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National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

Listen to the ocean

Decadal reanalysis of biogeochemical indicators and fluxes in the North East Atlantic ecosystem

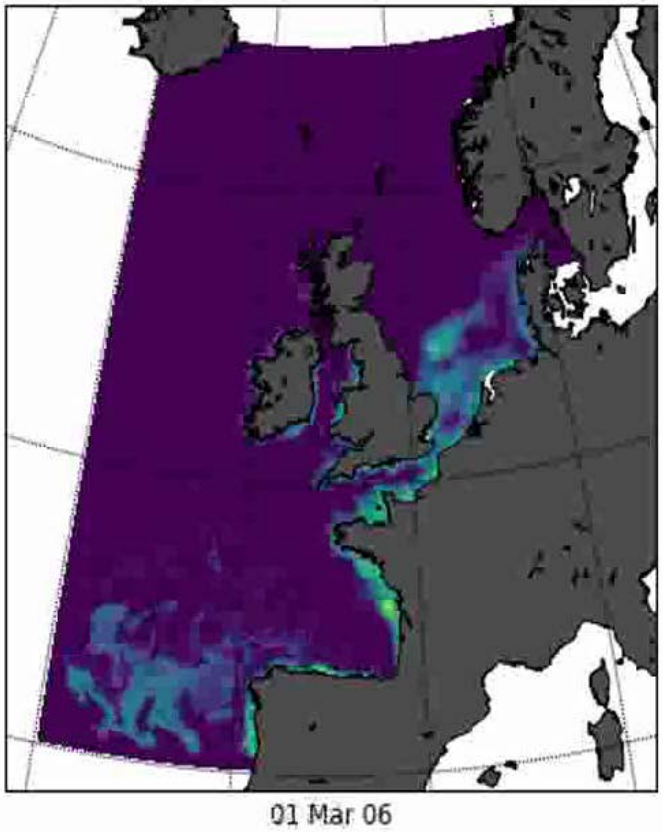
Stefano Ciavatta

s.ciavatta@pml.ac.uk

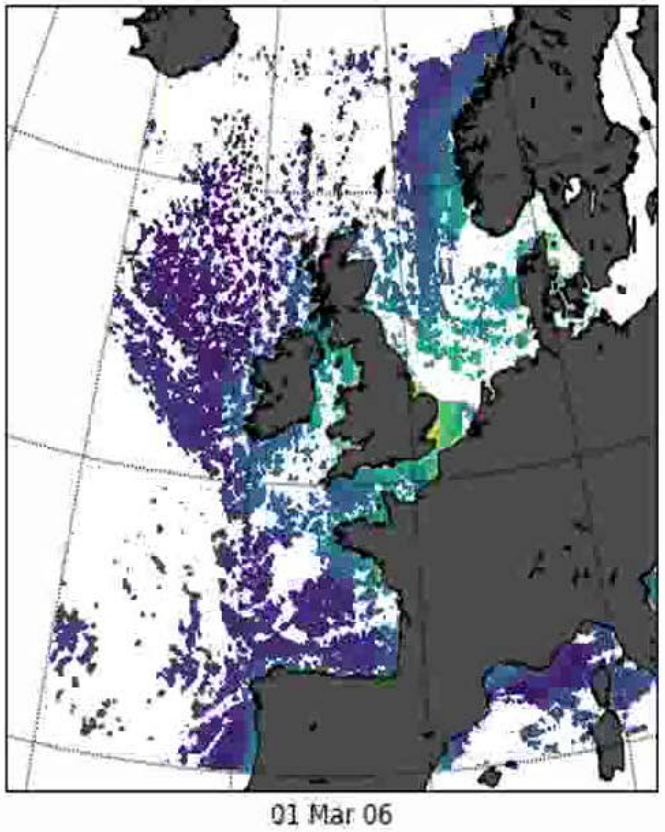
Atlantic from Space Workshop, 23-25 January 2019

Motivation for ocean-colour DA

Model (chl)



Ocean colour (chl)

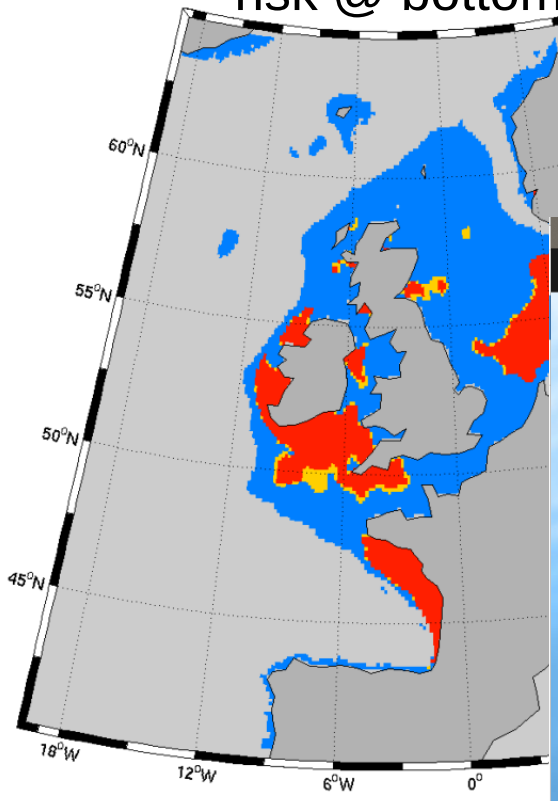


Data Assimilation

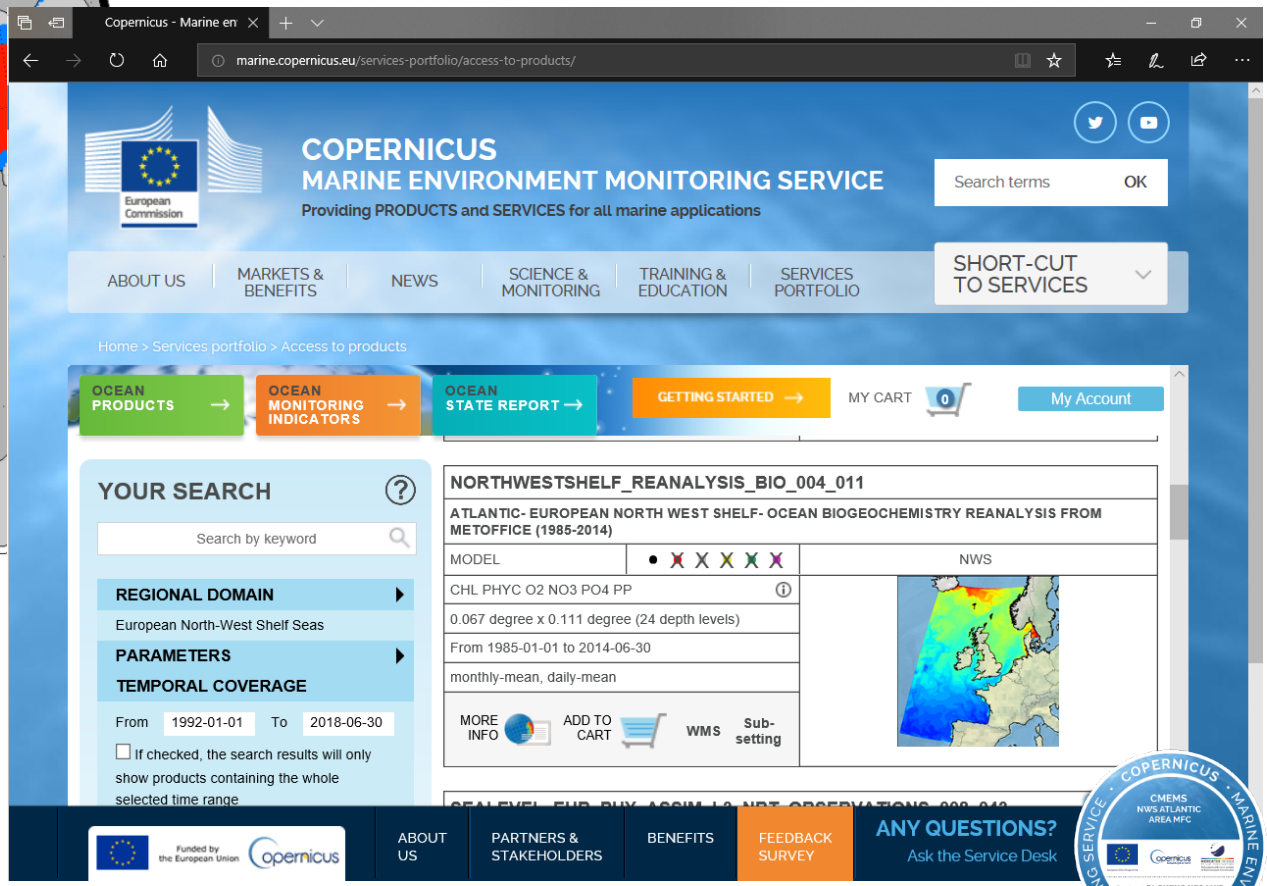
Estimates the true state
Taking account of model and data errors

Motivation for ocean-colour DA

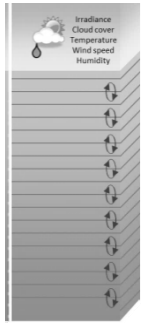
Oxygen deficiency risk @ bottom



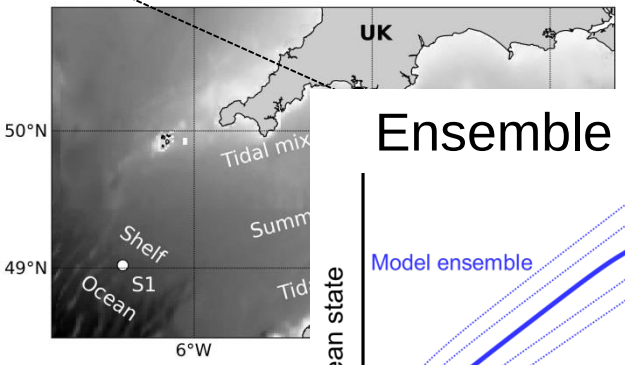
Ciavatta et al, JGR, 2016

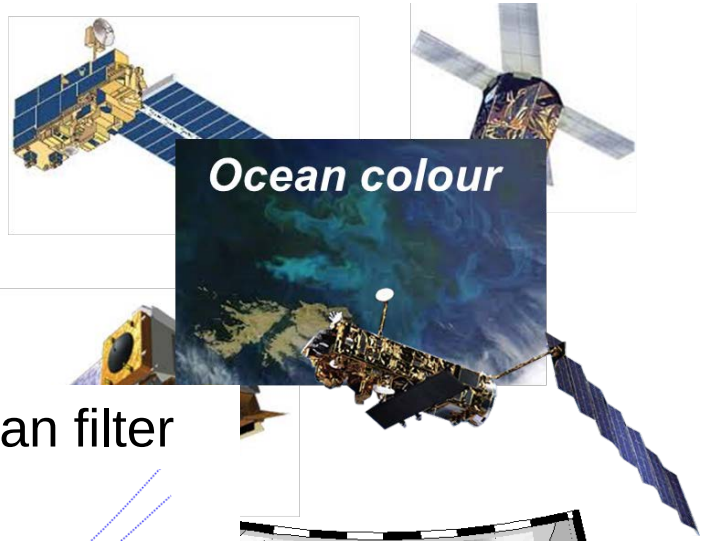


An overview of OC DA applications in the Atlantic

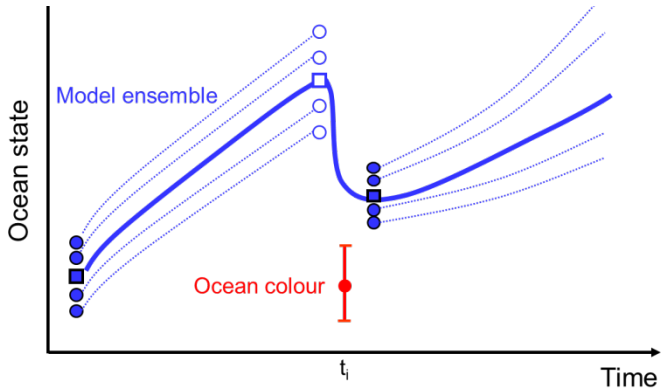


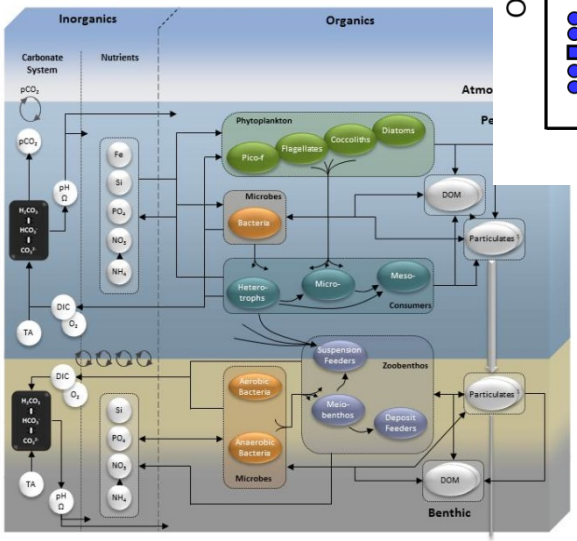
Site L4

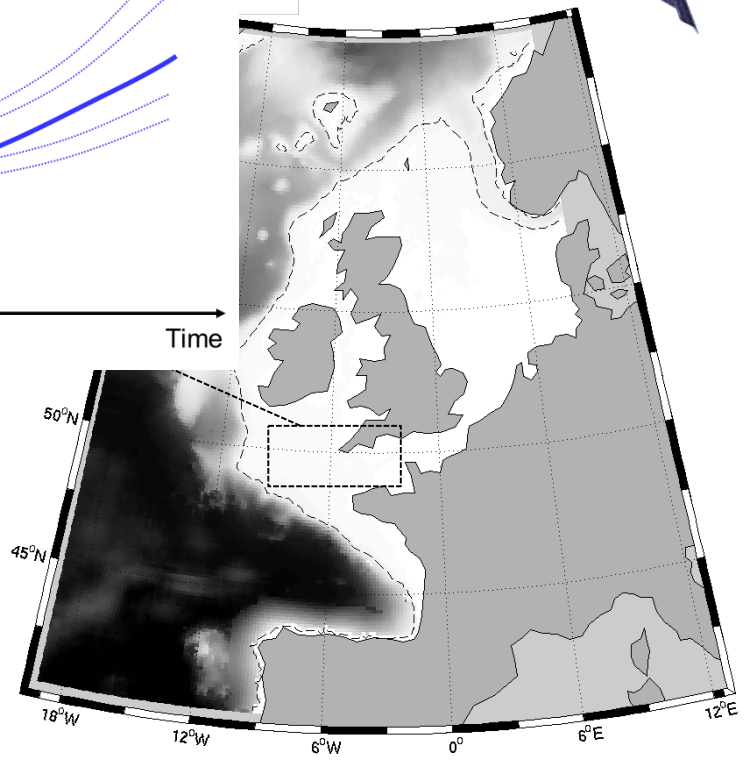




Ensemble Kalman filter

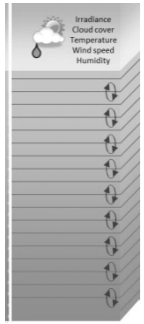






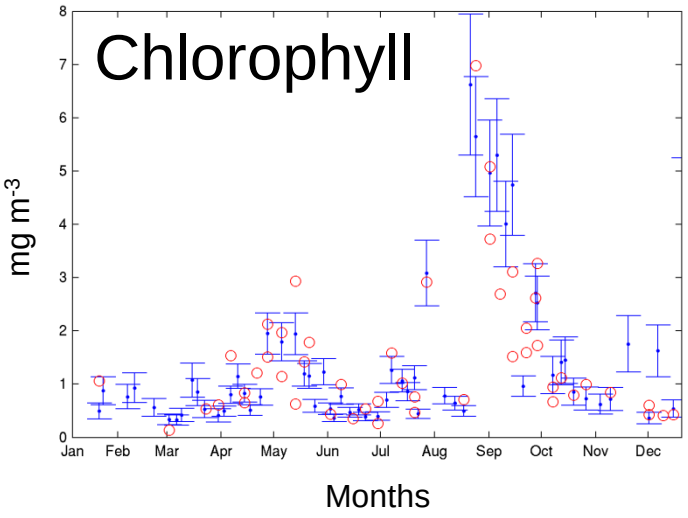
ERSEM Butenschön et al, GMD, 2016

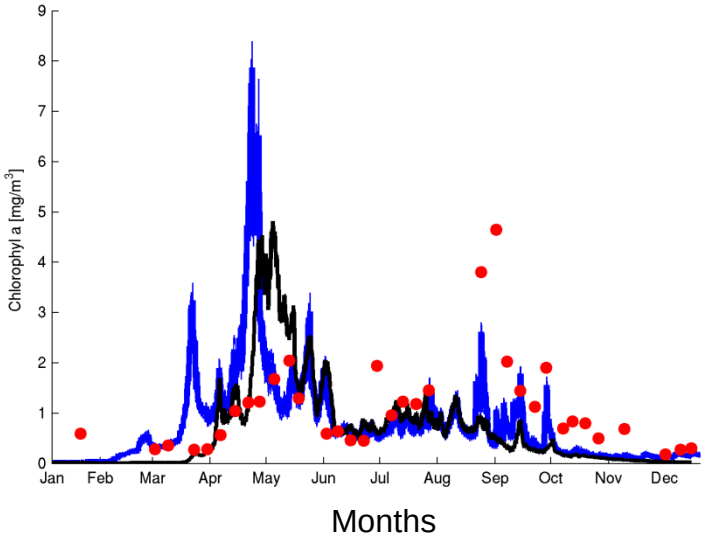
Assimilation of total chlorophyll: 1D site

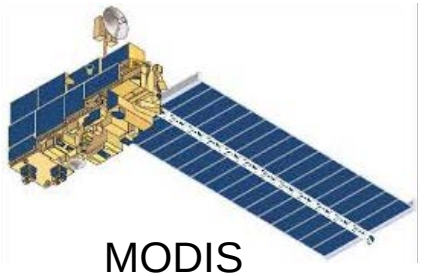


- Site L4

- ERSEM-GOTM
- Chlorophyll (MODIS)
- EnKF







MODIS

OC

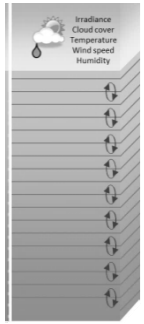
In situ data

Model

DA

Torres et al., JGR, in preparation

Assimilation of total chlorophyll: 1D site



- Site L4

- ERSEM-GOTM
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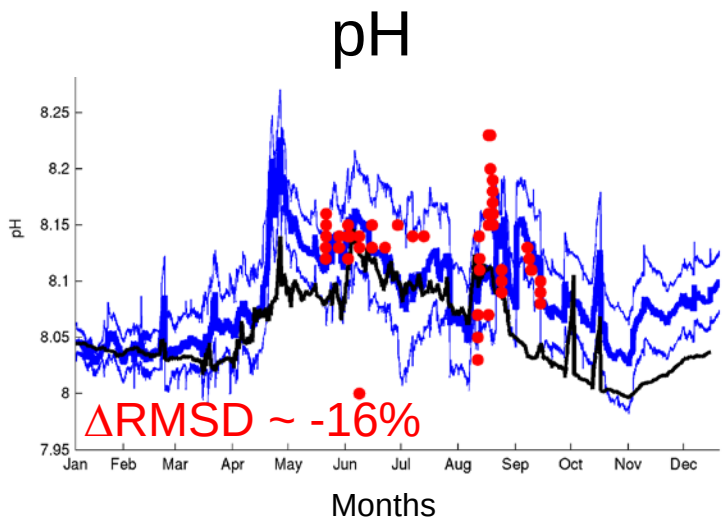
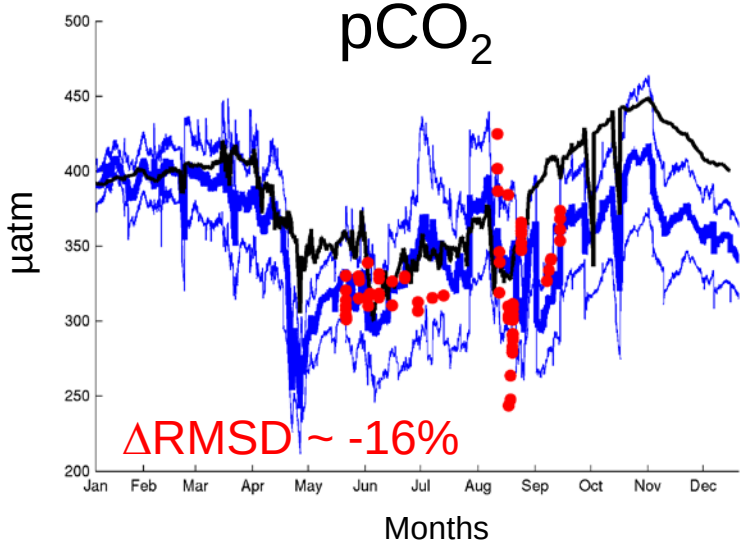


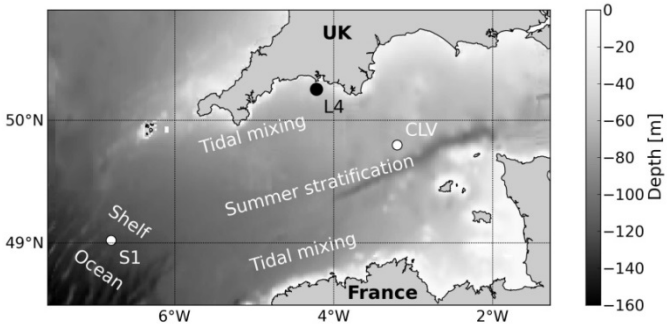


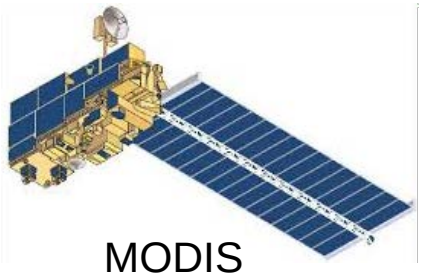
- In situ data
- Model
- DA
- DA error

Ocean colour DA improved the simulation of ocean acidification indicators

Torres et al., JGR, in preparation

Assimilation of total chlorophyll: 3D local



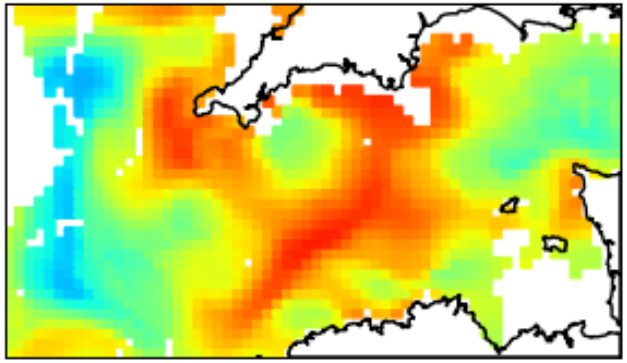


MODIS

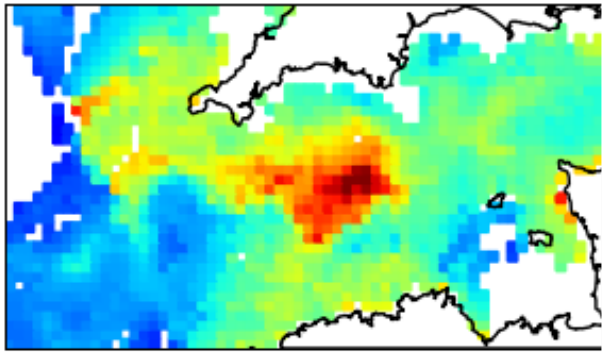
- ERSEM-POLCOMS (3D)
- Chlorophyll (MODIS)
- EnKF

Chlorophyll (day: 5 August 2006)

Reference run

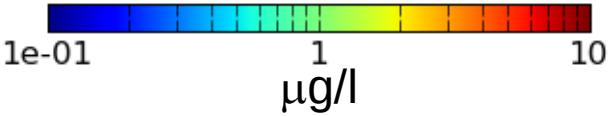


Satellite data



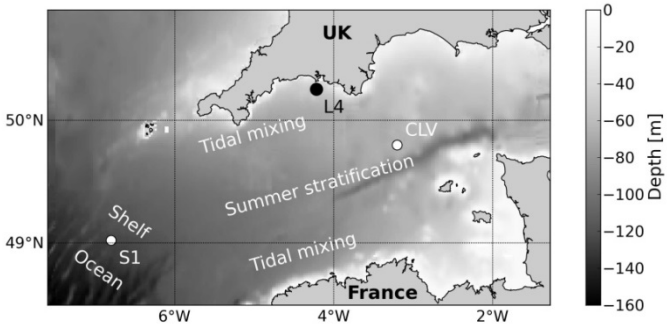
r = 0.44

RMSE = 1.57



Ciavatta et al, JGR, 2011

Assimilation of total chlorophyll: 3D local



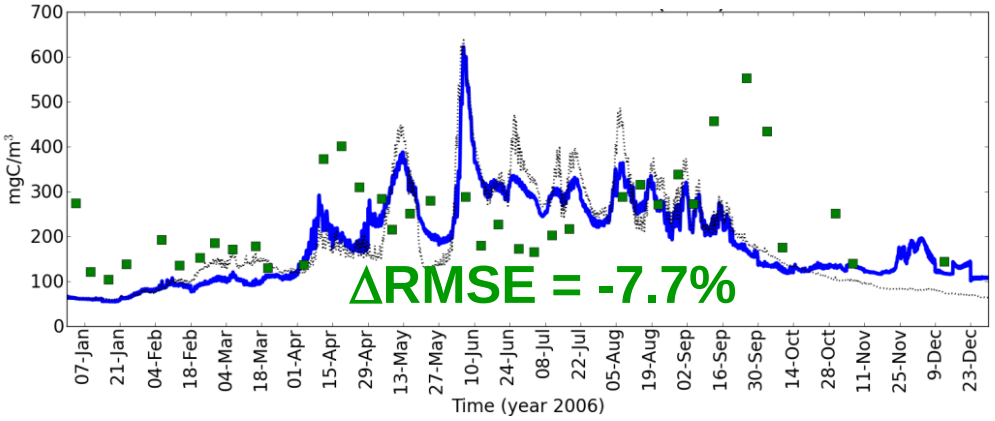
- ERSEM-POLCOMS (3D)
- Chlorophyll (MODIS)
- EnKF

In situ data

Model

DA

Total particulate carbon (TPC)

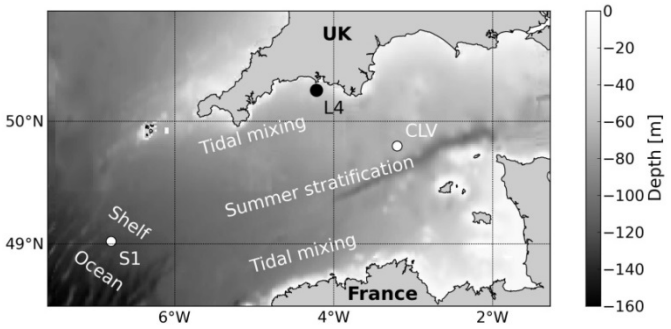


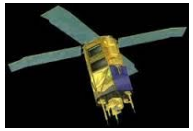
+ 8 other time series

Ocean colour DA improved the simulation of BGC indicators and C stocks

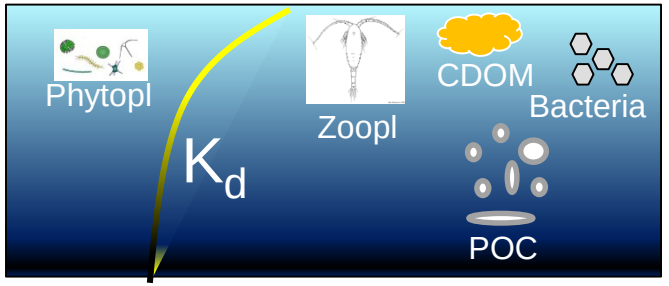
Ciavatta et al, JGR, 2011

Assimilation of diffuse light attenuation coeff $K_d(\lambda)$



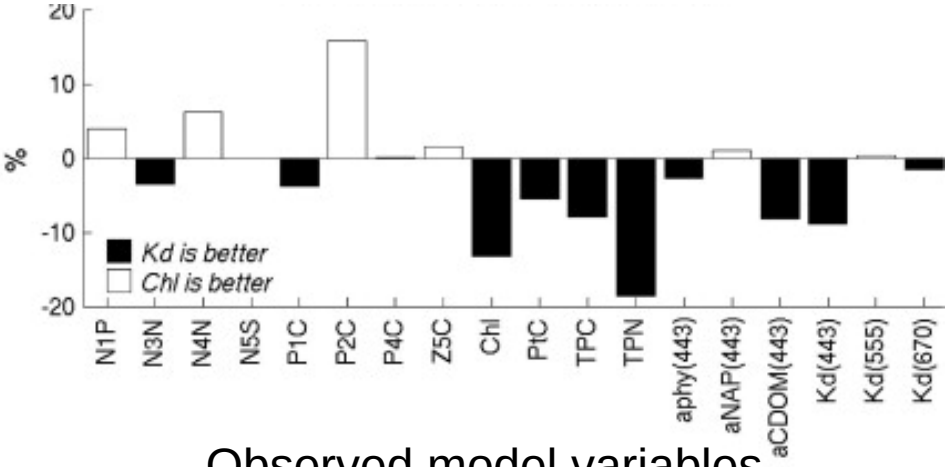


Bio-optical spectral module



- ERSEM-POLCOMS (3D)
- $K_d(443)$ (SeaWiFS)
- EnKF

RMSD K_d – RMSD Chl

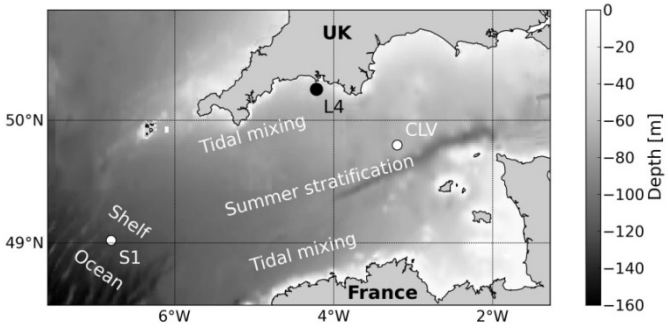


Observed model variables

Outperformed the assimilation of total chlorophyll in estimating biogeochemical indicators

Ciavatta et al, PiO, 2014

Assimilation of diffuse light attenuation coeff $K_d(\lambda)$



- ERSEM-POLCOMS (3D)
- $K_d(443)$ (SeaWiFS)
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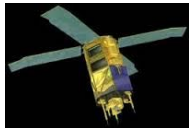
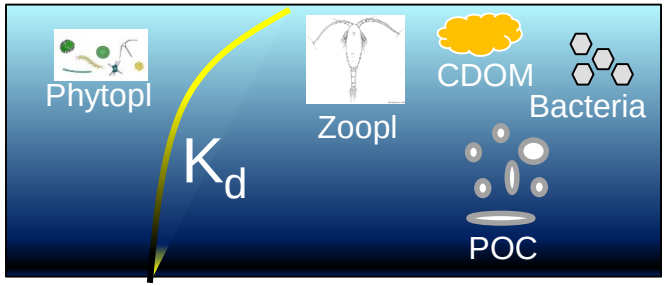
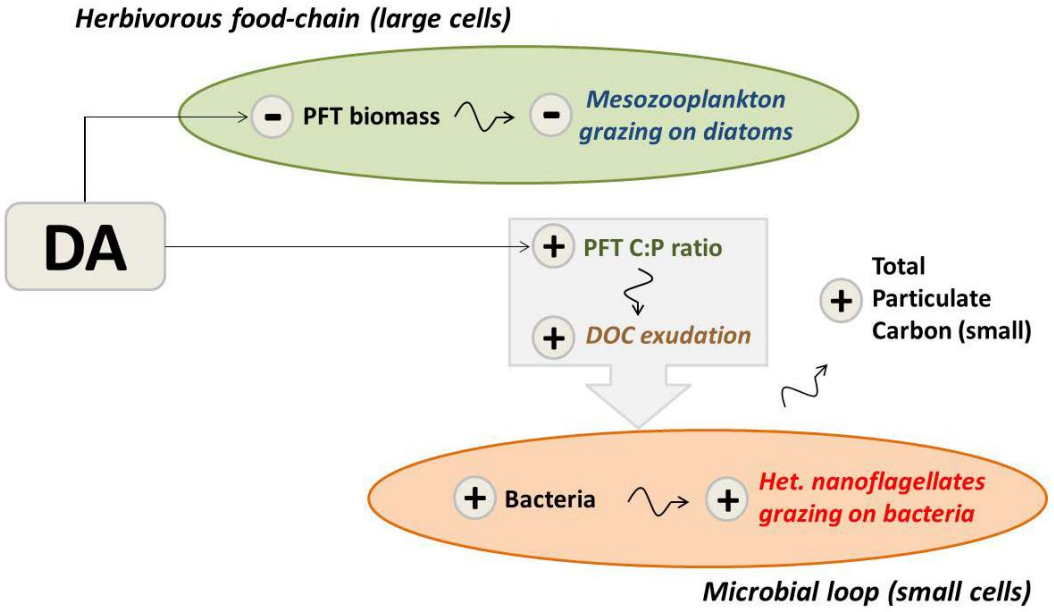


Bio-optical spectral module

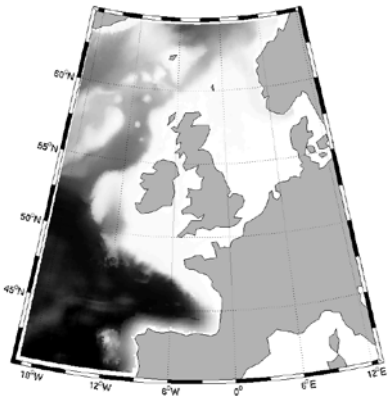




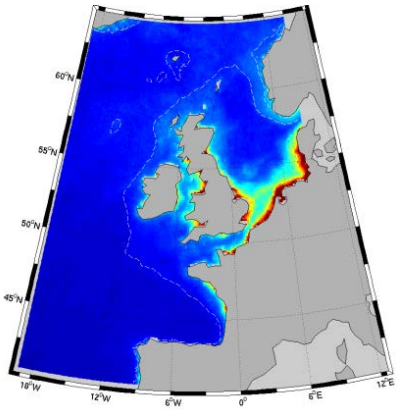
The trophic web shifted
Impacting C stocks & fluxes

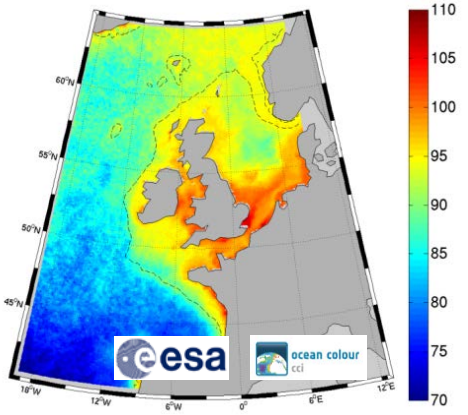
Ciavatta et al, PiO, 2014

Assimilation of total chlorophyll: 3D regional



ESA CCI ocean colour & RMSD





- ERSEM-POLCOMS (1998-2009)
- Chlorophyll (ESA's CCI) **with errors**
- EnKF

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28 March 2016 News

Oxygen deficiency is threatening Europe's crucial shelf-sea fishing areas

Large areas of the shallow seas around Europe are vulnerable to oxygen deficiency, and there is more variability in how they absorb carbon dioxide than previously thought.

→ Read more

EOS

BIOGEOSCIENCES Research Spotlight

Uncertainty Evaluations Improve Biogeochemical Simulations

Results from the first decade-long reanalysis simulation of northwest European shelf biogeochemistry show the importance of quantifying the uncertainty in these indicators to inform marine policy.

SOURCE: *Journal of Geophysical Research: Oc*

2013

MCCIP Marine Climate Change Impacts Partnership

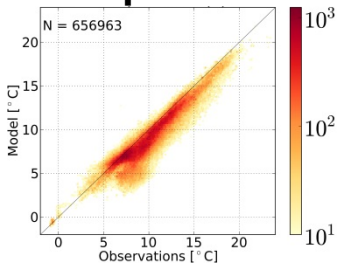
Marine climate change impacts

Report Card 2019

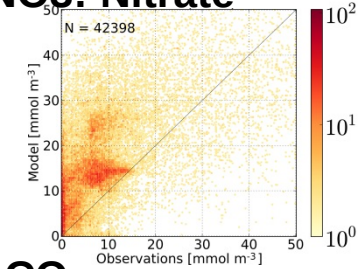
Highlights Ciavatta et al, JGR, 2016

Assimilation of total chlorophyll: 3D regional

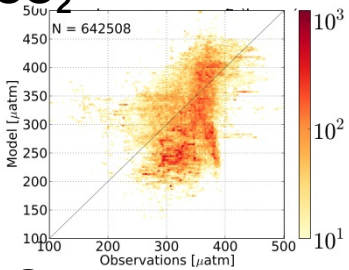
T : Temperature



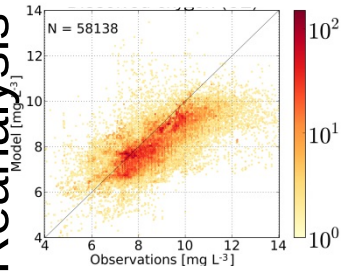
NO3: Nitrate



pCO_2



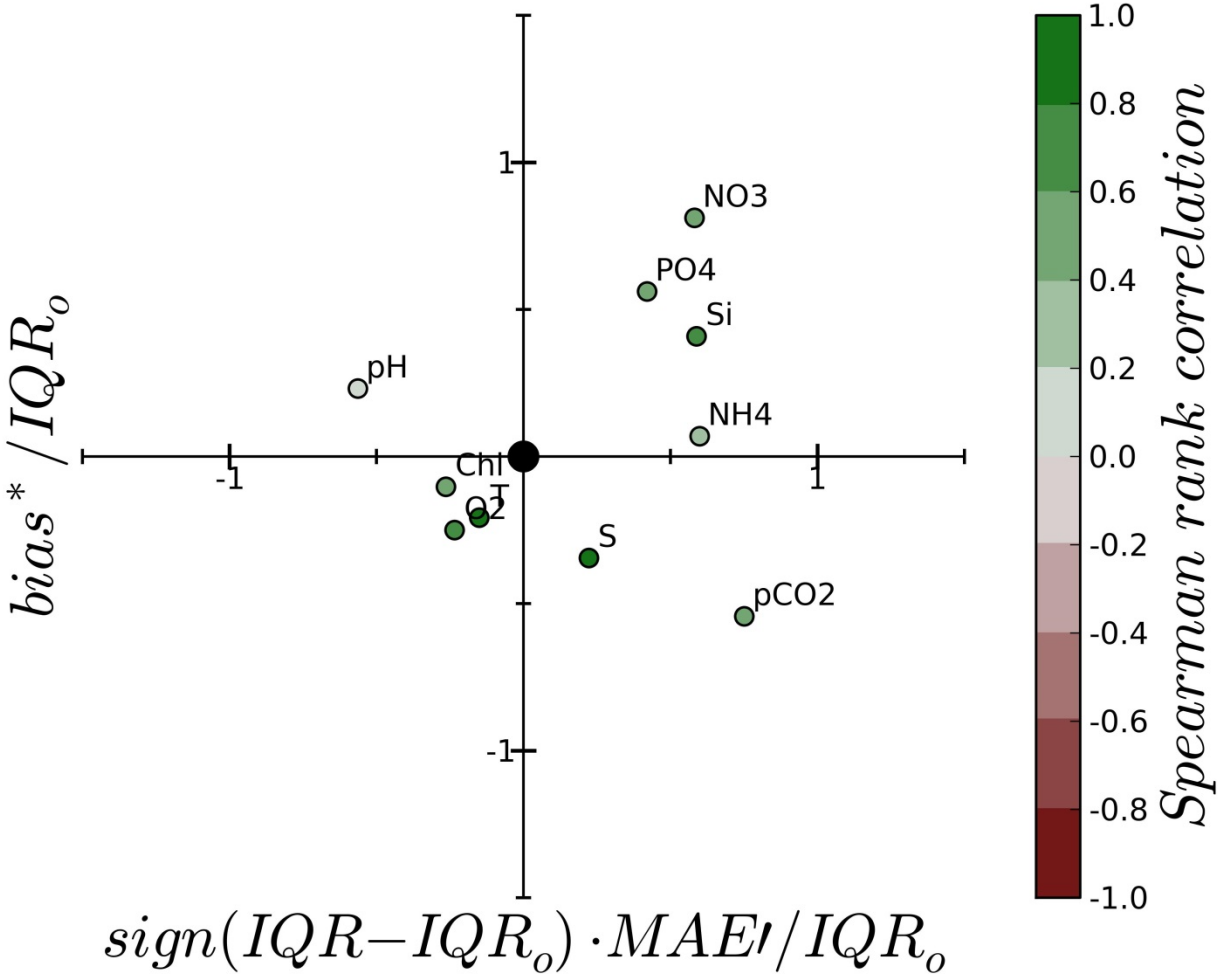
O_2



Reanalysis

Observations

In situ data for validation

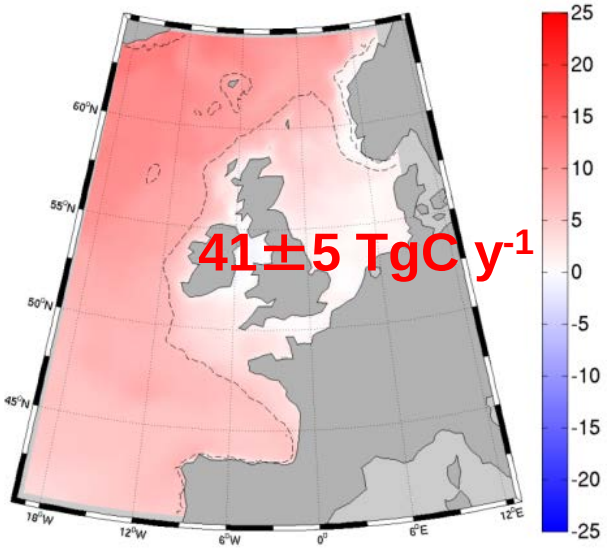


+ 6 more variables…

bias (median($M_i - D_i$);
Unbiased median absolute error (MAE', median[abs($M_i - D_i$ – median($M_i - D_i$))])

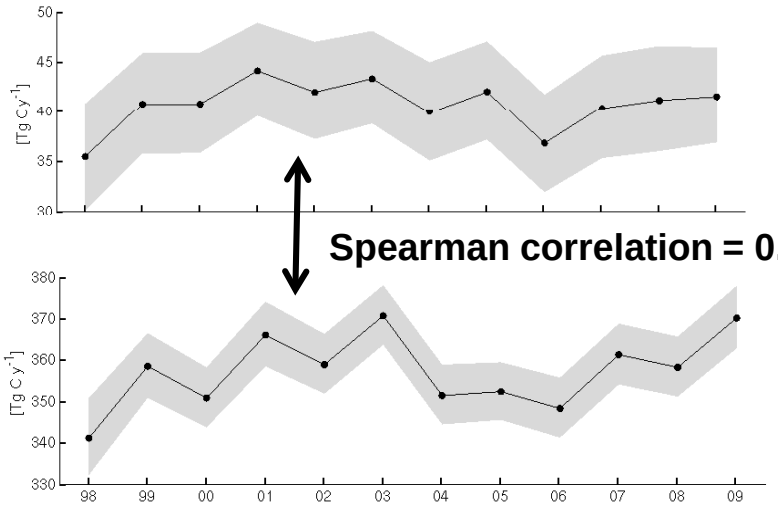
Assimilation of total chlorophyll: 3D regional

Carbon dioxide air-sea flux

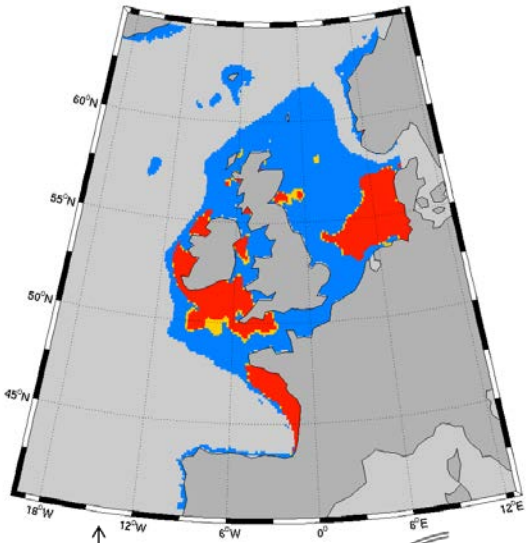


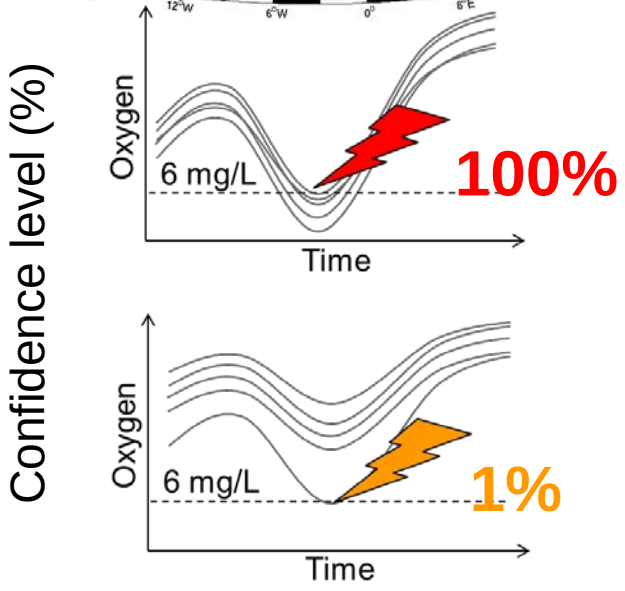
Air-sea CO_2 flux

Gross primary production of phytoplankton



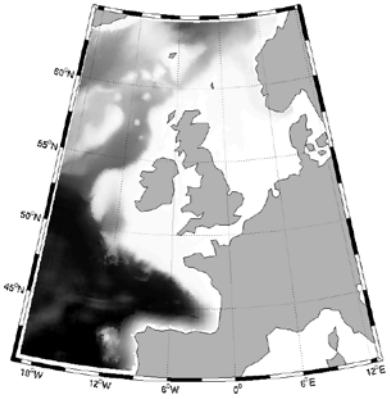
Oxygen deficiency risk

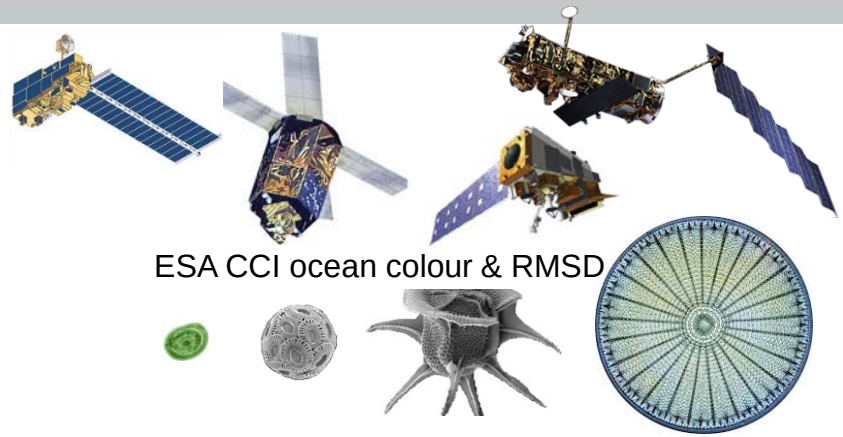




Ciavatta et al, JGR, 2016

Assimilation of phytoplankton functional types (PFT)

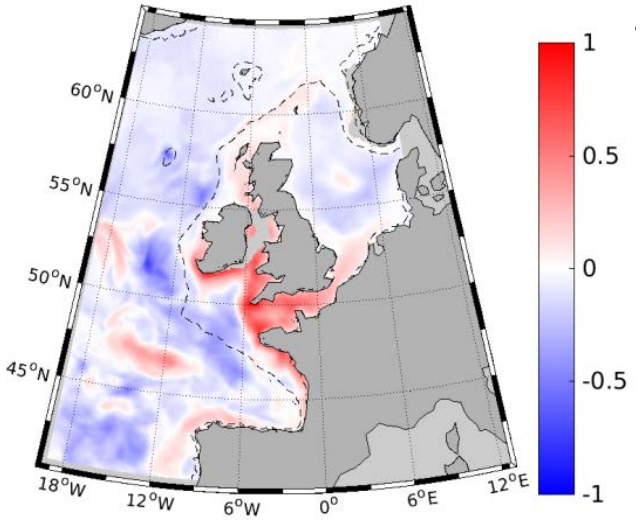




ESA CCI ocean colour & RMSD

- ERSEM-POLCOMS (1998-2003)
- PFTs (from ESA's CCI) **with errors**
- EnKF

Δflux CO_2
[mol C m^{-2}month^{-1}]



PFT DA reanalysis outperformed total chlorophyll DA, improved the simulation of some marine state indicators and revised estimates of carbon fluxes

TOSCA

See next talk for CMEMS application!

Ciavatta et al, JGR, 2018

Next Atlantic ocean-colour/DA/modelling

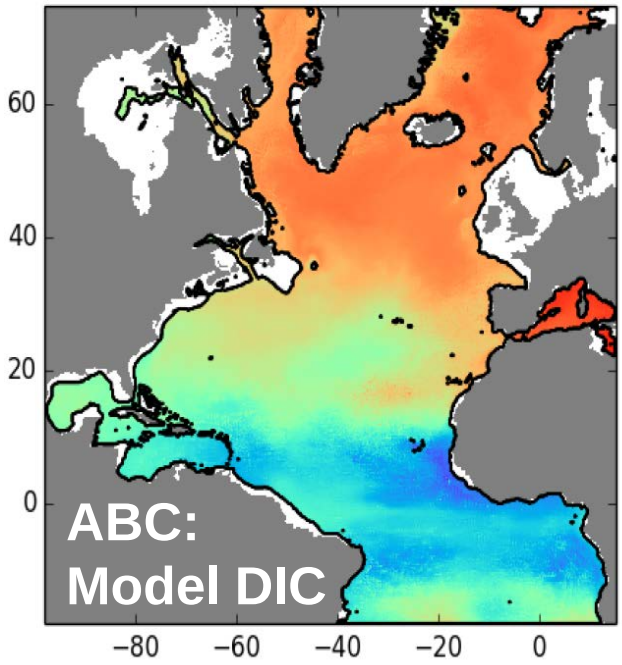
- Improving understanding and simulation of short-term, small-scale variability of **plankton production and oxygen depletion in Atl** by assimilating **glider data** along with ocean colour (UK NERC CAMPUS)

- Exploitation of reanalysis to define areas of **aquaculture sustainability in Atl** and in Mediterranean Sea (EU H2020 TAPAS)

- Analysis of the **global biological carbon pump and air-sea CO_2 flux** variability in the global ocean by assimilating **ocean-colour carbon** (and BGD-Argo possibly) data into a global model (UK NERC NCEO)

- Improve **operational indicators in Atl** by assimilating **PFT spectral absorption** (EU CMEMS OPTIMA) **Poster 11!**

- Analysis of biology-driven **carbon stocks & fluxes** along the RAPID-AMOC transect and North Atlantic (UK NERC RAPID-ABC) **Poster 12!**



Recommendations

- Investigate how the variability of **plankton** impacts carbon in the Atlantic ocean
- **Assimilate** ocean colour to simulate better science- , user- and policy-relevant BGC indicators and C stocks & fluxes not observable from space
- "**New" ocean-colour products** can outperform the traditional assimilation of total chlorophyll (e.g. K_d, PFTs, r_{rs} , carbon stocks): but be careful if like-for-like!
- EO scientist and modellers must plan **jointly**
- Let's combine assimilation of ocean-colour products and **in situ biogeochemical data** (e.g. gliders and hope bio-Argo)

Thank you !

I Allen, R Brewin, M Butenschön, D Ford, S. Kay, L Polimene, J Skakala, D Sursham, R Torres