Contributions of radiative transfer modelling to a stochastic biogeochemical forecasting system in the Black Sea

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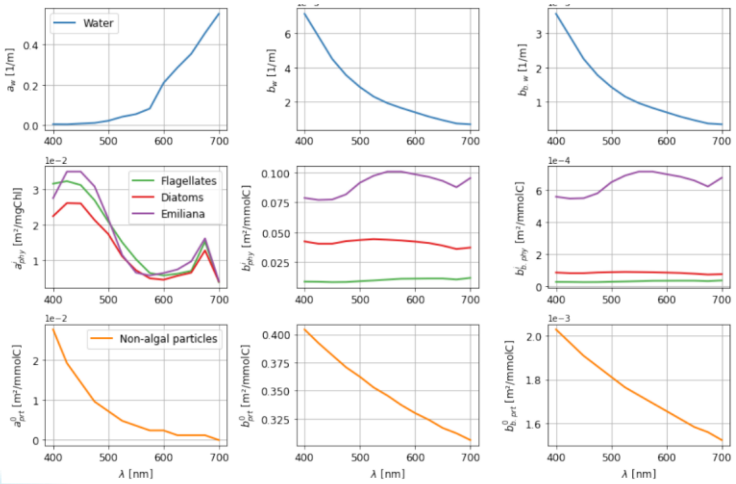
Ocean radiative transfer

- Physical framework of ocean colour remote sensing
- Description of the radiance field in the ocean based on the Inherent Optical Properties (IOPs) of sea water
- We use a 1D 3-stream model coupled to a physical-BGC model to solve water columns individually. The aims are:
  - To simulate radiometric variables that are comparable to observations
  - To assess the influence of uncertainties in their simulation

Inputs

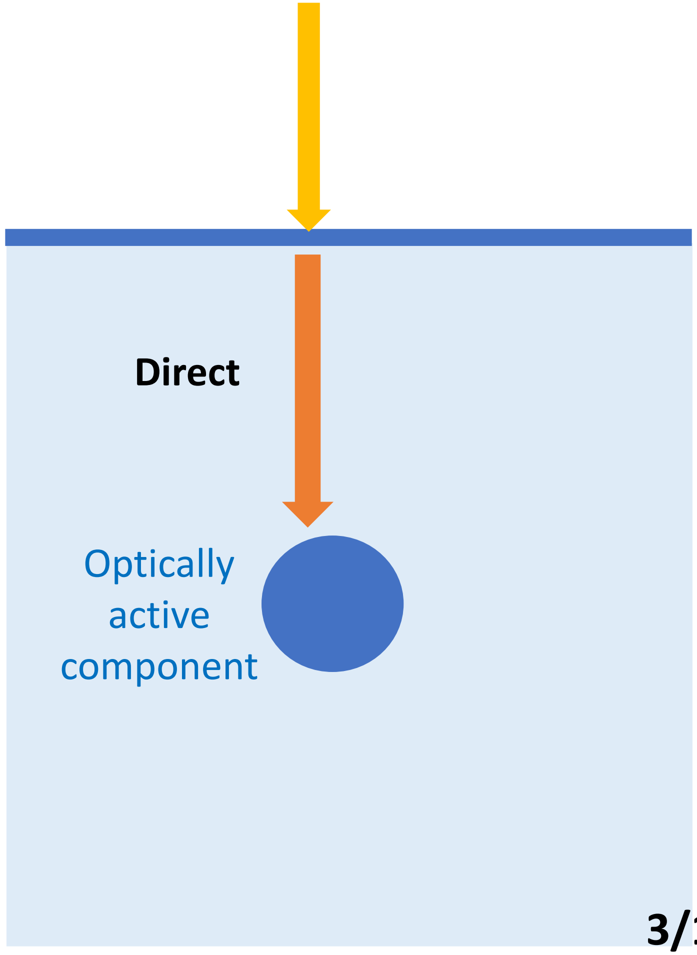
Direct and scattered (downward) surface irradiance



IOPs (absorption and scattering)

We solve 4 major constituents:

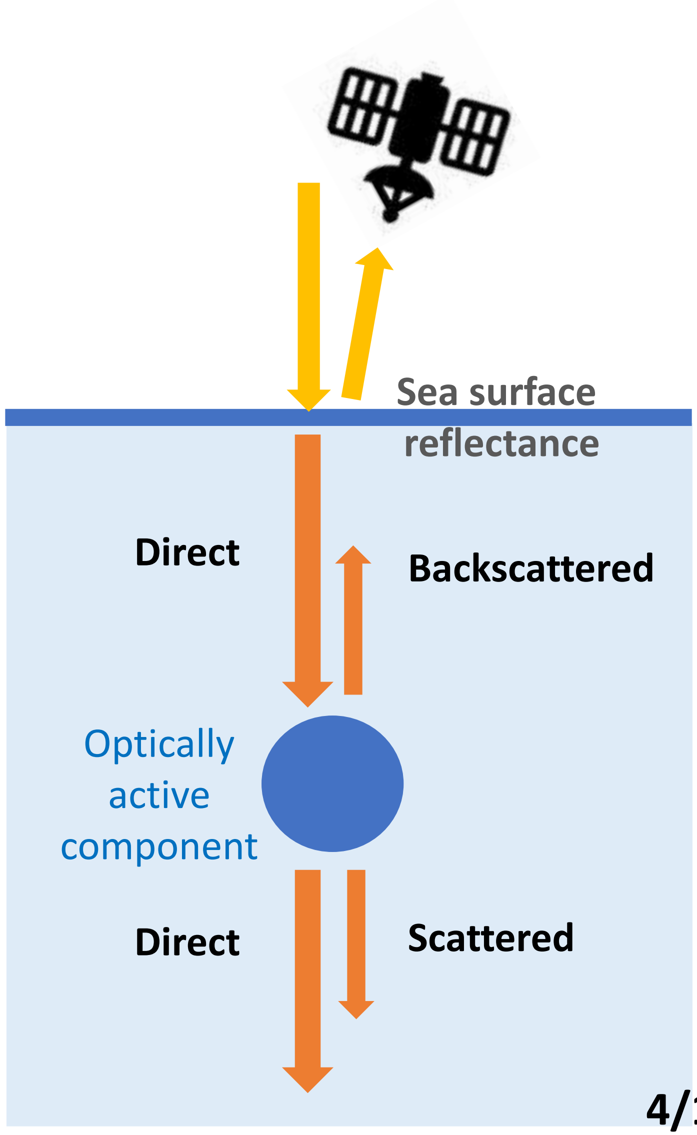
- Pure water
- Phytoplankton
- Non-algal particles
- CDOM



Outputs

In-water irradiance streams:
- Direct (downward)
- Scattered (downward)
- Backscattered (upward) -> Leaving-water irradiance

Sea surface reflectance (R_{RS})
- Ratio between upward and downward surface irradiance
- Model reflectance is transformed to remote-sensed reflectance by accounting for BRDF and the air-sea interface

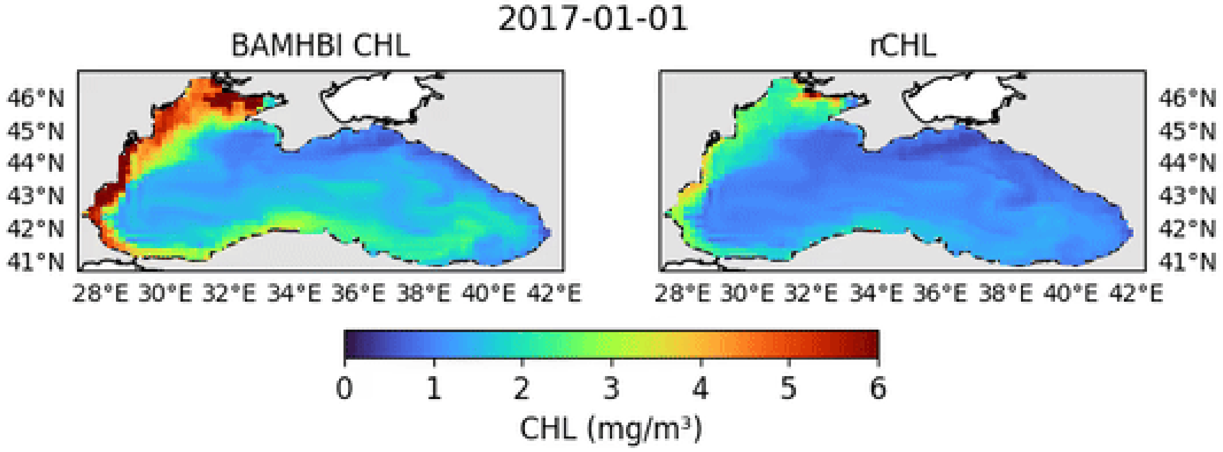


Reflectance-derived chlorophyll

We use a blue/green band ratio algorithm to derive reflectance-derived chlorophyll (rCHL), a proxy for surface chlorophyll.

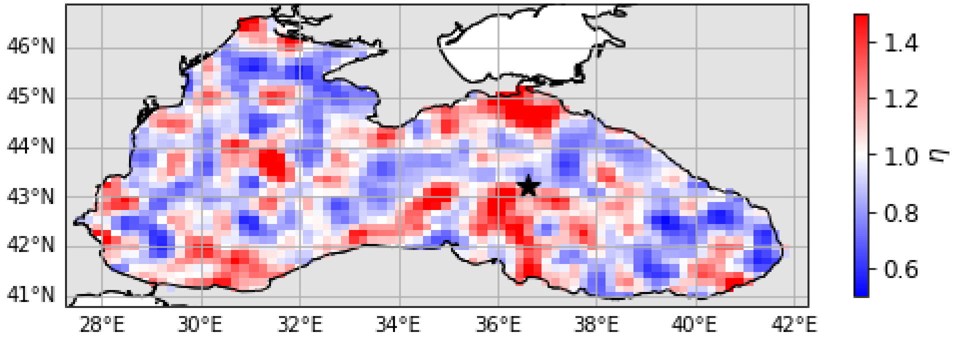
$$log(rCHL) = \sum_{k=0}^{3} c_k \times \left[log\left(\frac{R_{RS}(490)}{R_{RS}(555)} \right) \right]^k$$

with c_k coefficients as used in the CMEMS product for the Western Black Sea



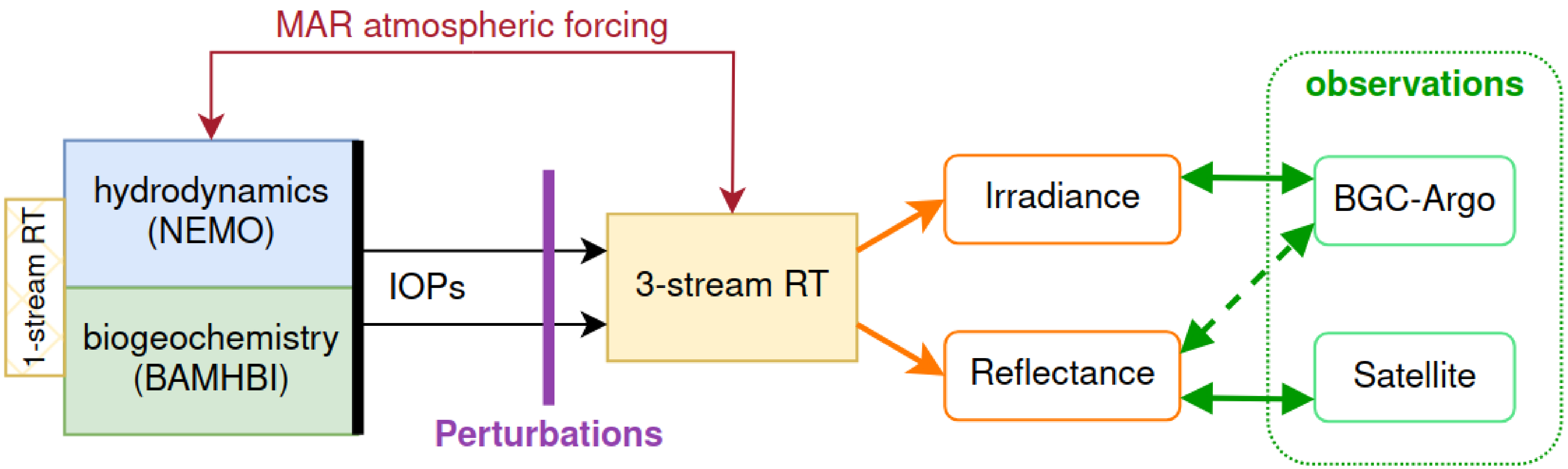
Uncertainties

- Here we consider uncertainties in the IOPs only, arising from:
  - Uncertainty on phytoplankton, non-algal particles and CDOM concentrations
  - Uncertainty on the absorption and scattering spectra
- We use 1st order autoregressive processes following a log-normal distribution to perturb IOPs.
  - Time correlation: 30 days
  - Space correlation: 75 km
  - Standard deviation: 50%
  - 20 members



Example of perturbation field

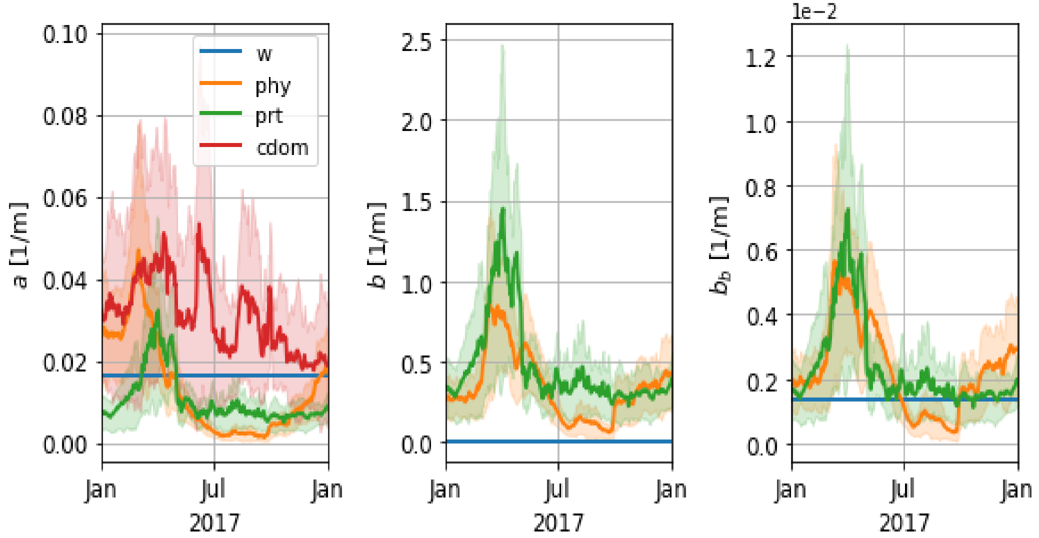
Coupled modelling framework



1-way coupling:

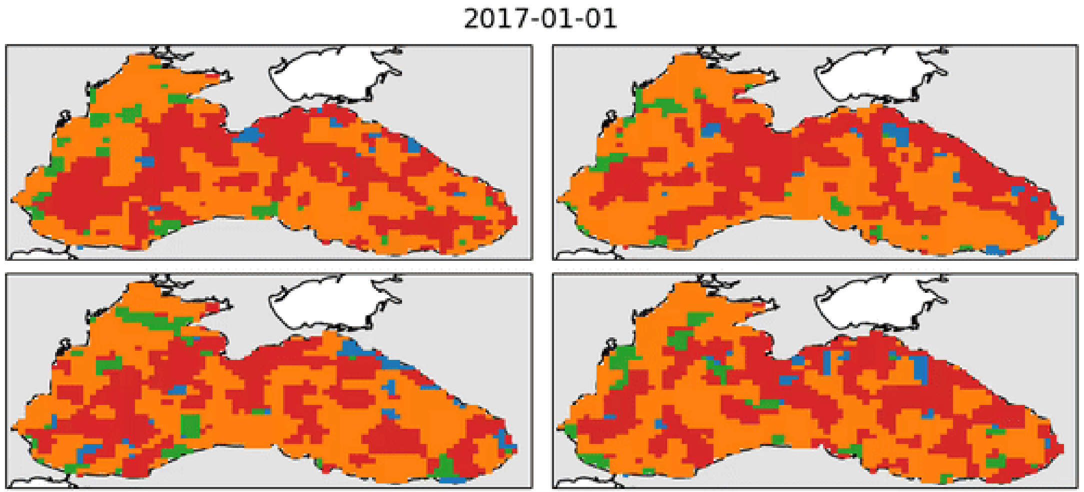
- No feedback from the 3-stream RT model towards NEMO and the BGC
- RT model is used as an observation operator, projecting model variables into the space of observations

Optical contributions



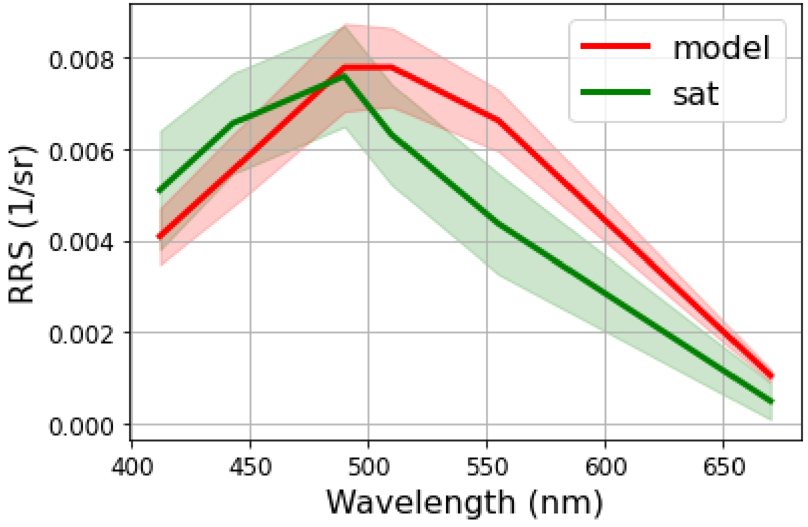
IOPs. 2017, eastern gyre

Absorption domination in 4 members:
water, phytoplankton, non-algal particles, CDOM

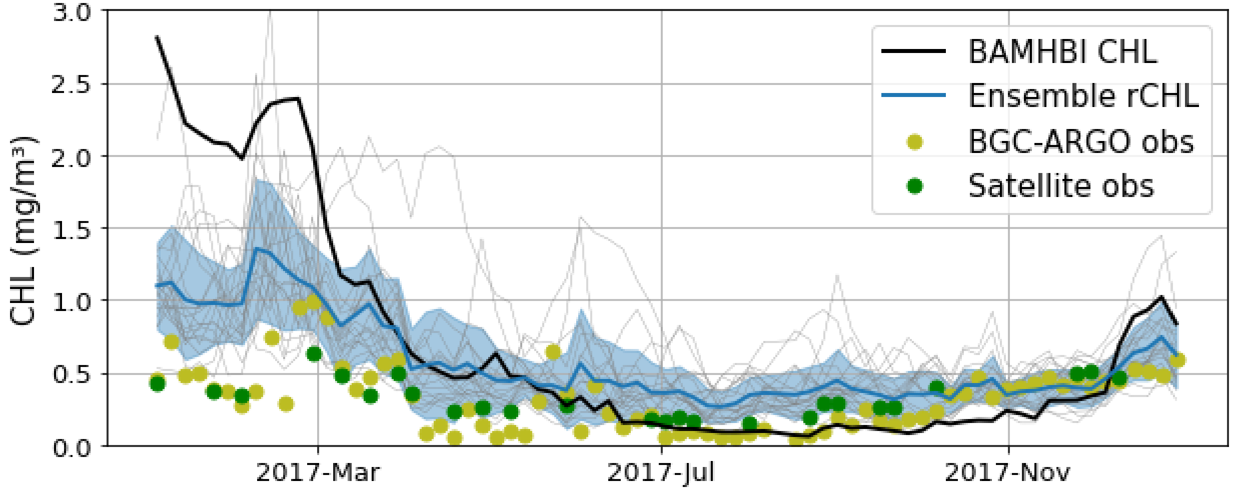


CDOM tends to dominate absorption outside of blooms,
Phytoplankton and non-algal particles have IOPs of similar magnitude.

Sea surface reflectance fields



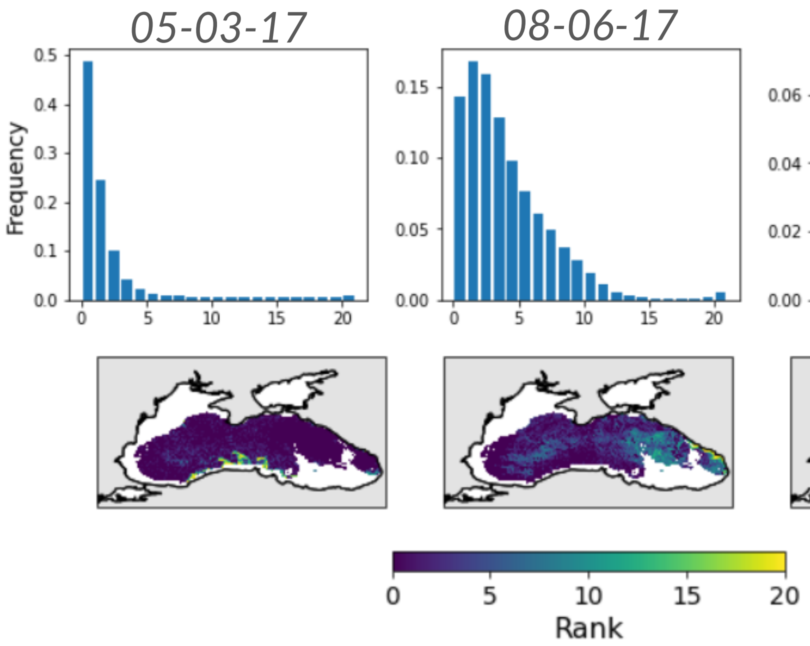
2017 basin-wide average



Along BGC-Argo 6901866 track, 2017

- Overestimation of reflectance in longer wavelengths.
- rCHL is closer to measured chlorophyll during winter/spring blooms, but does not capture all observations.

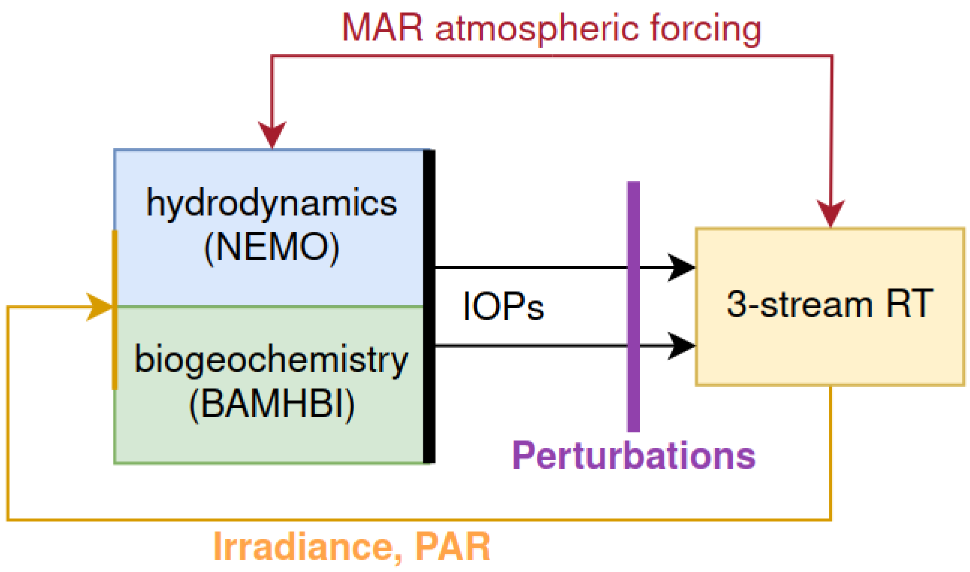
rCHL distributions

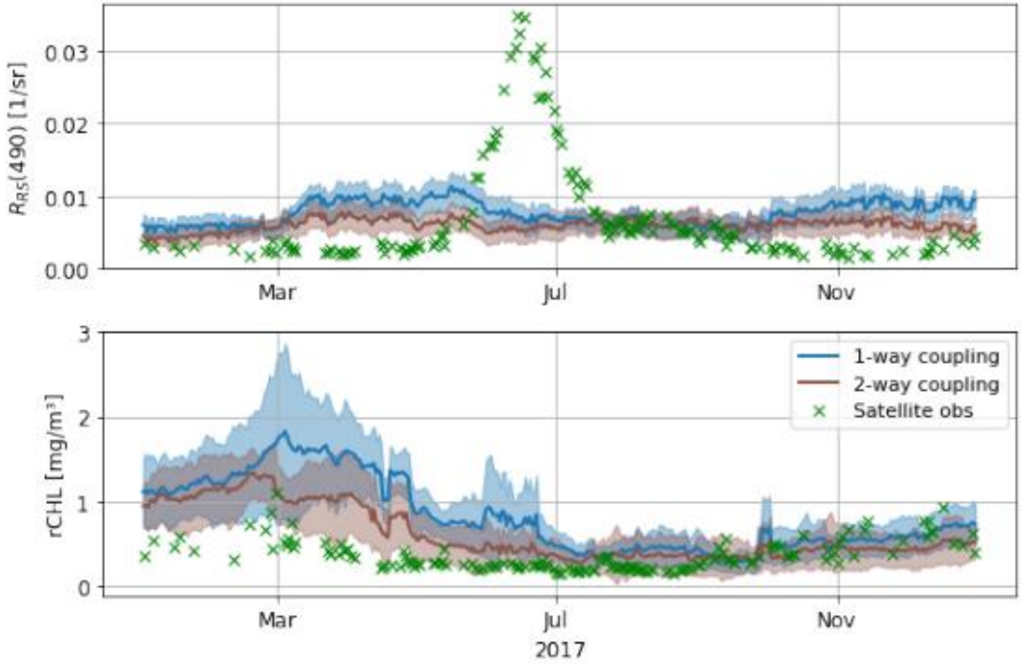


- Initial bias in the deterministic solution of rCHL.
- In some conditions, distributions of rCHL are consistent with observations:
  - In the deep basin
  - In summer/autumn

- Observations are not properly captured in winter/spring. Reasons can be:
  - The deterministic solution is not good enough
  - Other sources of uncertainty should be considered

2-way coupling ?





- RT feedback to physics and BGC may improve the computation of R_{RS} and rCHL.
- The influence on the physics and BGC has to be further assessed too.

Consequences of light perturbation

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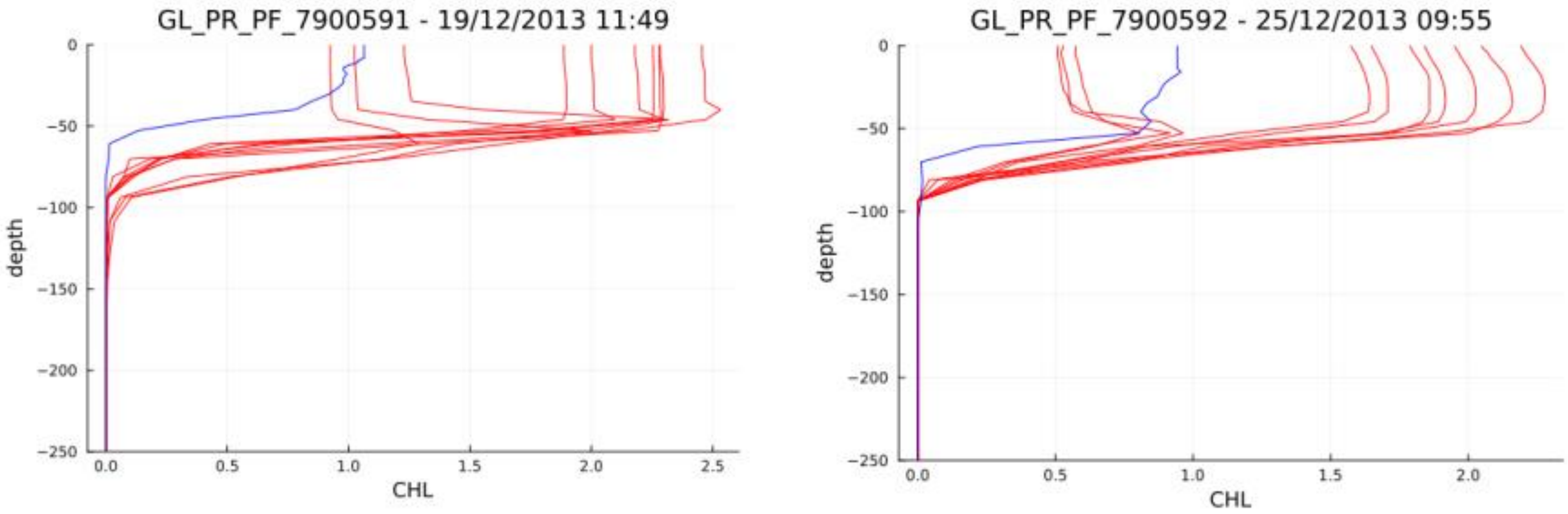

Perturbation of surface irradiance - BGC-ARGO profile / Ensemble members

Perturbation of light (both directly and indirectly) can have major consequences on ocean biogeochemistry.

Conclusions

- The use of RT model shows the importance of modelling irradiance and IOPs (esp. CDOM) correctly.
- With rCHL, we obtain estimates of surface chlorophyll that are closer to observations that BAMHBI chlorophyll.
- Distributions of rCHL do not always capture observations, further calibration will be required for bloom periods.
- RT models allow to make a better use of reflectance products.
  - Model calibration and validation
  - Data assimilation (poster by P. Verezemskaya, Monday)

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