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Towards probabilistic analyses and predictions of the Green Ocean using a stochastic NEMO-PISCES modelling system

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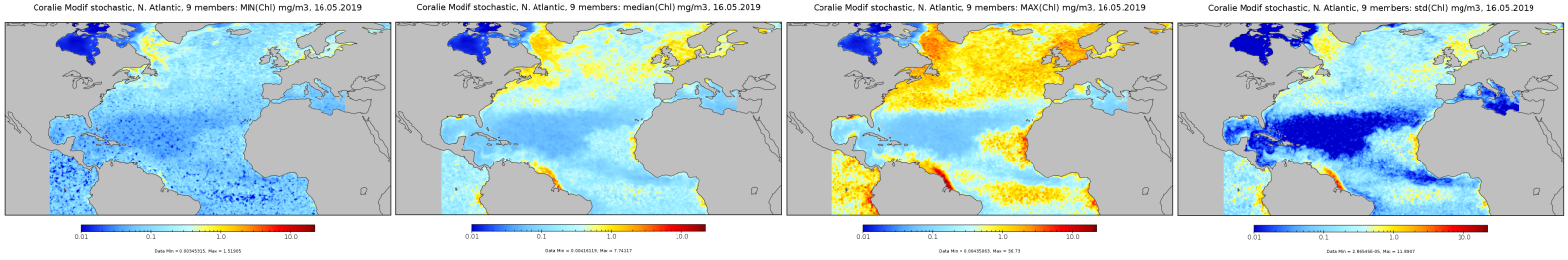
Context / motivations / goals

- H2020 SEAMLESS general objective and motivation : provide CMEMS with **robust modelling/assimilation methods** to deliver useful **indicators** of climate-change impacts and food security in marine ecosystems.
- Among the blocking points : Many **CMEMS MFC products** describing ocean ecosystems and BGC currently **do not include robust uncertainty estimates**.
- IGE team goals : Explore **innovative inversion methods to unlock pitfalls of CMEMS operational systems**, with a focus on GLO/IBI MFC "Green Ocean" applications, through:
  - ✔ Transition **from deterministic to probabilistic ocean BGC modelling** based on stochastic parameterizations of uncertainty sources, and
  - ✔ ...development of **ensemble-based inversion methods** dealing with non Gaussian pdfs to assimilate CMEMS L3 Ocean Colour data.

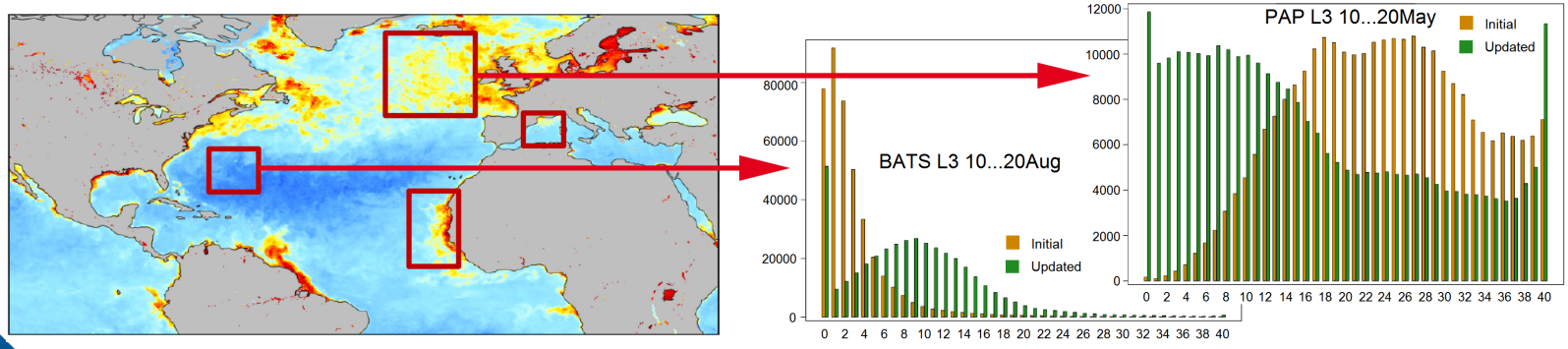
Methodology

Approach : ***Decoupling between (i) prior pdf generation using full-complexity physical/BGC model, and (ii) Bayesian inversion step*** (*including local anamorphic transformations, Brankart et al., 2012*)

(i) Prior pdf : 2019 GLO NEMO-PISCES 40-member ensemble NEMO-PISCES based on stochastic perturbations, assuming uncertain bio parameters, mesoscale feature locations and subgrid-scale processes (Garnier et al., 2016; Leroux et al., 2022).

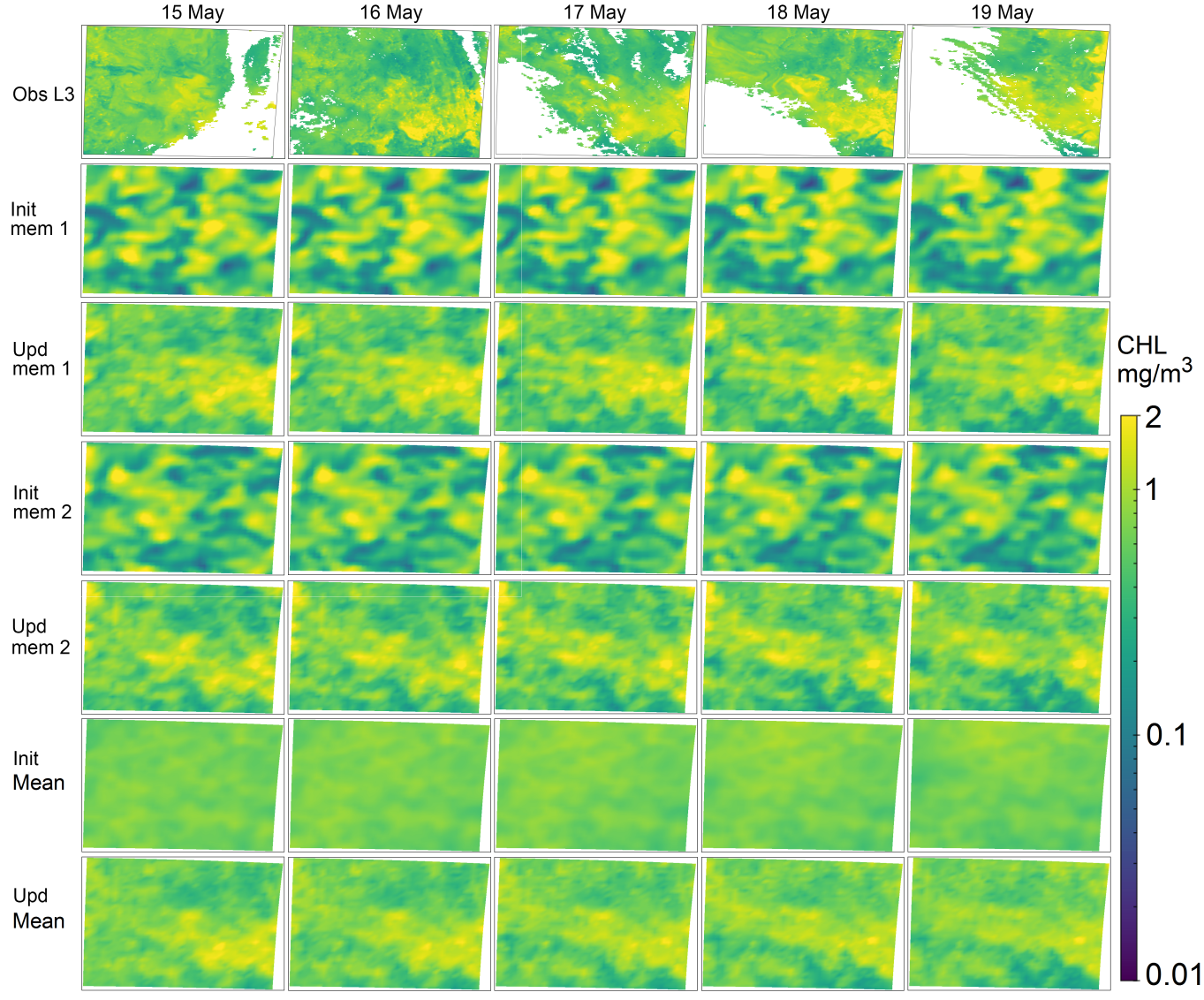


(ii) Posterior pdf : 4D multivariate regional inversions of L3 CMEMS OC data using LETKF/SEEK (smoother-like scheme with space-time localization).



Space-time estimation for PAP (16°30'W, 48°50'N)

Surface maps



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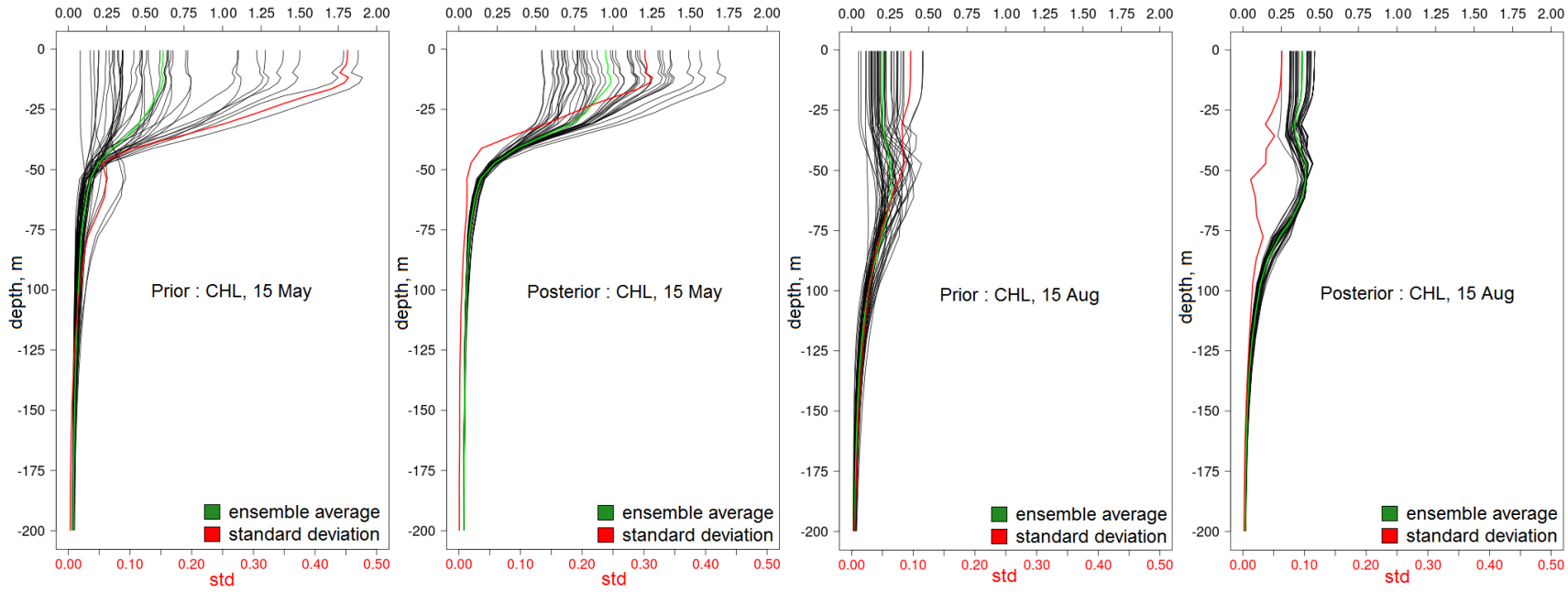
Space-time estimation for PAP (16°30'W, 48°50'N)

Projection of surface OC information on the vertical



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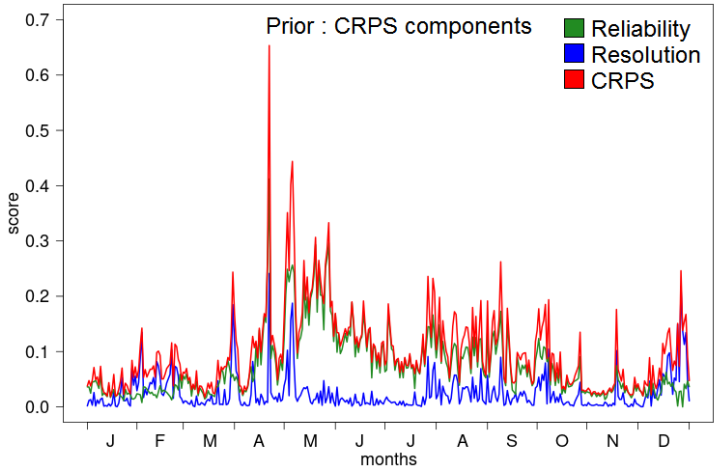
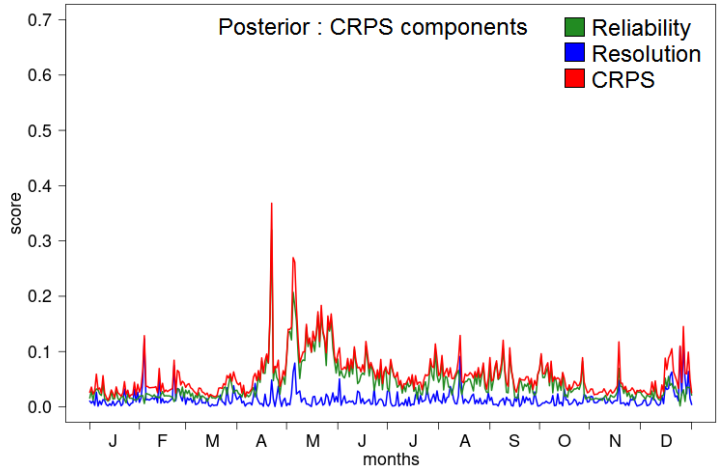
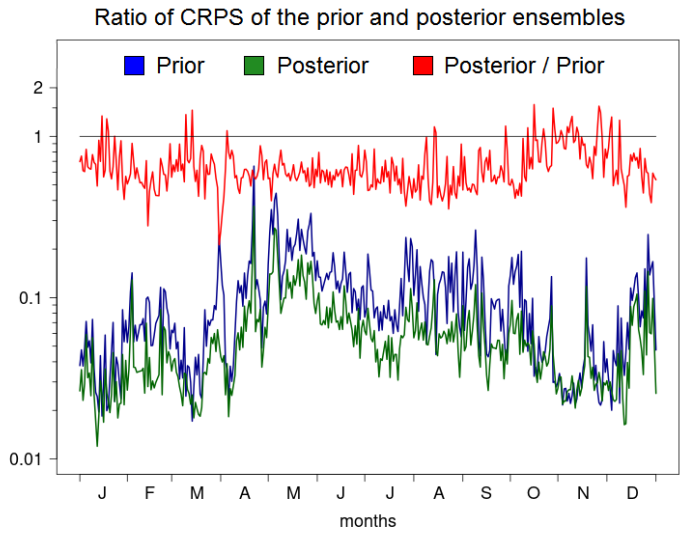
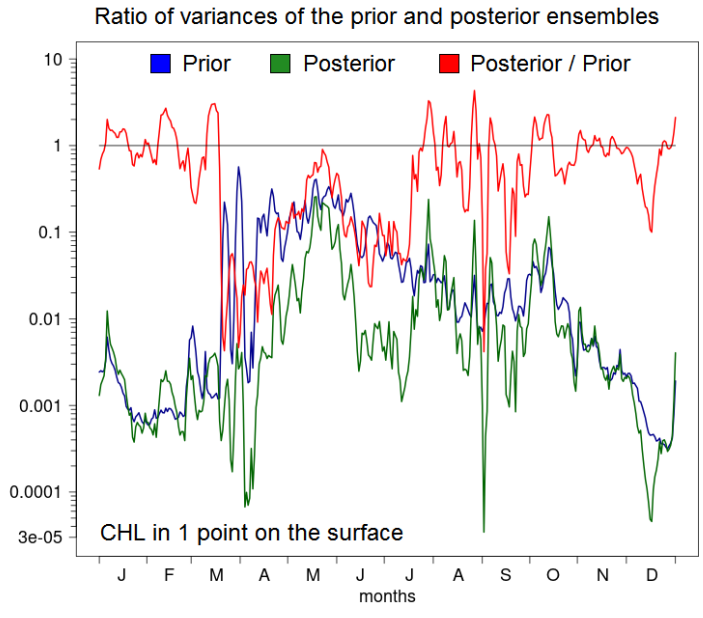
Metrics for PAP (16°30'W, 48°50'N)

Posterior/prior CRPS and ensemble variance in 1 point









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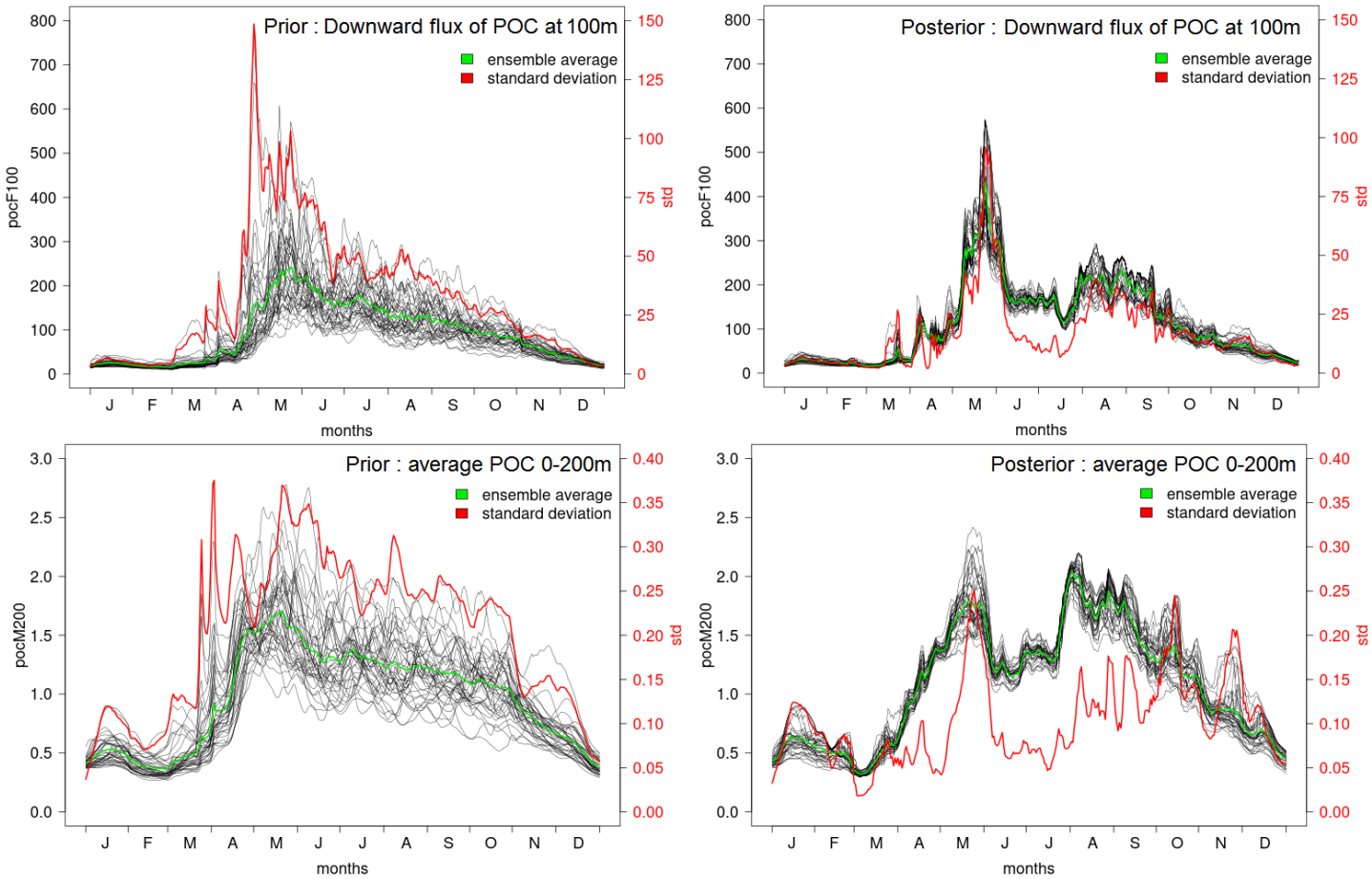
Uncertainty reduction for selected indicators

- ✔ Downward flux of Particulate Organic Carbon interpolated at 100m
- ✔ Average POC content, 0–200 m



Conclusions...

- A **new 4D space-time scheme** has been developed as a natural extension to sequential ensemble analysis/forecast in place today (such as LETKF) in CMEMS MFCs.
- **Controlability of key indicators** (POC, NPP, trophic efficiency) is demonstrated in PAP region, except for specific time periods. Other results (not shown here) suggest lower performance in BATS region.
- Accounting of additional (or **revising assumptions** about the) uncertainty sources in models and assimilated data is **part of the process**.
- The overall approach provides a **methodology to help decide whether to faithfully catalog a new product** with objective added value to users and scientists.

...and perspectives

- ✔ Ongoing : exploration of the skill of the method for **probabilistic forecasts** (and associated predictability time scales).
- ✔ Next step : **joint inversion of satellite ocean color and altimetric data**, bringing additional constraints and further reduction of uncertainties on estimated quantities.
- ✔ **Sensitivity to observation error statistics** needs further investigation.

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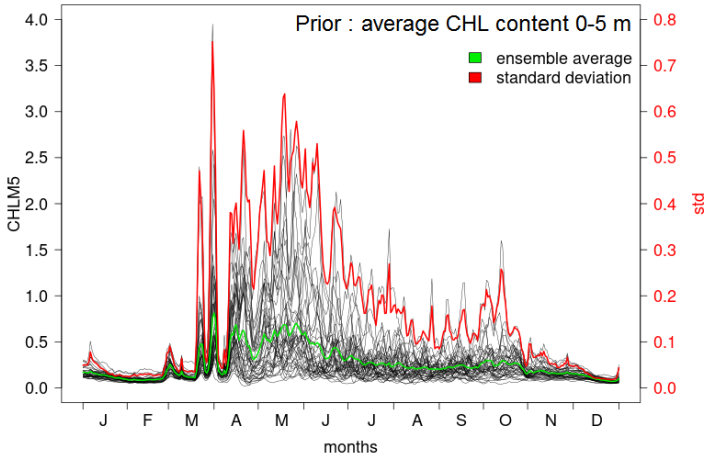
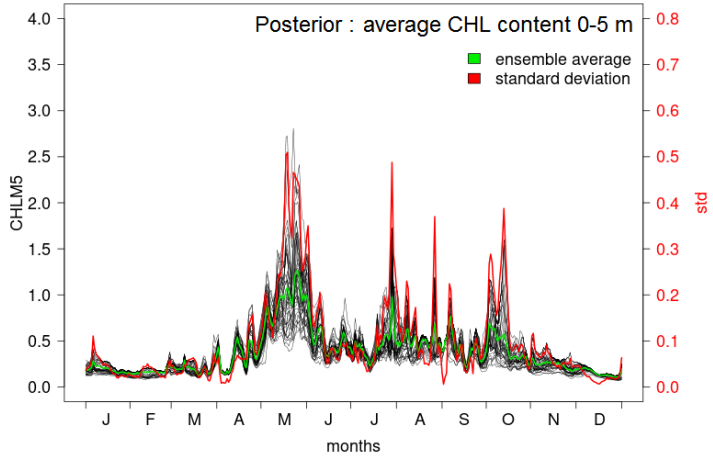
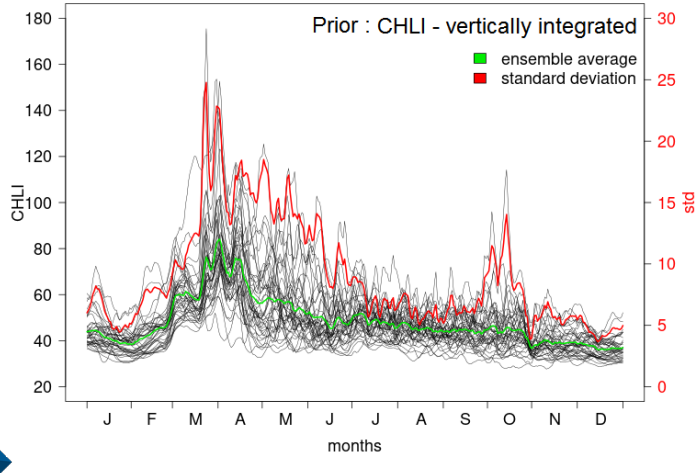
THANK YOU

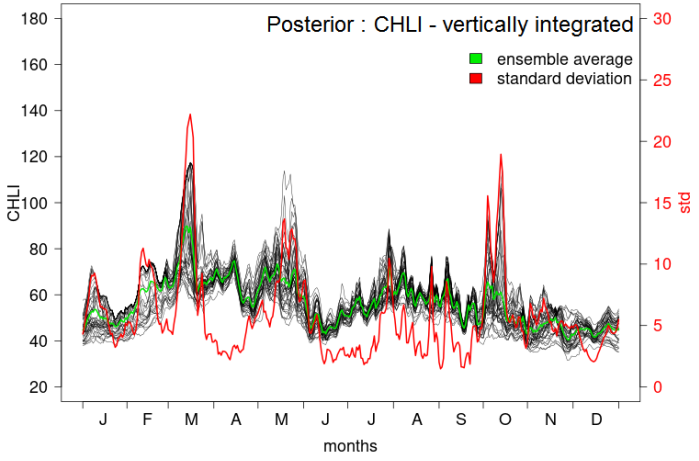
Appendix: Uncertainty reduction for selected indicators

- ✔ Chlorophyll average (0–5 m)
- ✔ Chlorophyll - vertically integrated (0 – bottom)









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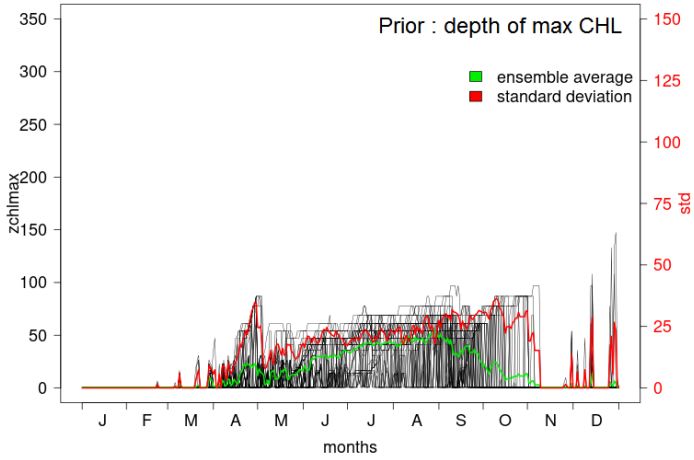
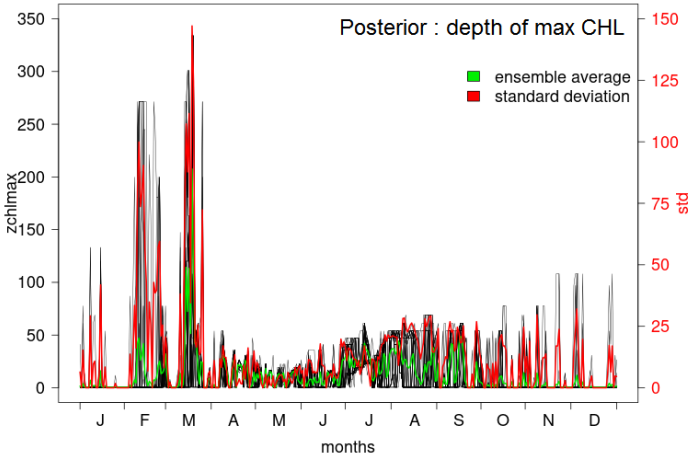
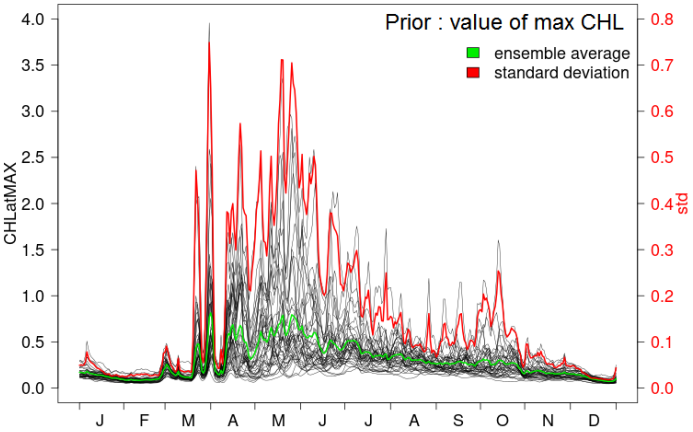
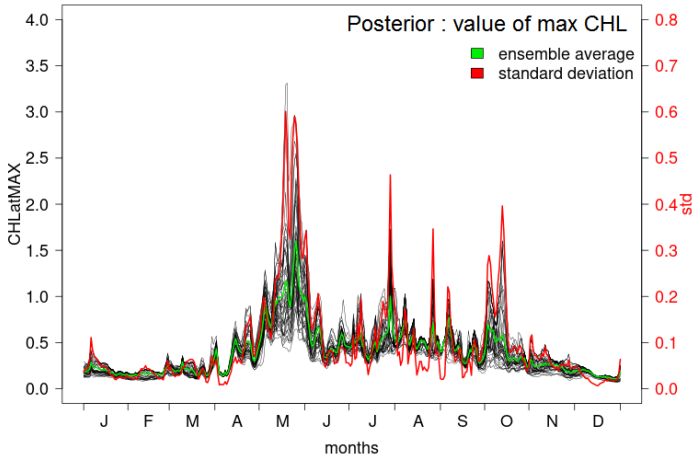
Appendix: Uncertainty reduction for selected indicators

- ✔ Depth of Max CHL (straight computation)
- ✔ Max CHL along the vertical









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Appendix: Uncertainty reduction for selected indicators

- ✔ Average (DIA/PHYTO) where TotPhyto>0.01
- ✔ Depth of max nitracline gradient