OceanPredict
Advancing the science of ocean prediction

Copernicus
Marine Service

Joint OP MEAP-TT / CMEMS BGC-DA meeting

"Ensemble generation and evaluation“

Agenda

- Welcome (Katja, Stefano, Julien, Annette)
- Intro to "Ensemble generation and evaluation" topic (Chris and Paul, ~10 minutes)
- Science talk "*Ensemble generation and evaluation for monitoring and forecasting the Green Ocean*" (Pierre Brasseur, ~20 minutes)
- Round of 1-slides (MEAP/BioDA-WG members: max 2 minutes each)
- Discussion (~30 minutes)
- AOBs (MEAP quad, UN Ocean Decade, next meeting)

MEAP Terms of reference

Mission: Advancing the underpinning science and tools for integration of biogeochemical and ecosystem models into operational systems.

A broad definition of **operational** products that includes:

- Climate projections
- Hindcasts/reanalyses
- Short-term & seasonal forecasts
- Scenarios

See rationale in our OceanObs WP at: https://doi.org/10.3389/fmars.2019.00089

Major scientific and societal applications:

1) Carbon cycle research, carbon accounting

- Quantification of carbon uptake
- National carbon accounting
- Sensitivity of carbon fluxes to climate forcing, shifting baselines
- Climate projections

2) Marine productivity/ecosystems

- Fisheries management
- Conservation of endangered species
- Design of MPAs
- Future projections for ecosystems
- Marine health indicators (eutrophication, acidification, deoxygenation)

Objective, structure & members

CMEMS Copernicus Marine Environment Monitoring Service

- implemented and operated by Mercator Ocean
- provides oceanographic products and services for maritime safety, coastal and marine environment, climate and weather forecasting and marine ressources users.
- embeds pan-European PHY + BGC analysis and forecasting systems and observation dataset production centers

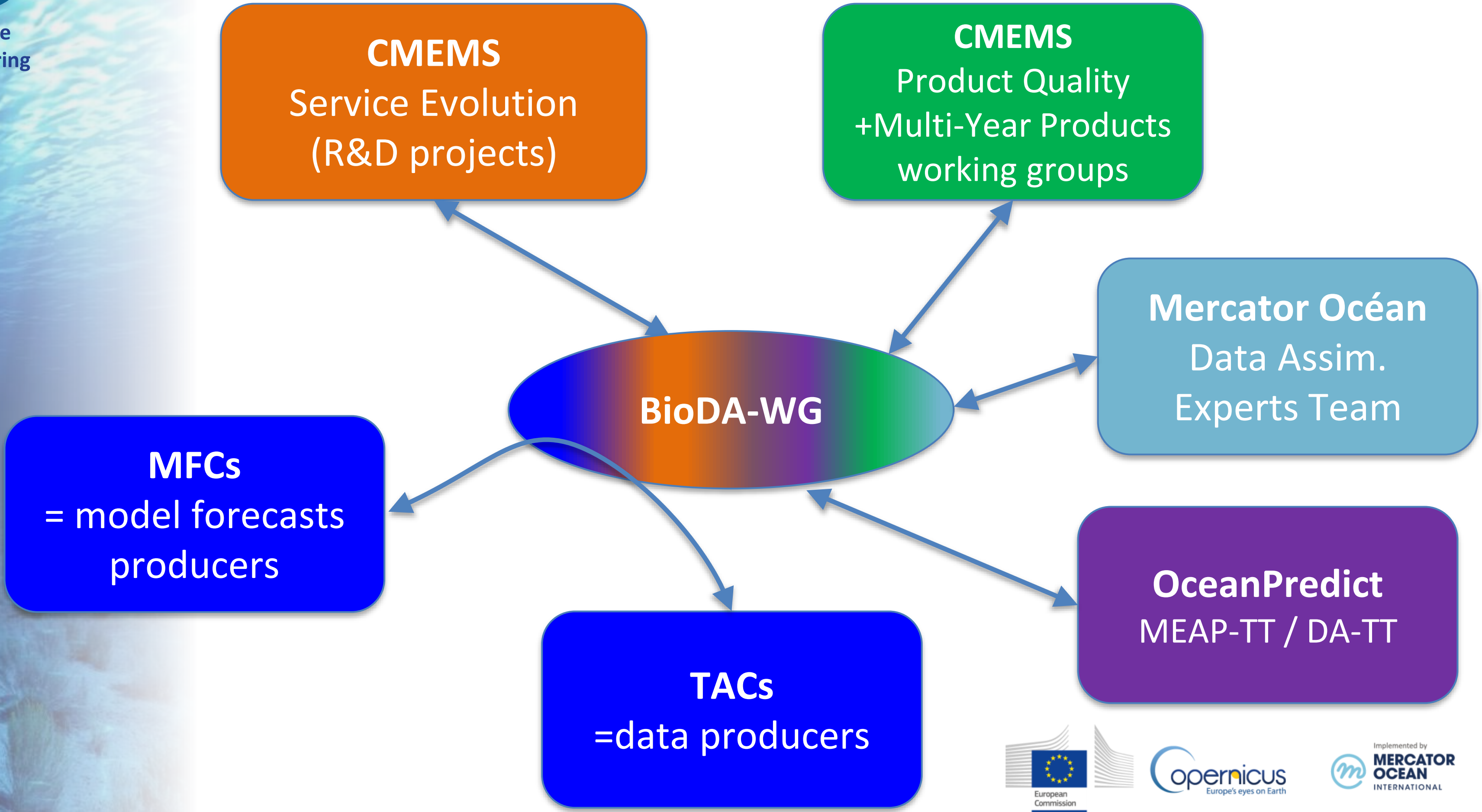
→ BGC Data Assimilation Working Group

Objective, structure & members

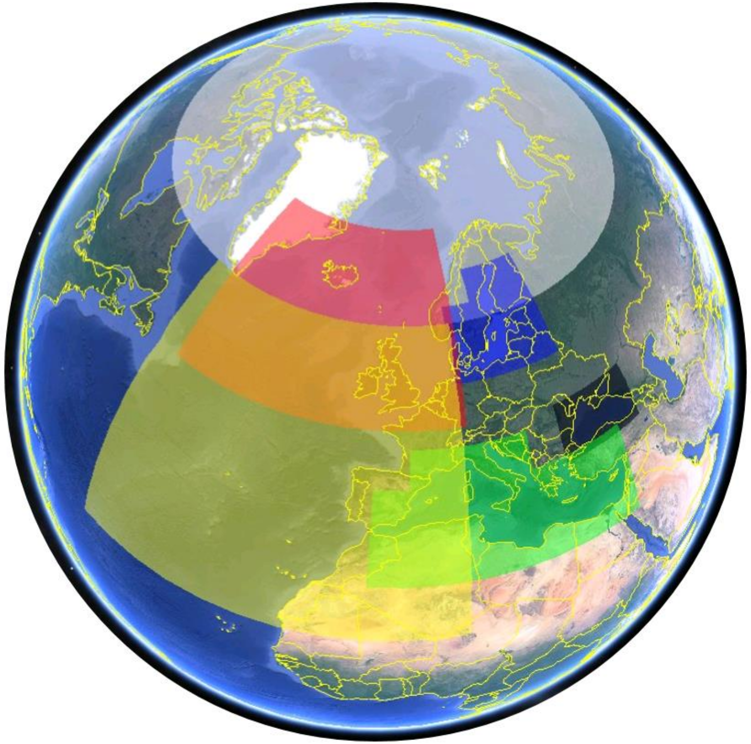
A BGC Data Assimilation Working Group in CMEMS: what for ?

- **Share experiences** on BGC data assimilation, e.g. methodologies, metrics, tricky points, etc.
- **Advocate / Provide visibility** to some important messages/requirements, e.g. need for in situ data with a global coverage, high-value and NRT data QC, impact of Physical Data Assimilation on models' BGC processes, etc.
- **Assess and improve the use of novel BGC data sets** e.g. BGC-Argo, Sentinel, PFTs, optical data, etc. – for assimilation and validation purposes ➔ strengthening links with BGCArgo community
- **Provide recommendations** for future evolutions of CMEMS BGC DA systems

Objective, structure & members



Objective, structure & members



ARC-MFC	Tsuyoshi Wakamatsu, Annette Samuelsen (NERSC)
BAL-MFC	Wibke Düsterhöft-Wriggers, Ina Lorkowski (BSH)
BS-MFC	Luc Vandenbulcke, Marilaure Grégoire, Arthur Capet (ULG)
GLO-MFC	Julien Lamouroux, Coralie Perruche, Alexandre Mignot (MOi)
IBI-MFC	Elodie Gutknecht (MOi), Marcos Garcias-Sotillo (PdE)
MED-MFC	Gianpierro Cossarini, Anna Teruzzi (OGS)
NWS-MFC	Stefano Ciavatta, Josef Skakala (PML), David Ford (MetOffice)
INS-TAC	Henning Wehde (IMR), Sylvie Pouliquen, Thierry Carval (IFREMER)
OC-TAC	Antoine Mangin, Marine Bretagnon (ACRI)
MOB-TAC	Raphaëlle Sauzède, Hervé Claustre (LOV), Stéphanie Guinehut (CLS), Trang Chau (LSCE)

Co-chair: Annette Samuelsen (NERSC/ARC-MFC) and Julien Lamouroux (MOi/GLO-MFC)

Meetings: from 2020, quarterly online meetings

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Ensemble generation

David, Met Office

- Not yet done for BGC, under development for physics
- Main aim is to develop hybrid ensemble-3DVar
- Physics approaches:
  - Use ensemble of atmospheric fluxes (from NWP or ERA5)
  - Stochastic physics (developed for NEMO by Andrea Storto at CMRE)
  - Perturb observations, river inputs, etc
- Potential BGC approaches:
  - Use and build on approaches above
  - Perturb parameters
  - Perturb model formulation (Anugerahanti et al., 2018, Biogeosciences)
  - See also Stefano/Jozef's slide

Jozef, PML

Ensemble plans in SEAMLESS project:

State of the art: Currently physical NEMO ensembles available on Met Office (MonSOON) systems for the NWES domain. They are based on 9 member (1 higher, 8 lower resolution) ensemble of ERA5 atmospheric forcing product. There is an alternative capacity to perturb forcing products (e.g. creating 30 members). Some work is being done on including riverine input perturbations and perturbing observations in the assimilation.

The existing capacity has been now expanded to include (spatio-temporally constant) perturbations of ERSEM biogeochemical model parameters. Early tests have shown that perturbing some selected parameters (4 PFT max chl-to-C ratios) by up to 30% increases in the free run the ensemble spread (on the weekly time-scale) roughly four-fold when compared to using only the ERA5 ensemble.

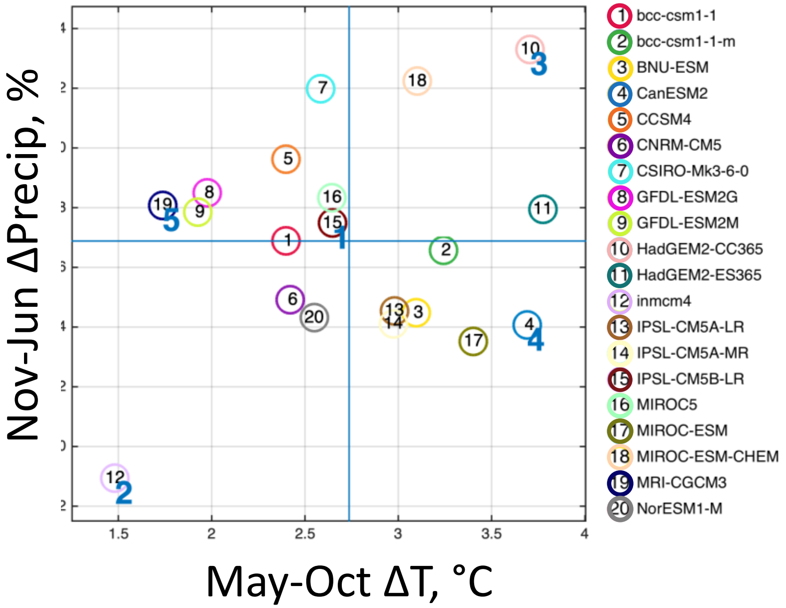
We will perform comprehensive sensitivity tests in 1D configuration, determine the SEAMLESS target indicators and parameters of highest sensitivity and include those perturbations in the 3D configuration along the atmospheric forcing ensemble. We will also consider implementing a scheme for 3D spatio-temporally varied parameters.

Projections of future Chesapeake Bay hypoxia: Impact of changing watershed loads

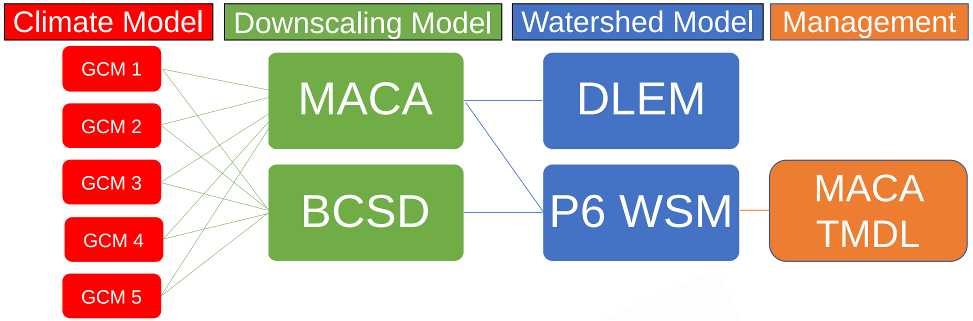
Kyle Hinson & Marjorie Friedrichs
Virginia Institute of Marine Science

Two Downscaling Models
Two Watershed Models
Two Management Scenarios

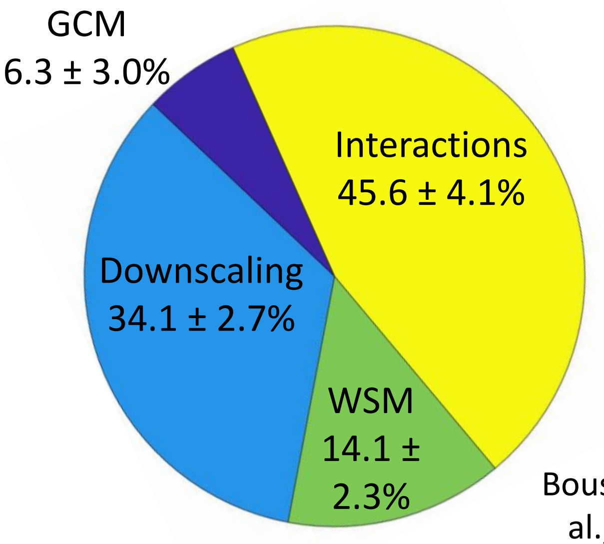
Select 5 GCMs



KKZ methodology
(Ross & Najjar, 2019)



Annual Hypoxic Volume



Boushard et al., 2013

Marjy, VIMS

Emlyn, CSIRO

- We have 6 parameters which we consider uncertain.
- We take a 100 samples from a 6 dimensional log-normal prior.
- Spin the model up for 6 months,
- Commence the data assimilation.
- We augment the 100 dynamic members with a further 120 static members to prevent ensemble collapse
- We use the EnKF-C software in our assimilation system.

Ensemble generation on ARC MFC BGC reanalysis system

Tsuyoshi Wakamatsu, Laurent Bertino, Annette Samuelsen
The Nansen Center (NERSC), Bergen Norway

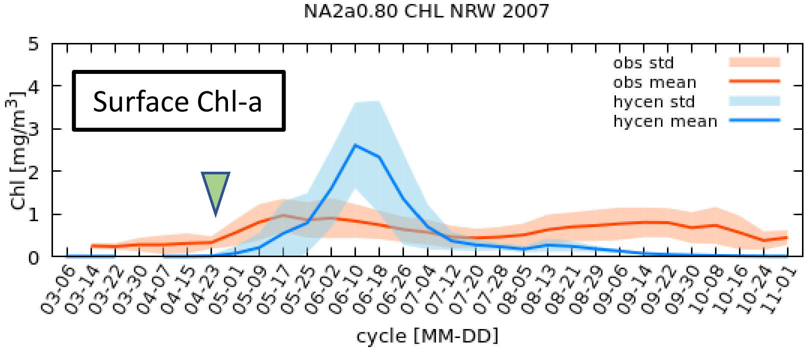
Stochastic Components for Ensemble Generation (**PHY BGC**):

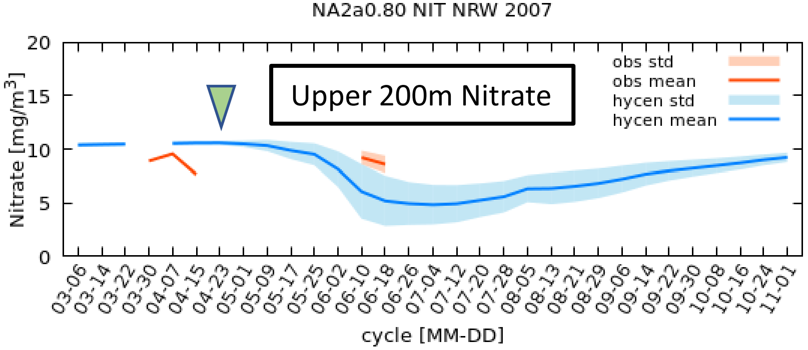
1 year integration with **wind forcing**, **initial T and S profiles (layer depths in Hycom)**
downward shortwave radiation, **BGC parameters (growth/mortality rates etc.)**

Spring Bloom Onset Timing (▽) in observation is significantly earlier than what deterministic/probabilistic model predicts.

Current ARC MFC probabilistic model does not produce enough ensemble spread during pre (model) Spring Bloom Onset.
> DA can not assimilate surface Chl-a and correct nutrients in meaningful way.

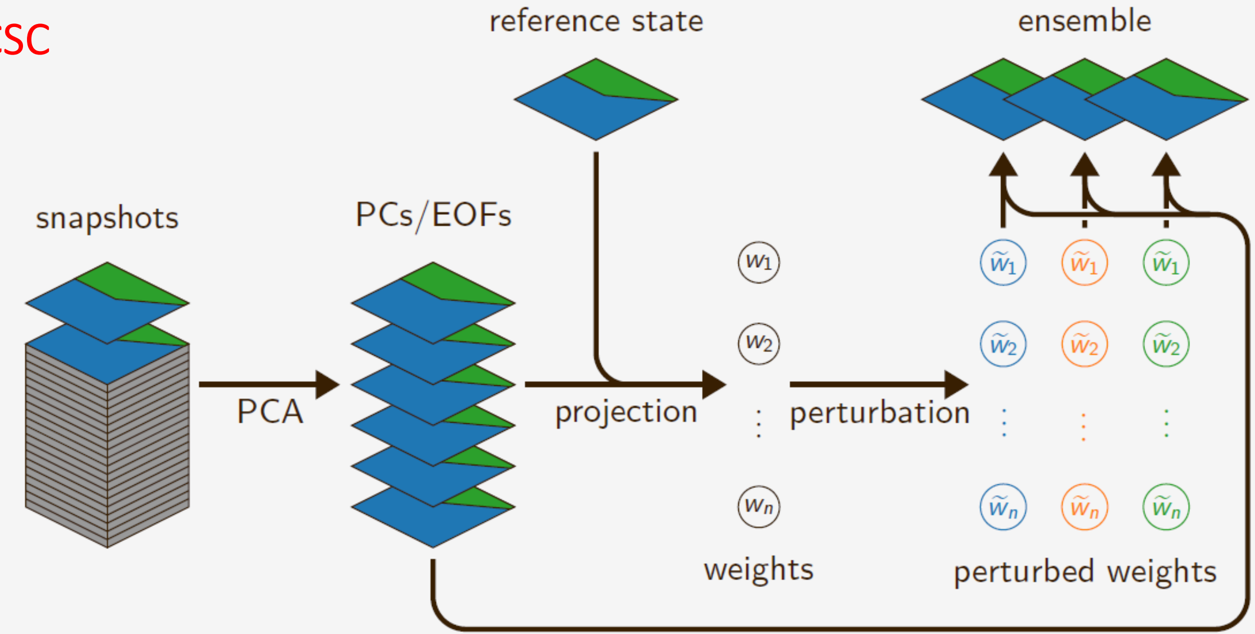
Model bias in ARC MFC ensemble model at the Norwegian Sea (NRW).
BLUE : Model Ensemble (80 members), ORAGNE: Satellite Chl-a (OC-CCI)





PCA-based ensemble generation

J Paul, UCSC



implementation details:

- snapshots are generated from a long, non-assimilative run
- perturbation of weights is based on multiplication with pseudo-random numbers
- currently using 25 leading PCs to generate 25 ensemble members

BGC model ensembles at PML/NCEO

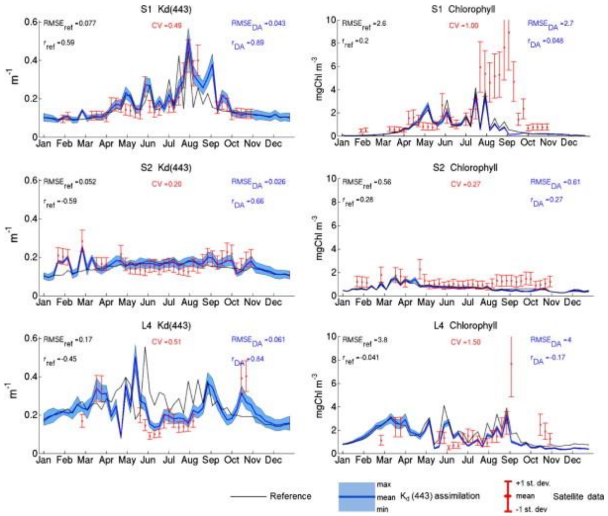
Ciavatta et al., 2011, 2014

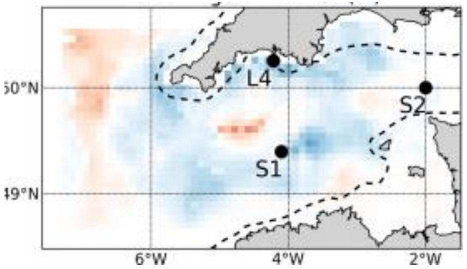
- One year OC chlorophyll DA
- Stochastic EnKF
- 100 members
- Log-transformation
- Localization

A) Stochastic perturbation of model parameter/forcing:
pseudo-random Gaussian errors with standard deviation equal to 20% of the diffuse attenuation coefficients values were applied to each ensemble member, at every model time-step, during the forecast phase.

B) Additive error to all model variables
Added pseudorandom Gaussian fields with standard deviation equal to 10% of the value of the variables, prior the analysis (error was lowered to 5% for variables defining the dissolved and particulate organic concentrations, to avoid divergences in the concentrations of the largest pool in the model)

The dispersion of the ensemble was comparable to the one of the observations for the assimilated variable (Kd); less for the diagnostic variable total chlorophyll





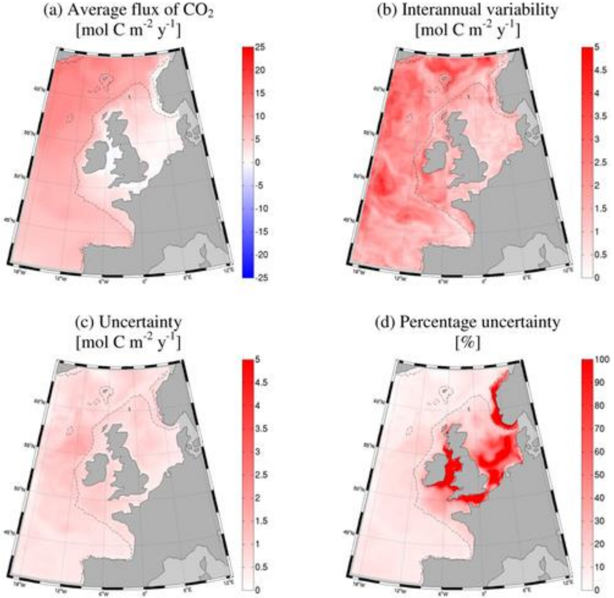
Stefano Ciavatta, PML

BGC model ensembles at PML/NCEO

Ciavatta et al., 2016, 2018, 2019

- Decadal OC chlorophyll DA
- Stochastic EnKF
- 100 members
- Log-transformation
- Localization

Air-sea flux of CO2



A) Stochastic perturbation of model forcing

Surface solar irradiance- A - Gaussian perturbation with standard deviation equal to 20% of the irradiance value is added during the model forecast step.

B) Perturbation of the ensemble initial condition

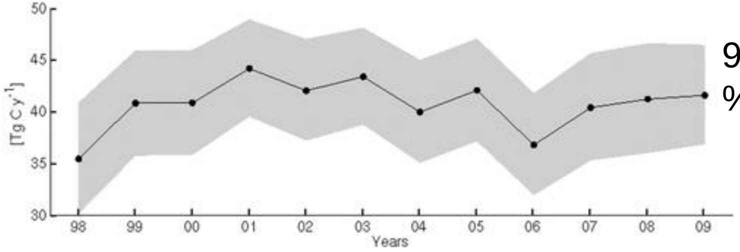
Gaussian pseudorandom fields with error equal to 30% of the value of the variables.

C) Additional error once a year

At the first assimilation step of each year, model error is added to all the variables undergoing the analysis, as white noise drawn from a distribution of pseudorandom fields with error equal to 10% of the value of the variables. The error is lowered to 1% for those variables that have relatively high average values (DIC, ammonia, and small particulate matter), to avoid divergences

Note: I would have preferred a larger dispersion of the ensemble, but problems of divergence if error added at each time step

Air-sea flux of CO2



95th %

5th%

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Quad chart describing the progress of annual activity in the MEAP-TT in 2021

Short description and objectives of the activities started /planned for this year:

Main objective: To promote the expansion, modelling and assimilation of global ocean observing capabilities with respect to biogeochemical and biological variables (e.g. via BGC Argo and gliders) to advance the prediction and exploitation of essential biogeochemical variables

Milestone: to kick-off the biogeochemical component of a UN Ocean Decade project for a predictable ocean ecosystem

Accomplishments of the TT this year:

- Contribution of the biogeochemical components of the UN Ocean Decade programme ForeSea and project SynObs proposals
- Editing the special issue of Biogeosciences/Ocean Science issue on "Biogeochemistry in the BGC-Argo era: from process studies to ecosystem forecasts"
- Contributions to the The Global Biogeochemical-Argo Fleet: Knowledge to Action Workshop, linked to the G7 FSOI
- Hold three video-meetings of the TT, hosting representatives of the OceanSites community and the CMEMS BGC-DA group
- Kick-off of the H2020 SEAMLESS project on ensemble biogeochemical data assimilation for operational oceanography

Future plans to continue/ improve current activities:

- to engage key observational (e.g. OceanSite, Bio-Argo, GOOS), modelling/assimilation (e.g. CMEMS BGC-DA) and policy (e.g. G7 FSOI) stakeholders
- to hold targeted team workshops and questionnaires on topics relevant to this year main objective, e.g. ecosystem ensemble simulations, multi-platform data assimilation, high trophic level modelling
- deliver the biogeochemical chapter of the ETOOFS manual on operational oceanography

Issues/ problems:

- difficulty to ensure a good representation of the biogeochemical modelling communities in the South American and African continents
- difficulty to carry out concrete actions (e.g. intercomparison projects) on best effort basis (enthusiasm during planning dies off rapidly as it implies extra work added to an in general already heavy load)

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OceanPredict's ForeSea Programme for the UN Ocean Decade was endorsed by IOC/UNESCO

ForeSea's vision is for strong international coordination and community building of an ocean prediction capacity for the future. The overarching goal are to (1) improve the science, capacity, efficacy, use, and impact of ocean prediction systems and (2) build a seamless ocean information value chain, from observations to end users, for economic and societal benefit. These transformative goals aim to make ocean prediction science more impactful and relevant.

Specific activities linked to MEAP-TT

6. Development of an integrated description of the 4D biogeochemical state of the ocean based on satellite and in situ observations that informs society on key issues related to ocean health and the management of marine resources (to be carried out jointly with the development of a global BGC Argo array) (Theme 1 and 2)
7. Biogeochemical (BGC) nowcasts and ecological forecasting as area for transformative progress addressing from stakeholder needs ranging from carbon accounting to ecosystem health (Theme 1 and 2)

MEAP contribution to the ForeSea's Project SynObs (Synergistic Observing Networks for Impactful and Relevant Ocean Predictions)

- In this project, we will explore methods to assimilate satellite ocean colour observations with Argo observations of physical and biogeochemical parameters, carry out observing system design experiments to determine the optimal investment in BGC Argo given metrics specific to different user needs, and to identify the best combinations of biogeochemical and physical observations.
- effective methods to represent the oceanic biogeochemical state through assimilation of both physical and biogeochemical parameters.

- Next meeting: 2nd half of September

Topics? Speakers?

“Predicting nekton and applications in fisheries and aquaculture” : please fill https://docs.google.com/document/d/1d5e6c3fkhL3FbWWSAdDtDa0TQFFsWaaqFD0MraZgUF0/edit

“Integrated assimilation of biogeochemical data from in situ and satellite platforms” (see also: https://www.youtube.com/playlist?list=PL3QW3GDV62CCT6mtFcX7PX2XblpWxSXj1