A multi-data assimilation scheme of Biogeochemical-Argo data for the CMEMS Mediterranean Biogeochemical model

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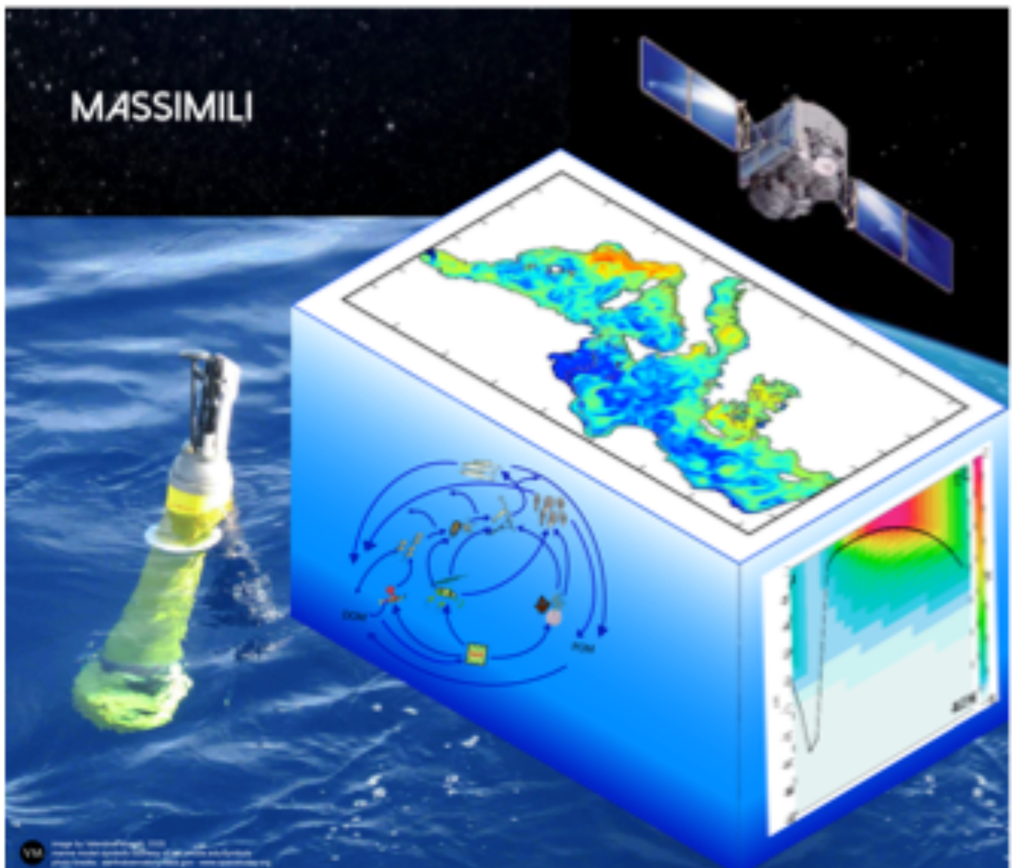
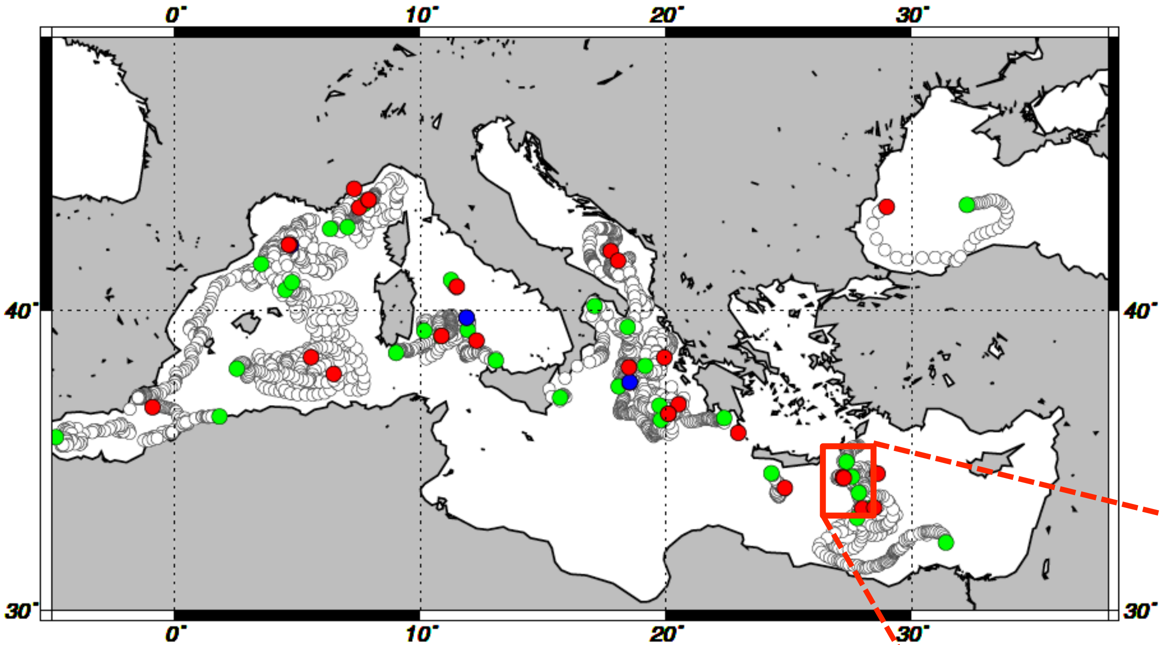
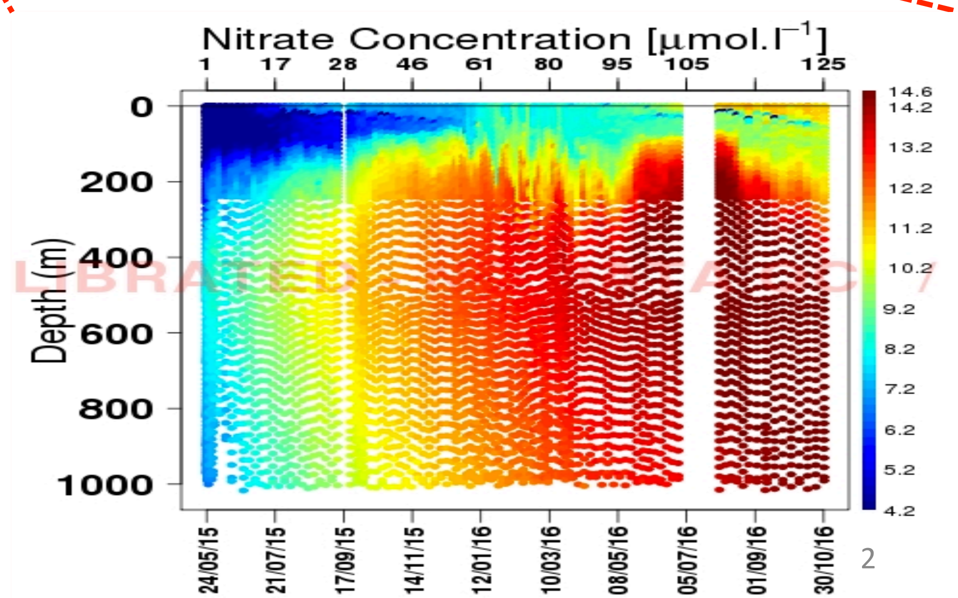


MASSIMILI: a CMEMS service evolution project

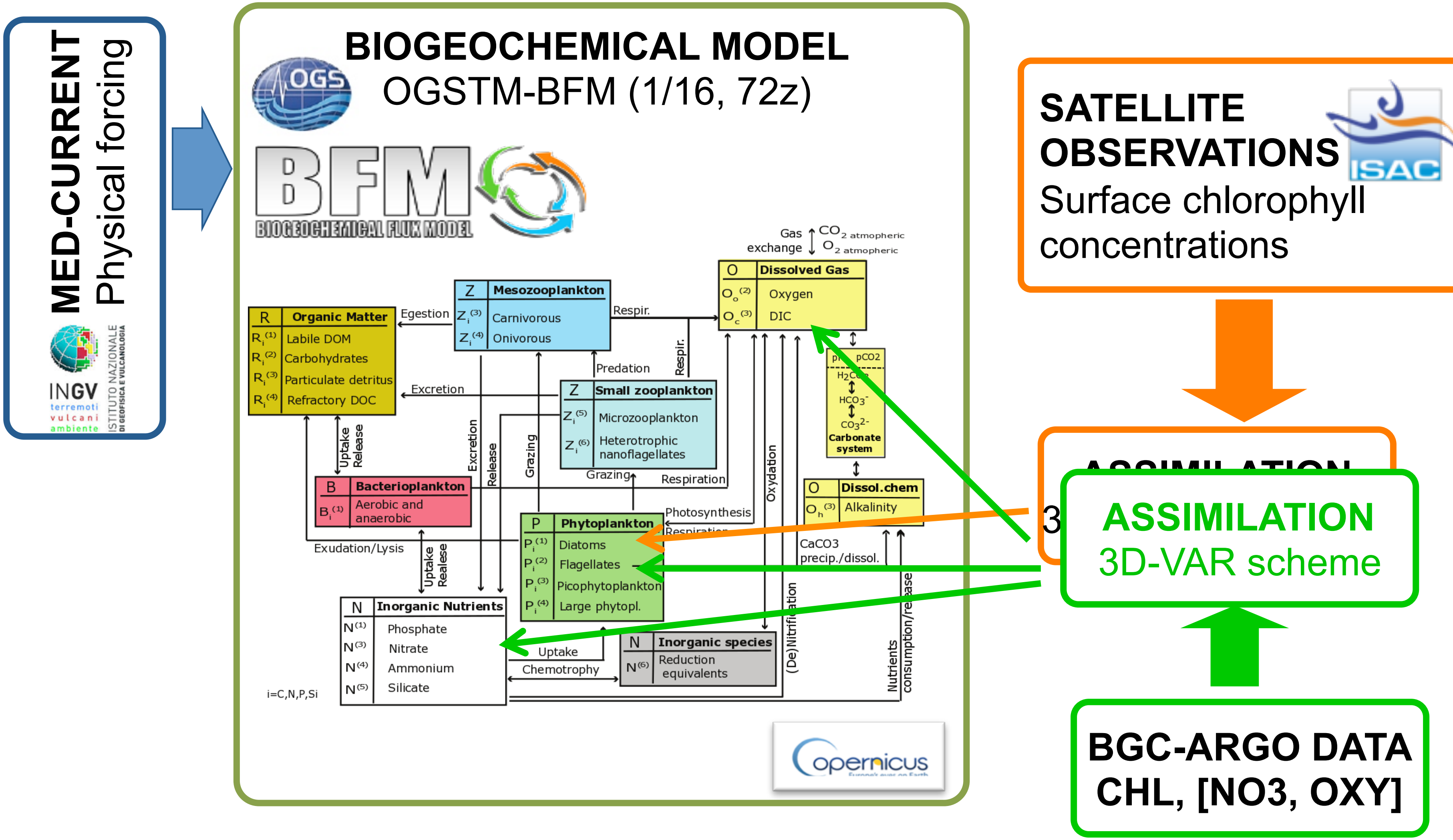
BGC-Argo floats: operational observations of the biogeochemical vertical proprieties



 # BGC-Argo floats: 12-16
BGC vars: Chla (14), Oxy (12), Nit (8)
Mission cycle: ~ 5 days
Parking depth: 1000m (slow moving)
Life-time: > 2years



Data assimilation in the CMEMS biogeochemical Med-MFC



MASSIMILI project: upgrading the 3DVAR-BIO to integrate BGC-Argo float data

3DVAR-BIO code: variational assimilation scheme

The analysis state is given by the minimization of the cost function

$$J(\delta \mathbf{x}_k) = \frac{1}{2}\delta \mathbf{x}_k^{\mathrm{T}} \mathbf{B}_k^{-1} \delta \mathbf{x}_k + \frac{1}{2}(\mathbf{d}_k - \mathbf{H}\delta \mathbf{x}_k)^{\mathrm{T}} \mathbf{R}_k^{-1} (\mathbf{d}_k - \mathbf{H}\delta \mathbf{x}_k)$$

$\delta x = x - x_b$: perturbation in model space around the background state x_b

B and **R** : background and observation error covariance matrices

H : linearized form of the observational operator, which transforms the state vector x in the observation space

$d = y - Hx_b$: misfit between observations **y** and background estimates

The solution of the cost function can be computed by means of a new control variable **v**:

$$\delta \mathbf{x} = \mathbf{V}\mathbf{v}$$

V : mapping operator representing the square root of the background-error covariance matrix **$B = VV^T$**, defined as a sequence of linear operators

$V = V_b V_H V_v$ (Dobricic and Pinardi, 2008; Teruzzi et al., 2014)

V_V vertical covariance → EOFs vertical profiles

V_H horizontal covariance → Gaussian horizontal filter

V_b biological covariance → covariance matrix among chlorophyll and other phytopl. model variables (C,N,P,Si in phytopl. groups)

Assimilation versus reference: winter and summer runs

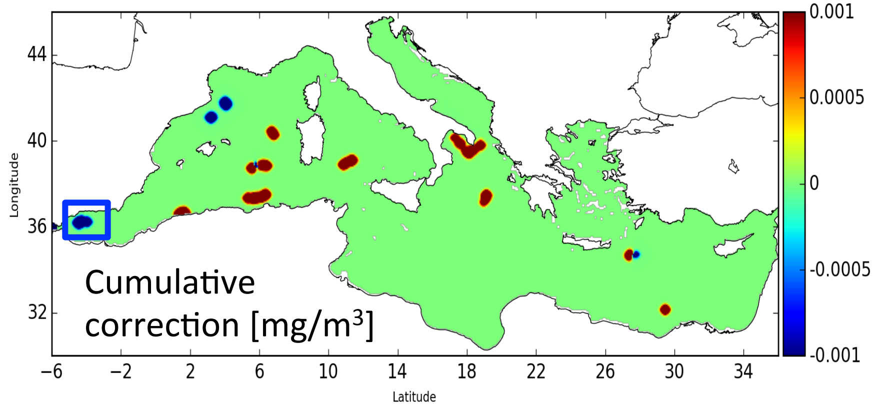
DA run, ass. cycle:

H	H	DA	H	H	H	H	H	H	DA	H	H	H	H	H	H

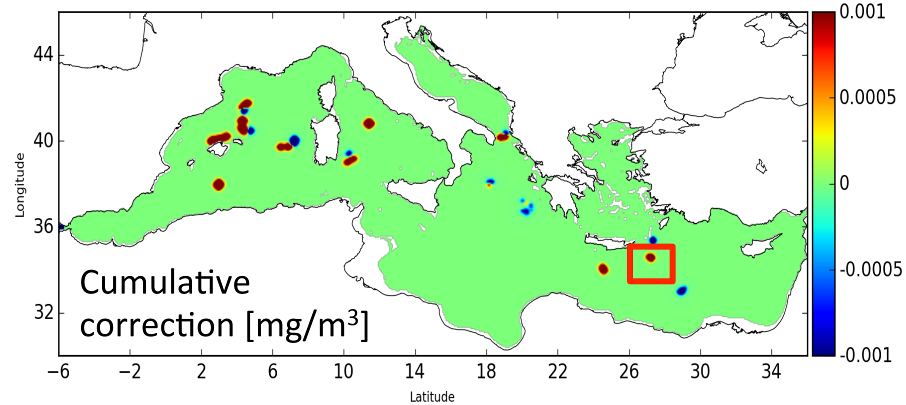
Reference run (REF):

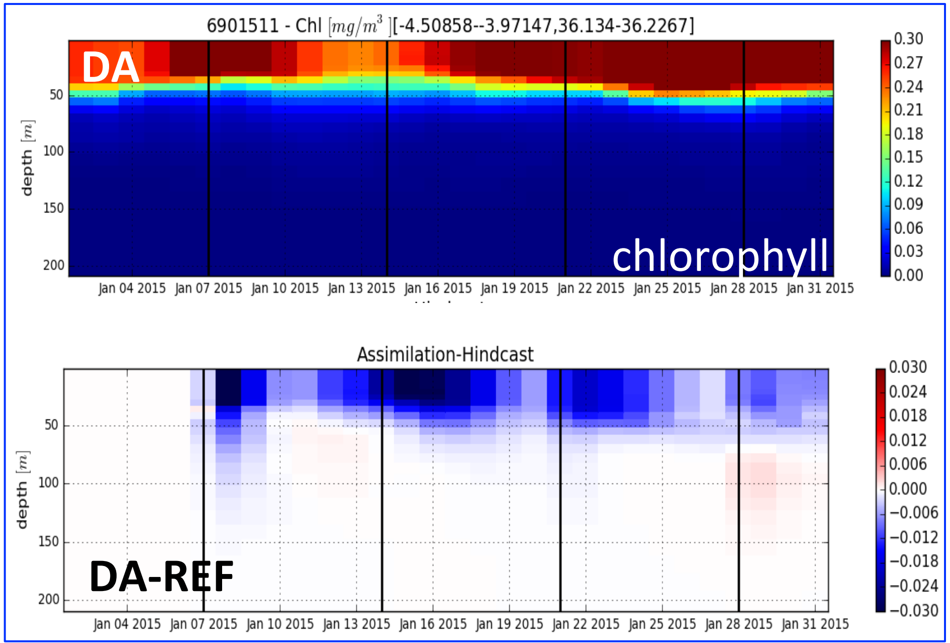
H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H

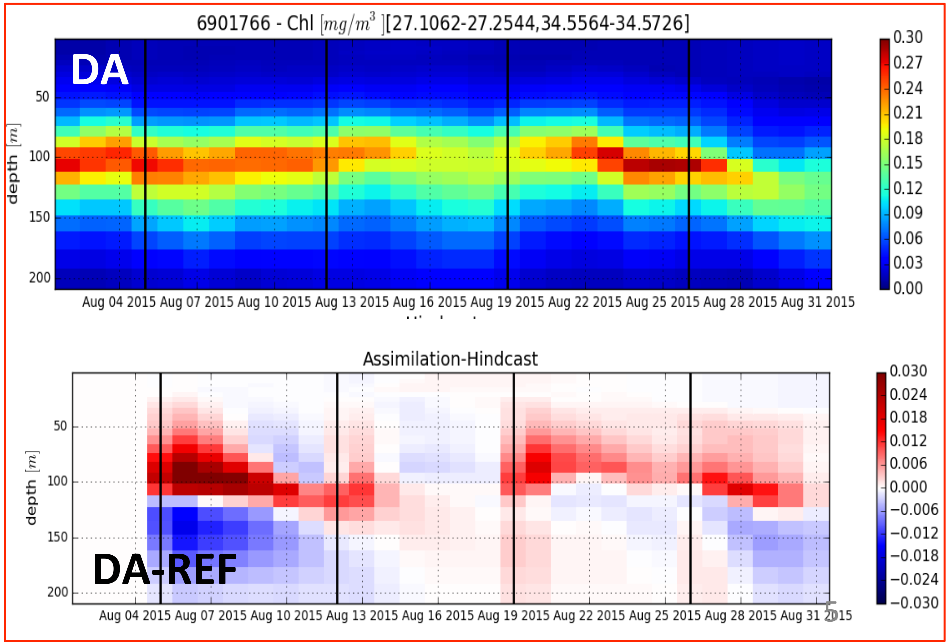
Winter: 1 Jan – 31 Jan 2015



Summer: 1 Aug – 31 Aug 2015



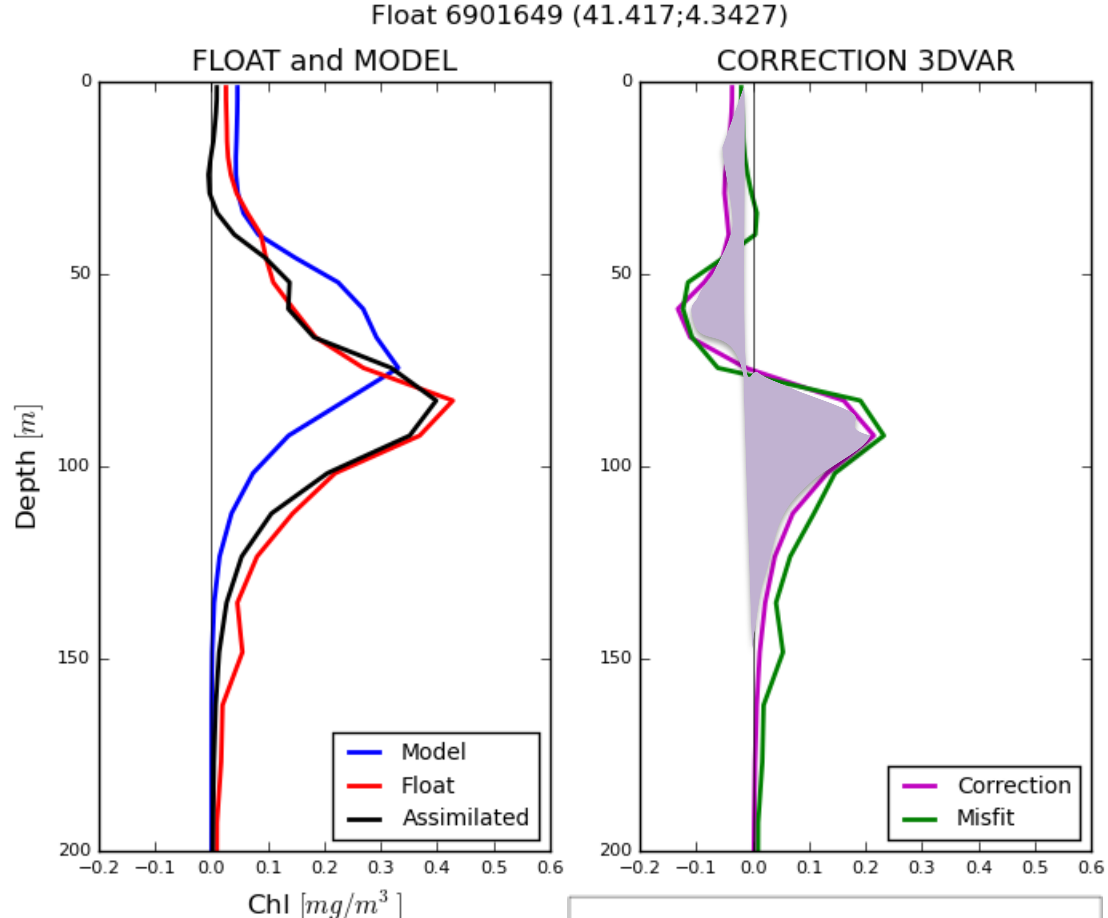




Estimating the impact of the assimilation

1) III: index of innovation intensity

$$III = \int_z |innovat|$$



$d = y - H\,x_b$

misfit = difference between observations and forecast

DA

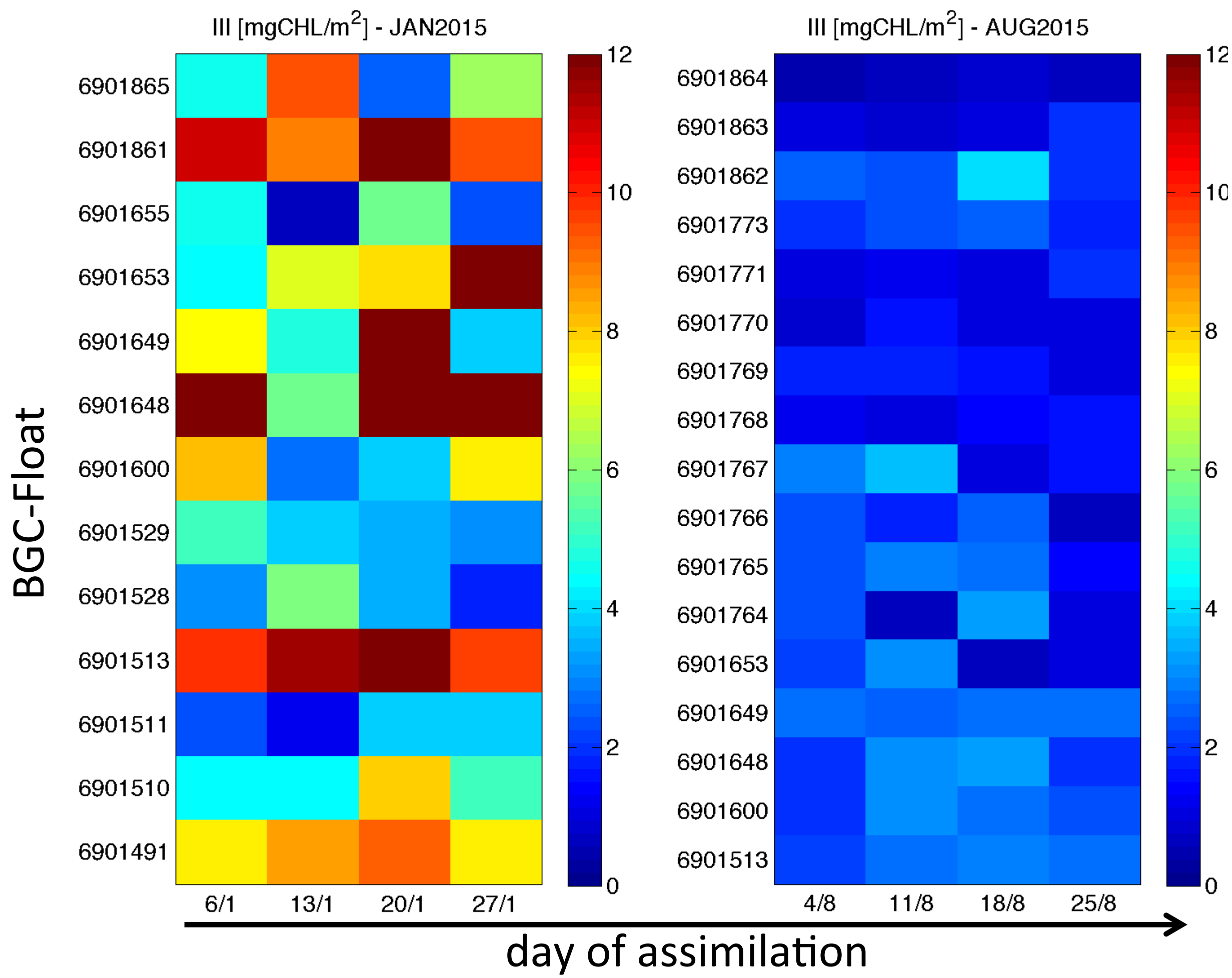
$x = x_b + dx$

new state = sum of forecast and innovation

Estimating the impact of the assimilation

1) III: index of innovation intensity

$$III = \int_z |innovat|$$



$\langle III\rangle_{Jan}=6.9$ mg/m^2 $\langle III\rangle_{Aug}=1.8$mg/m^2

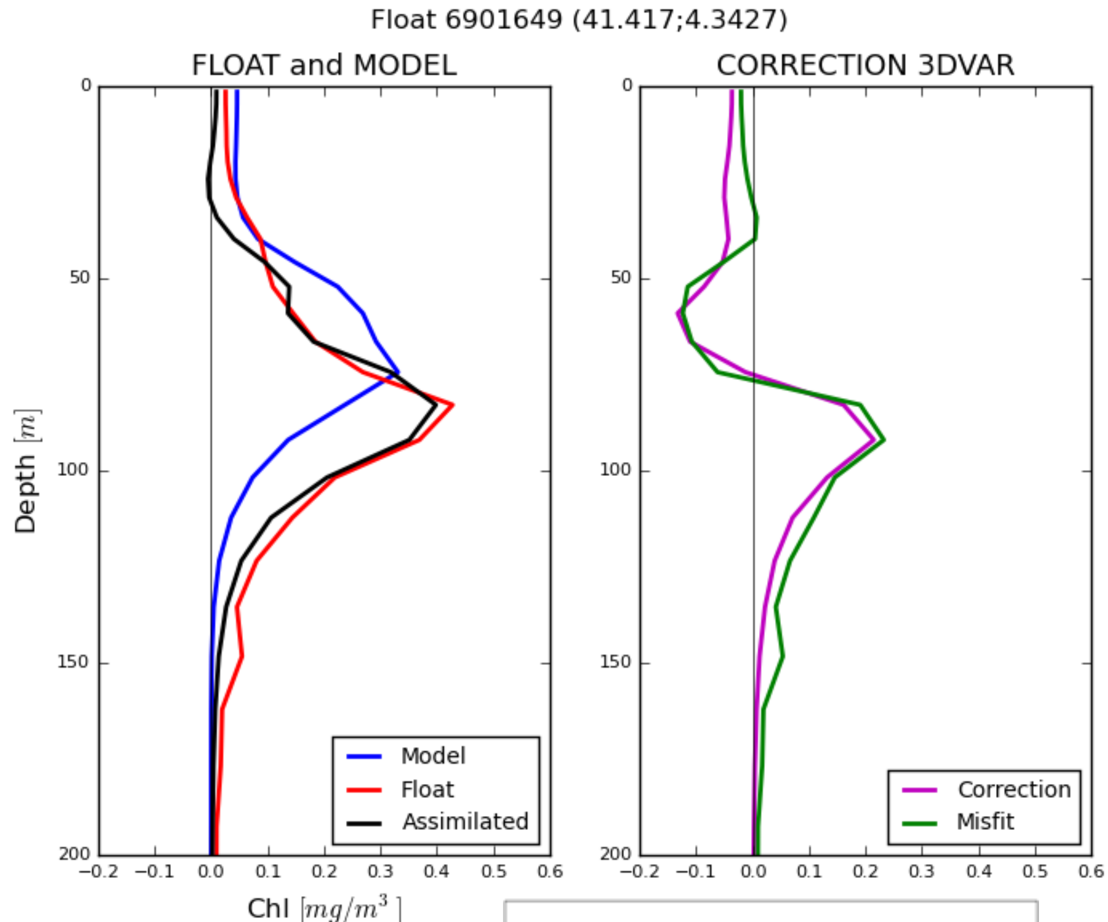
Estimating the impact of the assimilation

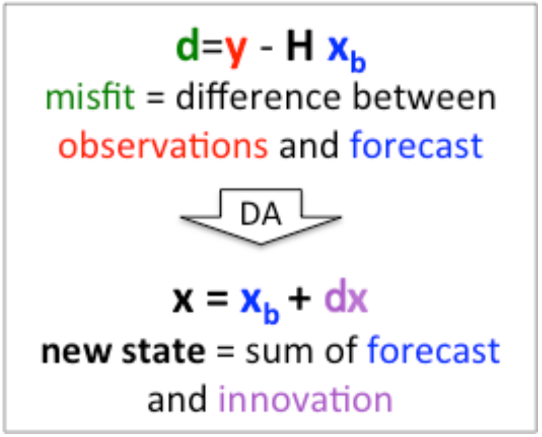
1) III: index of innovation intensity

$$III = \int_z |innovat|$$

2) IIP: index of innovation power

$$IIP = 1 - \int_z \left| \frac{innovat - misfit}{misfit} \right|$$





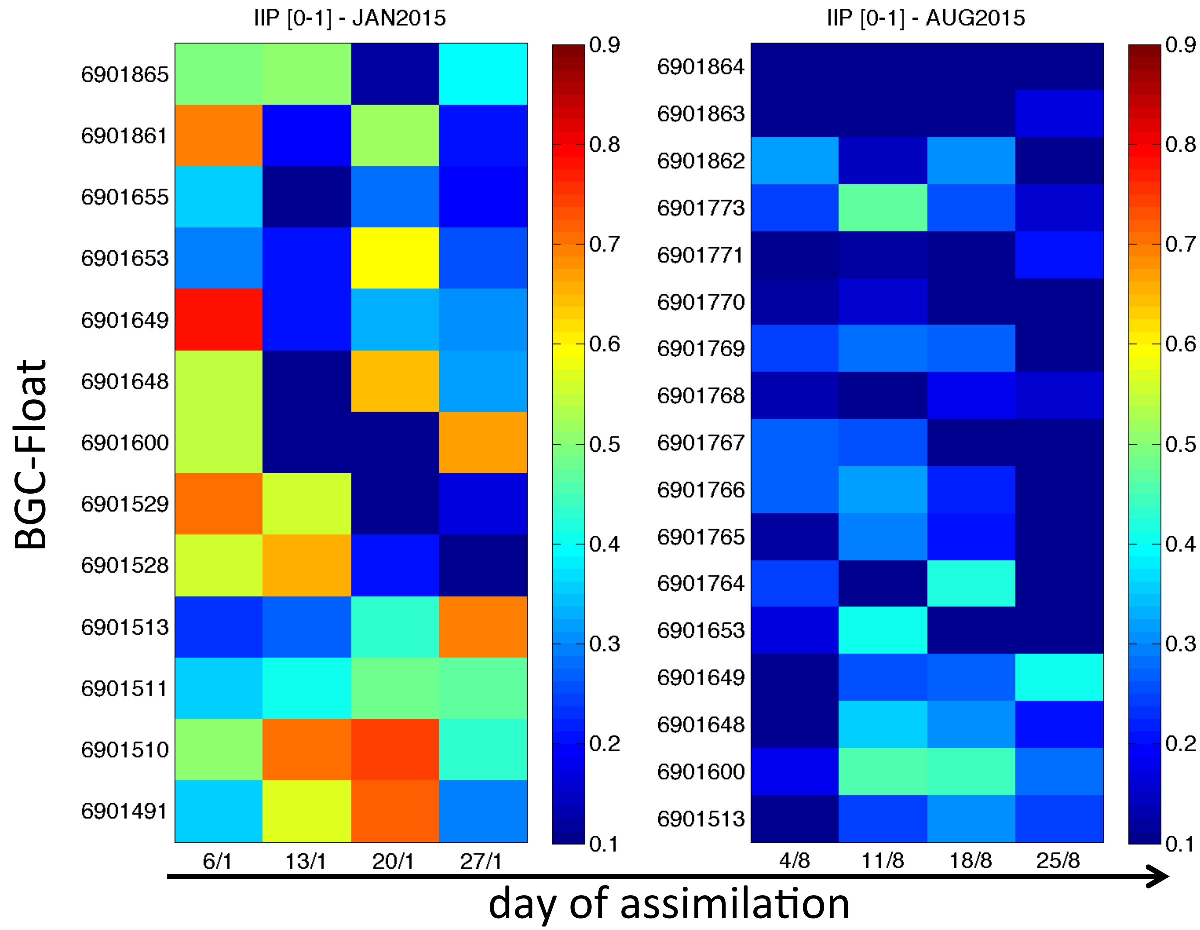
Estimating the impact of the assimilation

1) III: index of innovation intensity

$$III = \int_z \left| innovat \right|$$

2) IIP: index of innovation power

$$IIP = 1 - \int_z \left| \frac{innovat - misfit}{misfit} \right|$$

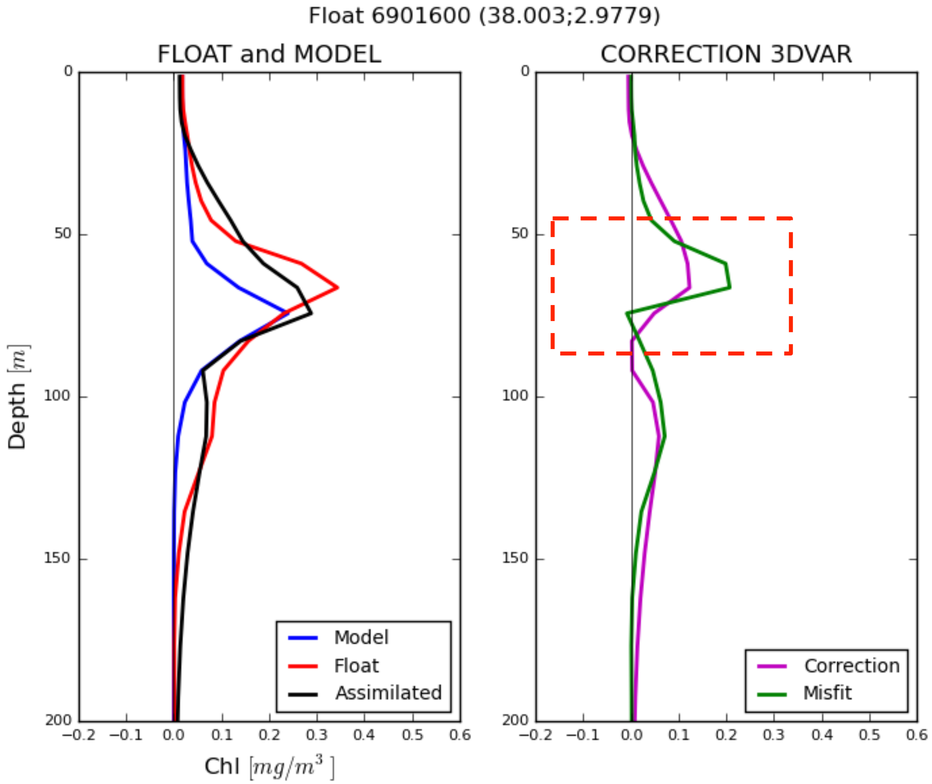


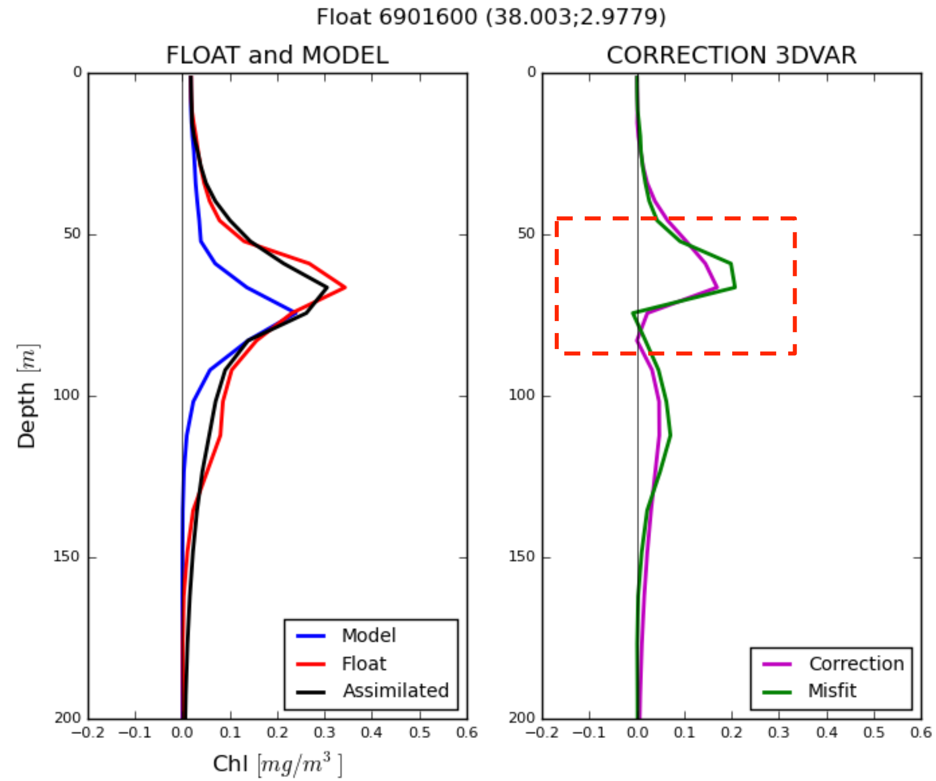
<IIP>$_{Jan}$=39%

<IIP>$_{Aug}$=20%

Sensitivity of DA to the vertical covariance operator (Vv)
Set of the vertical EOFs: $\mathbf{V_v} = S\Lambda^{1/2}$

5 EOFs **25 EOFs**





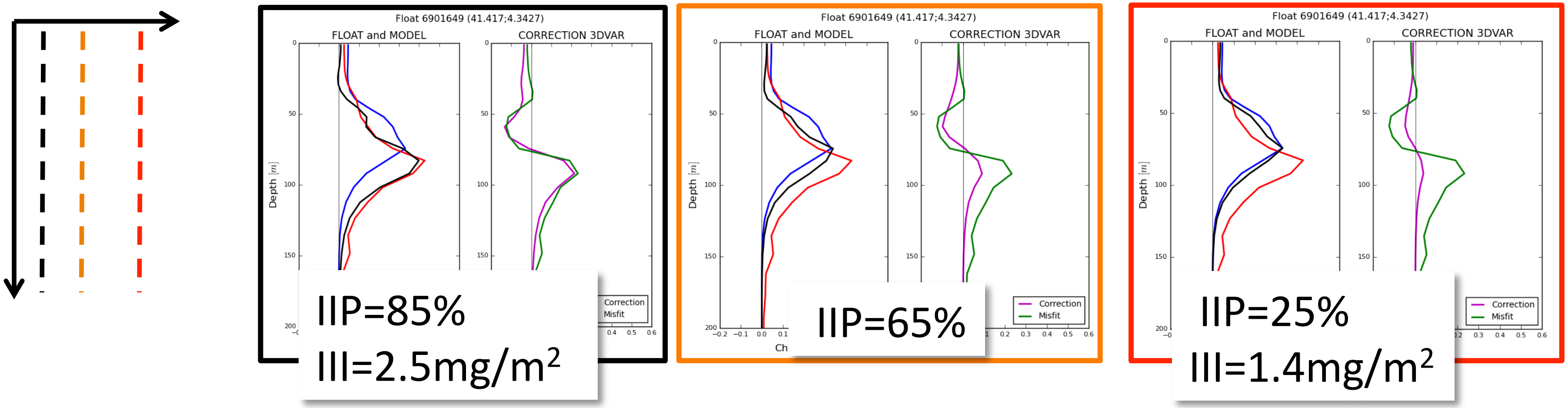
index of innovation intensity III: no significant changes

index of innovation power IIP: significant increase (mostly in summer)

Sensitivity of DA to the observation error definition (R)

Statistics of obs. error are not perfectly known **[Desroziers et al., 2005]**

Constant error profile (proportional to instrumental error [0.01, 0.05, 0.1 mg/m^3])



high error value ➔ the power of assimilation decreases

The aim is to identify criteria useful for tuning the observation error covariance in order to have ad effective assimilation while the consistency between model and observation errors is preserved.

Two methods:

- Desroziers et al., 2005, definition of the a-posteriori diagnostic observation and background errors
- "Estimation of BGC-Argo chlorophyll fluorescence and nitrate observational errors" Alexander MIGNOT, *LOV CNRS/UPMC – France (POSTER)*

Estimating the impact of the assimilation

1) III: index of innovation intensity

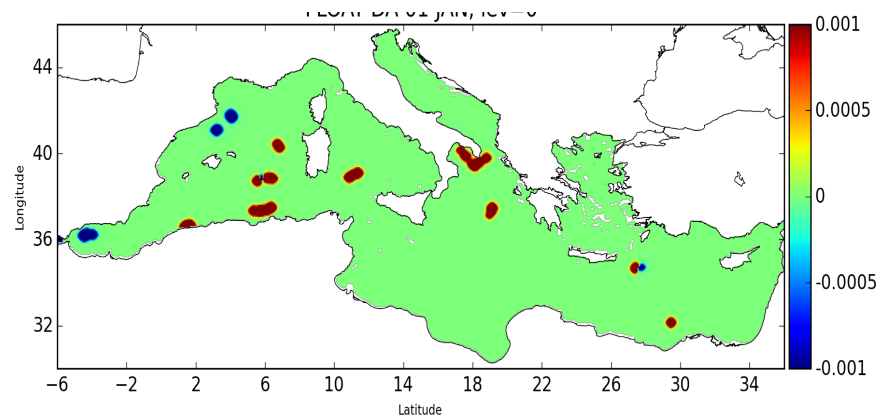
$$III = \int_z innovat$$

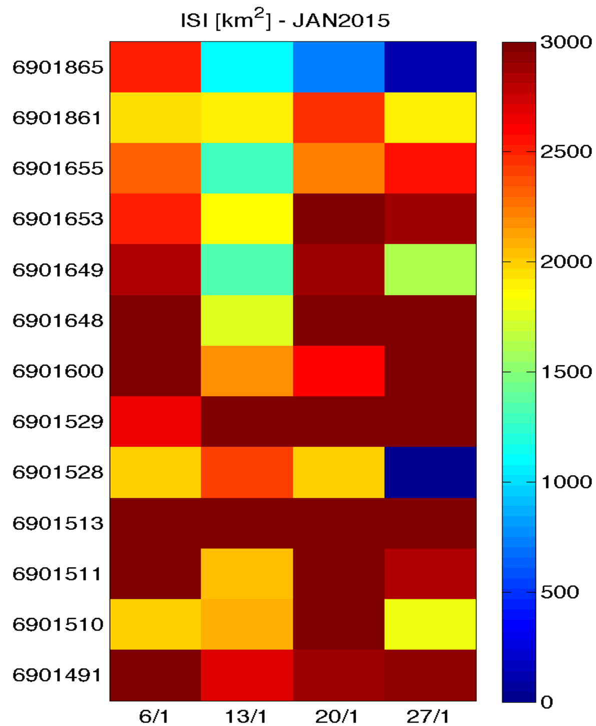
2) IIP: index of innovation power

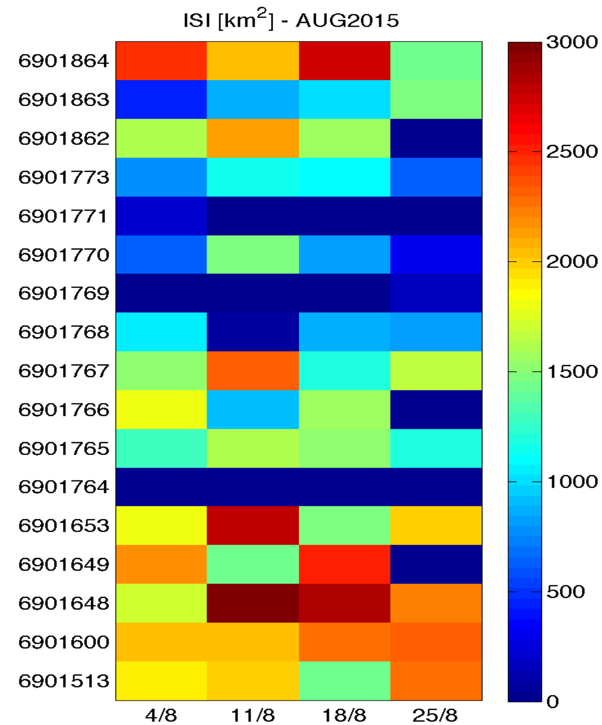
$$IIP = 1 - \int_z \left| \frac{innovat - misfit}{misfit} \right|$$

3) ISI: index of spatial innovation

$$ISI = \int_{x,y} SURF(|innovat| > T_{inn})$$







$<ISI>_{Jan} = 2500 km^2$

2.5% of med

$<ISI>_{Aug} = 1500 km^2$

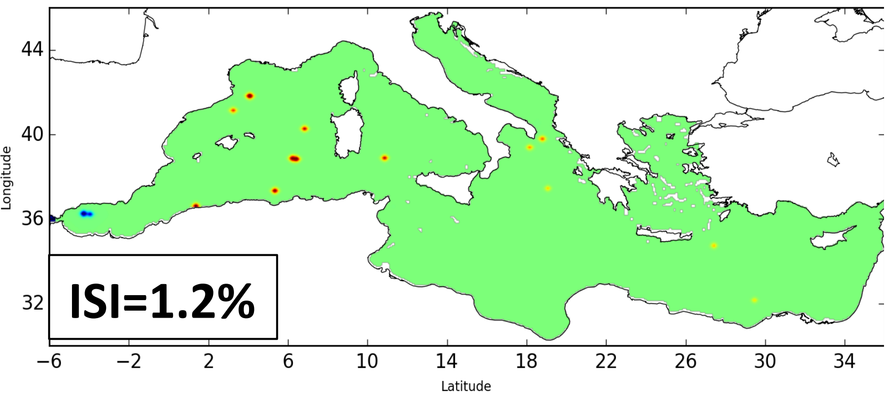
1.5% of med

Sensitivity of ISI to horizontal covariance operator

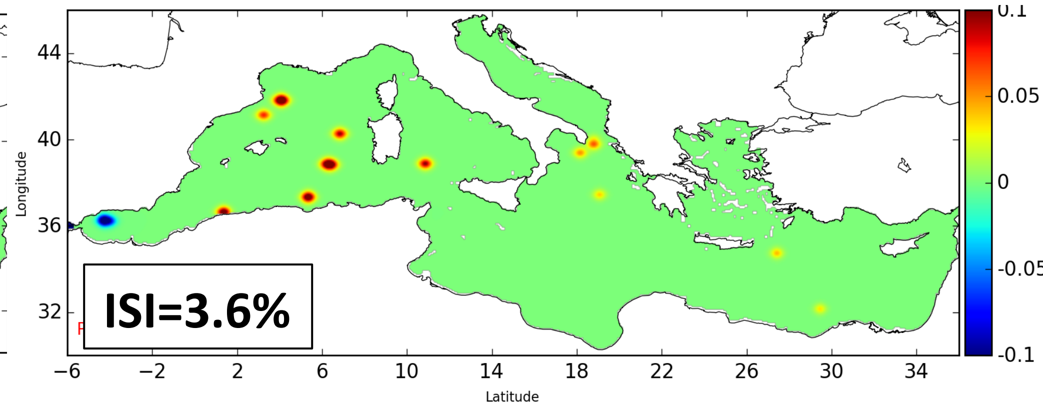
Gaussian recursive filter based on smoothing coefficients (corr. radius length scale)

Corr. radius length scale (Lr) is no uniform in x and y and varies with depth.

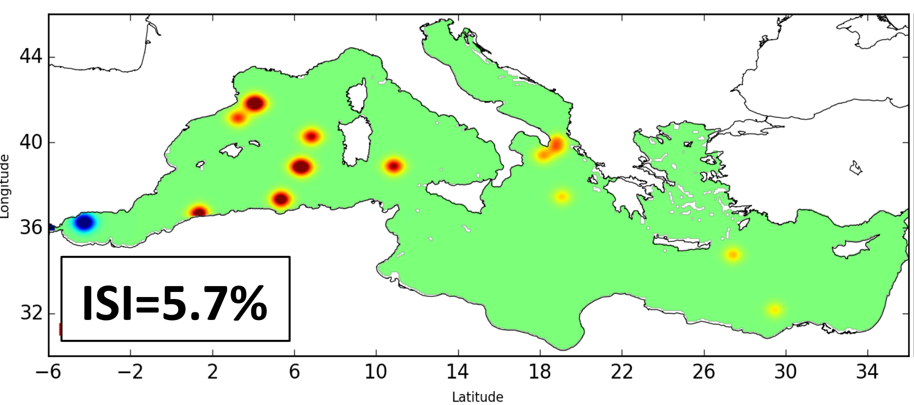
<Lr>=5km



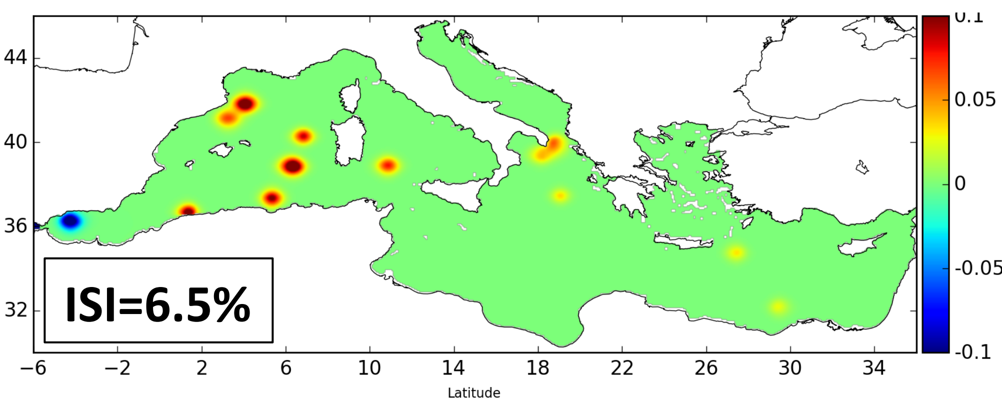
<Lr>=10km



<Lr>=15km

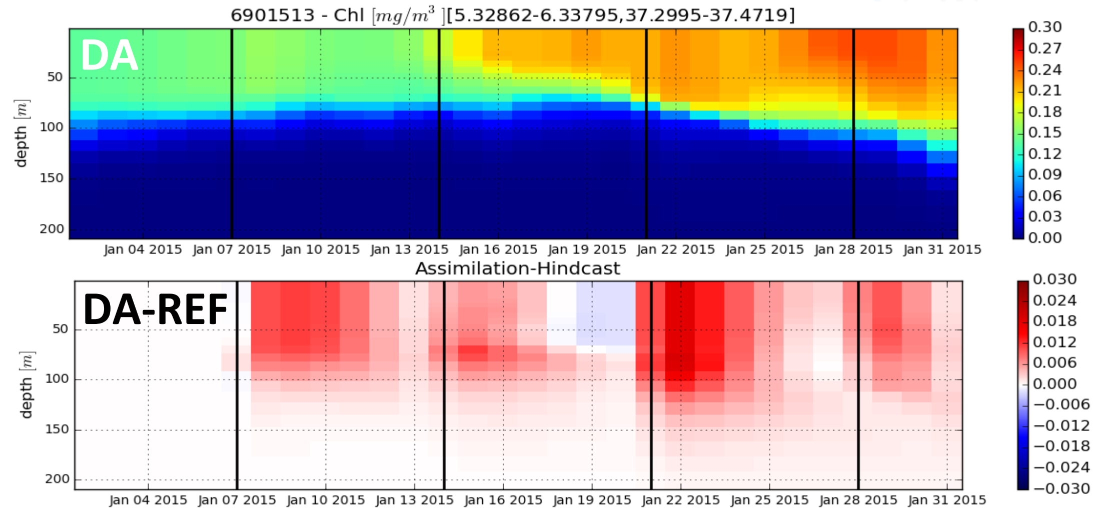


<Lr>=not uniform



Maps of the innovation (mgCHL/m^3)

Estimating the impact of the assimilation



1) III: index of innovation intensity

$$III = \int_z |innovat|$$

2) IIP: index of innovation power

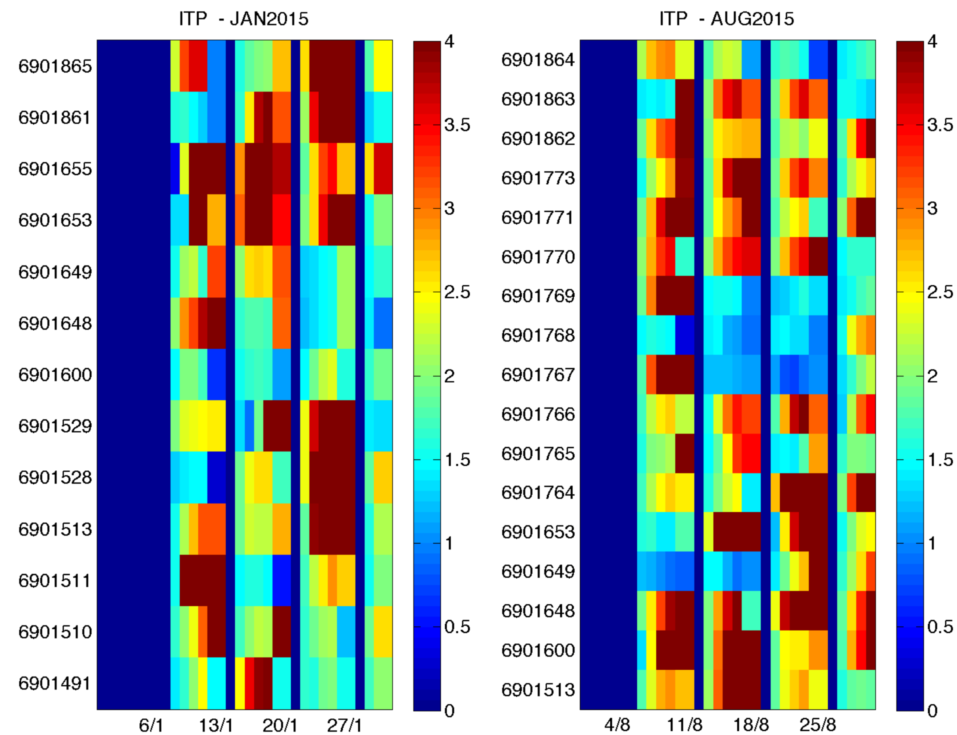
$$IIP = 1 - \int_z \left| \frac{innovat - misfit}{misfit} \right|$$

3) ISI: index of spatial innovation

$$ISI = \int_{x,y} SURF(|innovat| > T_{inn})$$

4) ITP: index of temporal persistence

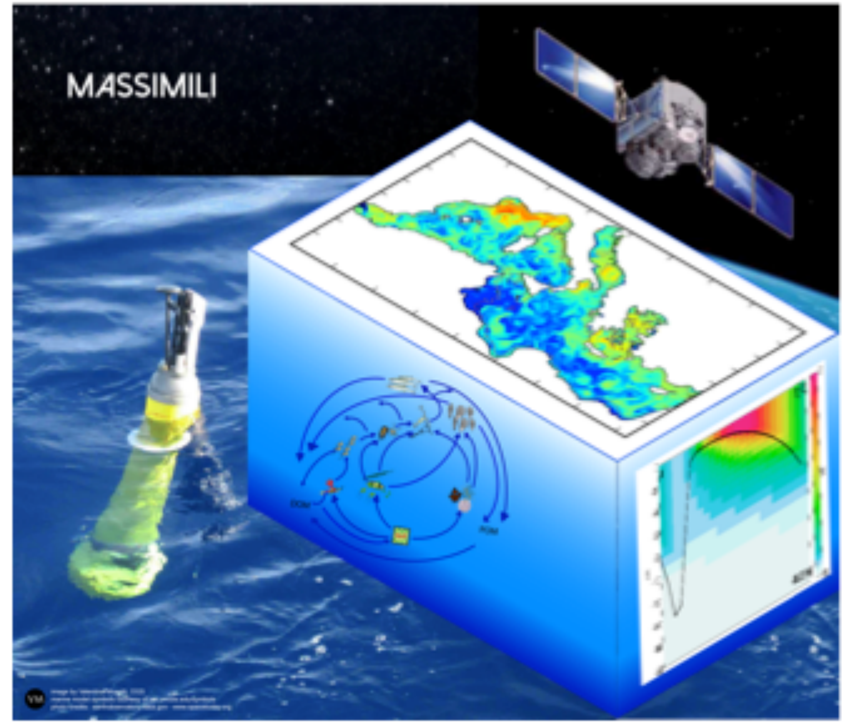
$$ITP = \int_{x,y,z} \left| (DA-REF)_0 / (DA-REF)_t \right|$$



$\langle ITP \rangle_{Jan} > 2$ in 2.9 days

$\langle ITP \rangle_{Aug} > 2$ in 2.4 days

Conclusions



- BGC-Argo float data crucial to constrain the CMEMS forecast model systems
- Upgraded 3DVAR-BIO assimilation scheme:
  - no uniform correlation radius
  - vertical EOFs
  - observation error
  - frequency of assimilation cycle

Next challenges of the MASSIMILI project (by 2018):

- Consistency of multivariate assimilation (CHL, NIT, OXY) → Vb operator (biological operator)
- Consistency between SAT and FLOAT chlorophyll data for multiplatform assimilation
- Evaluation of the performance of assimilation

Thanks