Ensemble consistency analysis in coastal ecosystems: the Bay of Biscay paradigm

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2018 GODAE OceanView Meeting | COSS-TT ICM6 | Puertos del Estado, Madrid, Spain | 19-21 September, 2018

CMEMS Service Evolution “SCRUM” project

- Which are the main physical/biogeochemical model **uncertainties** in regional and coastal systems and how can we estimate them? (MFCs)
- How can we **validate/repeal** Ensemble uncertainty estimates? (MFCs)
- Which **observations** are most useful to validate them? Are the current observational arrays fit for the validation of ensembles? (TACs)
- Can we illustrate the potential **benefit** of multivariate ensemble-based uncertainties in real DA systems? (MFCs & TACs)

➔ Develop appropriate R&D in NEMO-PISCES
➔ Apply in a subgrid of IBI36 in the Bay of Biscay

The poster

- The poster shows preliminary results! Work is ongoing.
- Are uncertainty estimates one can get from Model Ensembles consistent with “model minus data” uncertainty estimates? Which patterns are consistent/inconsistent?
- The poster concentrates on Chlorophyll, via two different data products: OCL3 and PFTs (Phytoplankton Functional Types)
- Differences wrt. data product used: OCL3 vs. PFT
- Differences wrt. perturbations in Ensemble: physics, bgc, both
- Differences between shelves and deep ocean

Ecosystem Model Ensembles

- Seasonal-range Ensembles of 40 members with NEMO-PISCES

- $$\partial_t C = \overbrace{\overbrace{-\underbrace{\nabla(u \cdot C)}_{advection} - \underbrace{K_h \nabla_h^2 C}_{\substack{horizontal\\ diffusion}} - \underbrace{\partial_z(K_z\, \partial_z C)}_{\substack{vertical\\ diffusion}}}^{Ens1} + \overbrace{\underbrace{SMS(C)}_{biology}}^{Ens2}}^{Ens3}$$
  - Ens1: perturbing physics
  - Ens2 perturbing bgc
  - Ens3 perturbing both

- Production of Ensembles based on an SPPT-AR1 stochastic approach
  - 1st order auto-regressive processes: $\xi(t+1)^i = a \cdot \xi(t)^i + b \cdot w + c$
  - $a = e^{-\frac{1}{\tau}}$, $b = \sigma \cdot \sqrt{1 - \alpha^2}$, $c = \mu \cdot (1 - a)$

Chl observations

- OC technique exploits different radiation wavelengths and reflectances emerging from the sea surface, affected by phytoplankton and corresponding to different water types.

- The **OCL3** surface total chlorophyll is produced for the Global Ocean in the framework of the ESA Climate Change Initiative (CCI) programme, made available through CMEMS.
  - This is a merged data records product from multiple sensors and ocean satellite passages provided in gridded format at $4\ km$ resolution. The spatial coverage has data gaps.
  - The data are daily composites created by accumulating all data from a given sensor for a particular day, band shifting MERIS and MODIS-Aqua bands to the SeaWiFS bands, and “merging” all data available for that day (whether from SeaWiFS, MODIS-Aqua and/or MERIS).

- Phytoplankton Functional Type (**PFT**)-based data are experimental OC products, providing fractions of size classes corresponding to pico, nano, diatoms and dino.

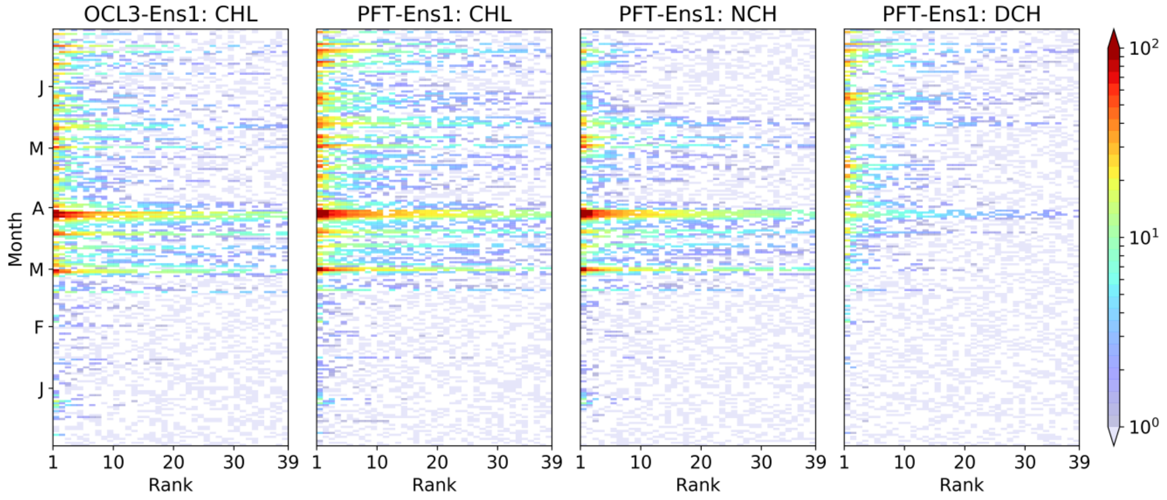
Array-space consistency analysis (ArMCA)

- Compare Ensemble of innovations with Ensemble anomalies + observational noise
- Do this in the space described by **array modes** = eigenmodes of the Representer Matrix = “antenna modes” of the array
  - Le Hénaff, M., P. De Mey and P. Marsaleix, 2009 : Assessment of observational networks with the Representer Matrix Spectra method – Application to a 3-D coastal model of the Bay of Biscay. Special Issue of Ocean Dynamics, 2007 GODAE Coastal and Shelf Seas Workshop, Liverpool, UK. Ocean Dynamics, 59, 3-20.
  - Lamouroux, J., G. Charria, P. De Mey, S. Raynaud, C. Heyraud, P. Craneguy, F. Dumas and M. Le Hénaff, 2016: Objective assessment of the contribution of the RECOPESCA network to the monitoring of 3D coastal ocean variables in the Bay of Biscay and the English Channel. Ocean Dynamics, 66(4), 567-588, http://dx.doi.org/10.1007/s10236-016-0938-y.
  - Charria, G., Lamouroux, J. and P. De Mey, 2016: Optimizing observational networks combining gliders, moored buoys and FerryBox in the Bay of Biscay and English Channel. Journal of Marine Systems, 162, 112-125, http://dx.doi.org/10.1016/j.jmarsys.2016.04.003.
- Use modified version of **ArM tools** from the SANGOMA toolbox (De Mey, 2015)
- Main interest: see which **uncertainty patterns** are consistent and which are not
  - Hovmöller diagrams of **SRM spectra**, incl. **ArM-CA consistency criterion** with tolerance=10% -- see Final Report for mathematical details
  - **Examples** of consistent and inconsistent array-space patterns.

How Chl data "see" model uncertainties

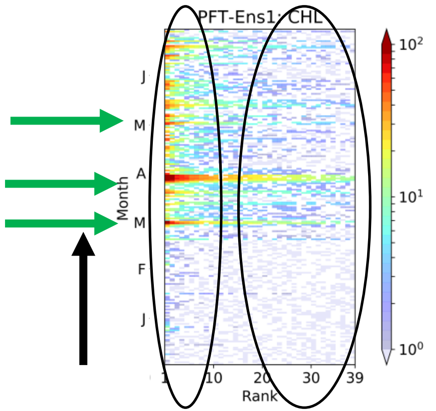
Ensemble Consistency Hovmöllers along array modes, f(ArM rank)

Chl ArM spectrum (t) – white cell = inconsistent (ArM consistency criterion)



Each ArM rank is associated with a pattern = eigenmode of SRM ➔ patterns (see poster)

Key: example of PFT Chl



- Statistical dominant error patterns in first ranks (mostly open-ocean large scale processes) appear consistent between Ensemble and model-data innovations
- Inconsistency (white areas, mostly in spectrum tails) means that other error processes, in addition to the ones generated in our stochastic protocol, must be active in the model (mostly small scale processes)
- ~3 months statistical ecosystem spin-up time, especially during winter with low primary production.
- RM spectra exhibit strong time variations, with peaks corresponding to “differential blooms” across the ensemble