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Listen to the ocean

Uncertainty and observability of target ecosystem indicators within the operational system for the North-West European Shelf

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National Centre for Earth Observation
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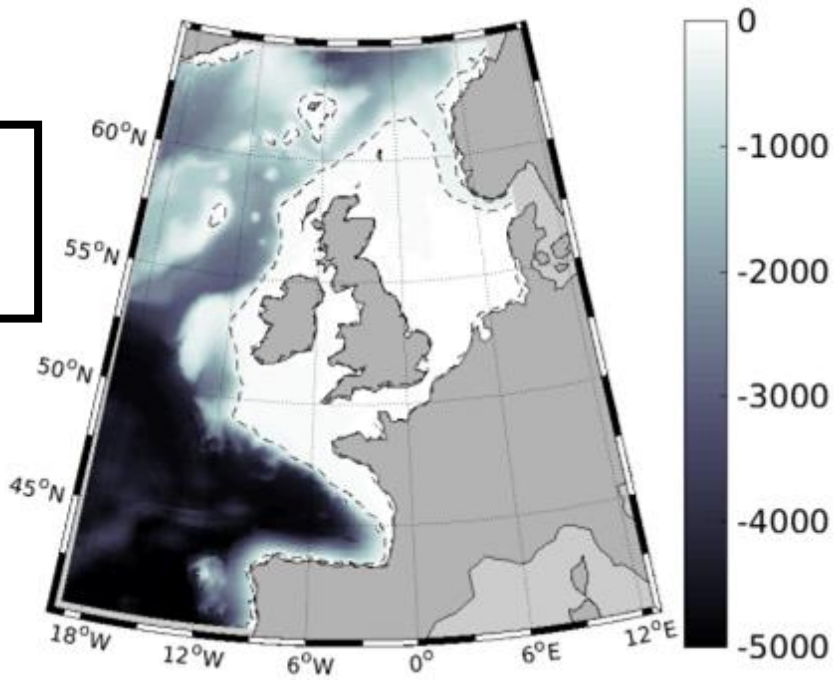
Existing system

NEMOVAR – 3DVar + FGAT, using parametrized background variances, monthly climatologies of an old ensemble run



Issues:

- reanalyses converge to assimilated observations
- poor estimates of uncertainties
- Q: is what we observe really so interesting from the ecosystem point of view?

The points of this work is to use ensemble DA to:

- better estimate the uncertainties of specific ecosystem health target indicators
- improve the estimates of key biogeochemical variables through better uncertainty estimates
- identify how observable are the target ecosystem health indicators through the standard observational data-sets

Target indicators:

- 1. **phytoplankton phenology** (timing and magnitude of bloom),
- 2. **depth-integrated net primary production**,
- 3. **near-bottom oxygen**,
- 4. **POC fluxes near the sea bottom/500m depth**,
- 5. **trophic efficiency** (depth-integrated total zooplankton carbon biomass / depth-integrated total phytoplankton carbon biomass),
- 6**. phytoplankton community structure** (depth-integrated total macrophytoplankton carbon biomass / total depth-integrated phytoplankton carbon biomass),
- 7. **pH**

Sources of uncertainty

- structural model uncertainties / model formulation, including resolution

very important source, but hard to address… needs multi-model ensembles… **x *don't represent***

- uncertainties in model inputs: initial value conditions, atmospheric/riverine forcing, boundary conditions

important source and much easier to address..

- *boundary values,* ***in development***
- *riverine forcing,* ***in development***
- *atmospheric forcing ..* ✓ ***do represent***
- *initial value conditions* **x *don't represent***

- uncertainties in model parameter values

- *bgc model can have many hundreds uncertain parameters (!),* ✓ ***do represent***
- *phys models have significant uncertainties e.g in vertical diffusion parameters* ***freshly included***

Types of uncertainty

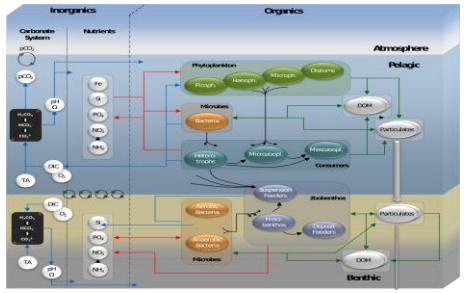
- associated with missing phenomena in the model, they can be represented by stochastic noise with a certain structure - frequentist

In reality: MIXED

- associated with lack of knowledge (e.g of parameter values) – Bayesian

Uncertainties represented Monte Carlo: prior PDFs are evolved with an ensemble of simulations

Model: NEMO – FABM – ERSEM
+ ensemble – NEMOVAR (3DVar) DA



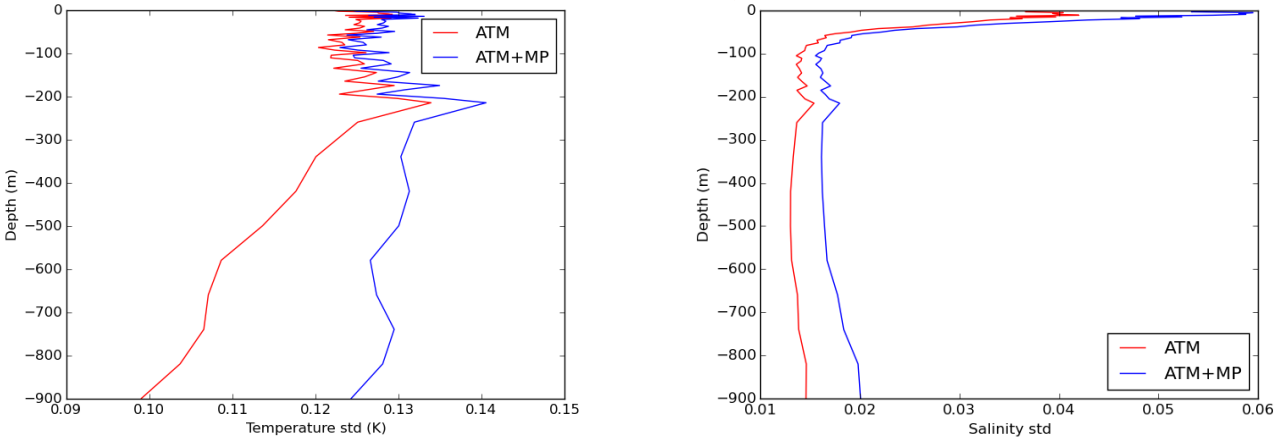
Developed for global domain and physics in *D. Lea et al (2022), QJRMS*, and adopted here for AMM7 and bgc DA. Bkg variances and lengthscales are here fully calculated from the ensemble (in horizontal we use localization lengthscales). The balancing module is retained from the current system.

Prior PDFs:

atmospheric - 10 member ERA-5 ensemble available, described prior directly
ERSEM parameters – 1D sensitivity analysis, based on which 6 most sensitive parameters were identified (3 for bacteria and 3 for diatoms). The priors were chosen to be uniform distributions on an interval of ±30% around the current value.
NEMO parameters – perturbations adopted from Lea et al (2022) of SPP and SKEB schemes (SPP perturbations were introduced to GLS scheme used at AMM7)

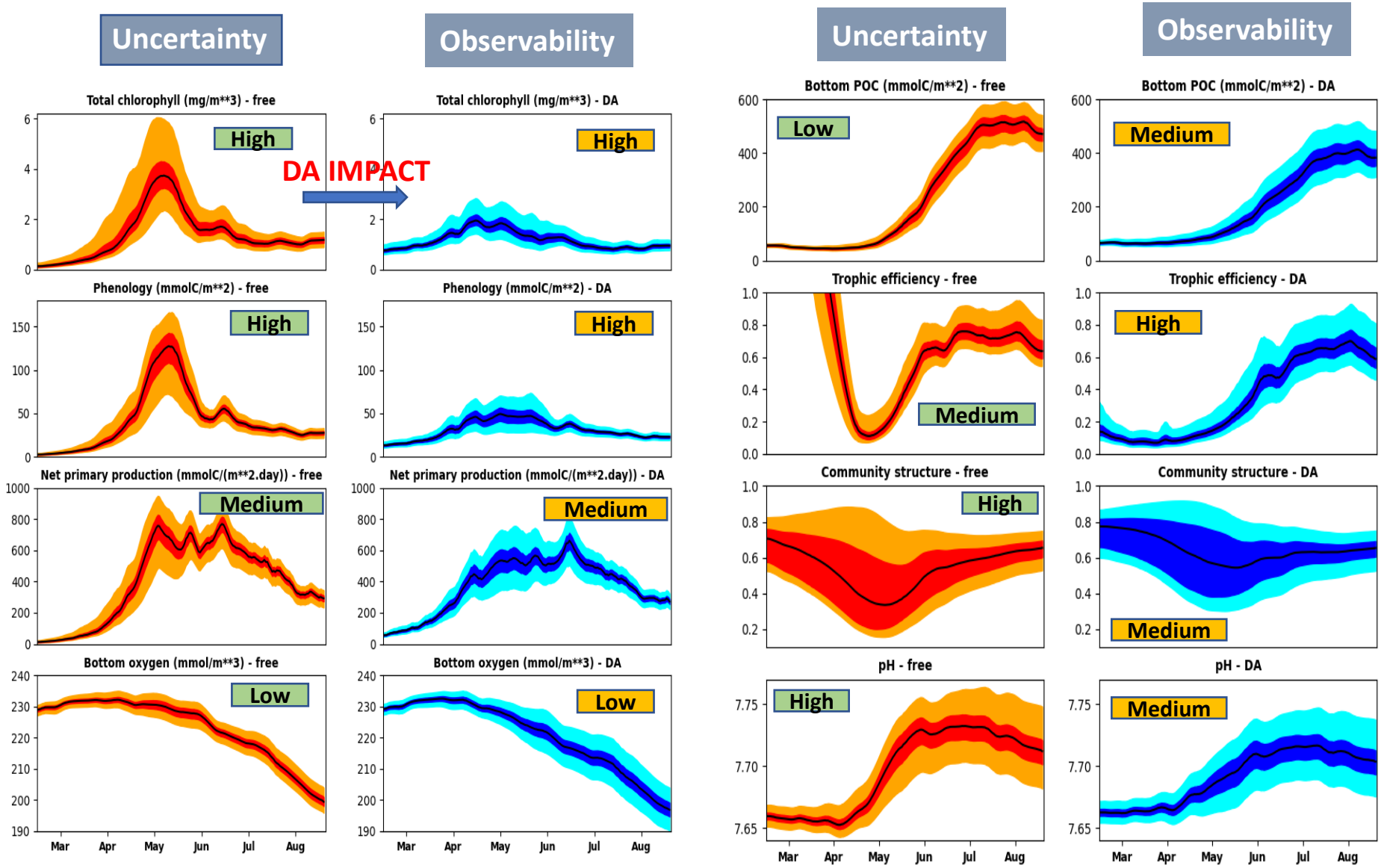
Relative impact of different sources of uncertainty

Phys ens spread vs phys perturb



Type of pert	*atmospheric*	*physical pars*	*bgc pars*
physical	Small-medium	Small-medium	small
biogeochem.	small	small	huge

Uncertainty and observability of target indicators in March – August 2018

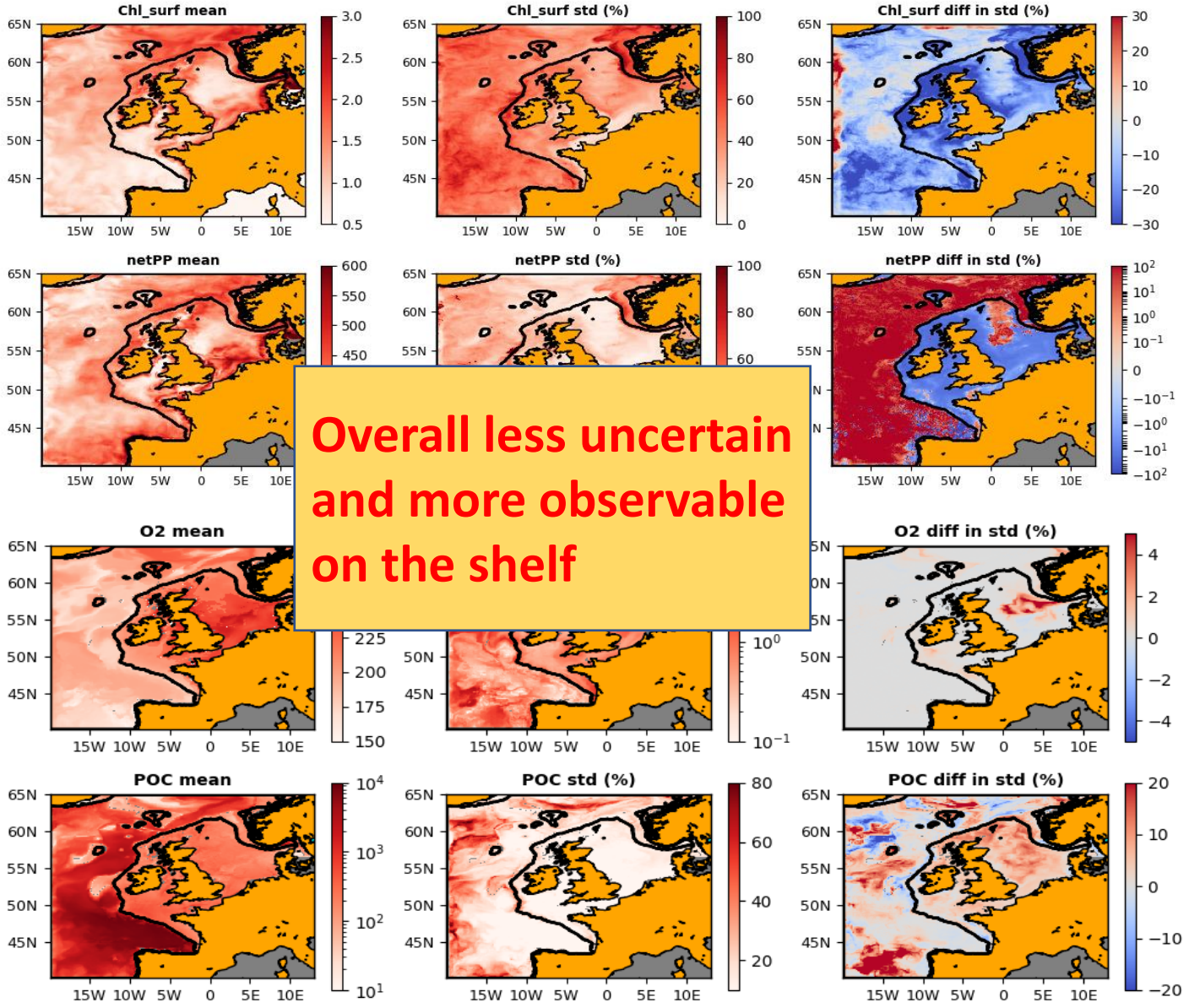


Chl

netPP

Bottom O2

Bottom POC

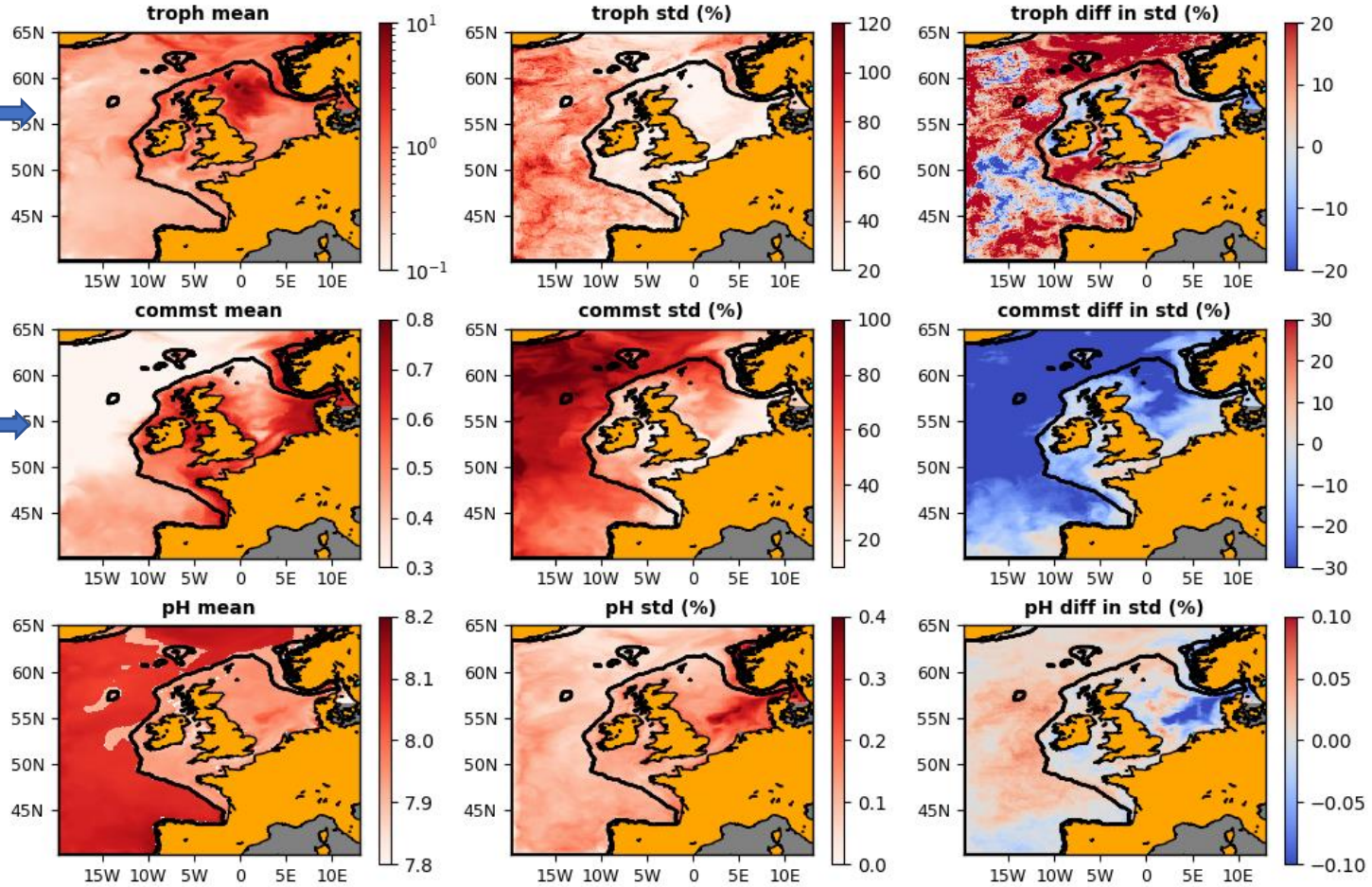


Overall less uncertain and more observable on the shelf

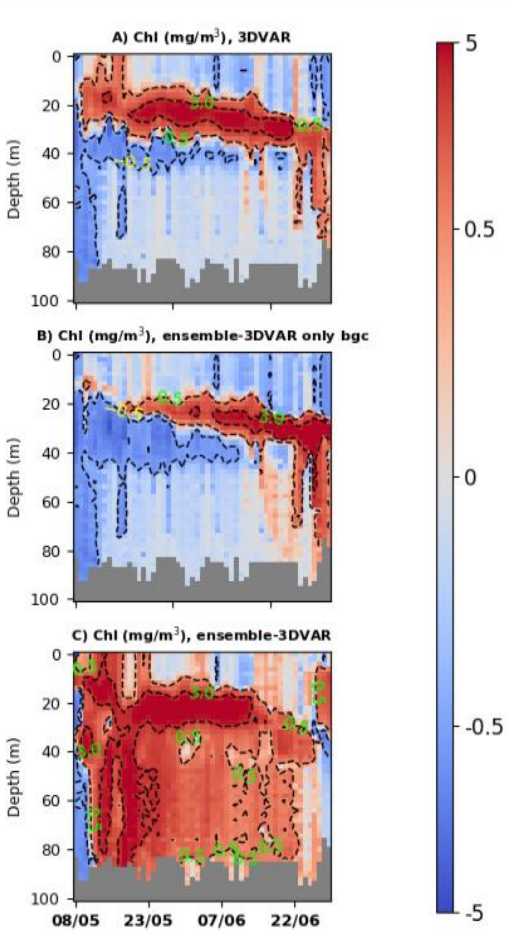
Trophic eff

Comm str

pH



What is the impact of the new ensemble-variational system on the re-analyses?



The ensemble-variational system constrains much less ``tightly'' the analysis state (it does not converge to the observations).

A ``paradox'': the chl RMSE is reduced when we turn from NEMOVAR to the new system, when only OC chlorophyll is assimilated, but it increases relative to NMOVAR when both physical data and OC chlorophyll are assimilated.
The explanation: physical DA degrades model skill in representing chlorophyll, but 3DVAR constrains chlorophyll very tightly with observations and removes this degradation. Since the ensemble-variational system is less constraining, the degradation is not removed and overtakes the initial improvement due to OC chlorophyll assimilation.

A classical problem of error-cancellation: Improvement in the estimates of uncertainties may lead to degradation in chlorophyll estimates !

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Conclusions:

Estimating uncertainties is a colossal task, but we are making important steps in the right direction…

<u>The target indicators were classified as:</u>

- **with high uncertainty:** phenology, community structure, pH
- **with medium uncertainty**: trophic efficiency, net primary production
- **with low uncertainty:** bottom oxygen, POC

<u>As for their observability through OC-CCI surface total chlorophyll:</u>

- **highly observable:** phenology, trophic efficiency
- **medium observable**: net primary production, bottom POC, community structure, pH
- **little observable**: bottom oxygen

- on the Shelf part of the domain the TI's are less uncertain and more observable….

Improved uncertainties have been shown to be capable to improve the DA skill of the system, but we need to overcome some error cancelations, i.e. negative impact of phys DA on certain key bgc tracers.

<u>Future work:</u> *short-term* - introduction of new types of perturbations, long term validation of the ensemble-3DVar system's impact on reanalysis, *long-term* – multivariable DA, strongly coupled phys-bgc DA

Thank you for your attention!
Questions, comments?