Roadmap for the deployment decision of the NAOS Bio-Argo Mediterranean floats

History of doc:

30-07-2010 Version 0.1: First draft by F. D'Ortenzio

30-08-2012 Version 0.2: Draft corrected by V. Taillandier and Louis Prieur

01-09-2012 Version 0.3: Draft corrected by M. Ribera

1 Synopsis

NAOS (Novel Argo Observing System) is a French project aiming to prepare the evolution of the Argo observing system (PI PY Le Traon). One of the WPs of NAOS is specifically devoted to the design, the implementation and the scientific exploitation of a network of Bio-Argo floats (see paragraph 3) in the Mediterranean Sea (PI F. D'Ortenzio).

The main scientific objective of the NAOS-Med activity is the (re)evaluation and the comprehension of the main mechanisms driving the biogeographical subdivision of the basin, as derived from ocean colour satellite analysis (D'Ortenzio and Ribera d'Alcalà, 2009, figure 1).

This subdivision is based on phytoplankton phenology, meaning that each bioregion displays statistically similar seasonal cycles. Three main bioregions, which were interpreted as reflecting different trophic regimes, were identified in the open sea areas of the basin: a "Bloom-Like" (in the Gulf of Lions/Provencal basin and in the Ligurian sea, referred here as "Bloom" regime), a "Tropical-like" (in the oligotrophic regions, although with important differences between Algerian, Ionian and Levantine seas, referred here as "No-Bloom") and an "Intermediate" state (in the Tyrrhenian, South Adriatic and Rhodes areas, referred here as "Intermittent"), which shares characteristics of the first two regimes and it is strongly influenced by interannual variability.

Having different seasonal cycles and phenology, the bioregions and their trophic regimes have to be (or maybe not) sampled in different ways, if we aim at a correct reconstruction of the underlying mechanisms. Consequently, the decisions about the strategy of deployment and sampling of the NAOS floats are critical to maximize the scientific exploitation of the network. The point is not trivial, because biogeochemical dynamics is, in many aspects, different from that of physical dynamic. This implies that the present day Argo strategy and its Mediterranean declination (as implemented in the Med Argo programme, Poulain et al, 2007) could be not adapted to a Bio-Argo network.

2 Objective of the roadmap

The main objectives of this roadmap are:

1. to determine the most appropriate sampling and deployment strategy for the NAOS floats;
2. to identify additional scientific questions, which could be addressed with the NAOS Bio-Argo network, in parallel with the main NAOS scientific question (i.e. explain observed bioregionalisation).

The approach that I propose is to determine a group of few potential contributors (see paragraph 8 for the list of the contacted persons) among the oceanographers interested in the Mediterranean biogeochemical functioning. They are invited to participate to the network design, in particular in the brainstorming dedicated to the strategy, which will be summarized in this document (which will be a "work in progress"). They will also contribute, if possible and if interested, to the deployments, in the areas where they have planned cruises or have specific scientific questions. Finally, they will participate to the scientific exploitation of the data, in collaboration with the others participants of the group and under the supervision of the NAOS Scientific Committee (PY LeTraon, S. Pouliquen, S. LeReste, V. Thierry, F. D'Ortenzio, H. Claustre, M. Babin).

The first version of the document has been realized after a short meeting held in Villefranche in Mai, 2012 (participants F. D'Ortenzio, M. Ribera, L. Prieur).

3 Description of the NAOS floats

The NAOS biogeochemical float is based on the PROVOR CTS3 profiling float (Xing et al, 2011, D'Ortenzio et al, 2012). Differently from the "classical" temperature and salinity sensors, NAOS floats are equipped with two fluorometers calibrated on the Chl and on the CDOM, a backscaterometer for Bb, a PAR sensor and an Irradiance sensor at three wavelengths (we refer to this type of float as "RemA"). A small group of NAOS floats is additionally equipped with NO3 and O2 sensors ("RemA+NO3/O2"). Additional batteries allow a declared lifetime of 150 profiles. The floats are equipped with an Iridium antenna, which allows large data transfer and a two-way communication (i.e. sampling and mission parameters could be changed during the mission).

Sampling parameters could be finely chosen, separately for physical and biogeochemical sensors: vertical resolution of sampling, number of points for average, on/off of the sensor. Mission variables could be also parameterized (see figure 2): parking depth (i.e. the depth at which the float navigates between two profiles), profiling depth (max 1000m), frequency of profile (min. 3 times per day).

For 2013, a first lot of 9 RemA and 5 RemA+NO3/O2 is available for the Mediterranean activity. A second lot (10 RemA and 4 RemA+NO3/O2) is planned for 2015/2016.

4 Proposed deployment and sampling strategies

In the following paragraphs I intentionally took the description of the different proposed strategies at the extreme. In fact, I think that a profitable synthesis can be easily reached but my point is not to reach an agreement among different point of view but to select the best strategy to obtain the information we want.

The strategies proposed to date are described in different paragraphs and the name of proponent is associated at each paragraph.

4.1 "Med Argo" strategy (Louis Prieur)

Rationale

More than 50 Argo floats have been deployed in the Mediterranean Sea in the recent past. They are for the most (although not exclusively) programmed with the MedArgo sampling protocol (Poulain et al, 2007), which is an adaptation of the global Argo protocol to the Mediterranean Sea (see later). Geographical deployment in the framework of MedArgo was for the most analysed in view of assimilation (Griffa et al, 2006), although the coverage of the basin has been relatively exhaustive (see Figure 3).

Concerning the "MedArgo" strategy for the NAOS floats, the main assumption is that following the MedArgo protocol for the NAOS floats should be the best way to exploit the statistics on the existing Mediterranean floats. In some way, existing trajectories are the only real information that we have about float dispersion in the Med. Different strategies, better adapted in theory, could result in unexpected results in practice, providing little or no information for the NAOS objectives.

Data analysis of the existing data shows that, after a reasonably small time period, the coverage of the basin should be relatively complete, and therefore bioregions should have been extensively sampled. As a consequence, the cross analysis with bioregions will be performed on the ensemble of the network data and not on the float-by-float basis (see the other strategies). Moreover, statistics on the existing data show that:

1. Floats deployed on the southern part of the basin tend to be trapped along the southern coasts. Floats deployed on the northern bounds of the basin tend to floats southward.
2. Floats deployed in a sub-basin tend to remain in the same sub-basin.

Finally, the low accuracy of the NO3 sensors suggests that their deployment should be avoided in the Levantine basin.

Proposed deployments areas and periods

For the "Med Argo" strategy, the 14 NAOS floats should be then deployed in the points depicted in figure 4. Concerning the deployment timing, the best periods should be late fall/early winter (i.e. December).

Proposed sampling strategies

The "Med-Argo" strategy proposed for the NAOS floats follows, with some slight modifications, the MedArgo strategy for the Mediterranean physical floats (Poulain et al, 2007): parking depth 350 m (to track the LIW), cycle frequency 5 days, profiling depth 700 m or 2000 (the last performed every 5 shallow cycles). The only slight modification proposed here concerns the profiling depth, which should be maintained constant at 1000m.

4.2 "Process Study" (Maurizio Ribera)

Rationale

Bioregional subdivision suggests the existence of different forcing mechanisms (D'Ortenzio and Ribera d'Alcalà, 2009, but see also Lazzari et al, 2010). For each bioregion, the seasonal cycle of chlorophyll, as determined by satellite, is the result of several processes, which certainly comprise:

1. Large, sub basins and mesoscale physical dynamics
2. Nutrients and light availability, driven by both physical and biological process
3. Specific nutrients dynamic of the basin and of the sub-basins
4. Grazing pressure
5. Coastal influence
6. ….

In the Mediterranean basin the spatial scales are reduced, implying that all the above processes play probably a role on the chlorophyll seasonal cycle, which ultimately determines the distribution of bioregions. If only abiotic forcing are considered (as NAOS floats have no way to directly monitor purely biological mechanisms as grazing), a hierarchy of processes could be identified for each bioregion. They will be then linked to the biogeochemical response, in order to identify their effect on the phenological traits of each bioregion.

The rationale for the "Process Study" deployment strategy is than to target, for as many bioregions as possible, the main abiotic mechanisms, and to adapt the sampling strategy to provide observations on, at least, a complete seasonal/annual cycle. Not all the bioregions will be sampled, although the three main regimes ("Bloom", "No Bloom", "Intermittent") should be imperatively covered. About sampling (see later), two types of strategies are envisaged, "Lagrangian" and "Eulerian". In the first case, the float should be programmed to drift inside a specific water masses or layer (which should characterize the bioregion), in order to specifically evaluate the biological response along its path; in the second case, the float will be programmed to sample as long as possible the same bioregion or area, giving then more emphasize to the temporal variability.

The "Process study" strategy explicitly implies a "float-by-float" analysis of the data. Each float will be then deployed and programmed to characterize a specific bioregion and its (presumed) main abiotic forcing.

Proposed deployments areas and periods

For the "Process Study" strategy, the 14 NAOS floats should be then deployed in the points depicted in figure 5, following the criteria listed in Table 1.

Proposed sampling strategies

Two parameters have to be considered: the "Parking depth" and the "Cycling frequency". They should change according to the sampling mode ("Eulerian" and "Lagrangian") but also to the specificities of the bioregion. In any case, sampling strategy could be adapted to some specific conditions during the float lifetime. Profiling depth should be fixed for all the floats at 1000m.

Eulerian mode.
On average, Mediterranean deep circulation is relatively stable and slow. Less time a float spent on surface and less rapidly it should move away from the target area. Consequently, the parking depth should be fixed at the maximum possible depth (i.e. 1000m) and the floats should be programmed with a low cycling frequency (i.e. 5/10 days). In some cases, however, the parking depth should be fixed at shallow depths (for example, when a surface or sub-surface structure is pointed, the parking depth should be fixed to maintain the float inside the structure). Similarly,

cycling frequency should be increased during the periods of high phenological variability (i.e. before and during a Bloom).

Lagrangian Mode
In the Lagrangian mode, the float is supposed to track a specific water mass or layer. Parking depth should be then different, according to the bioregions and to target area.

Floats sampling protocol, mode, target areas and deployment region for the "Process study" strategy are shown in table 1.

4.3 "Observing system" strategy (Vincent Taillandier)

Rationale

The observing system strategy is based on the results of a Lagrangian dispersion numerical study, analysed in the framework of the bioregions of D'Ortenzio and Ribera d'Alcalà (2009). Basically, a very large number of Lagrangian numerical particles (simulating floats) were released in a general circulation model of the Mediterranean basin (NEMO-WRF, configuration MED12, period 1998-2001, Beranger et al, 2010). Different deployment and sampling strategies for the numerical floats are tested and the resulting trajectories, obtained from the daily 3D estimations of the simulated currents, are then cross-compared with the Mediterranean bioregions. Several metrics are further calculated, in order to verify the sensitivity of the resulting dispersion statistics to the deployment and sampling strategies (details are in Taillandier et al, in preparation).

One question analysed concerns the "best" floats sampling strategy (cycling frequency and parking depth) to optimize the possibilities that a float samples the same bioregion for at least one complete annual cycle (then without leaving out or failing along the coasts). The numerical tools to perform the simulations, as well as the metrics to analyse the results, are presently configured. Others strategies can be then tested in such numerical framework.

Proposed deployments areas and periods

For the "Observing System" strategy, the 14 NAOS floats should be then deployed in the points depicted in figure 6.

Proposed sampling strategies

Presently, the sampling protocol for the "Observing System" strategy is based by on the evaluation of the maximum probability that a float samples the bioregion of deployment for at least an annual cycle.

The sampling protocols for the different floats in the "Observing System" strategy are depicted in table 2. Profiling depth should be fixed for all the floats at 1000m.

5 Synthesis (by Fabrizio and Maurizio)

Strategy 1:
- pro: high likelihood of sampling all the bioregions based on real data
- con: an individual float does not necessarily follows the mean/median. Having very few floats we may get marginal information or we may miss information in crucial times.

Strategy 2:
- pro: possibility to follow the complete seasonal cycle of some bioregions
- con: risk of having the profiler drifting in marginal areas

Strategy 3:
- pro: high likelihood of sampling all the bioregions based on very large statistical 3D set
- con: again, the very small number of floats with the risk of our floats being on the tail of distribution missing crucial time windows

6 Figure captions

Figure 1. Biogeographical provinces in the Mediterranean Sea (on the left) and the associated phenological seasonal cycles of the normalized surface chlorophyll (on the right). See D'Ortenzio and Ribera d'Alcalà, 2009 for details.
Figure 2: Diagram of a NAOS float mission. In the grey boxes, the mission and sampling parameters that could be fixed are indicated.
Figure 3: Trajectories of the MedArgo physical floats (from the MedArgo web site).
Figure 4: Deployment plan for the "MedArgo" strategy. Brown points represent the 5 RemA+NO3/O2 floats.
Figure 5: Deployment plan for the "Process Study" strategy. Brown points represent the 5 RemA+NO3/O2 floats.
Figure 6: Deployment plan for the "Lagrangian" strategy. Brown points represent the 5 RemA+NO3/O2 floats.

7 References

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8 Tables

Table 1

Sampling protocols for the "Process Study" strategy. In the table, LIW states for Levantine Intermediate Water, AW for Atlantic Water. #### in the Parking Depth row indicates that the final value will be fixed when the target area will be set. In the sampling mode row, "E" states for "Eulerian", "L" for "Lagrangian".

Float	Bioregion	Main physical forcing process	Deployment Region Target Area	Sampling Mode	Parking Depth	Cycling frequency
Bloom1 NO3/O2 **Bloom4**	Bloom	Deep convection, mesoscale activity	Gulf of Lion (Deep convection area)	E	1000	2 (winter spring) 5/10 (fall summer)
Bloom2 NO3/O2	Bloom	Deep convection, mesoscale activity	Gulf of Lion (outside deep convection region	E	1000	2 (winter spring) 5/10 (fall summer)
Bloom3 NO3/O2 **Bloom5**	Bloom	Deep/Intermediate convection	Ligurian Sea (region where Deep convection is episodically observed)	E	1000	2 (winter spring) 5/10 (fall summer)
NoBloom Alg	NoBloom	AW Spreading	Western area of Algerian Sea (outside Alboran gyres)	L	300	1-2
NoBloom Tyrr	NoBloom	LIW spreading, bathymetric effects, mesoscale gyres	Central area of the sub-basin, not in the Bonifacio Gyre	L	300	3
NoBloom Ion S1 NO3/02 **NoBloom Ion S2**	NoBloom	AW and LIW Spreading	Central area of the sub-basin	L	1000	5
NoBloom Ion N	NoBloom	Adriatic/Ionian waters interplay	South of Otranto strait	L	1000	5
NoBloom Lev 1	NoBloom	Mesoscale effects on the seasonal dynamic	South of Greece, in a recurrent structure (Iera Petra? Pelops?)	E	####	2 (winter spring) 5/10 (fall summer)
NoBloom Lev 2	NoBloom	Mesoscale effects on the seasonal dynamic	Around Cyprus, in a recurrent structure (Cyprus? Shikomona??)	E	#####	
Int Rhodes 1 NO3/O2 **Int Rhodes 2**	Intermittent	Rhodes gyre, LIW formation and spreading	Rhodes Gyre	E	700 700	2 (winter spring) 5/10 (fall summer)

Table 2

Sampling protocols for the "Observing System" strategy.

Float	Bioregion	Deployment Area	Parking Depth	Cycling frequency
Bloom1 NO3/O2	Bloom	Gulf of Lion	350	2
Bloom2 NO3/O2	Bloom	Ligurian Sea	1000	5
Bloom3 NO3/O2 **Bloom4**	Bloom	Ligurian Sea	1000	5
NoBloom Alg1 **NoBloom Alg2**	NoBloom	Western area of Algerian Sea	1000	5
NoBloom Alb	NoBloom	Alboran Sea	150	2
NoBloom Tyrr	NoBloom	South Tyrrhenian	350	4
Inter Tyrr	Intermittent	North Tyrrhenian, in the Bonifacio Gyre	350	1
Inter Prov	Intermittent	Provencal Basin, southward of the Balearic front	350	2
NoBloom Ion N	NoBloom	North Ionian Basin, south of Otranto strait	1000	8
NoBloom Ion S	NoBloom	South Ionian Basin	1000	8
NoBloom Lev 1	NoBloom	Levantine Basin	1000	8
NoBloom Lev 2	NoBloom	Levantine Basin	1000	8

9 Appendix. Contacted persons

Maurizio Ribera D'Alcalà, SZN Italy

Daniele Iudicone, SZN Italy

Louis Prieur, LOV France

Vincent Taillandier, LOV France

Hervé Claustre, LOV France

Miro Gacic, OGS, Italy

Giuseppe Civitarese, OGS, Italy

Carlos Duarte, IMEDEA, Spain

Susana Augusti, IMEDEA, Spain

Tommy Moore, IMEDEA, Spain

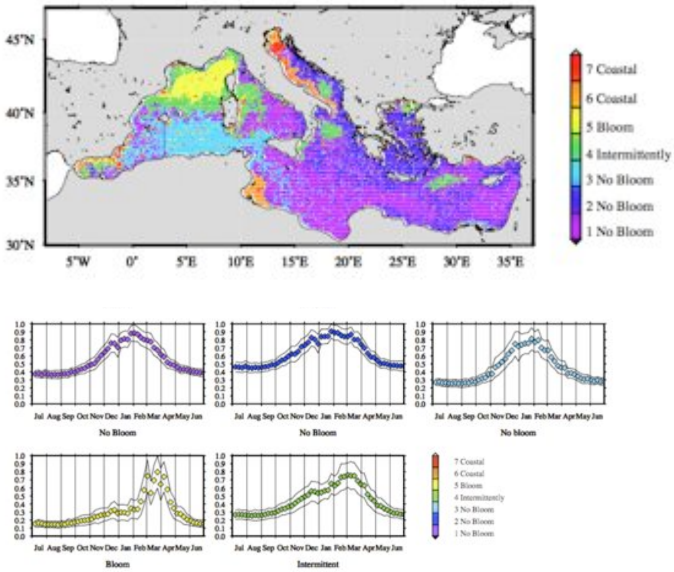

Figure 1.
Biogeographical provinces in the Mediterranean Sea (on the left) and the associated phenological seasonal cycles of the normalized surface chlorophyll (on the right. See D'Ortenzio and Ribera d'Alcalà, 2009 for details.

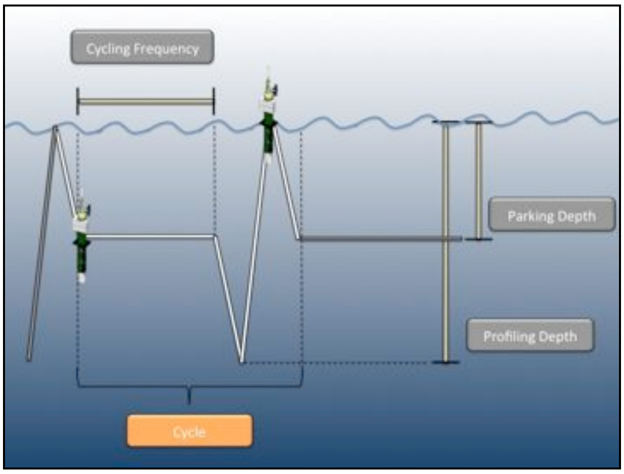

Figure 2
Diagram of a NAOS float mission. In the grey boxes, the mission and sampling parameters that could be fixed are indicated.

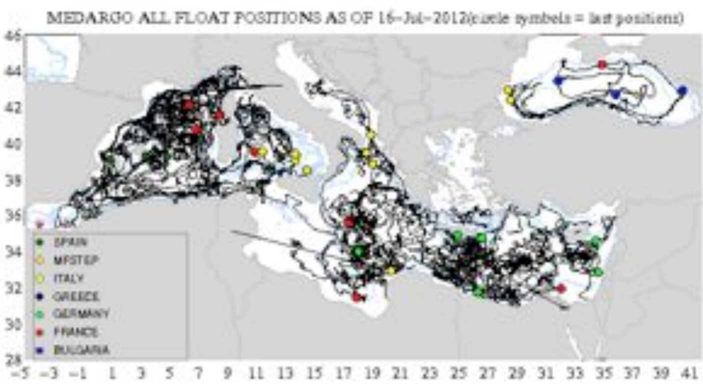

Figure 3
Trajectories of the MedArgo physical floats (from the MedArgo web site).

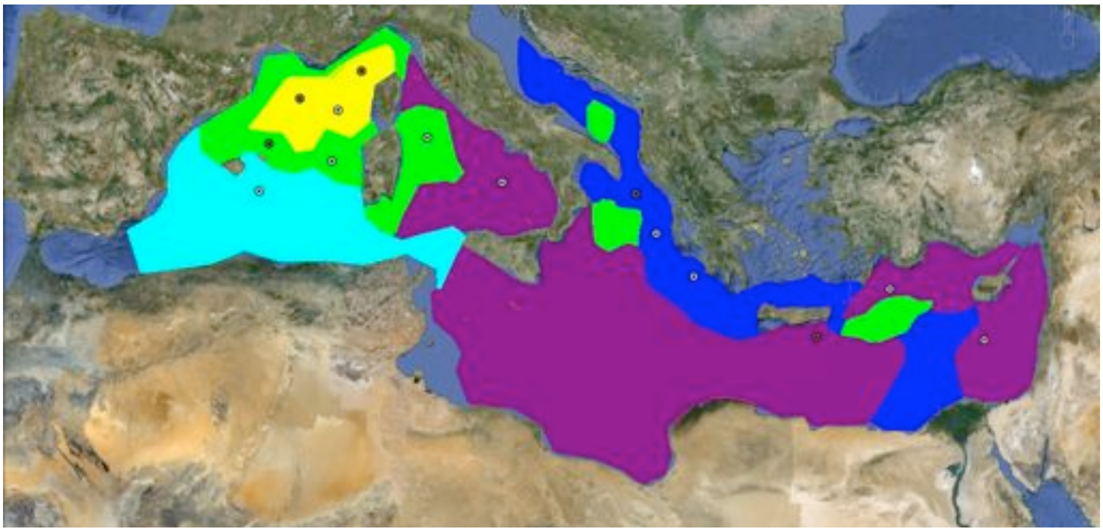

Figure 4
Deployment plan for the “MedArgo” strategy. Brown points represent the 5 RemA+NO3/O2 floats.

Figure 5
Deployment plan for the “Process Study” strategy. Brown points represent the 5 RemA+NO3/O2 floats.

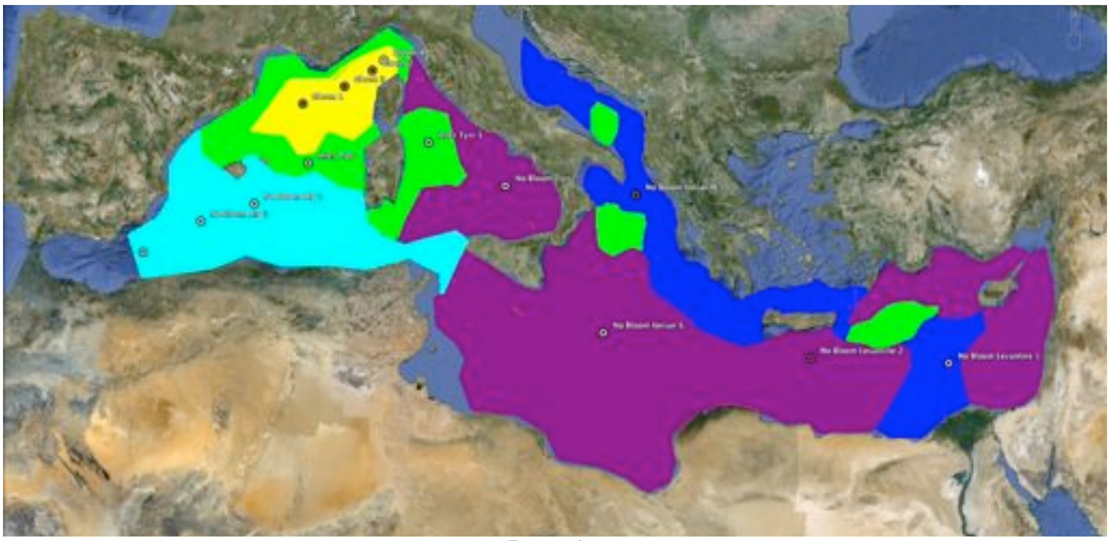

Figure 6
Deployment plan for the “Lagrangian” strategy. Brown points represent the 5 RemA+NO3/O2 floats.