biogeochemical and ecosystem model', Biogeosciences 12, 4447–4481. **2 –** *Zibordi, G., Mélin, F., Berthon, J.-F. & Talone, M. (2015), 'In situ autonomous optical radiometry measurements for satellite ocean color validation in the western black sea', Ocean Science 11, 275–286.* **3 -** *Candille, G. & Talagrand, O. (2004), '"Evaluation of probabilistic prediction systems for a scalar variable"', Quarterly Journal of the Royal Meteorological Society 131(609), 2131–2150.*