Ocean data assimilation – biogeochemistry

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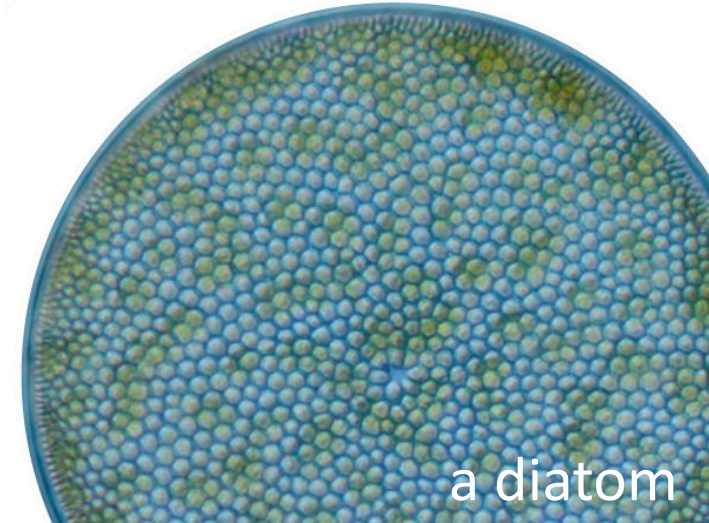
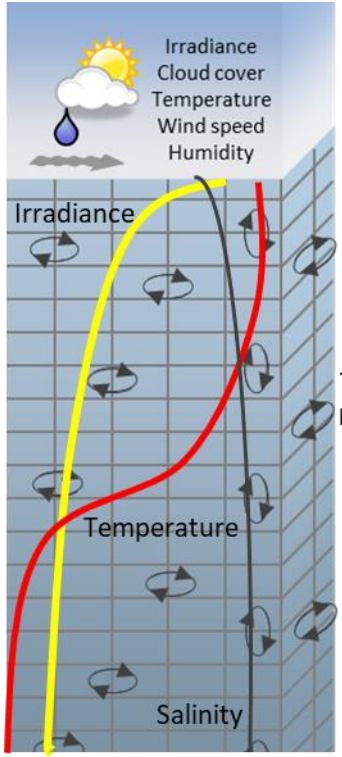


Outline

- **Why** are we assimilating biogeochemical data?
- **What data** to assimilate?
- **Some issues** (non-Gaussianity, physical DA)
- Conclusions

Why are we assimilating biogeochemical data into ecosystem models?

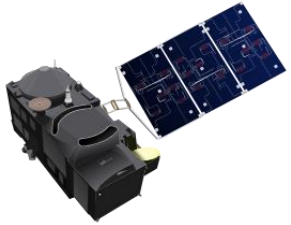


Physical (PHY) model

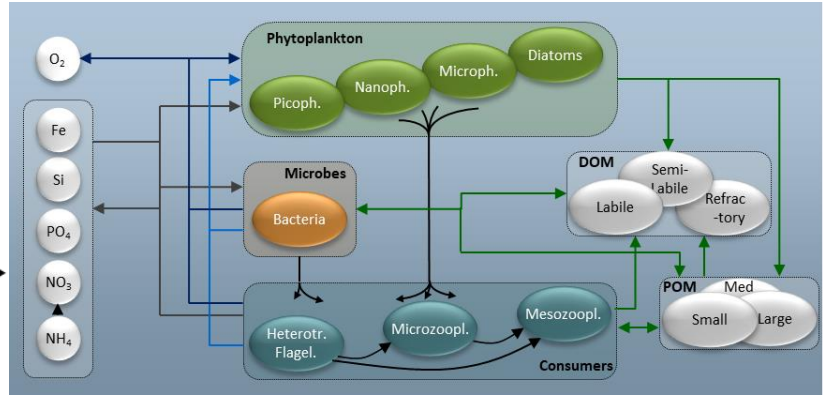
Transport

T,E,S

Ocean colour



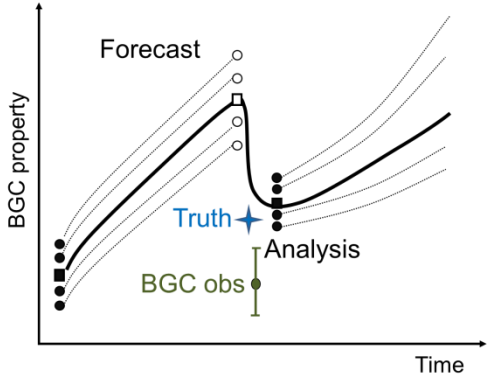
· Phytoplankton chlorophyll
· Phytoplankton functional types
· Remote sensing reflectance
…



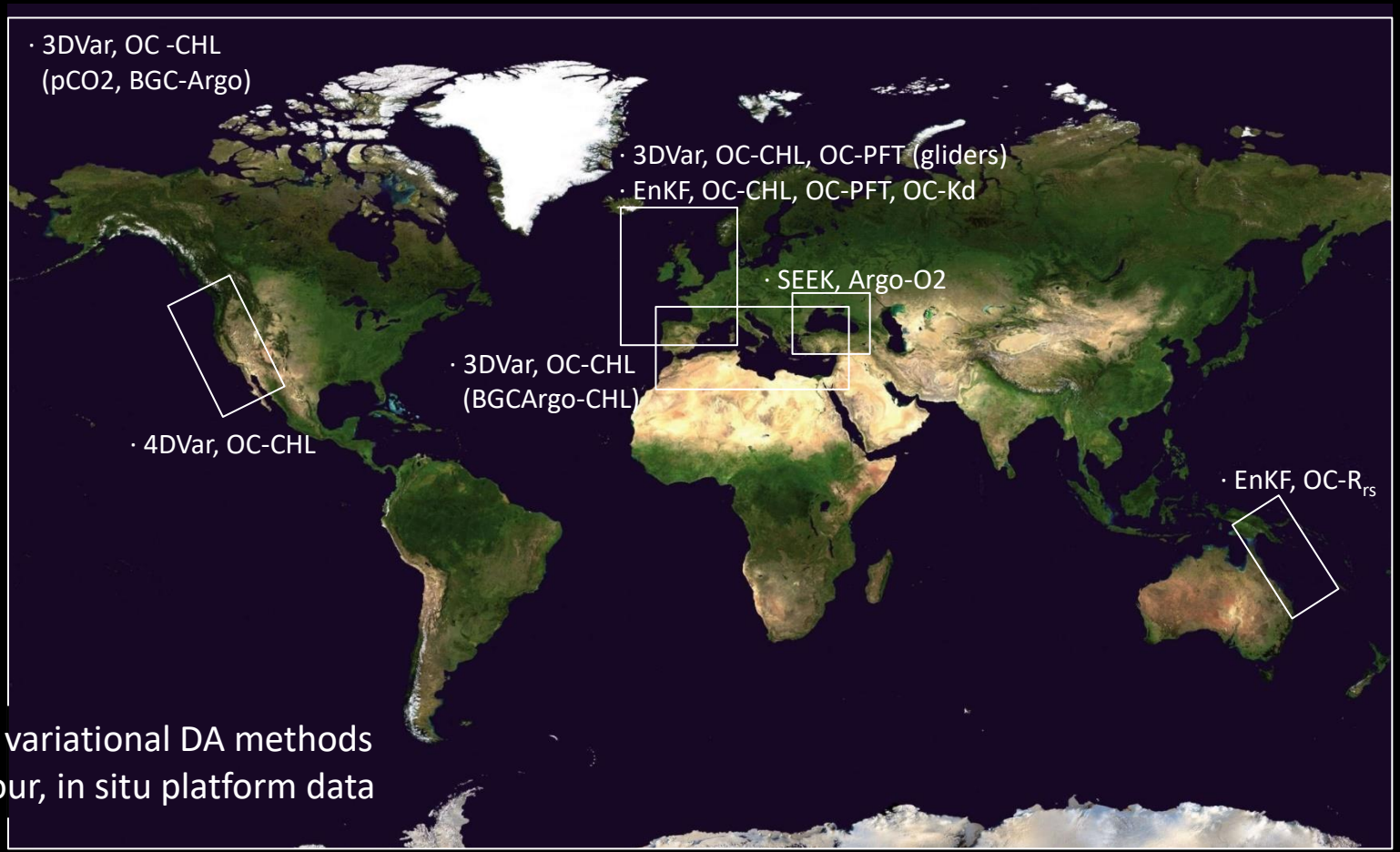
In situ observations: Chlorophyll, oxygen, nitrate , pH…

To improve the estimation of the "biogeochemical truth"

Data assimilation (DA) algorithm



Why are we assimilating biogeochemical data into ecosystem models?



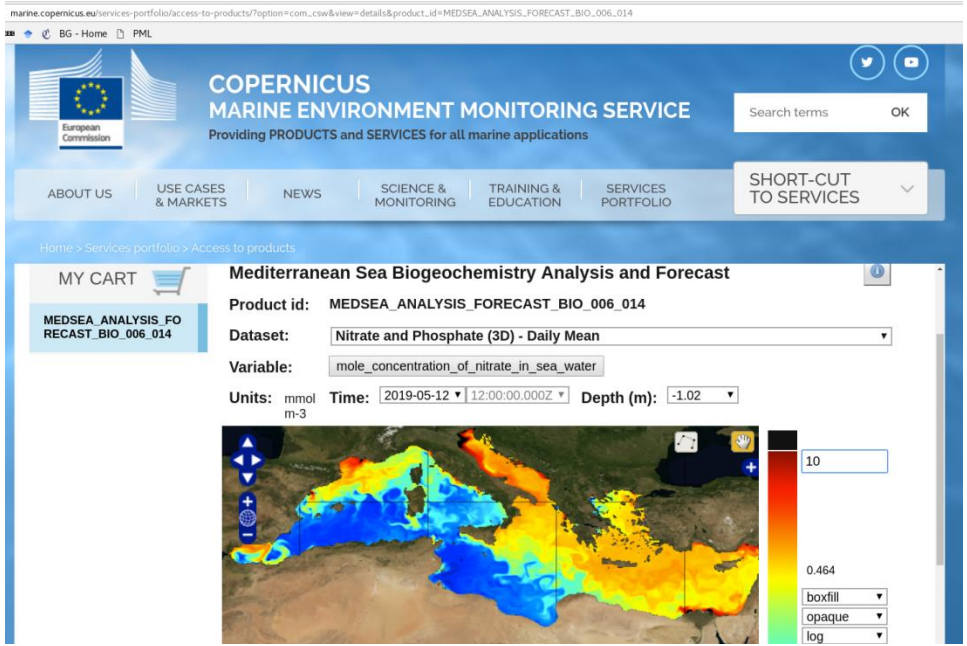
- Ensemble, variational DA methods
- Ocean colour, in situ platform data

Fennel et GODAE MEAP TT, 2019

Why are we assimilating biogeochemical data into ecosystem models?

Operational forecasts

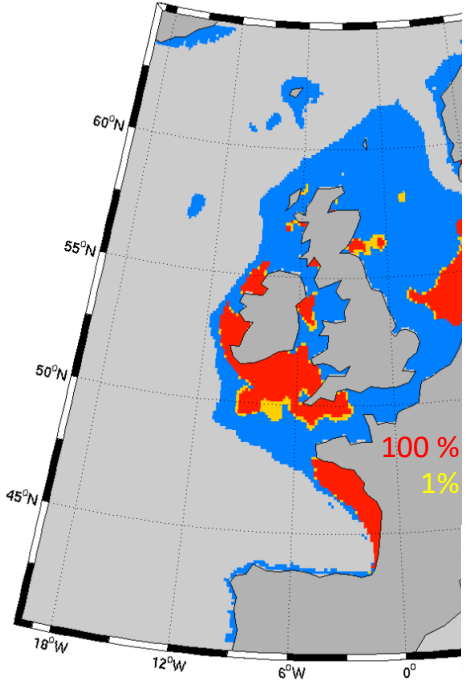
Nitrate: next Sunday prediction



Teruzzi et al., 2014

Reanalysis

Oxygen: historical deficien



Ciavatta et al., 2016

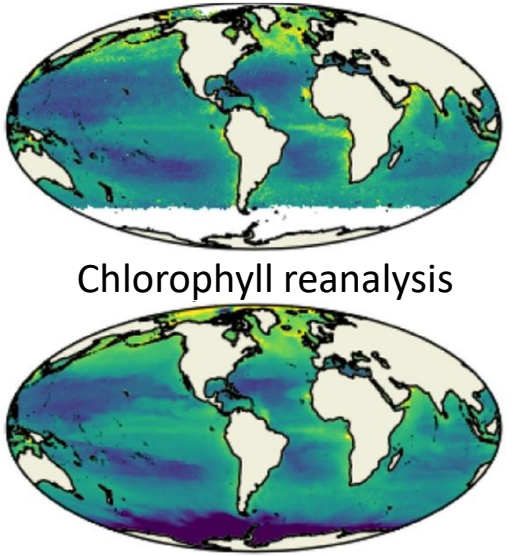
European Commission

Policy

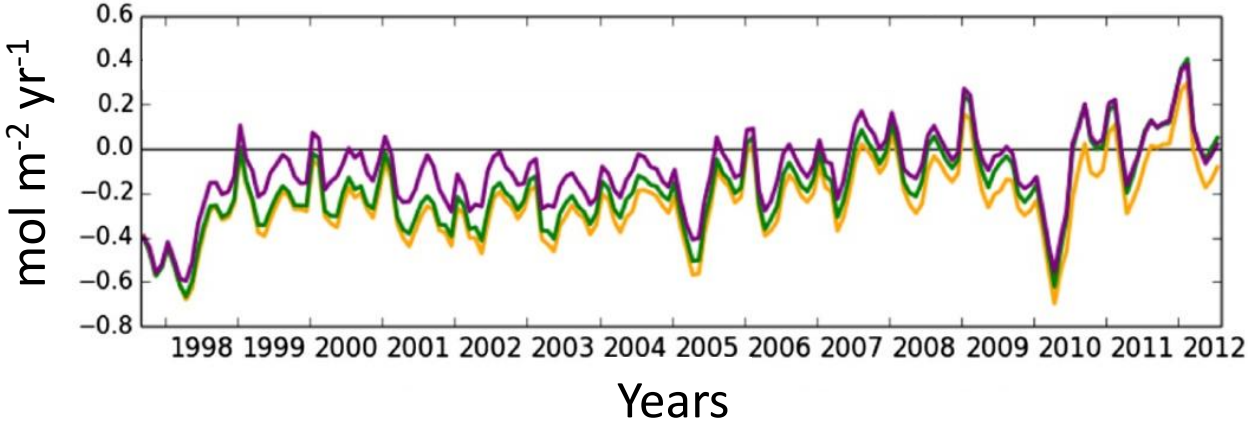
Why are we assimilating biogeochemical data into ecosystem models?

Reanalysis – climate studies

Chlorophyll ocean colour



Air-sea CO2 flux – Tropical Atlantic

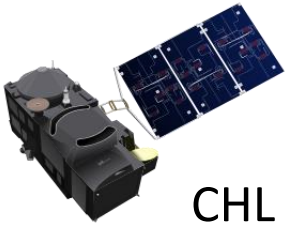


Control (= model without DA)
REAN- GC
REAN- CCI

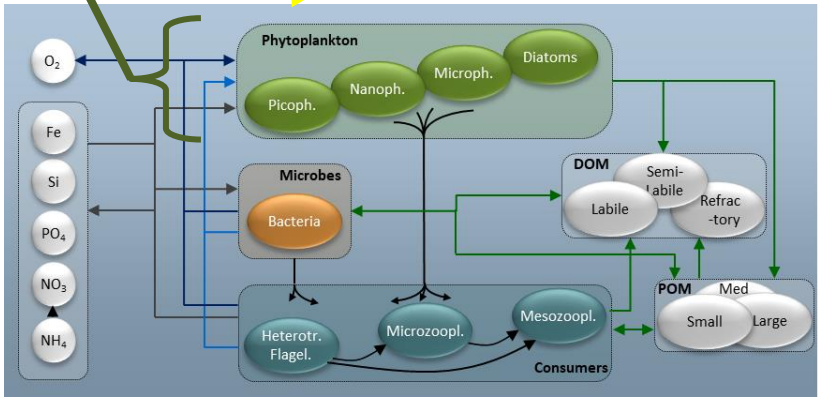
Ford and Barciela, 2017

What biogeochemical data to assimilate?

Ocean colour total chlorophyll



$$CHL = f\,(R_{rs})$$



Addressable by DA of:

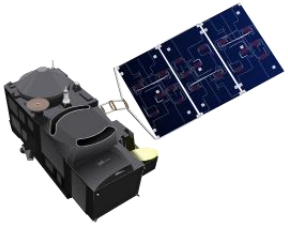
← PFTs

← Optical data

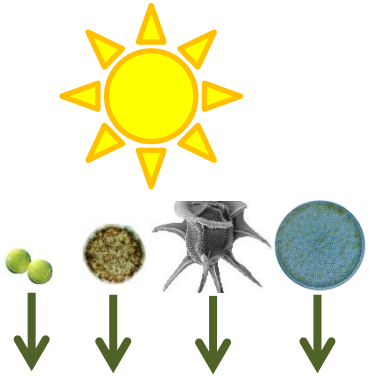
← BGC-Argos

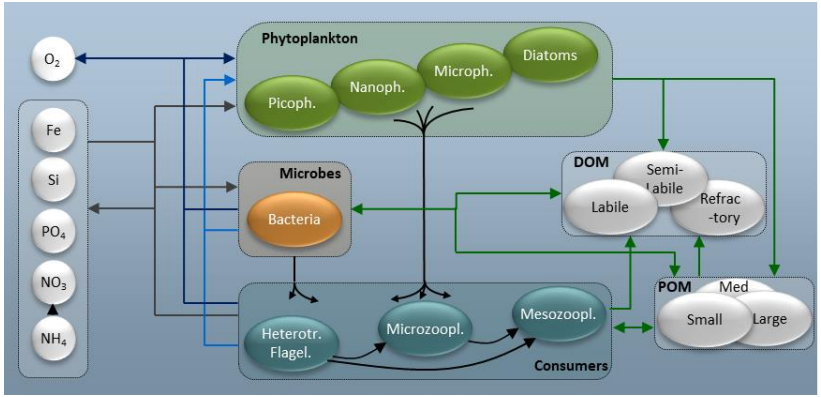
What biogeochemical data to assimilate?

Phytoplankton functional types (PFTs)



PFT Chlorophyll





Xiao and Friedrichs, 2014
Ciavatta et al., 2018

What biogeochemical data to assimilate?

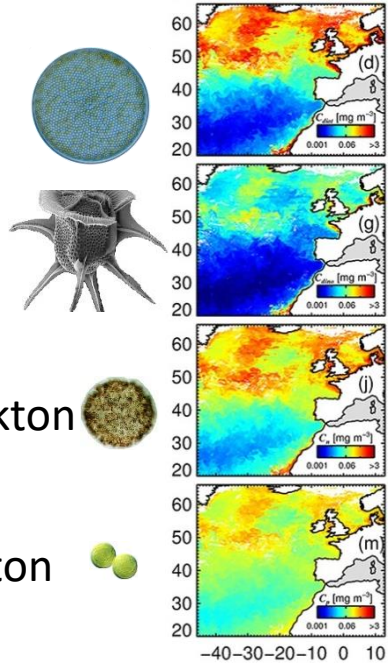
Phytoplankton functional types (PFTs)

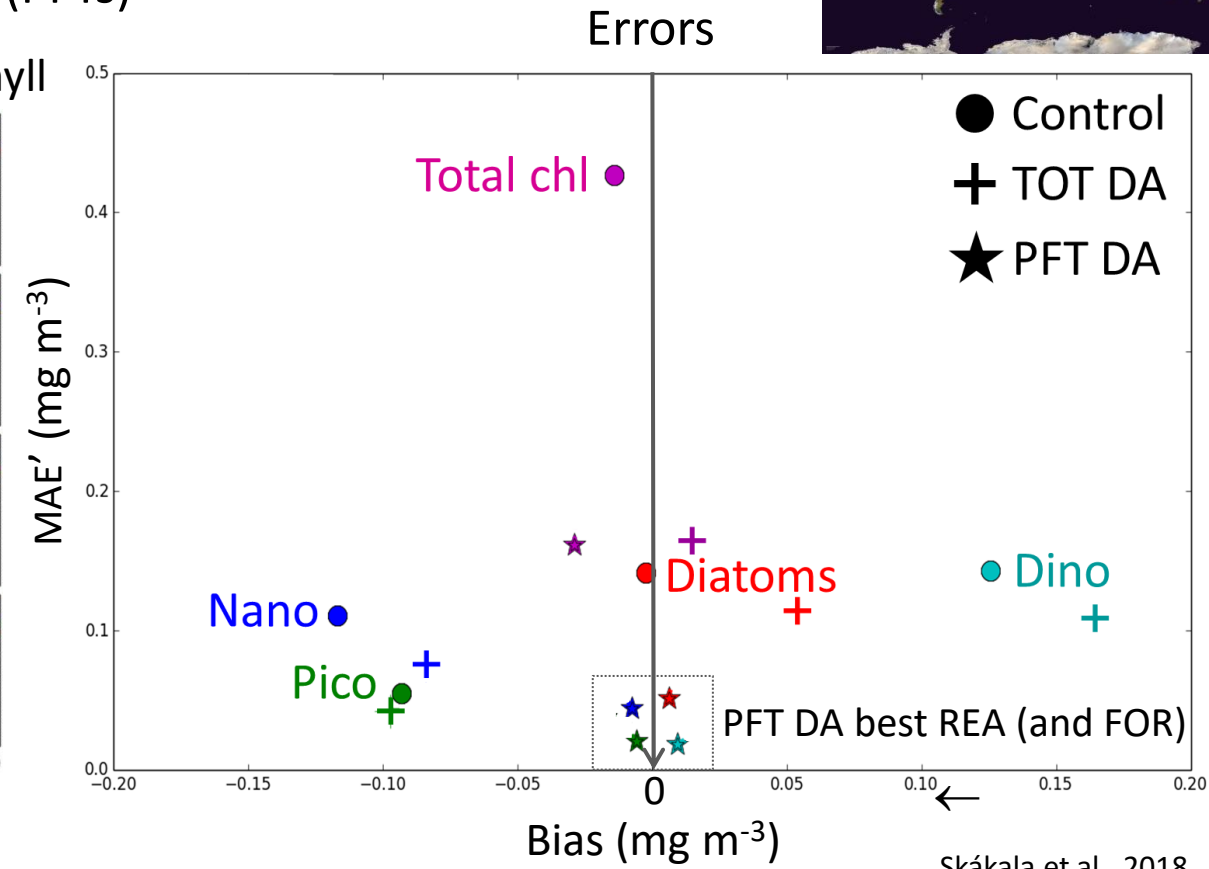
Diatoms

Dinoflagellates

Nanophytoplankton

Picophytoplankton



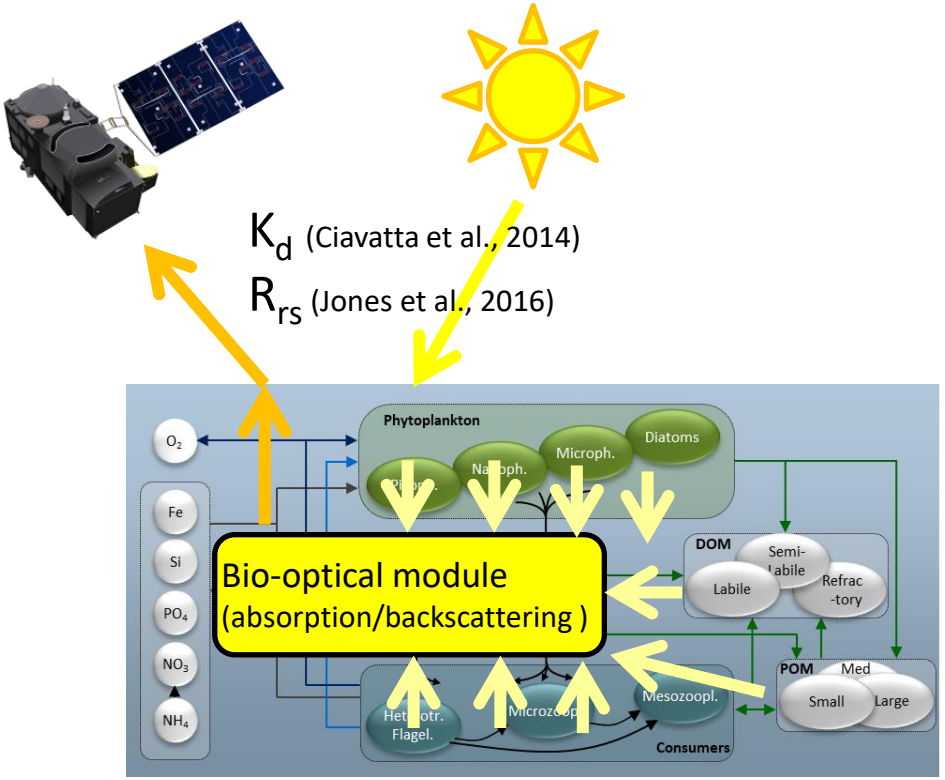


Brewin et al., 2017

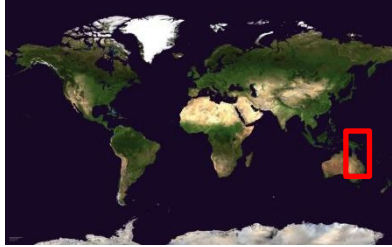
Skákala et al., 2018

What biogeochemical data to assimilate?

Optical properties (“bulk”)

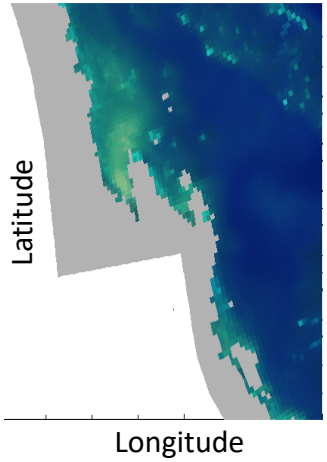


What biogeochemical data to assimilate?



Remote sensing reflectance: $R_{rs} = f(\text{CHL,TSS,CDOM})$

True color simulated (DA)



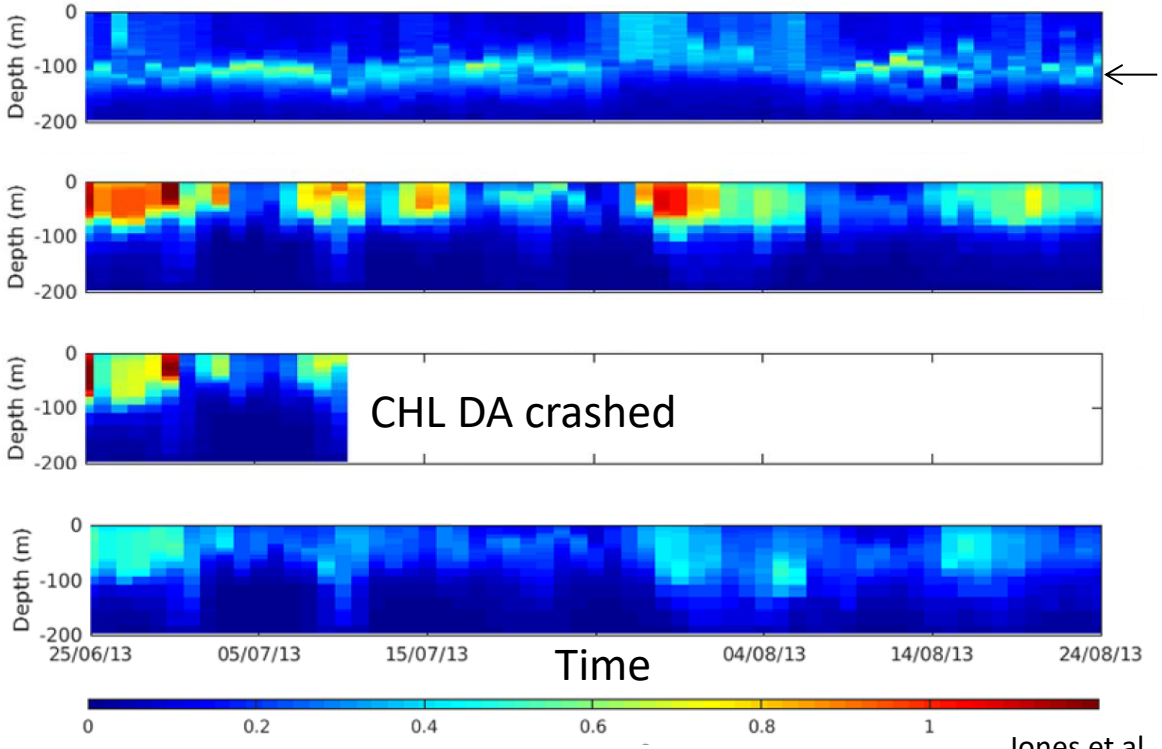
Chlorophyll @ depth

Data

Control

CHL DA

R_{rs} DA

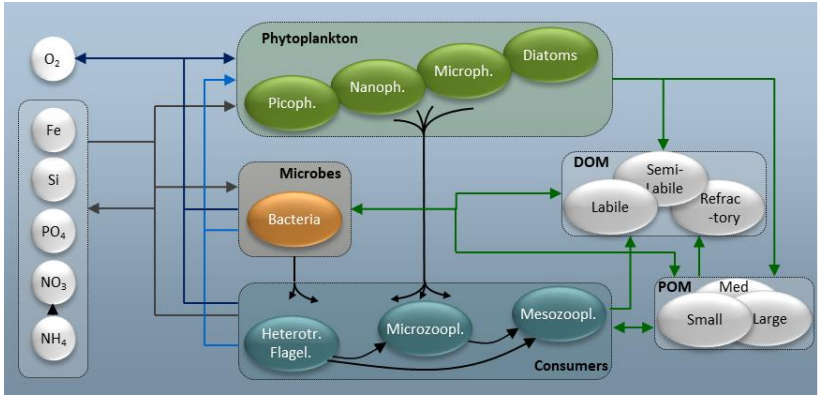


Deep Chl Max

Jones et al., 2016

What biogeochemical data to assimilate?

Autonomous underwater vehicles



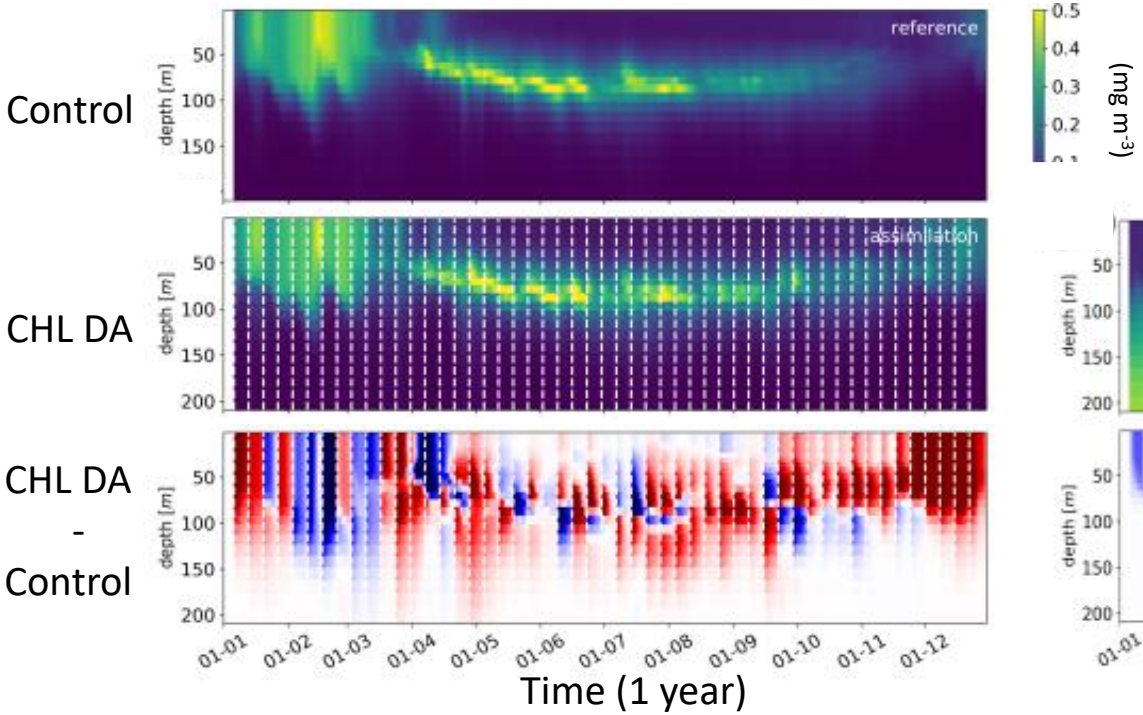
Gliders

BGC-Argos

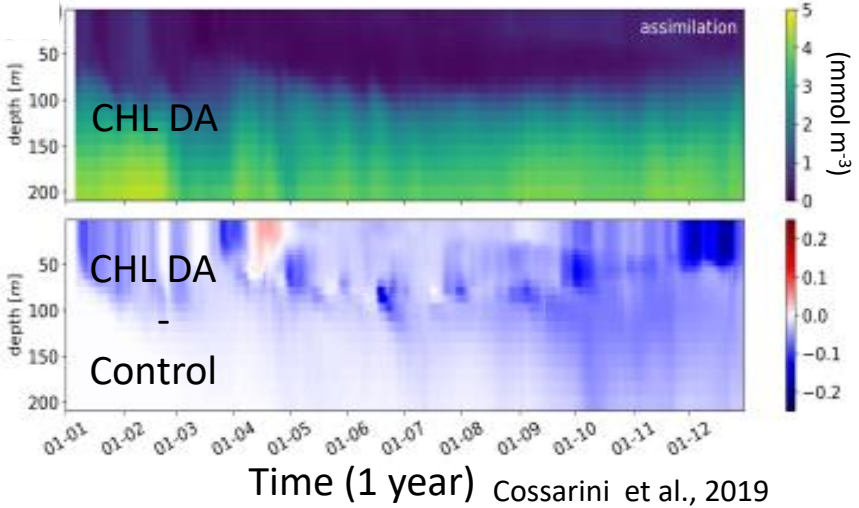
What biogeochemical data to assimilate?

Biogeochemical-Argo: chlorophyll

Chlorophyll @ depth



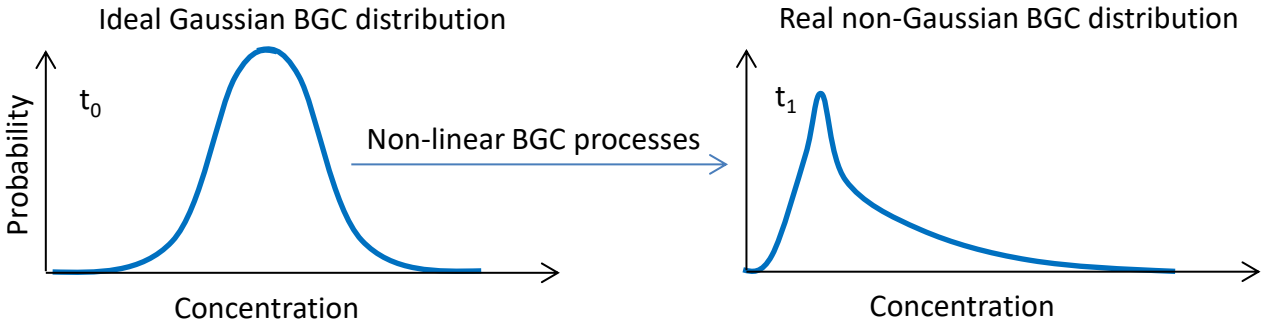
Nitrate @ depth

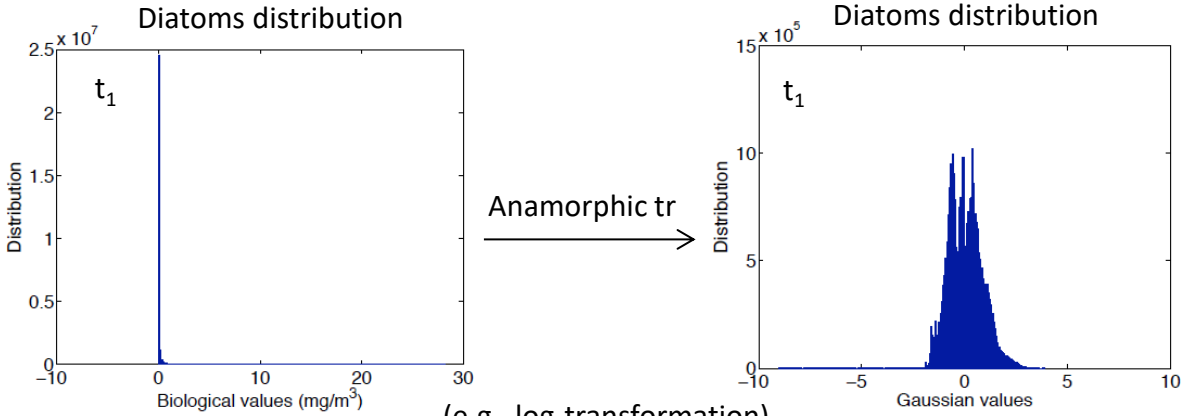


Cossarini et al., 2019

Addressing non-Gaussianity/non-linearity

Anamorphic transformation



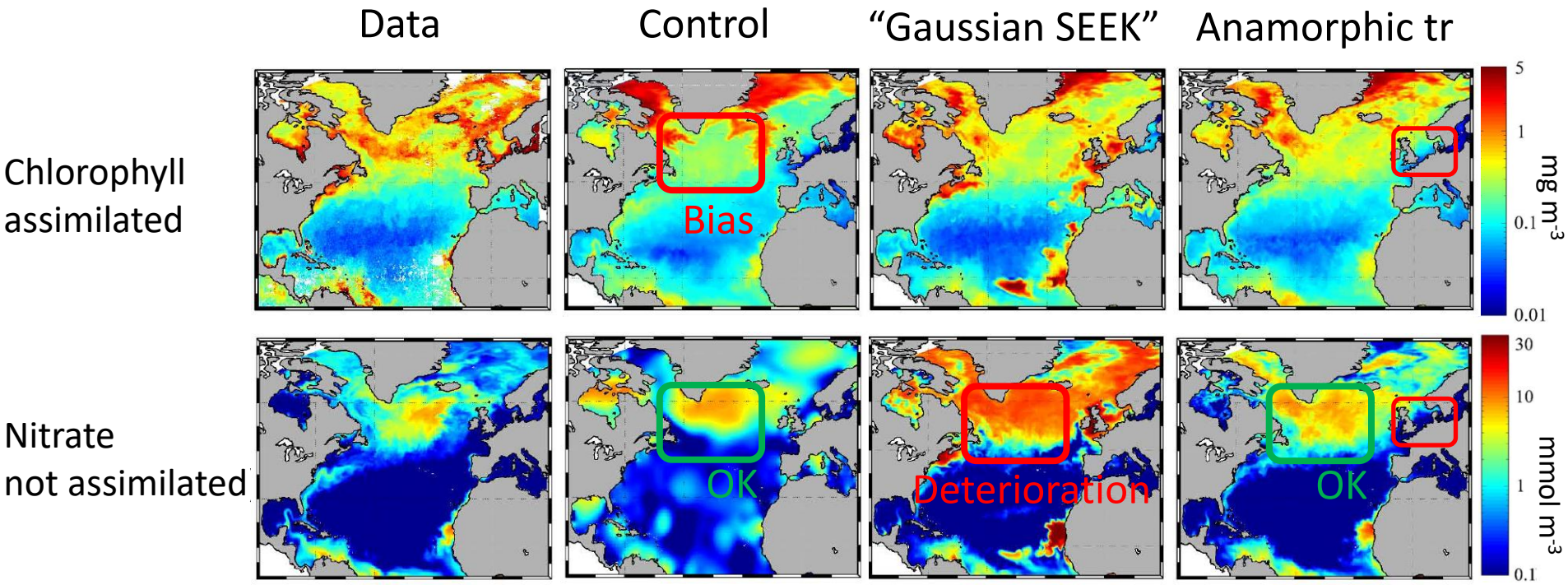


(e.g., log-transformation)

Simon and Bertino, 2009

Addressing non-Gaussianity/non-linearity

Anamorphic transformation



Mean values July-August 2006

Biases => BGC DA can deteriorate not-assimilated variables

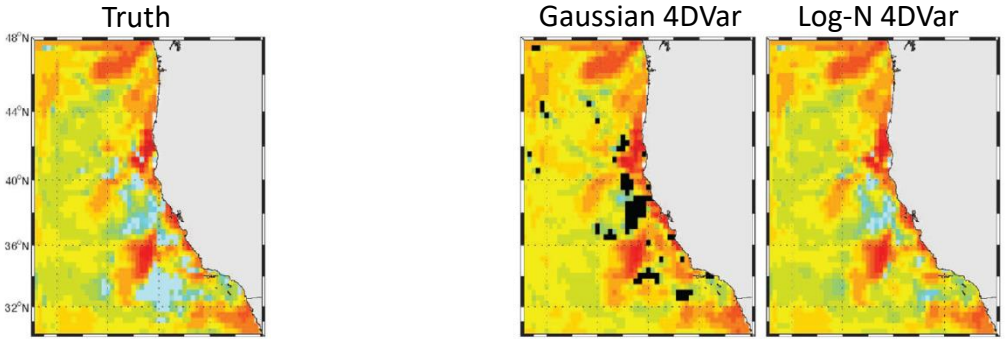
But...

Fontana et al., 2013

Addressing non-Gaussianity/non-linearity

Log-normal 4D-var

Chlorophyll



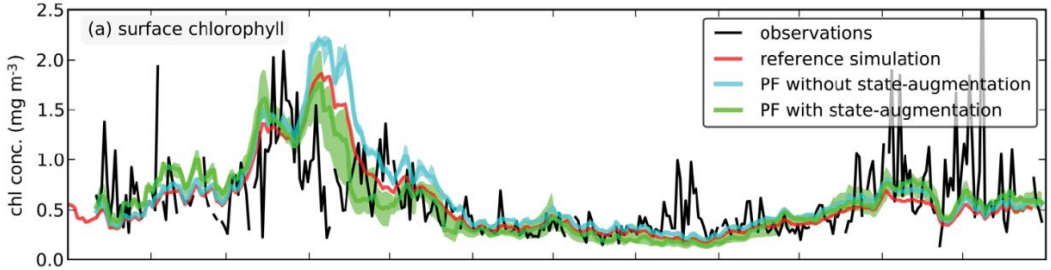
Pros
- It tackles non-G/non-l

Cons
- Not easy to code

Song et al., 2016a

Particle filters

Chlorophyll



Pros
- It tackles non-G/non-l

Cons
- It requires few tweaks

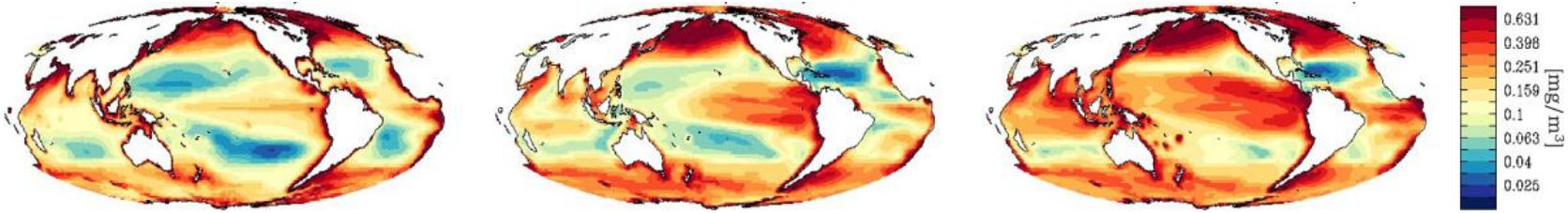
Mattern et al., 2013

… but the issue is not resolved yet

Coupled physical and biogeochemical data assimilation (BGC helps PHY)

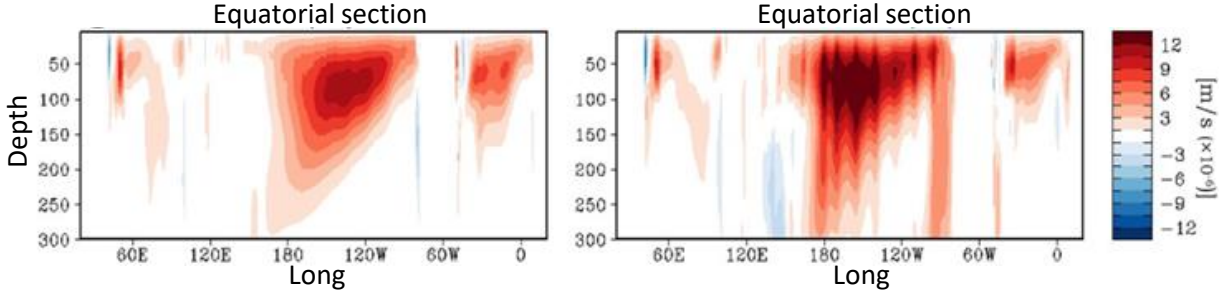
Data | Control | PHY-DA

Chlorophyll

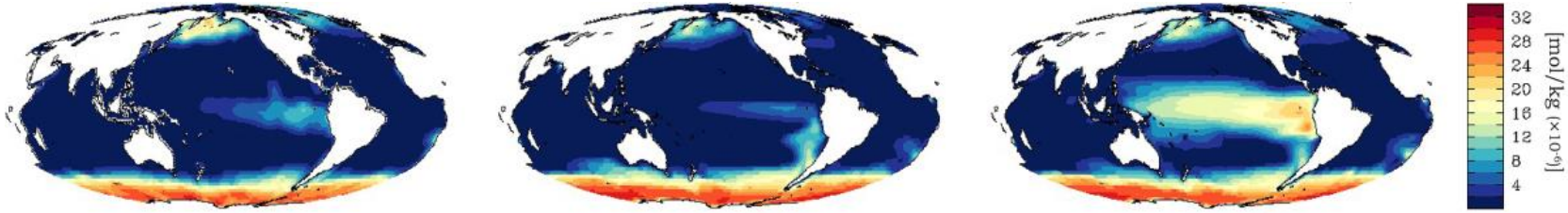


Vertical velocity

…is deteriorated*



Nitrate

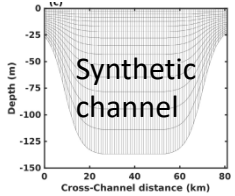


- "Incremental pressure corrections" (Waters et al., 2017)
- "Pragmatic fixes" (Park et al., 2018)

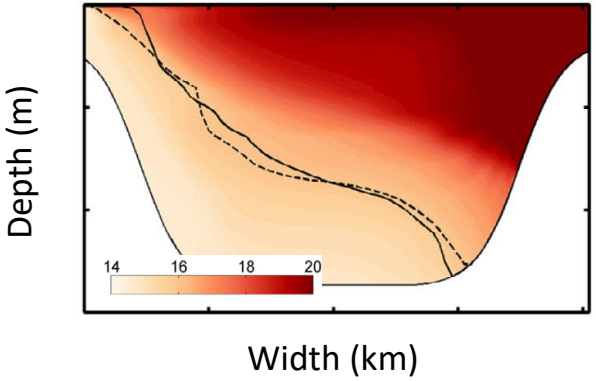
…did not really fix the issue

Park et al., 2018

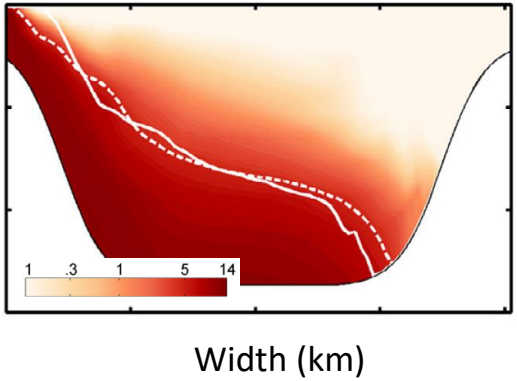
Coupled physical and biogeochemical data assimilation (BGC helps PHY)



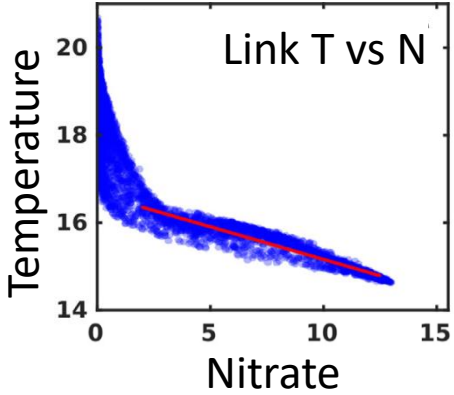
Temperature (°C)



Nitrate (mmol m^{-3})

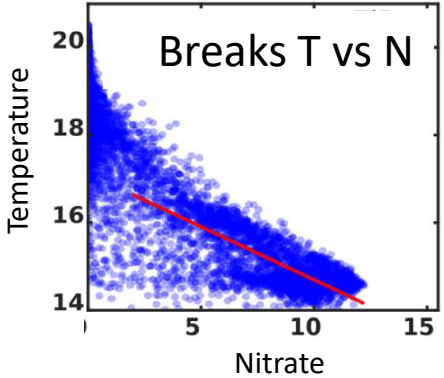


Control

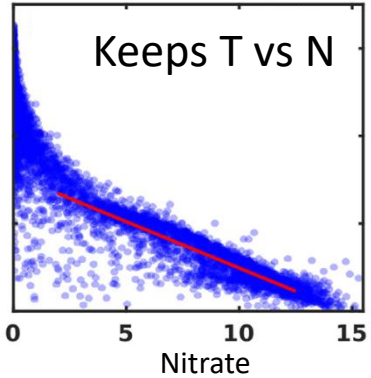


DA trials

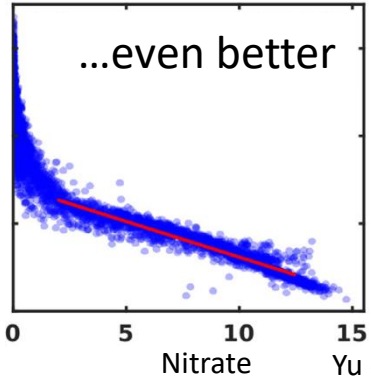
DA PHY to correct PHY



DA PHY to correct PHY & BGC

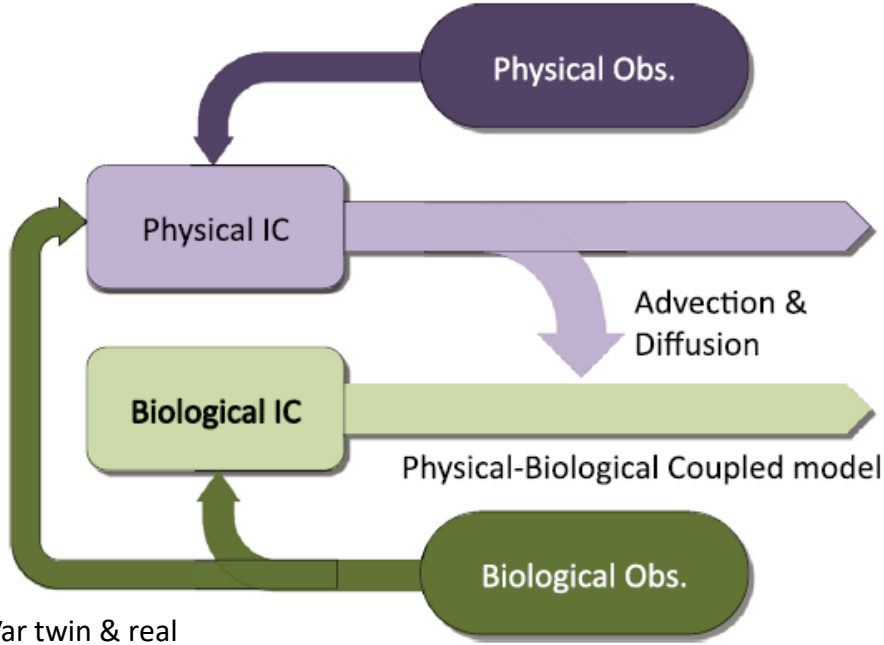


DA BGC to correct PHY & BGC

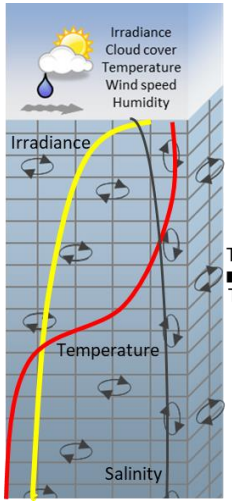


Yu et al., 2018

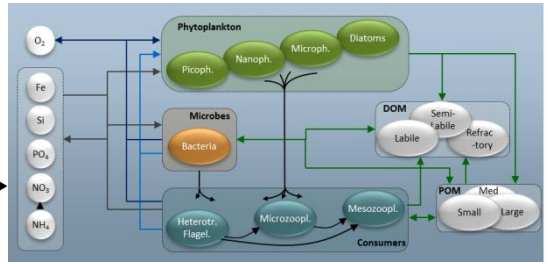
Coupled physical and biogeochemical data assimilation (BGC helps PHY)



4DVar twin & real



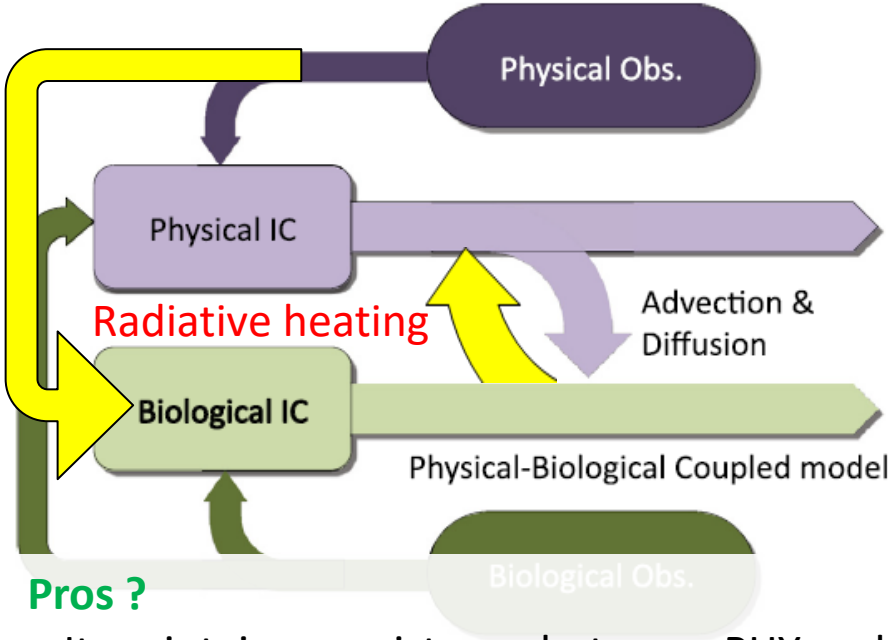
Transport
T,E,S

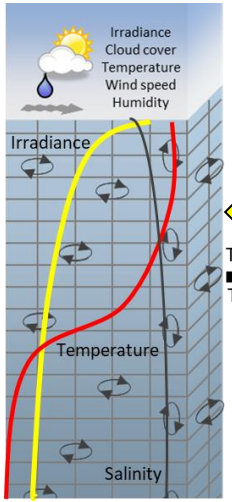


Song et al., 2016b

Coupled physical and biogeochemical data assimilation

Joint PHY-BGC DA with two-way coupled PHY-BGC modelling?

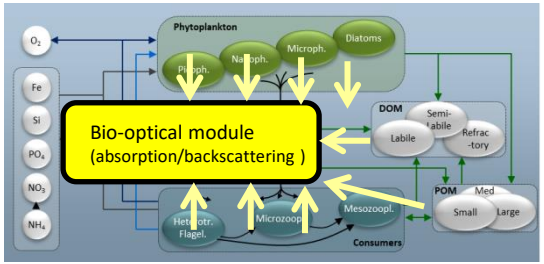




E

Transport

T,E,S



e.g. Manizza et al., 2005

Pros ?

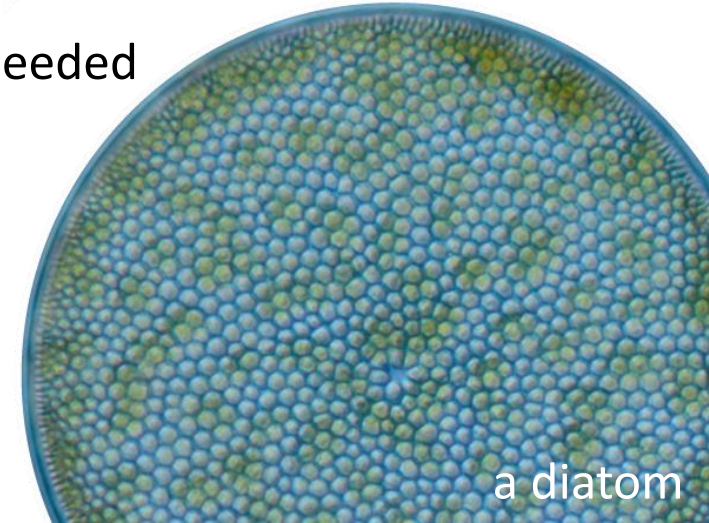
- It maintains consistency between PHY and BGC fields
- It increases the number of useful data (including PHY, BGC Argos & R_{rs})

Cons ?

- It might just mask further the real issues (e.g. model biases, spurious vertical velocities)

Concluding remarks

1. BGC DA can **improve prediction of BGC indicators** … and “help” PHY DA
2. Need to improve PHY-BGC assimilative models (**solve the biases**)
3. **“New” data** (PFTs, optics, BGC-Argos): pros & cons
4. **Non-Gaussianity**/non-linearity issue: more work needed
5. **Two-way coupling** of PHY-BGC modelling & DA



a diatom

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