How Bio-Argo profiling floats can help to improve our understanding of mean chlorophyll seasonal distribution? A case study in the Mediterranean Sea

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Phytoplankton seasonality

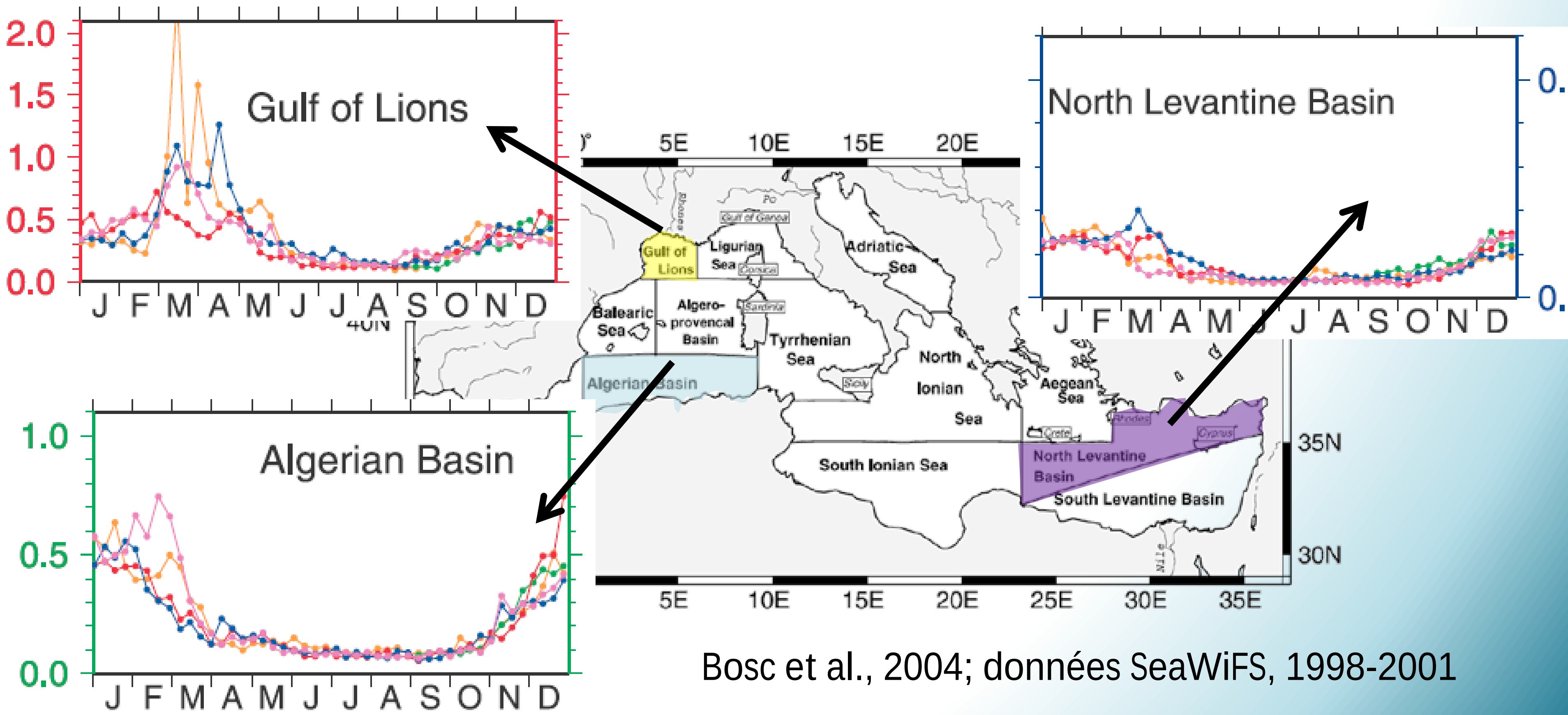
- Ø Indicates on the general ecosystem functioning (Longhurst, 1998).
- Ø Phytoplankton blooms contribute to oceanic new primary production (oceanic NPP = 50% of the total NPP, Fields et al., 1998).
- Ø Higher trophic levels depend on the timing of phytoplankton blooms (Platt et al., 2003; Edwards and Richardson, 2004)

è phytoplankton biomass is commonly estimated by **chlorophyll-a concentration** (Chl-a).

Ocean color satellite data highly contributes to increase our understanding of Chl-a over the Mediterranean Sea

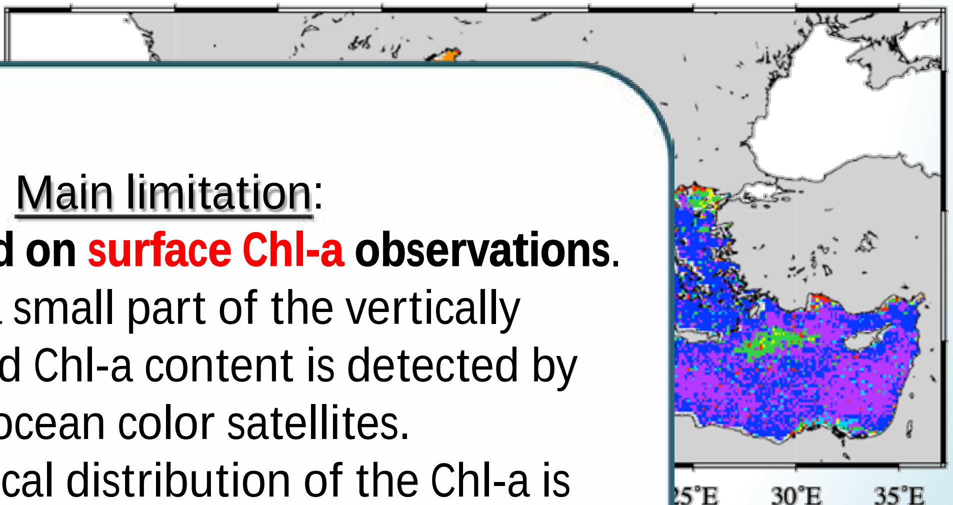
From ocean color data, a variety of annual cycles of surface Chl-a were observed over the Mediterranean basin.

- Some areas display a **mid-latitude** like seasonality (characterized by a spring bloom).
- Other areas display a **subtropical** like seasonality (characterized by higher surface Chl-a values during winter than during summer).



Bosc et al., 2004; données SeaWiFS, 1998-2001

Annual cycles of Chl-a derived from ocean color data allowed for the production of a **bioregionalization** of the Mediterranean Sea (D'Ortenzio and Ribera d'Alcalà, 2009)



Objective analysis
spatial distributio
surface Chl-a sea
cycles.

<u>Main limitation</u>:

It is only based on surface Chl-a observations.

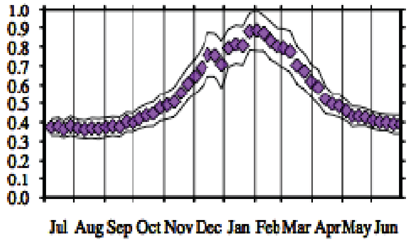
è Only a small part of the vertically integrated Chl-a content is detected by ocean color satellites.

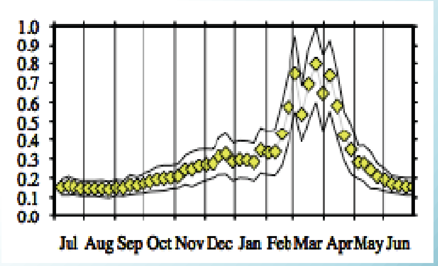
è The vertical distribution of the Chl-a is missed.

Two main types of seaso

Ø No bloo
(blue and purples areas)

id-latitude
(yellow areas)





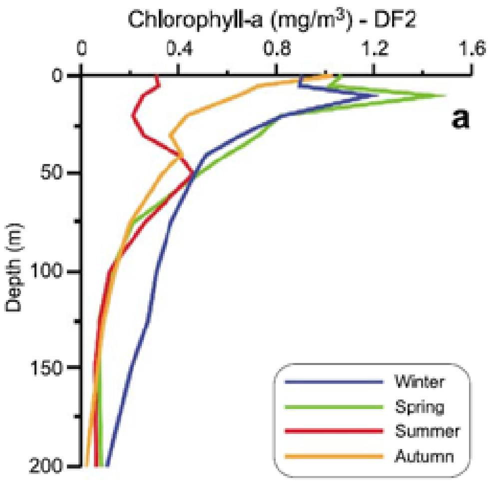
What is known about the seasonality of the vertical distribution of Chl-a in the Mediterranean?

MEDATLAS Chl-a climatology (MEDAR/MEDATLAS project, Maillard and Coauthors, 2005).

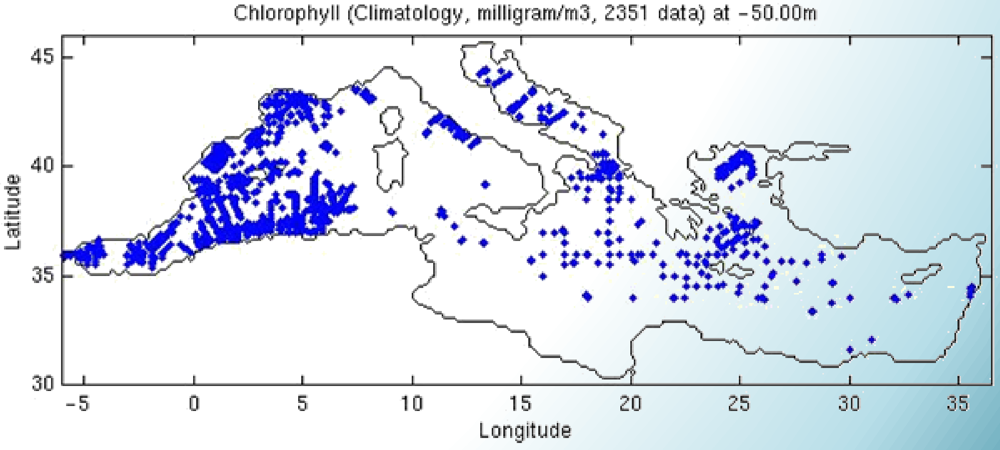
- Deep Chlorophyll Maximum (DCM) is ubiquitous from May to September.
- “mixed” profiles have been observed during winter.
- At spring, profiles with high surface Chl-a values have been observed in at the Med North-West.

Main limitations:

ü Based on Chl-a estimations derived from seawater samples (very scarce)
ü Seasonal climatology
ü Low vertical resolution (12 points on the vertical)



Mean seasonal variations of Chl-a in the Gulf of Lion region. (Manca et al, 2004)



Available Chl-a observations at 50m depth, in the MEDAR database. (http://modb.oce.ulg.ac.be/)

The Chl-a fluorescence to overcome constraints related to Chl-a data derived from water samples

Chl-a Fluorescence is proportional to Chl-a concentration

Advantages

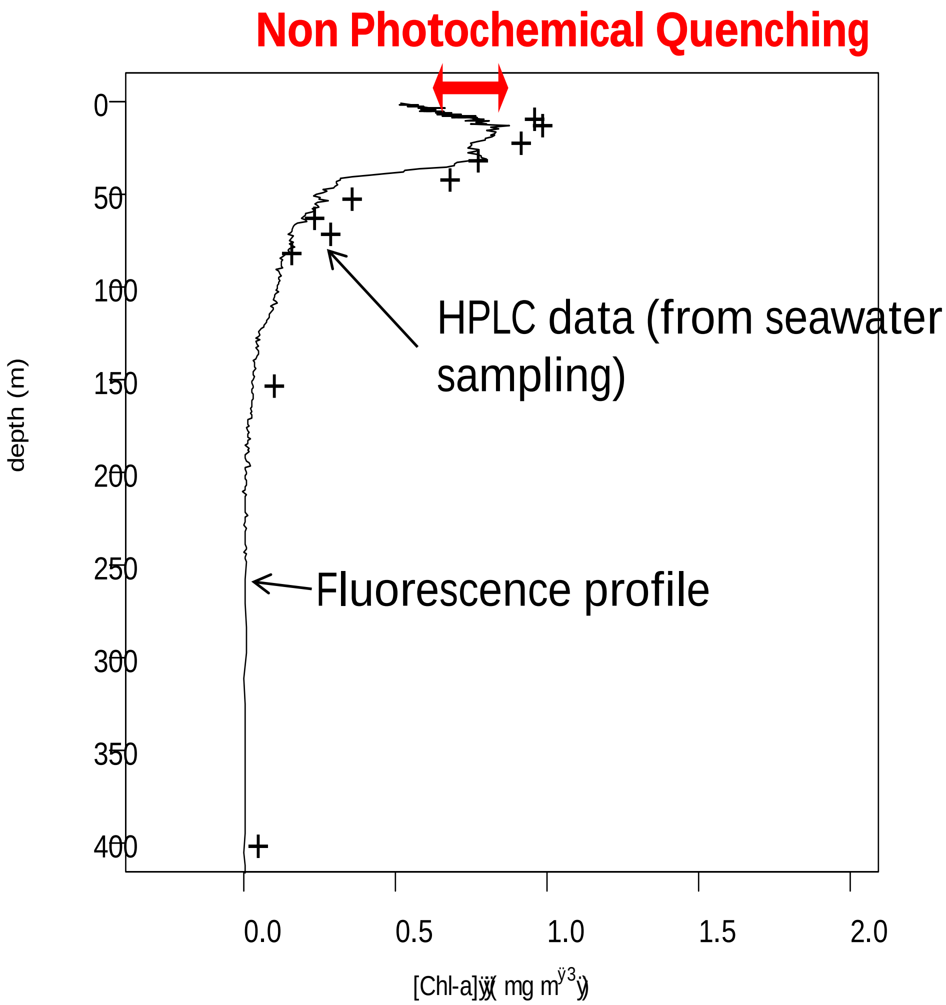
- ü Robust and non-invasive measure
- ü Continuous vertical profiles
- ü Big potential, with the integration of fluorometers on gliders and Bio-Argo floats.

Limitations

High variability of $\frac{FLUO}{Chl-a}$

- ü To determine calibration coefficients for each cruise or profile.
- ü To correct specific artefacts due to the non linearity of the $\frac{FLUO}{Chl-a}$ over the water columns (ex: NPQ).

Non Photochemical Quenching



In response to supra-optimal light intensity, phytoplankton cells trigger photoprotection mechanisms which drive to a decrease of fluorescence emission.

The Chl-a fluorescence to overcome constraints related to Chl-a data derived from water samples

Chl-a Fluorescence is proportional to Chl-a concentration

Advantages

- Robu... meas...
- Conti... profil...
- Big p... integ... fluor... and B...

New methods, independent of water sample Chl-a have been developed.

Mignot et al., 2011
Xing et al., 2011
Xing et al., 2012
Lavigne et al., 2012
Sauzede et al., 2014

Limitations

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Objective

Create a Chl-a database from fluorescence profiles and investigate the seasonal variability of the vertical distribution of Chl-a in the Mediterranean Sea.

- Mean seasonal behaviors
- Changes in the shape of the vertical Chl-a distribution
- Comparison with satellite data

The fluorescence database: main sources of data

Temporal range: 1994-2014

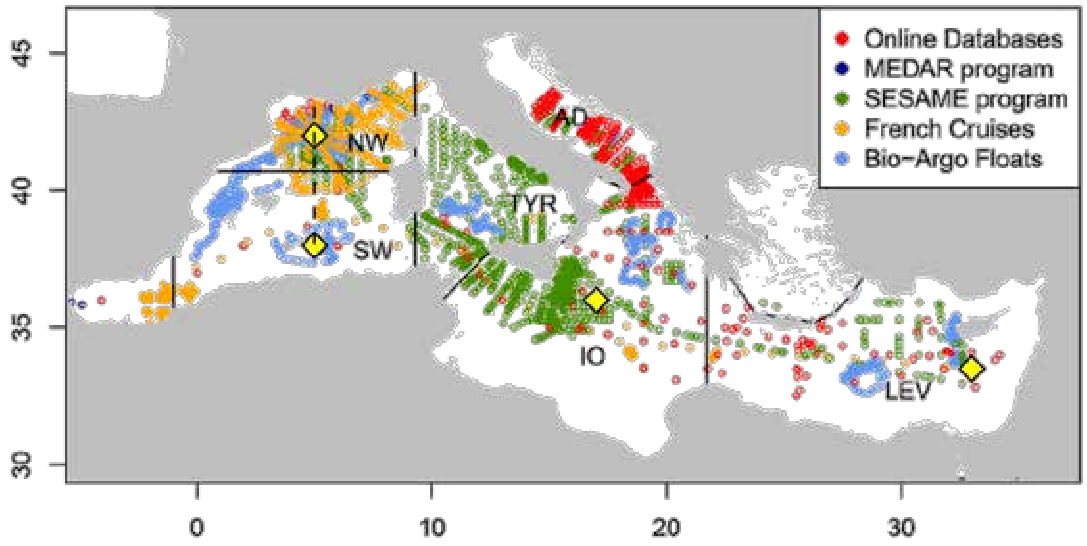
Data source	Number of profiles
Online databases (PANGAEA, SISMER, WOD09, OGS database)	986
French cruises (PROSOPE, DYNAPROC, BOUM, ALMOFRONT, DYFAMED, MOOSE-GE, DEWEX)	2670
SESAME Program	1815
MEDAR Program	228
Bio-Argo (PABO and NAOS projects)	1091
TOTAL	6790

16% of database

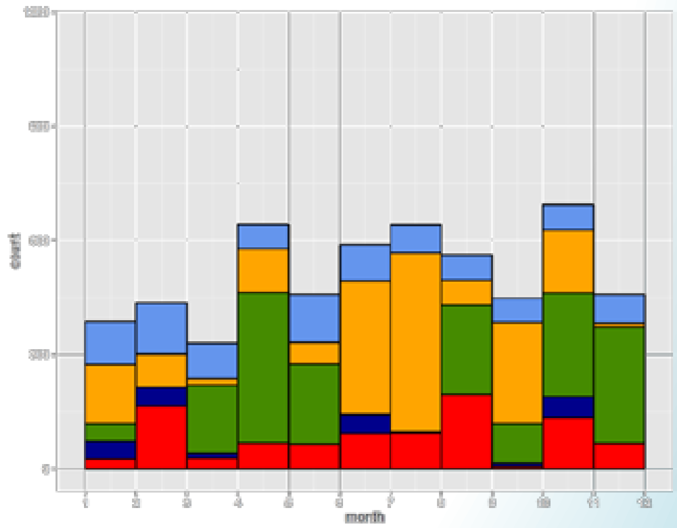
(44% of data after 2008).

The fluorescence database:

Spatial distribution



Seasonal distribution



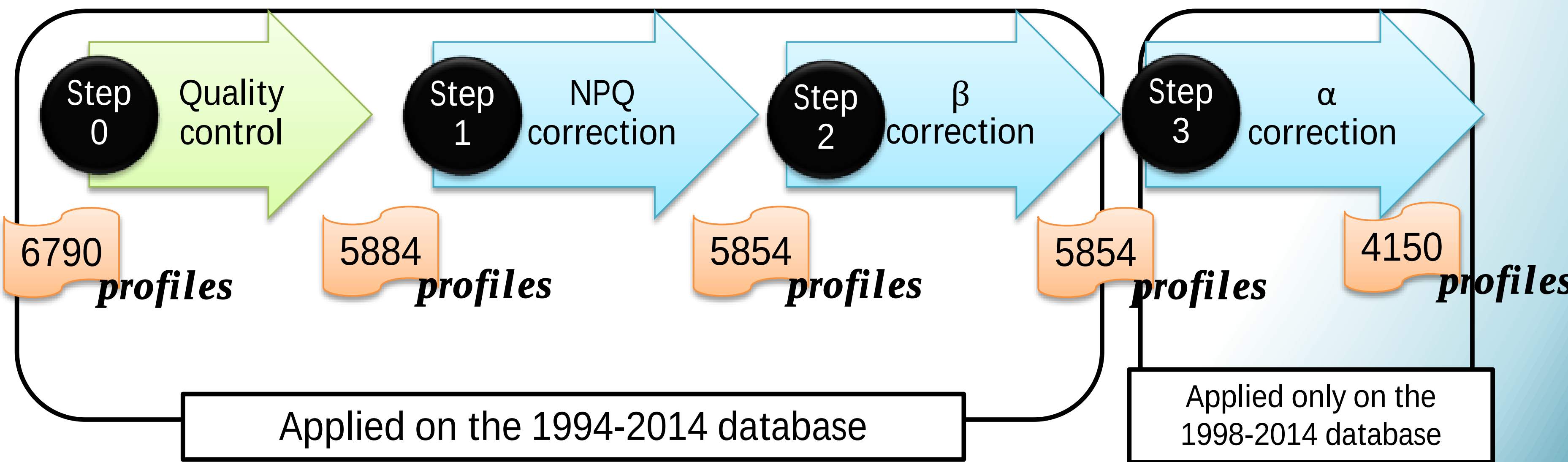
- ü Bio-Argo data allow for an homogeneous distribution of observations, especially in remote areas.
- ü Bio-Argo data allow for an homogeneous seasonal sampling.

Quality Control and Calibration

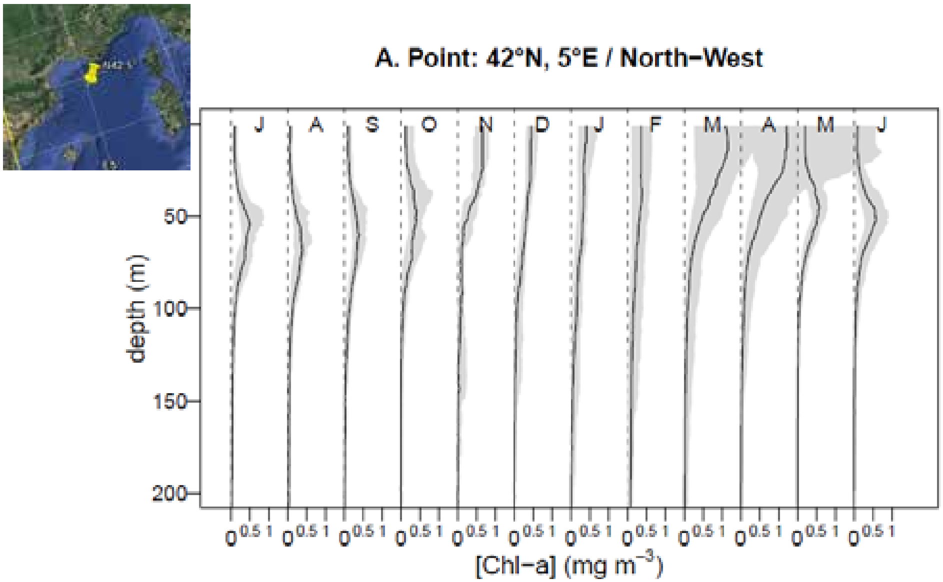
Quality Control

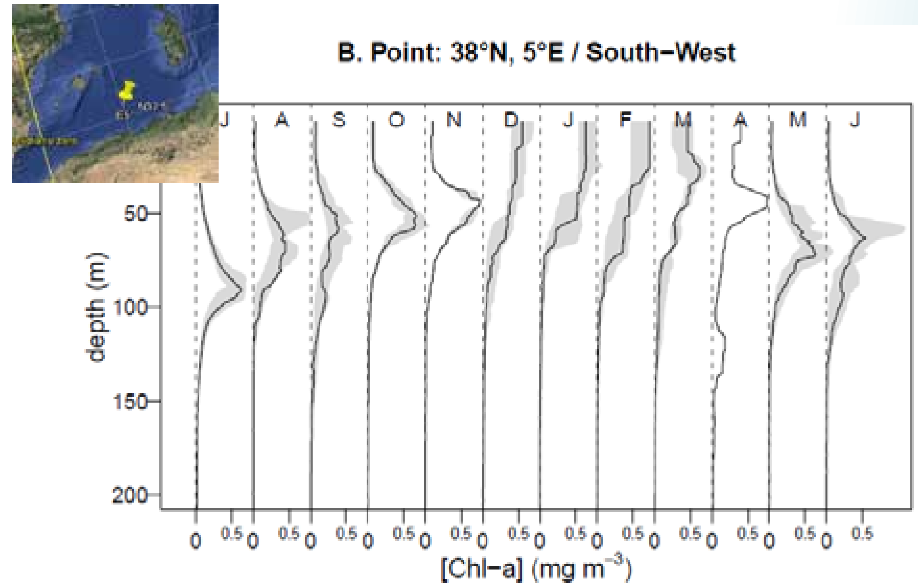
Calibration procedure (Lavigne et al., 2012)
Based on **ocean color** observations

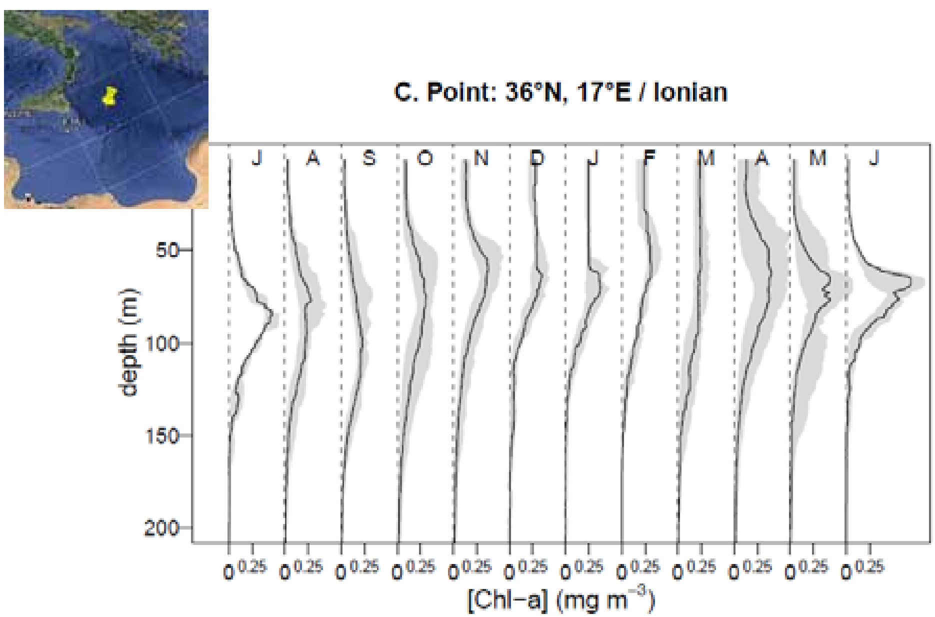
$$Chl-a = \alpha . (FLUO_{NPQc} - \beta)$$

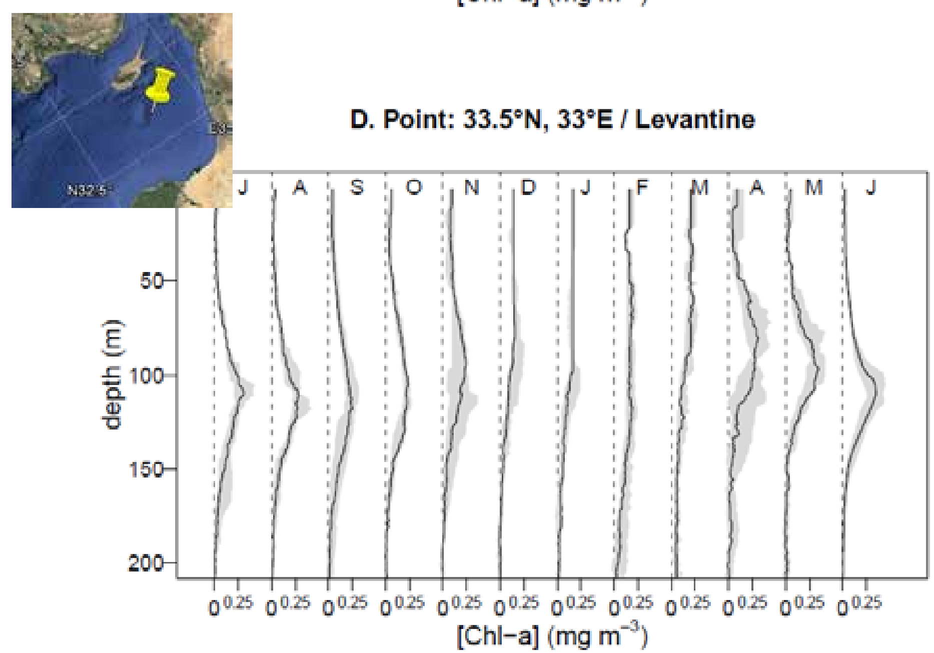


Mean seasonal variability of the vertical distribution of Chl-a in 4 locations of the Mediterranean Sea



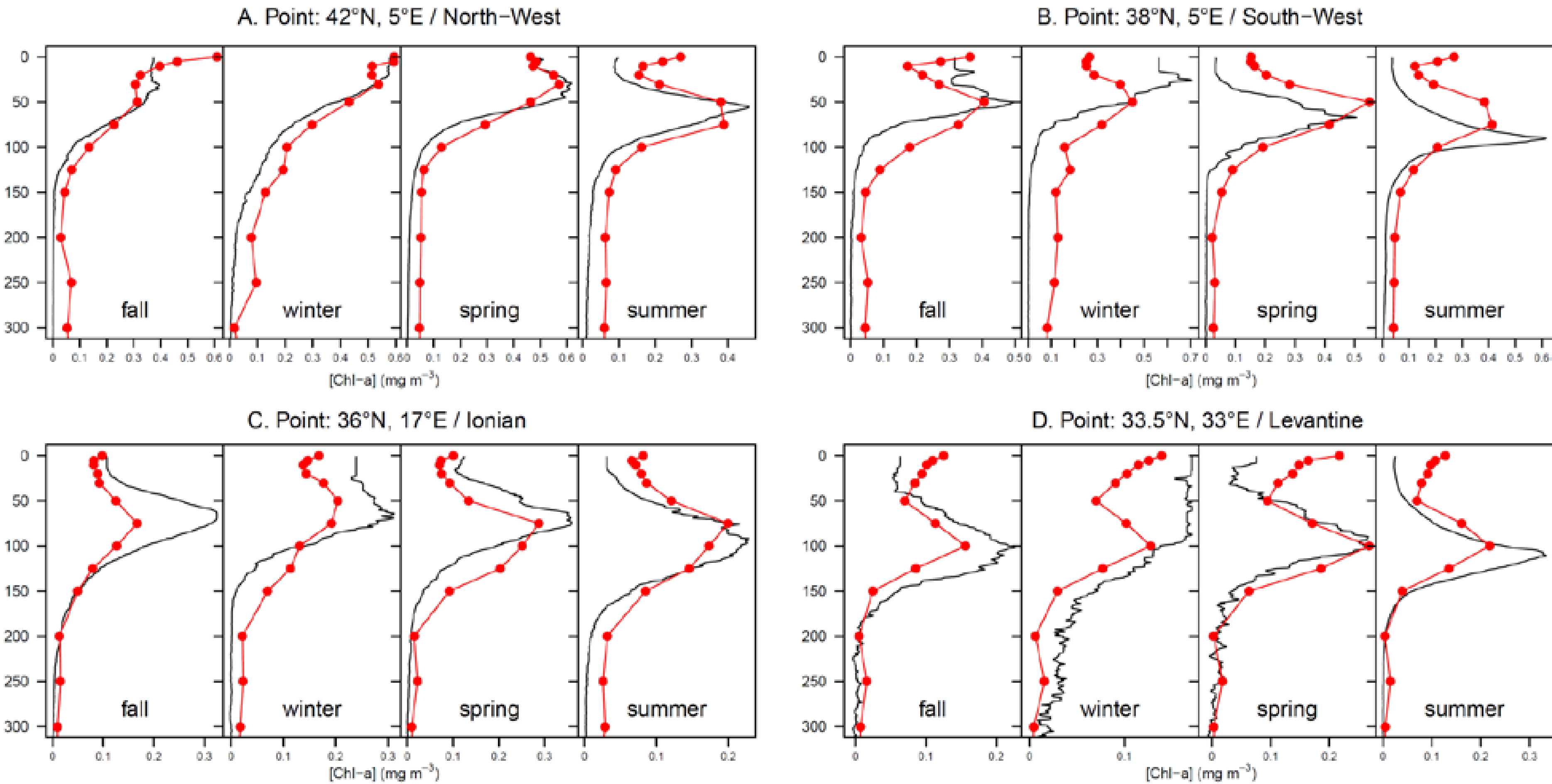






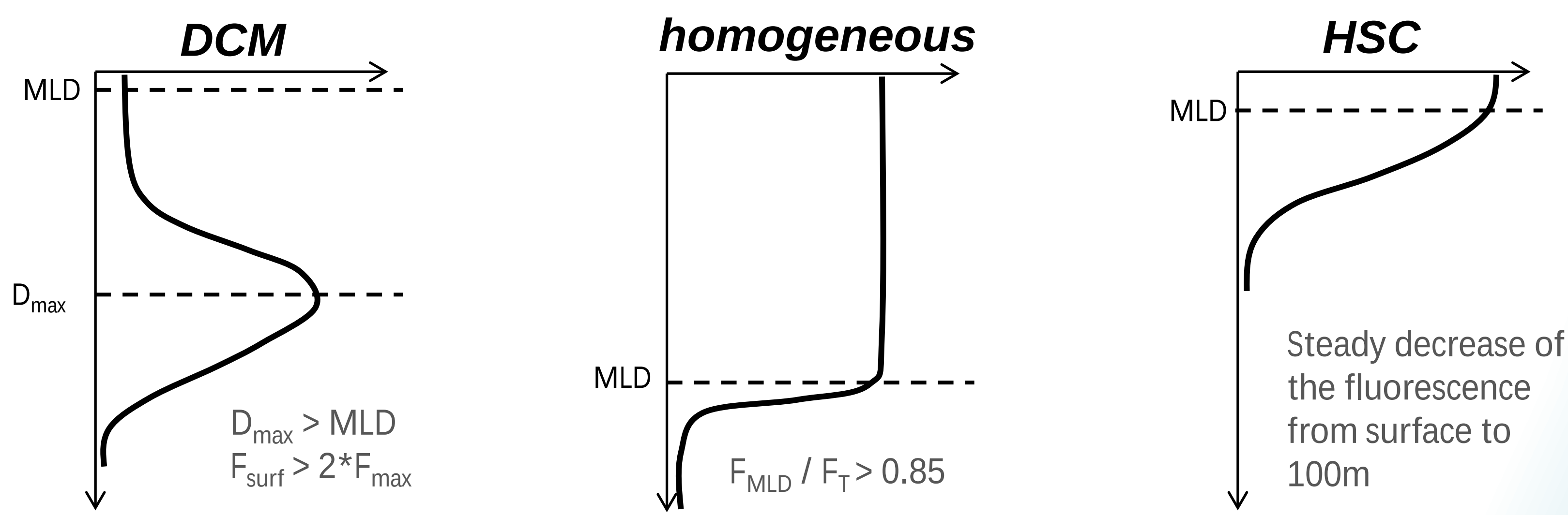
Comparison/Validation with MEDATLAS

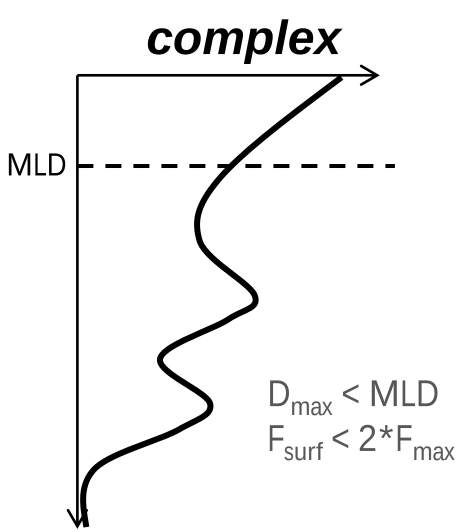
- • MEDATLAS
- — Chl-a from fluorescence

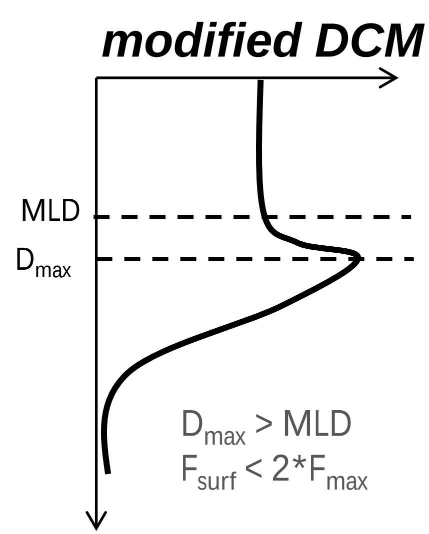


Analysis of the general shape of the fluorescence profile:

5 standards shapes have been identified in the database and a simple algorithm was proposed to automatically categorize a fluorescence profile

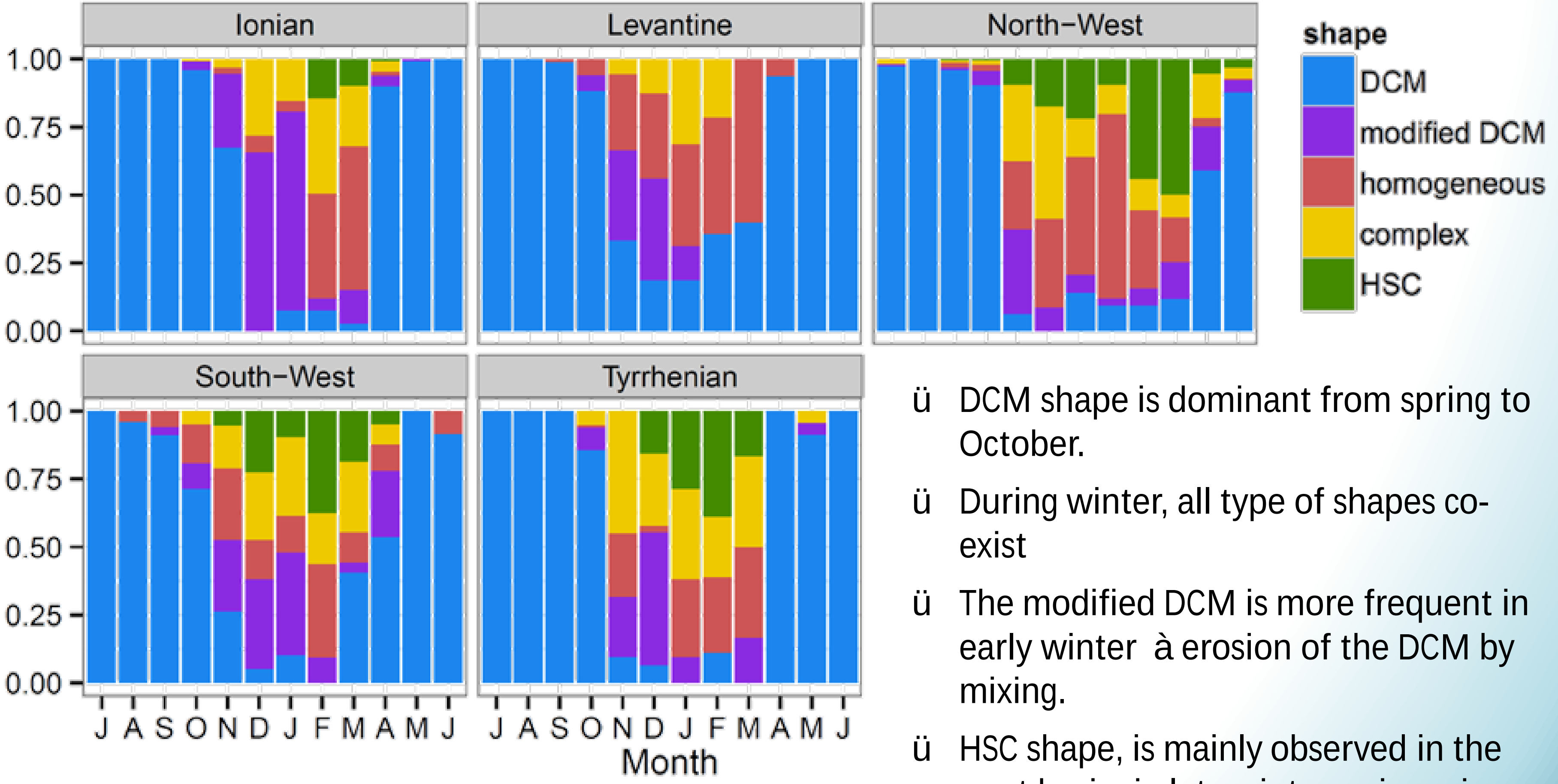






Dmax : depth of the fluorescence value.
MLD: mixed layer depth,
F_{surf}: integrated fluorescence in the surface layer (0-20m).
F_{max}: integrated fluorescence round Dmax (+/-10m).
F_{MLD}: integrated fluorescence in the MLD.
F_T: integrated fluorescence in the total water column.

Seasonal distribution of the standards profiles shapes in main Mediterranean regions

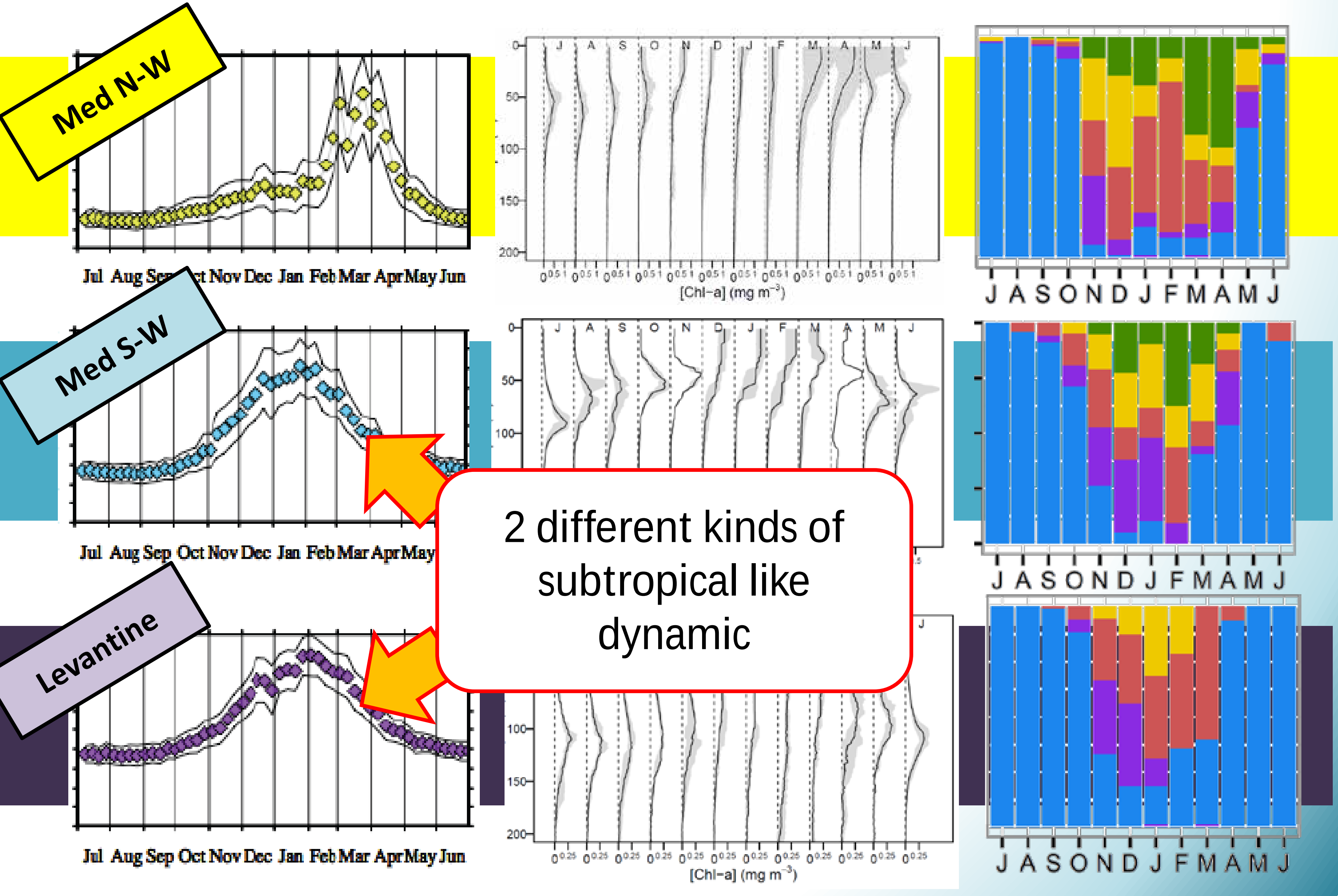


- ü DCM shape is dominant from spring to October.
- ü During winter, all type of shapes co-exist
- ü The modified DCM is more frequent in early winter à erosion of the DCM by mixing.
- ü HSC shape, is mainly observed in the west basin, in late winter or in spring. This shape is representative of bloom situations.

Satellite ocean color data

Climatology from fluorescence

Shape analysis



2 different kinds of subtropical like dynamic

Conclusions and Perspectives

- Fluorescence Chl-a profiles contribute to improve our understanding of the Chl-a seasonal variability.
- Seasonal changes in the shape of the Chl-a profile could be considered as an indicator of the trophic regime.
- These data are fundamental to complete satellite observations.

PERSPECTIVES

Updating the database in a few years with more Bio-Argo data

Analyzing mechanisms which control phytoplankton seasonality

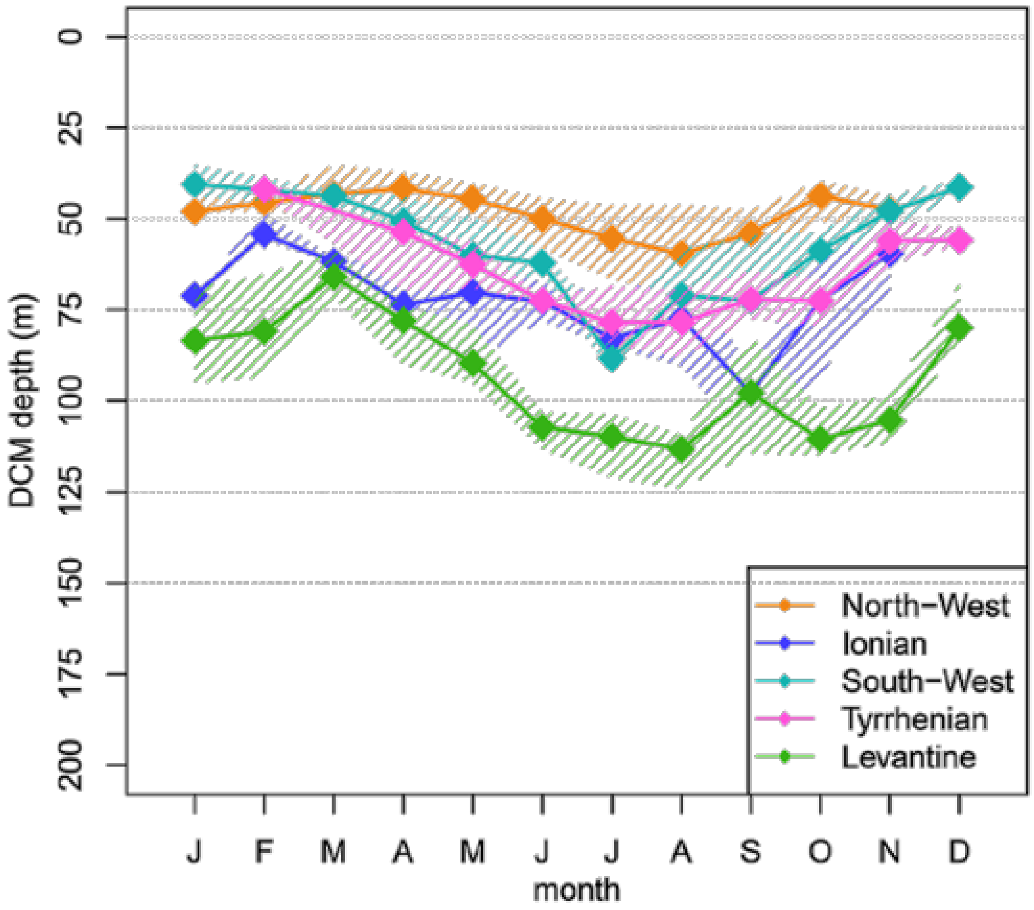
-> Bio-Argo time-series

Thank you for your attention

For more details:

- Lavigne, H., D'Ortenzio, F., Claustre, H. and A. Poteau. Towards a merged satellite and in situ fluorescence ocean chlorophyll product. *Biogeosciences* 9, 2111–2125. 2012.
- Lavigne, H., D’Ortenzio, F., Ribera d’Alcalà, M., Claustre, H. and R. Sauzède. On the vertical distribution of the chlorophyll-a concentration in the Mediterranean Sea: A basin scale and seasonal approach. Biogeosciences Discussion. Submitted.

Seasonality of the DCM depth



In each region of the Mediterranean Sea, DCM depth deepens from March to August and then shallows.

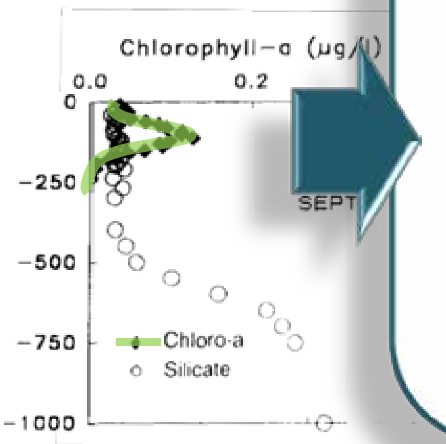
These observations are consistent which a recent theory according which the DCM depth is driven by PAR and follows an isolume (Letelier et al., 2004; Mignot et al., 2014)

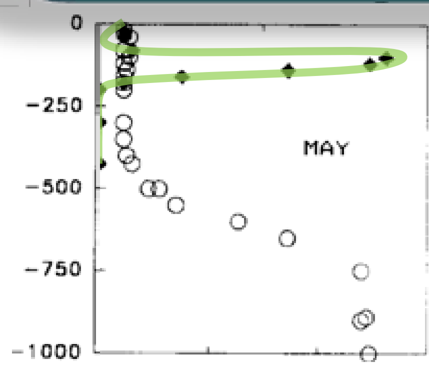
What is known about the seasonality of the vertical distribution of Chl-a in the Mediterranean?

- Deep Chlorophyll Maximum (DCM) is ubiquitous from May to September.
- “mixed” profiles have been observed during winter.
- At spring, profi… observed in at the DYFAMED…

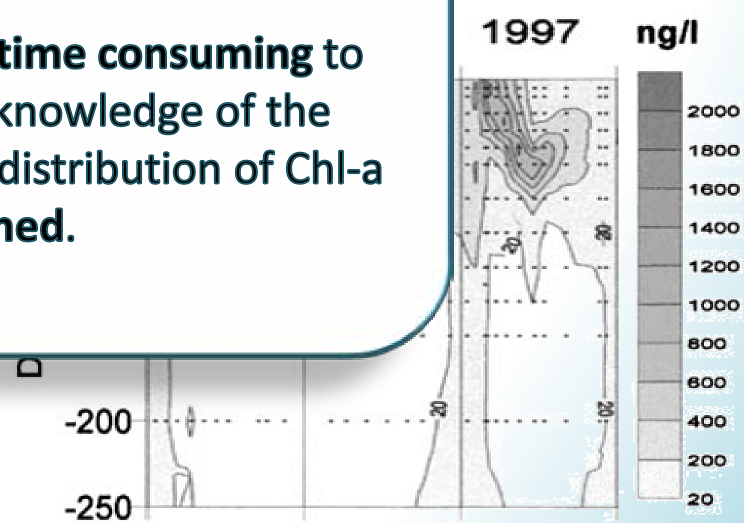
These information come from in situ observations derived from water samplings.

Because it is **costly** and **time consuming** to obtain such data, our knowledge of the variability of the vertical distribution of Chl-a is **restrained**.





Chl-a vertical profiles for different periods of the year in the Levantine Sea (redraw from Krom et al., 1992)



Seasonal variation of the Chl-a at the DYFAMED station (redraw from Marty et al., 2002)

Quality Control and Calibration

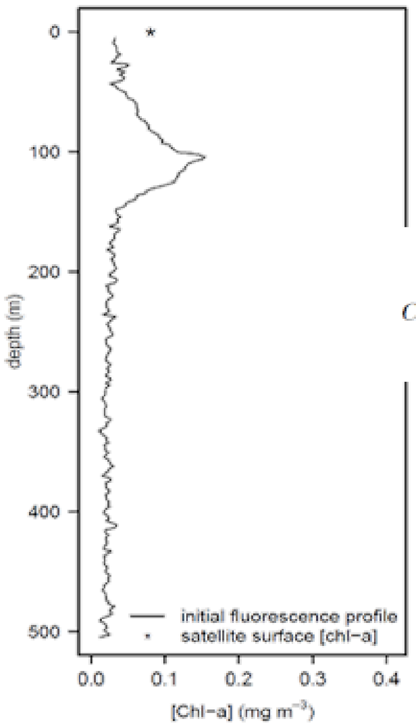
$$[Chl - a] = \alpha \cdot (FLUO - \beta)$$

Step 0 — Quality control

Step 1 — NPQ correction

Step 2 — Beta correction

Step 3 — Alpha correction



- ü Test a uniquene
- ü Spike test
- ü Test for signs of
- ü Test for the max

è **5584** fluorescen
Control

Non Photochemi
to a decrease of f
surface, not paral
diminution of the

To correct NPQ ef
fluorescence valu
the mixed layer is
the surface.

To correct systematic instrumental offset.

$$\beta = median\ (10\ deepest\ obs.)$$

Applied only, if the MLD is shallower than the deepest fluorescence observation.

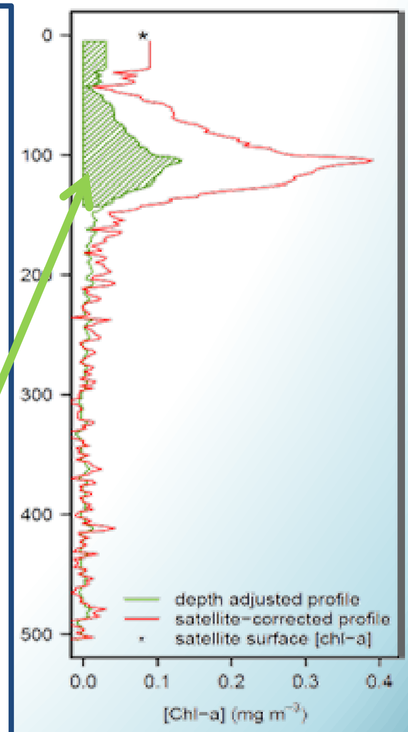
Quality Control and Calibration

$$[Chl - a] = \alpha \cdot (FLUO - \beta)$$

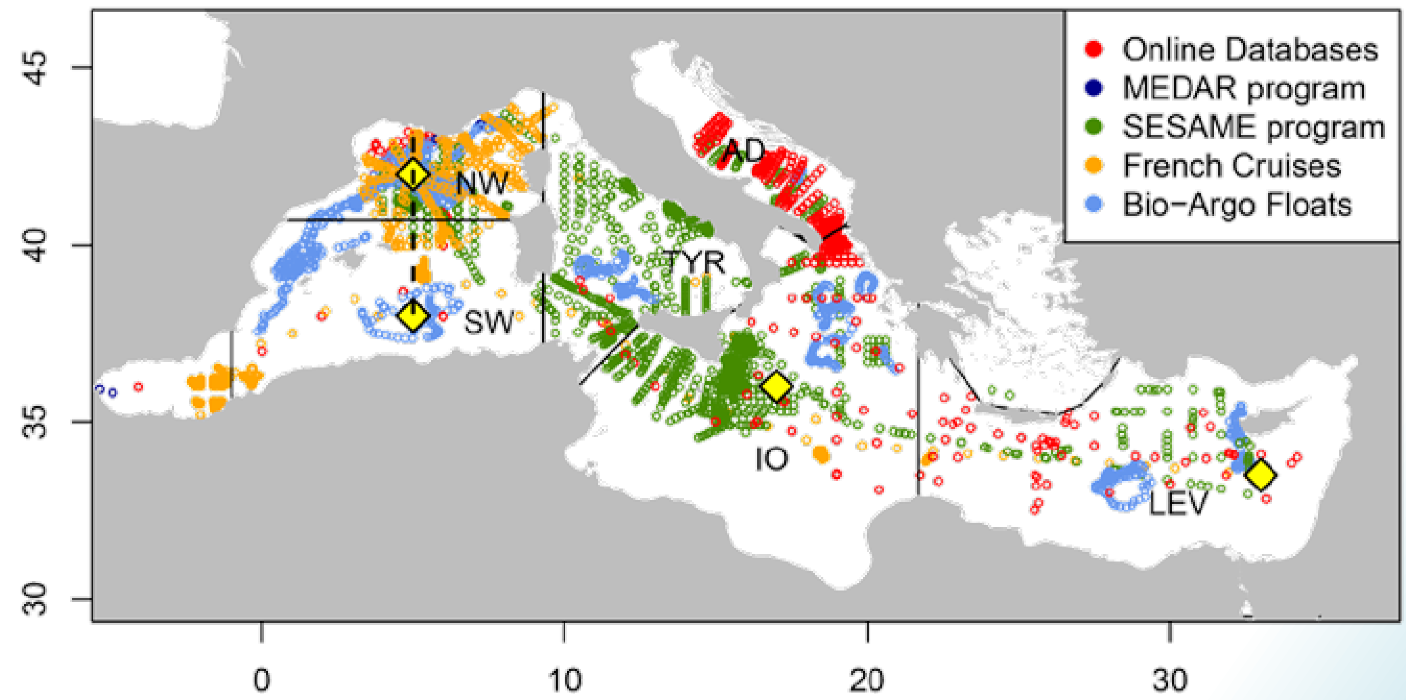
- Step 0: Quality control
- Step 1: NPQ correction
- Step 2: Beta correction
- Step 3: Alpha correction

Estimated Chl-a integrated content from surface satellite concomitent observation.
Uitz et al. (2006) equations

$$\alpha = \frac{< Chl - a >_{1,5.Ze}}{\int_0^{1,5.Ze} (FLUO(z) - \beta)\, \mathrm{d}z}$$



The fluorescence database: spatial distribution



Bio-Argo float data allow for an homogeneous distribution of observations, especially in remote areas.