Operationally estimating the biogeochemical state of the North Atlantic through the assimilation of surface chlorophyll into a coupled ensemble simulation

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1. Introduction

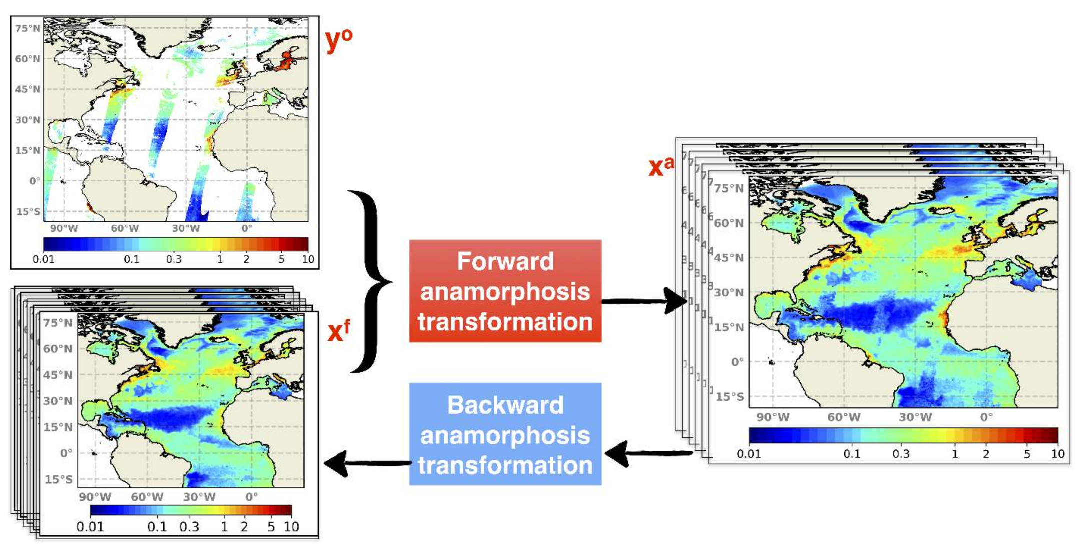
Estimating the **biogeochemical state of the ocean** is fundamental under the climate change context due to its key role mediating the global stocks of carbon. The optimal combination of observational data with the dynamical equations embedded in models through **data assimilation** [1] offers perspectives to produce data potentially more accurate and with a higher spatio-temporal coverage than that provided either by observations or models alone. In that framework, we daily integrate **satellite chlorophyll data** into a **high resolution probabilistic coupled model** with the aim of operationally provide the best possible estimates of the biogeochemical state of the ocean.

2. Methodology

One year of MERIS chl-*a* observations are daily integrated into a 24-members probabilistic configuration of a NEMO-PISCES simulation for the North Atlantic using an **ensemble approach** with the SEEK algorithm [2] to daily update the ensemble forecast. An analogous free run experiment is carried out for comparison purposes.

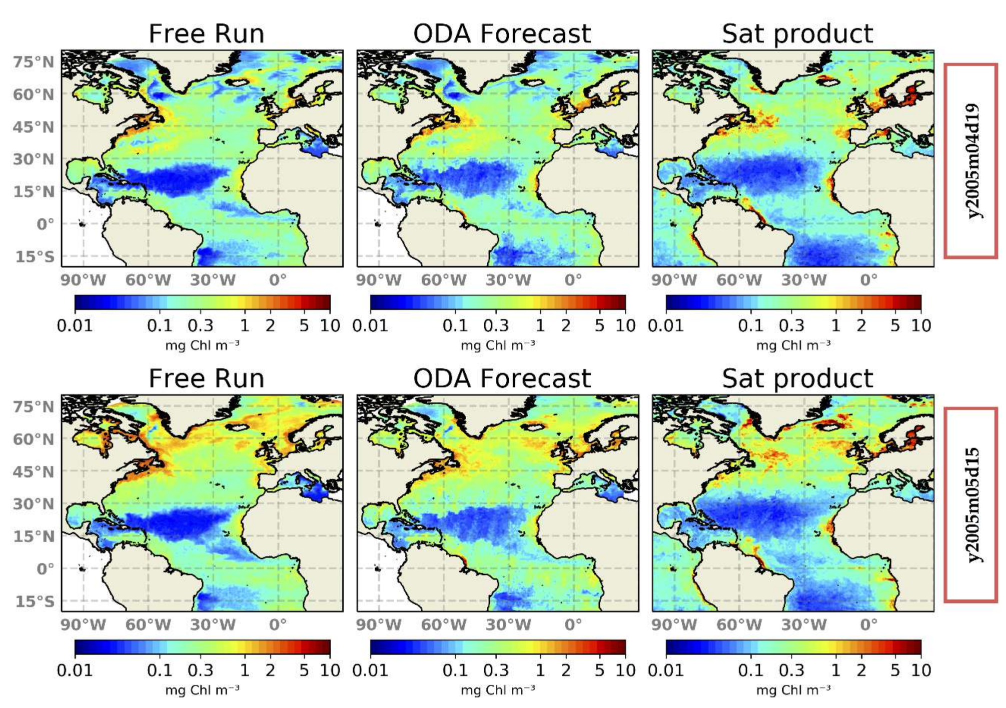
The assimilation scheme proceeds in two steps: (1) a **forecast** (x^f) in which each ensemble member is propagated using the full model equations, and (2) an **analysis** (x^a) in which the statistical information contained in the ensemble is combined with observations (y^o) to update the forecasted state vectors. Only biogeochemical variables are updated. The **multivariate** updated ensemble is used as initial conditions for the subsequent daily forecast.

To partially overcome the difficulty of working with non-Gaussian distributions, **anamorphosis transformations** are apply to both observations and each variable of the state vector prior to the analysis. Corresponding inverse transformations are performed after update.



3. Skills reproducing chl-*a*

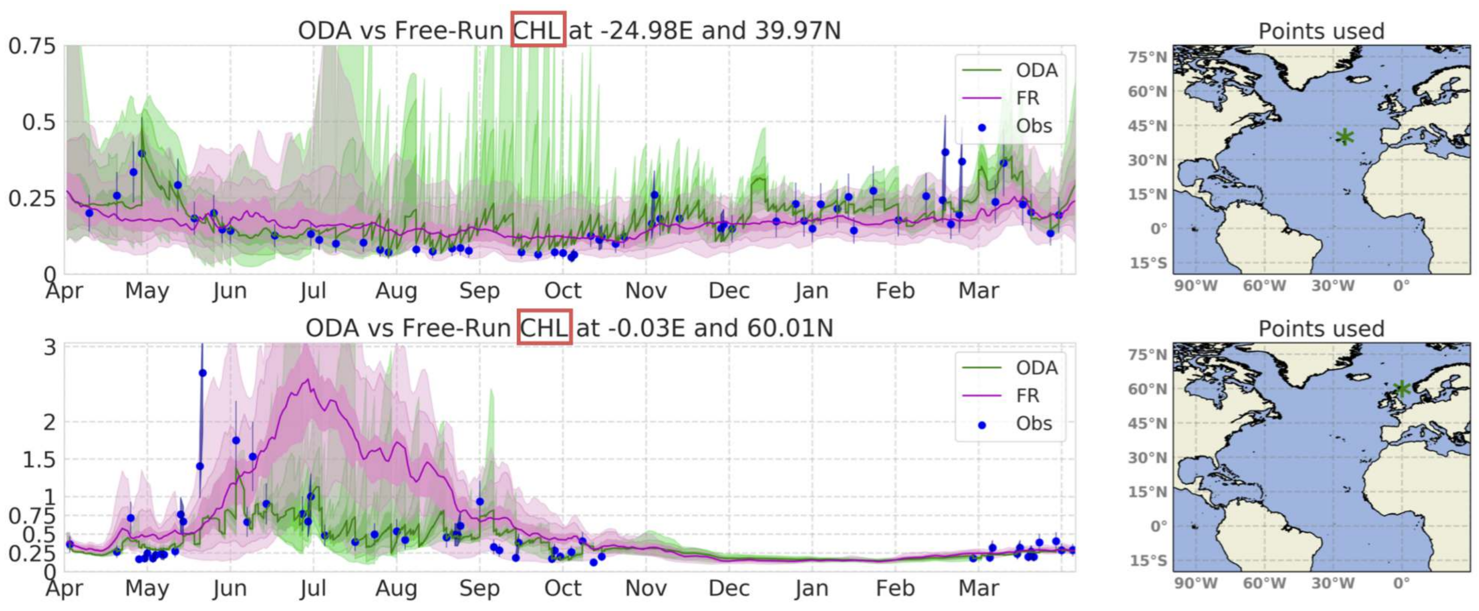
The **surface chl-*a* large-scale distribution is captured** by the simulation that improves several misfits associated with the free run. Main problems, however, arise in the subtropical gyre where a **too strong gradient** separates the oligotrophic conditions from temperate waters northwards. Previous non-assimilation studies [3, 4, 5] as well as the free run simulation display a similar misfit, suggesting that some issues occur with the coupled NEMO/PISCES model in that region.



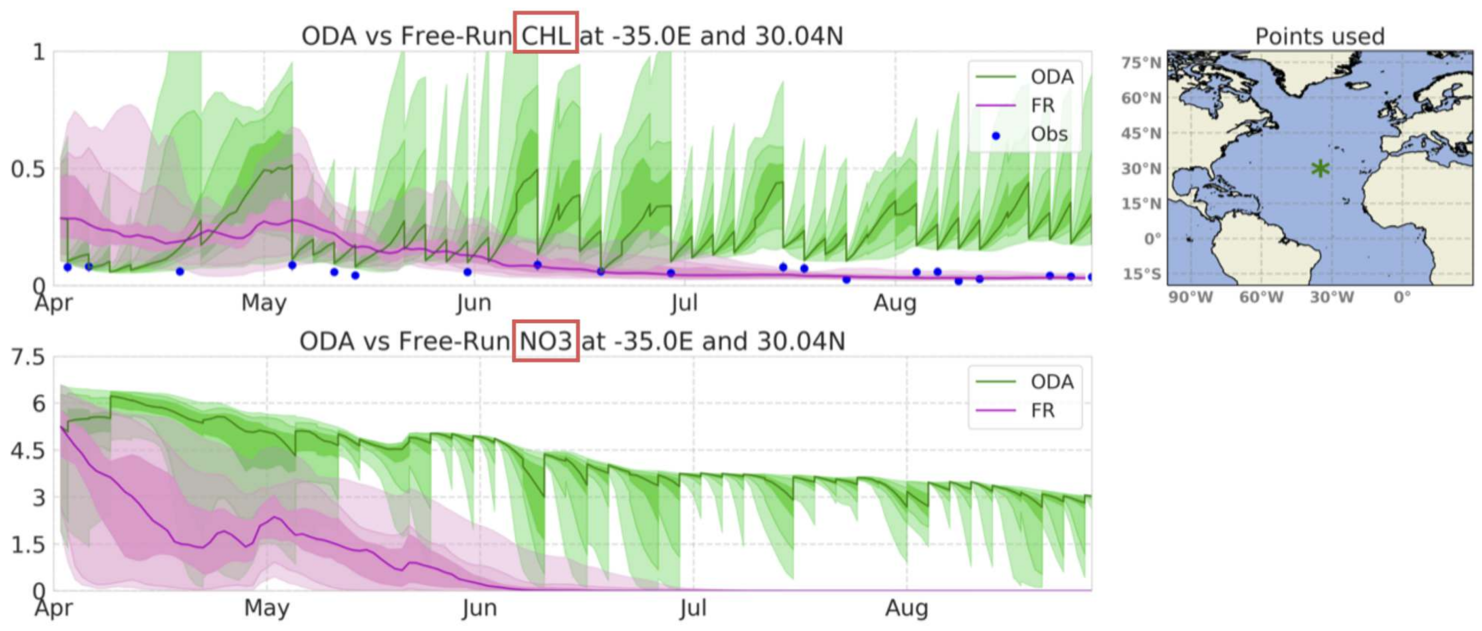
4. A daily updated probability distribution

Yearly time-series of quantiles (mean in bold) of the analysis and forecast ensembles (on green), and the free run (on magenta) show how their **probability distributions evolve in time**.

Depending on the particular area, the **assimilation system gains the MERIS information** every 6-7 days; an update frequency that is **coherent with the persistence of the assimilated information** within the forecast (∼1 week). The system digests the incoming info by **reducing drastically the spread**. The subsequent **forecast restores it** accordingly to match the satellite's for the next update. In general, the probabilistic simulation consistently generates a sufficient level of dispersion that **includes most of the information given by the observations** (blue dots).

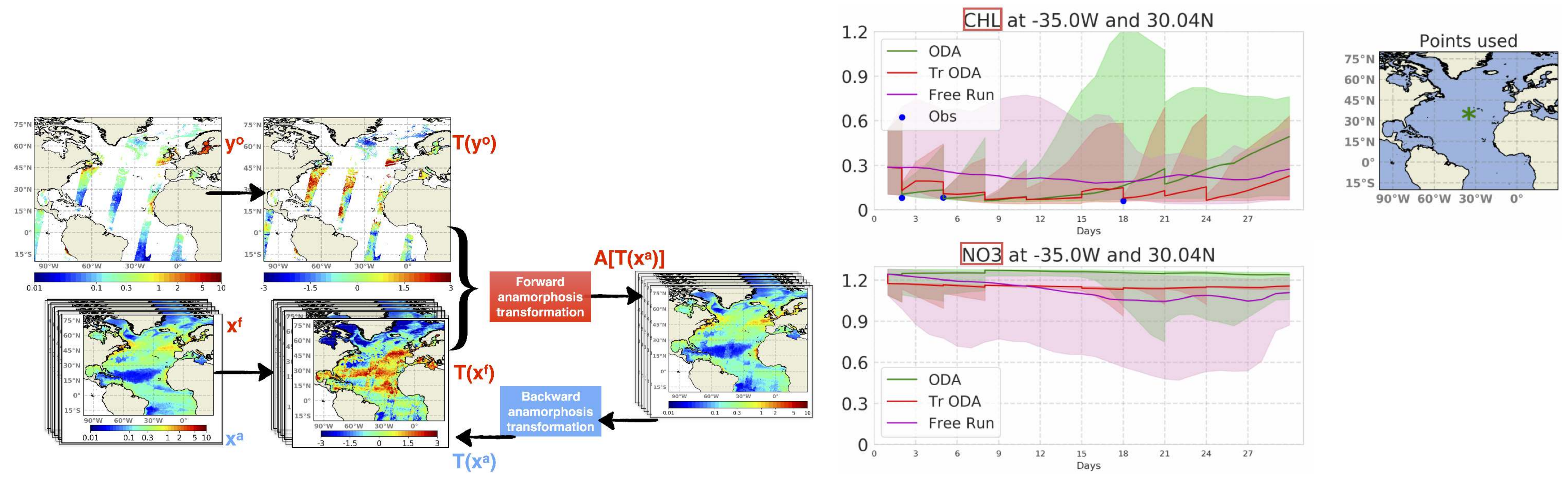


The assimilation of ocean colour data exhibits a variety of difficulties due to the **complex correlations between observed and non-observed variables** [e.g., 6]. In the transition zone between oligotrophic to temperate waters, an **imbalance between chl-*a* and nutrients** seems to be responsible for an overestimation of primary production.



5. Application of corrections to the fluctuating component

To deal with inconsistencies found in the system, we have implemented a methodology that permits to perform data assimilation only to the **fluctuating component** of the model. It consists on **applying** *time-independent* transformations to both the observations and the forecast ensemble using their respective **climatologies** prior to the analysis. Backward transformations are done after the update.



We expect these transformations **smooth out the influence of the assimilation** in those region where model attractors are too strong. In addition, transformations would presumably **increase the agreement between observations ($T(y^o)$) and forecast ($T(x^f)$) distributions** before entering the analysis update.

Preliminary results show corrections made on chl-*a* does not degrade correlations with nutrients in the region of interest.

6. Conclusions

1. A non-gaussian coupled ensemble assimilation system is performed representing the assimilation problem in probabilistic terms
2. It improves several misfits associated with non-assimilated solutions, indicating that the parameterizations used here are valid for a major part of the model domain
3. An imbalance between the observed variable and nutrients seems to be responsible for an overestimation of primary production at the transition zone between the North Atlantic subtropical gyre and temperate waters
4. To alleviate these inconsistencies, data assimilation is applied only to fluctuations in order to smooth the influence of the corrections on the equilibrium between model state vectors
5. First results show that nutrients are not overestimated in those regions where inconsistencies appeared

7. References

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