Seasonal variability of nitrate concentrations in the Mediterranean Sea: Contribution of Bio-Argo floats

O. Pasqueron de Fommervault, F. D'Ortenzio, A. Mangin, R. Serra, K. Johnson, H. Claustre, C. Schmechtig, E. Leymarie, C. Migon, P. Conan, F. Besson, G. Obolensky, and A. Poteau

5TH Euro-Argo User Workshop
March 2015 – Brest, France

Outline

I. Introduction

II. NAOS project
III. Nitrate sensor calibration
IV. Results
V. Conclusion

Introduction

<u>The Mediterranean Sea</u>

- One of the most studied oceans of the world (*Williams, 1998*)
- Low nutrient concentration basin (*McGill 1966, Krom et al. 1991*)
- One of the largest nutrient-depleted area in the world (*Ignatiades et al. 2009*)

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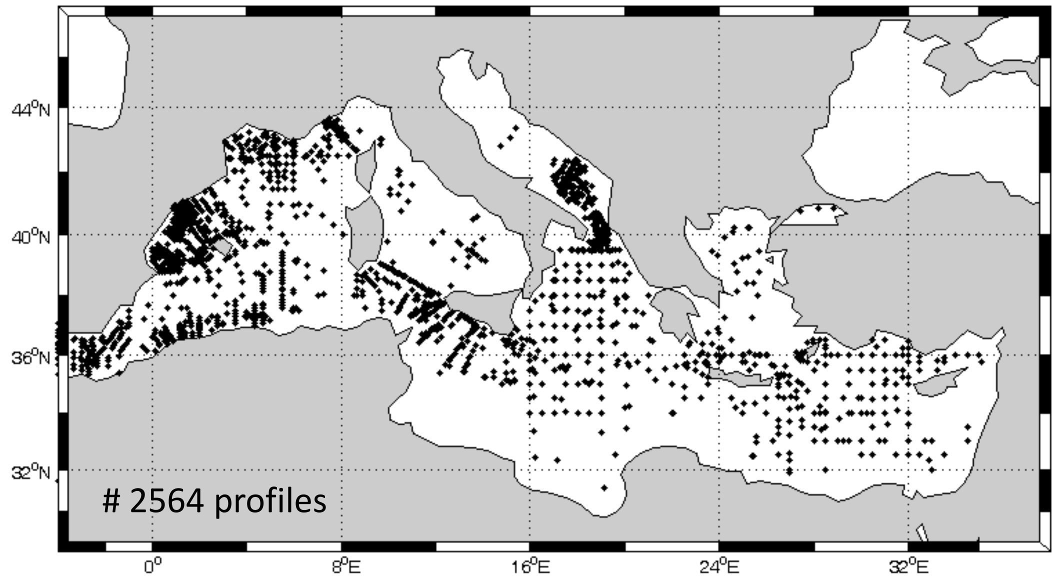
The nutrient dataset

❖ MEDAR-MEDATLAS, MATER and SESAME programs as well as from specific cruises (*Lavezza et al., 2011*)
❖ Quality-controlled data (*Lavigne et al., 2013*)



Introduction

Spatial distribution

Good description of the spatial distribution of $[NO_3]$

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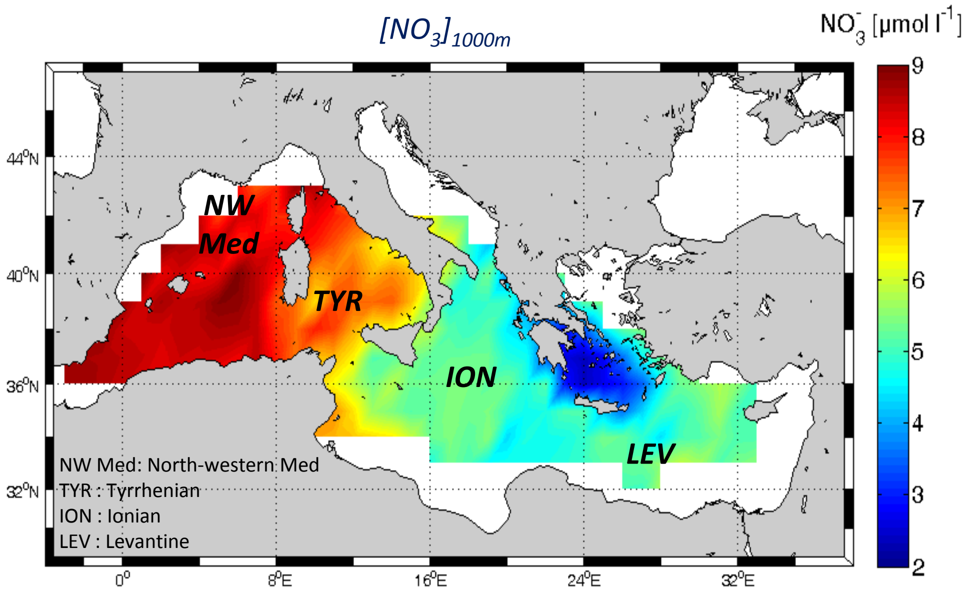
$[NO_3]_{1000m}$



❖ West-to-east gradient of decreasing concentrations (*e.g. Moutin et Prieur 2012; Pujo-Pay et al., 2011; Ribera d'Alcalà et al., 2003*)

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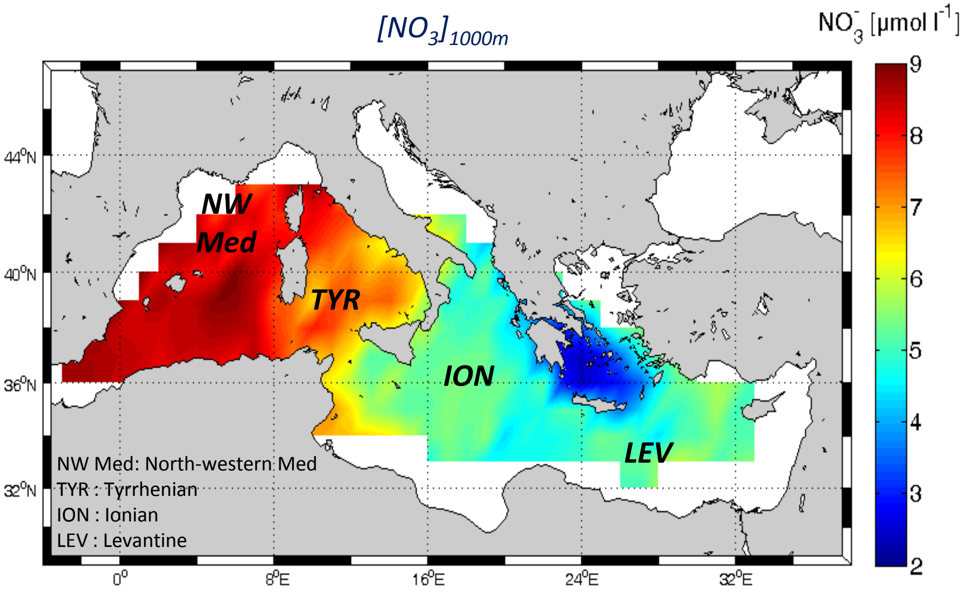

Temporal distribution

Seasonal variability poorly known

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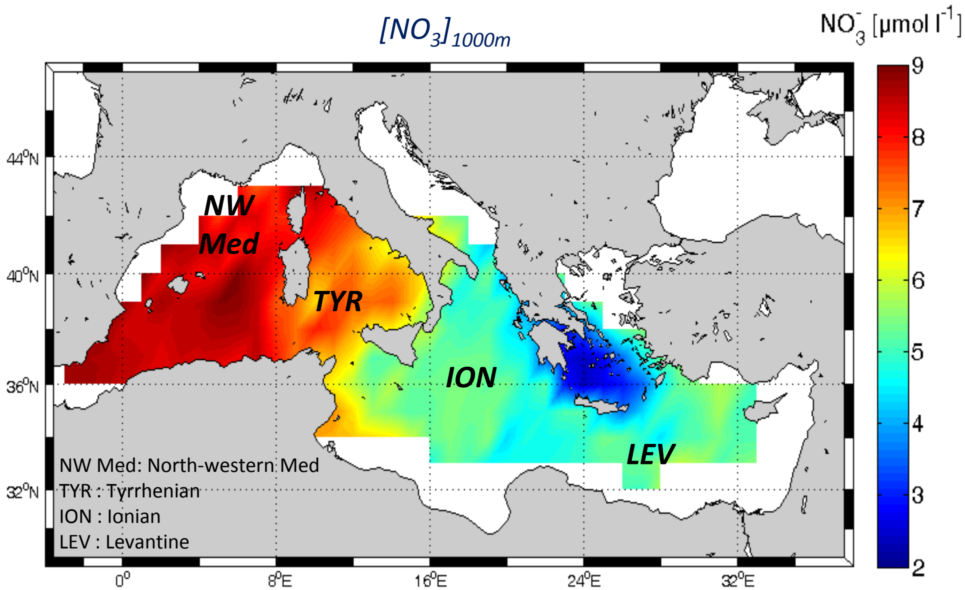

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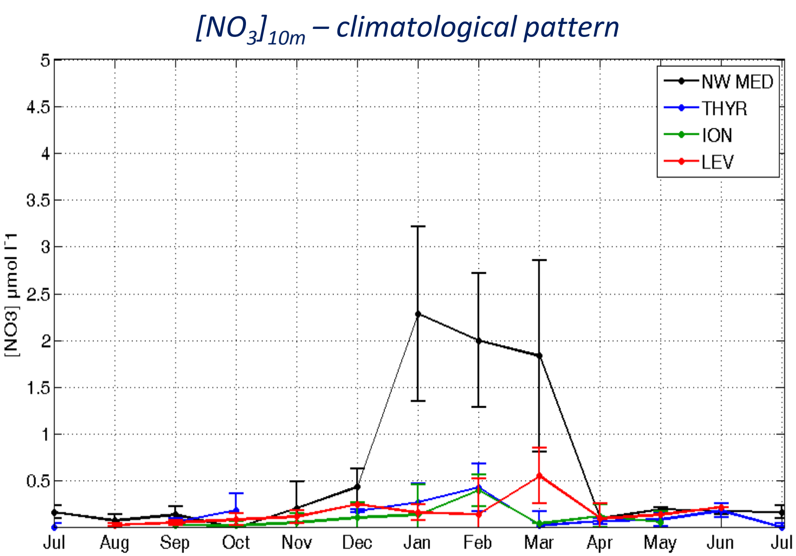

- West-to-east gradient of decreasing concentrations (*e.g. Moutin et Prieur 2012; Pujo-Pay et al., 2011; Ribera d'Alcalà et al., 2003*)
- Clear seasonal pattern in the NW Med → [NO_3]$_{surf}$ increase from December to March

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NAOS Project

What is NAOS (Novel Argo Ocean observing System) ?

- A French long-term project (EQUIPEX 2009-2019)
- Aims to improve the French and European contributions to Argo
- Implement the first basin scale network of Bio-Argo floats

33 Bio-Argo floats deployed in the Mediterranean Sea
(in two successive waves: 2013 and 2015)

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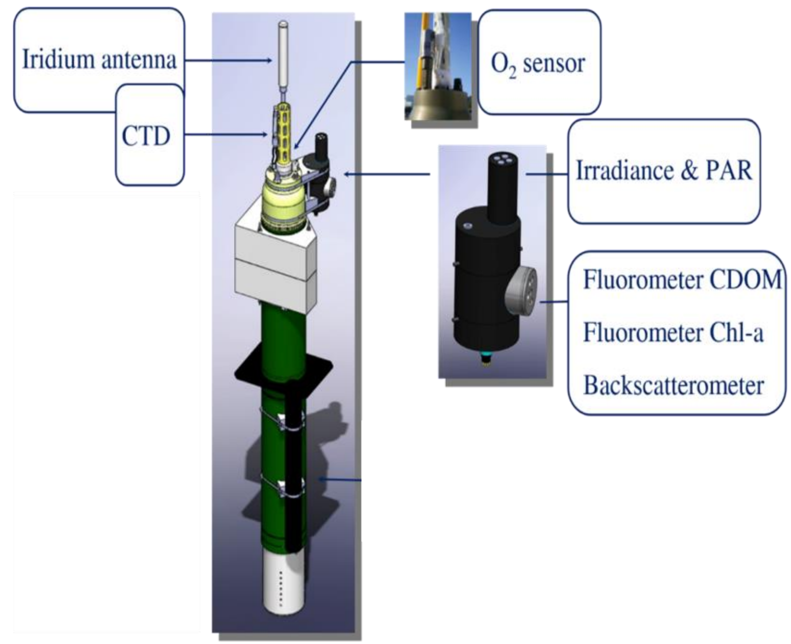

Bio-Argo floats

- PROVOR CTSO3 equipped with IRIDIUM antenna
- Profile realized from 0 to 1000m
- Vertical resolution from 10 to 30m
- Temporal resolution of 5 days, improved (*i.e.* 1 day) during transition periods

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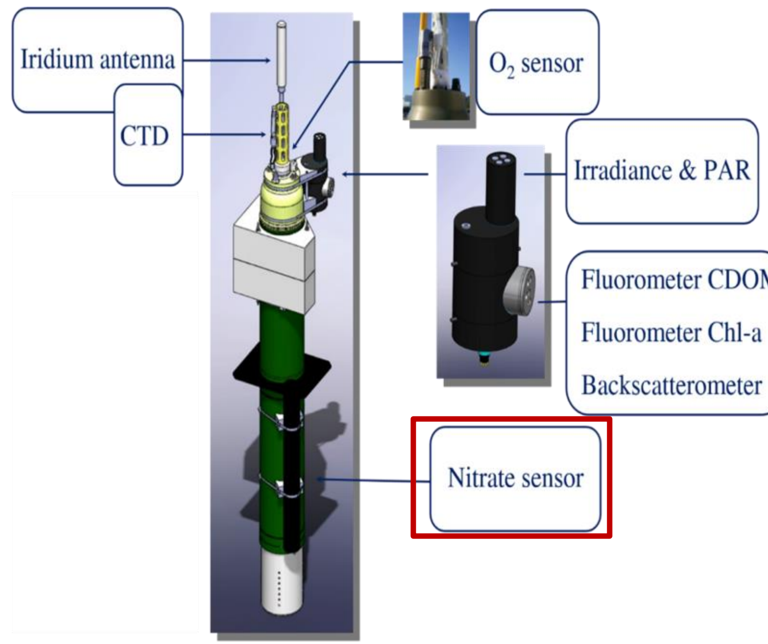
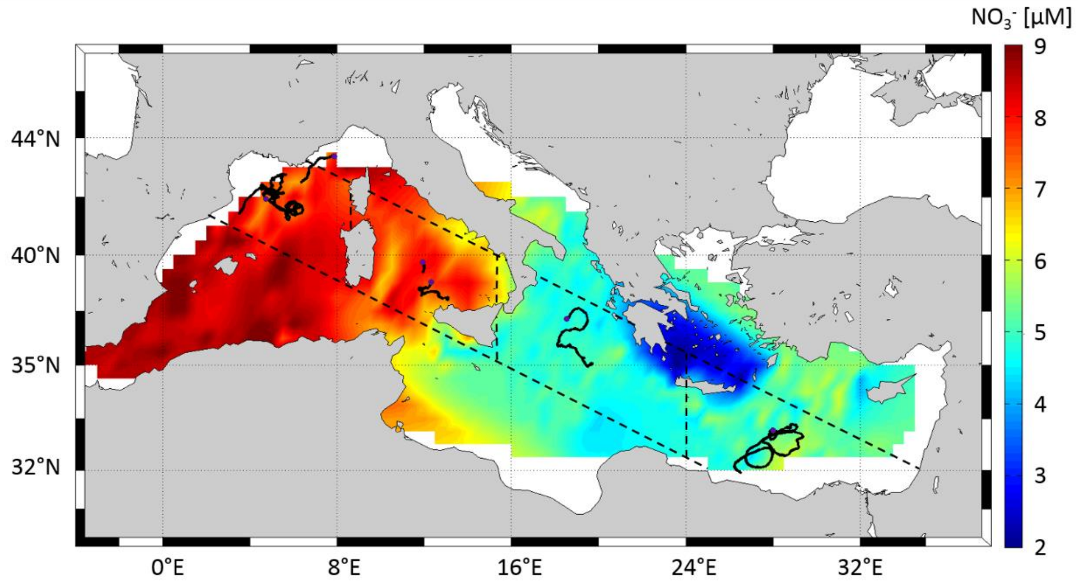
Only six [NO3] floats in the first wave

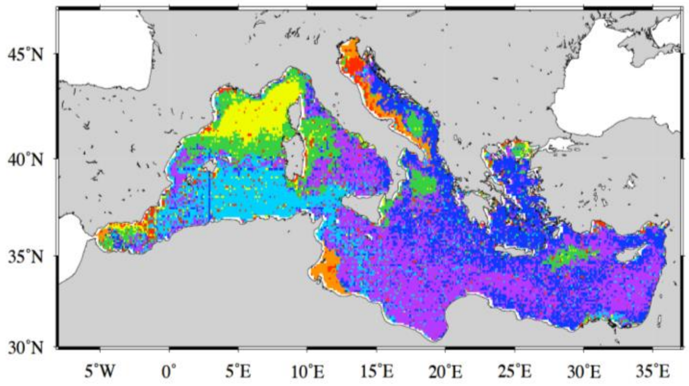


NAOS Project

Deployment plan

- ❖ Cover the west-to-east gradient of decreasing nitrate concentrations
- ❖ Deployment strategy based on international consensus in order to maintain as long as possible floats in a “homogenous” zone.





From D’Ortenzio and Ribera D’Alcalà (2009)

Details

http://en.naos-equipex.fr/News/Roadmap-for-the-deployment-decision-of-the-NAOS-Bio-Argo-Mediterranean-floats

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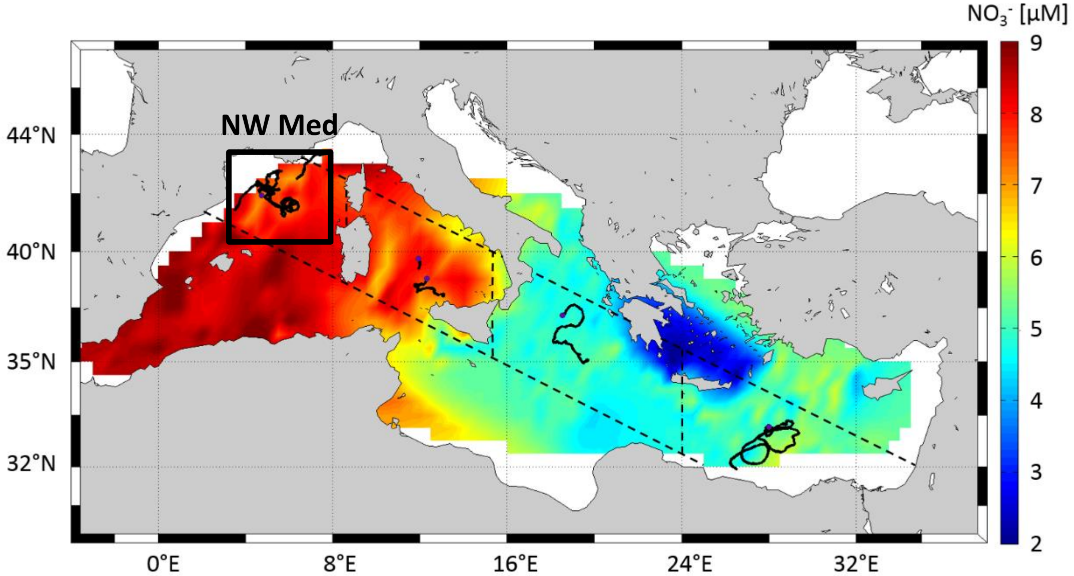

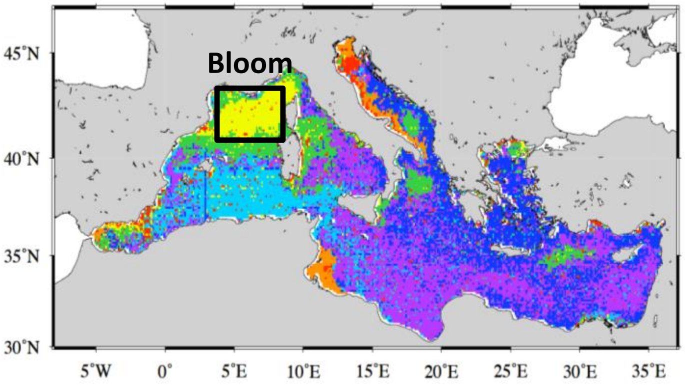

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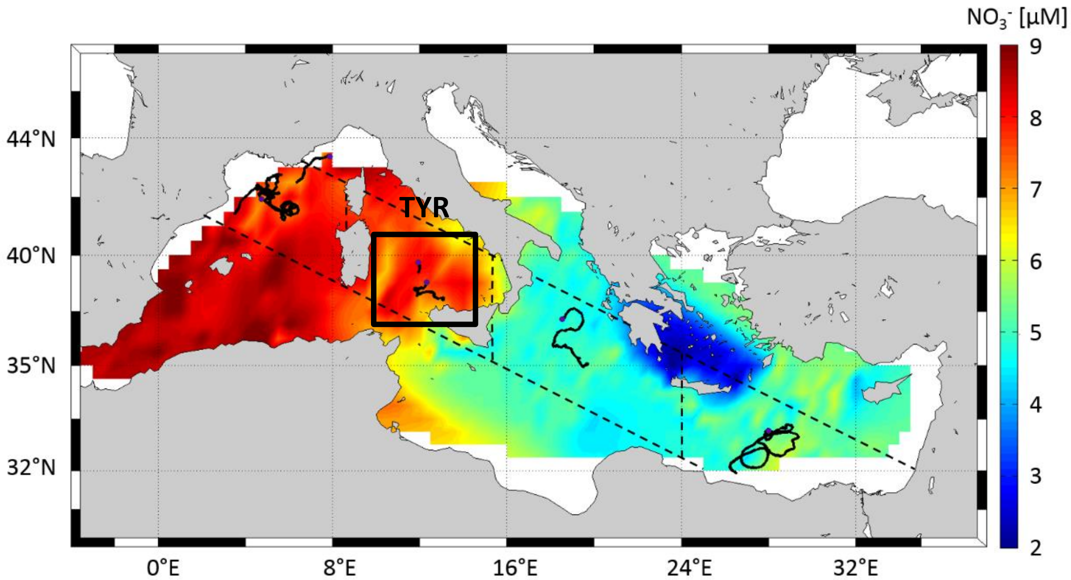

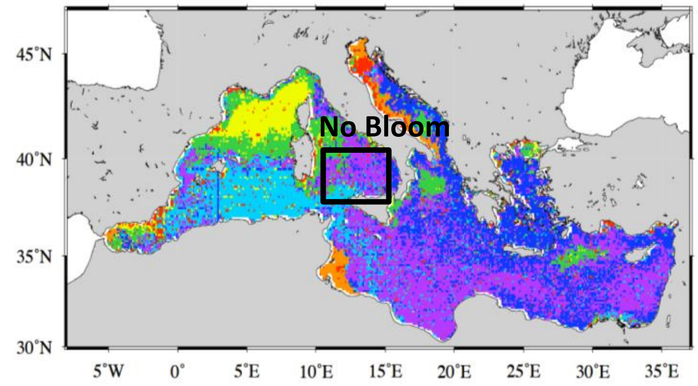

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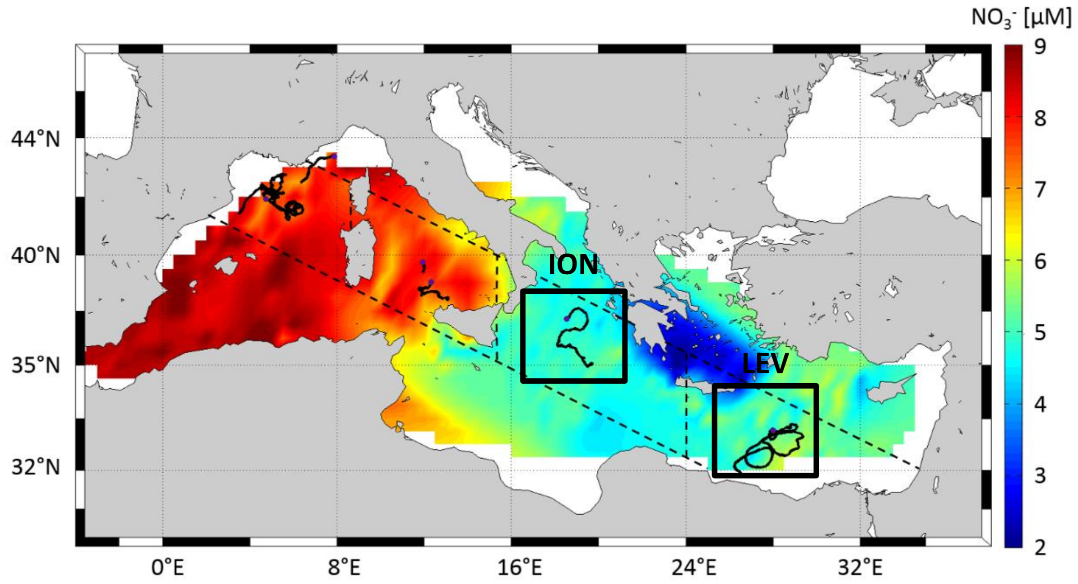

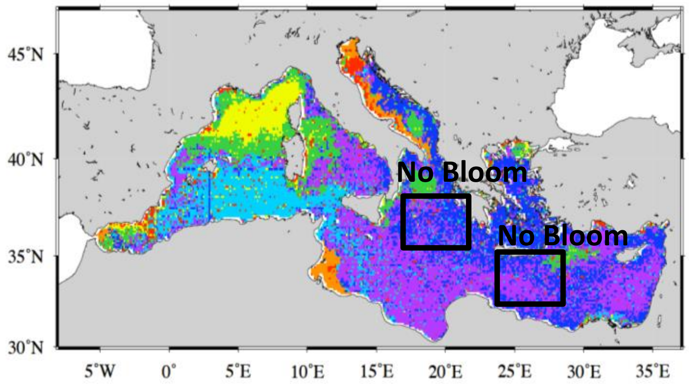

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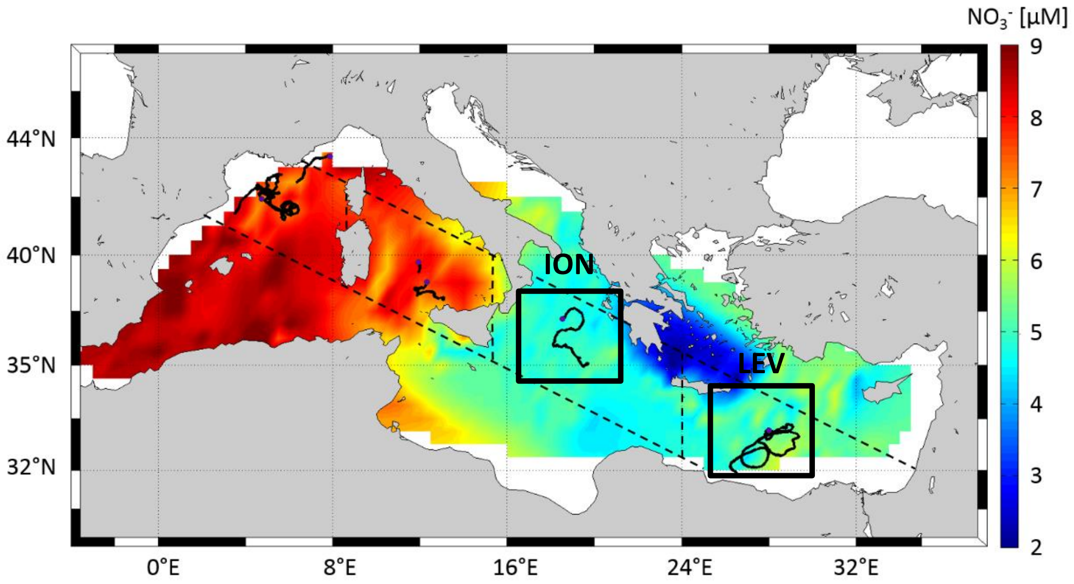

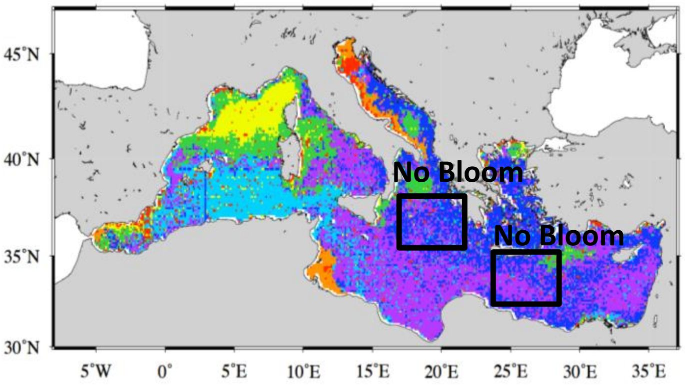

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Extrapolation of float data at bioregion level

Details

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Nitrate sensor calibration

Measurement principle

- absorption of light at ultraviolet wavelengths (217-240nm)
- Beer-Lambert law $A(\lambda) \; = \; [C_1].\,\varepsilon_1(\lambda) + \; [C_2].\,\varepsilon_2(\lambda) + \; \ldots$

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TCSS algorithm (*Sakamoto et al., 2009*)

- The observed salinity directly taken into account and subtracted to the total absorbance

Nitrate absorption

$$A(\lambda) - \boxed{S.ESWtis(\lambda)} = \boxed{[NO_3]ENO3(\lambda)} + \alpha_1 + \alpha_2.\lambda$$

Extinction coefficients are reported in the calibration file (*© Satlantic)*

Sea water absorption with temperature correction

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The measurement is sensitive and problematic in the Mediterranean Sea

- ✓ *Low concentration (from 0 to 9µM)*
- ✓ *High salinity*

Nitrate sensor calibration

Additional corrections

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Not specific to the Mediterranean Sea
important contribution to the measured value

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<u>Pressure correction</u>

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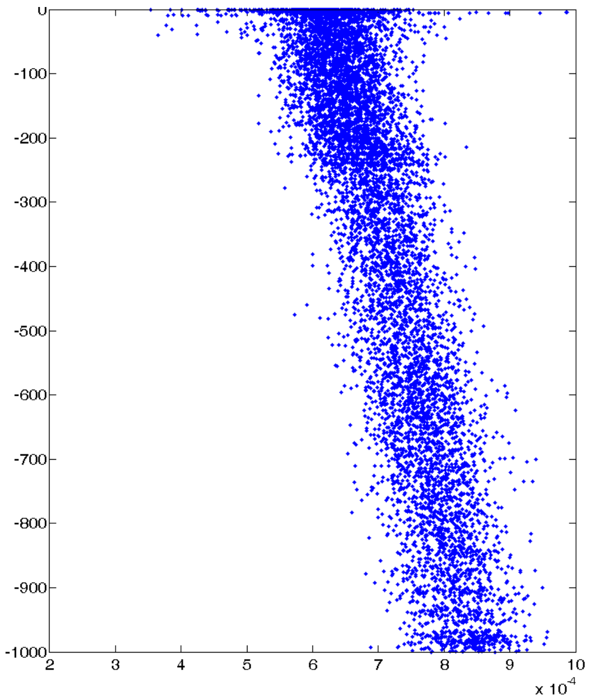

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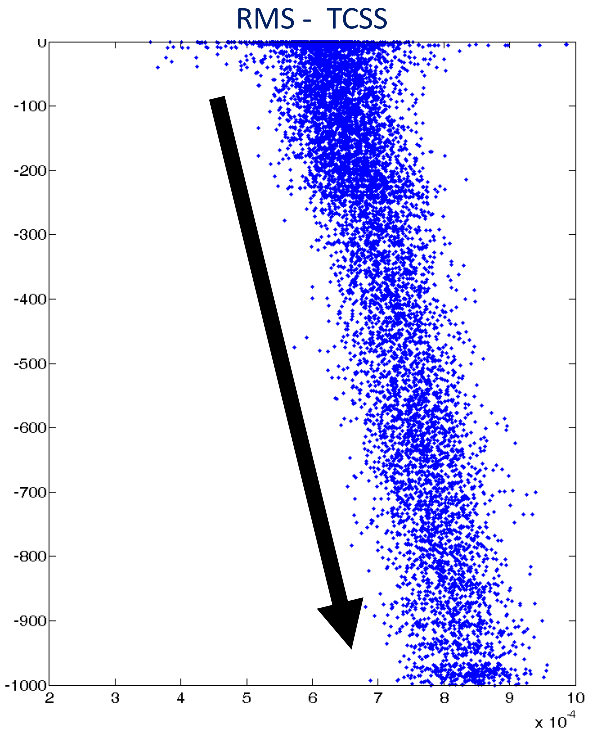

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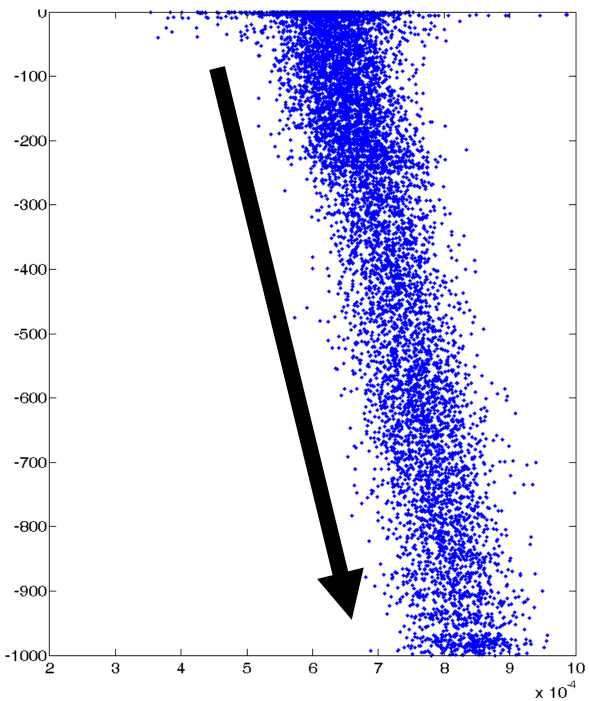
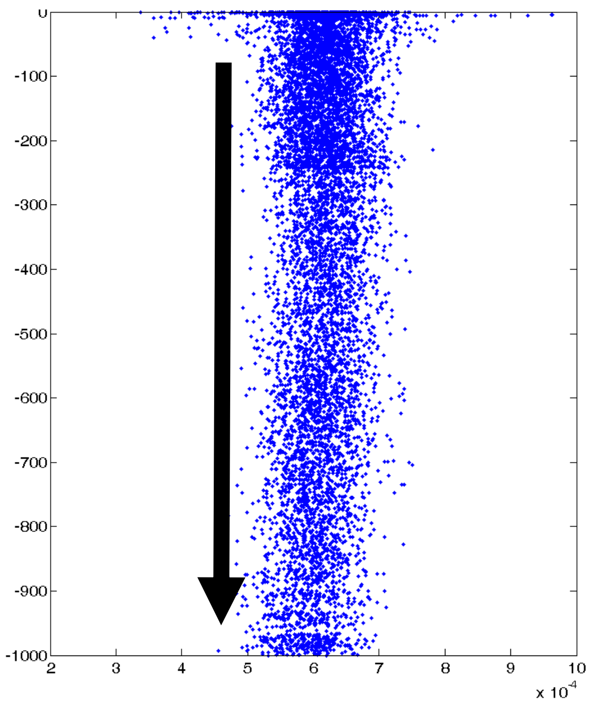
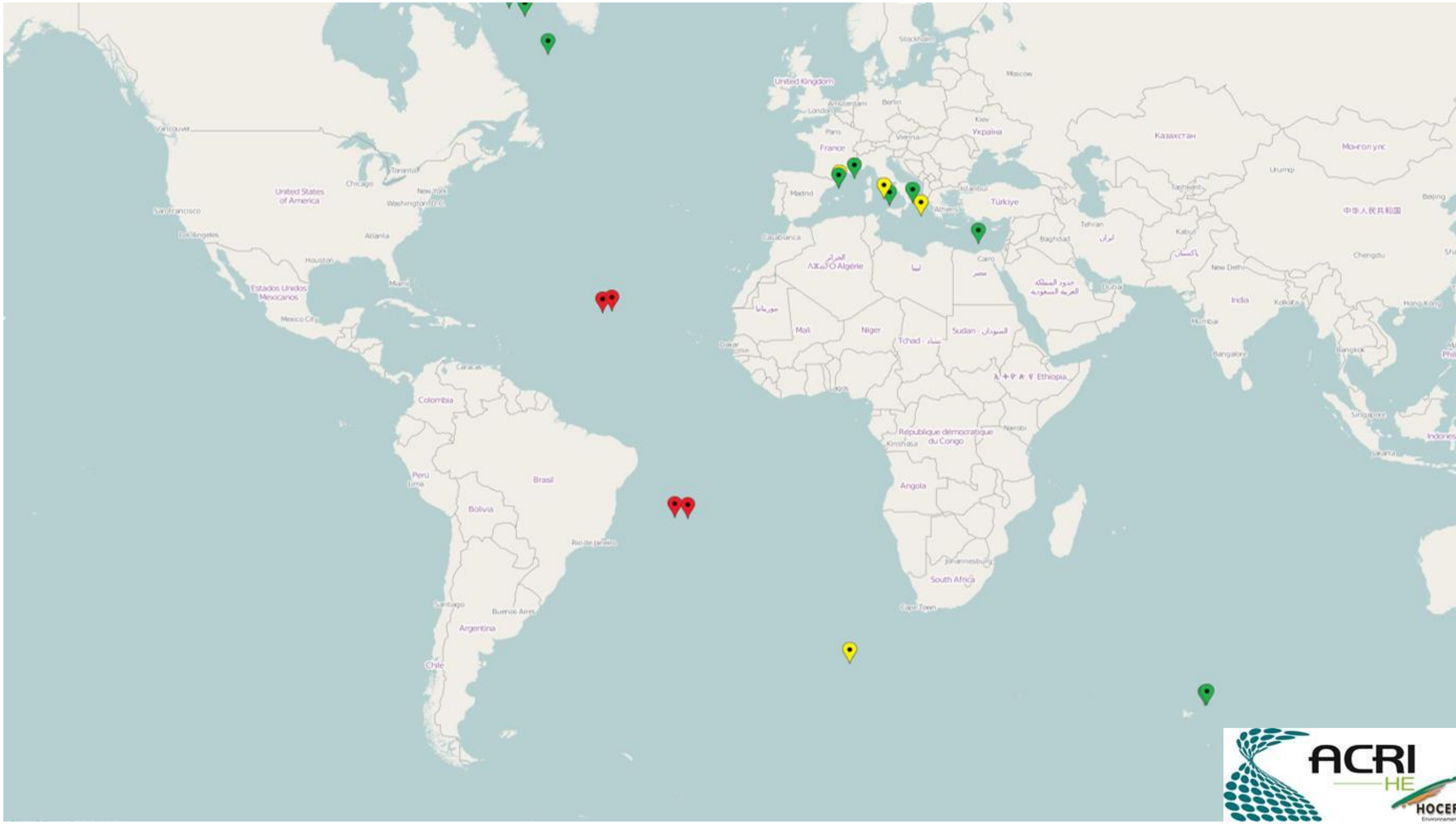


RMS - TCSS 2% Pressure correction



Nitrate sensor calibration

Seasiderendezvous



Romain.Serra@acri-he.fr

http://www.seasiderendezvous.eu

Nitrate sensor calibration

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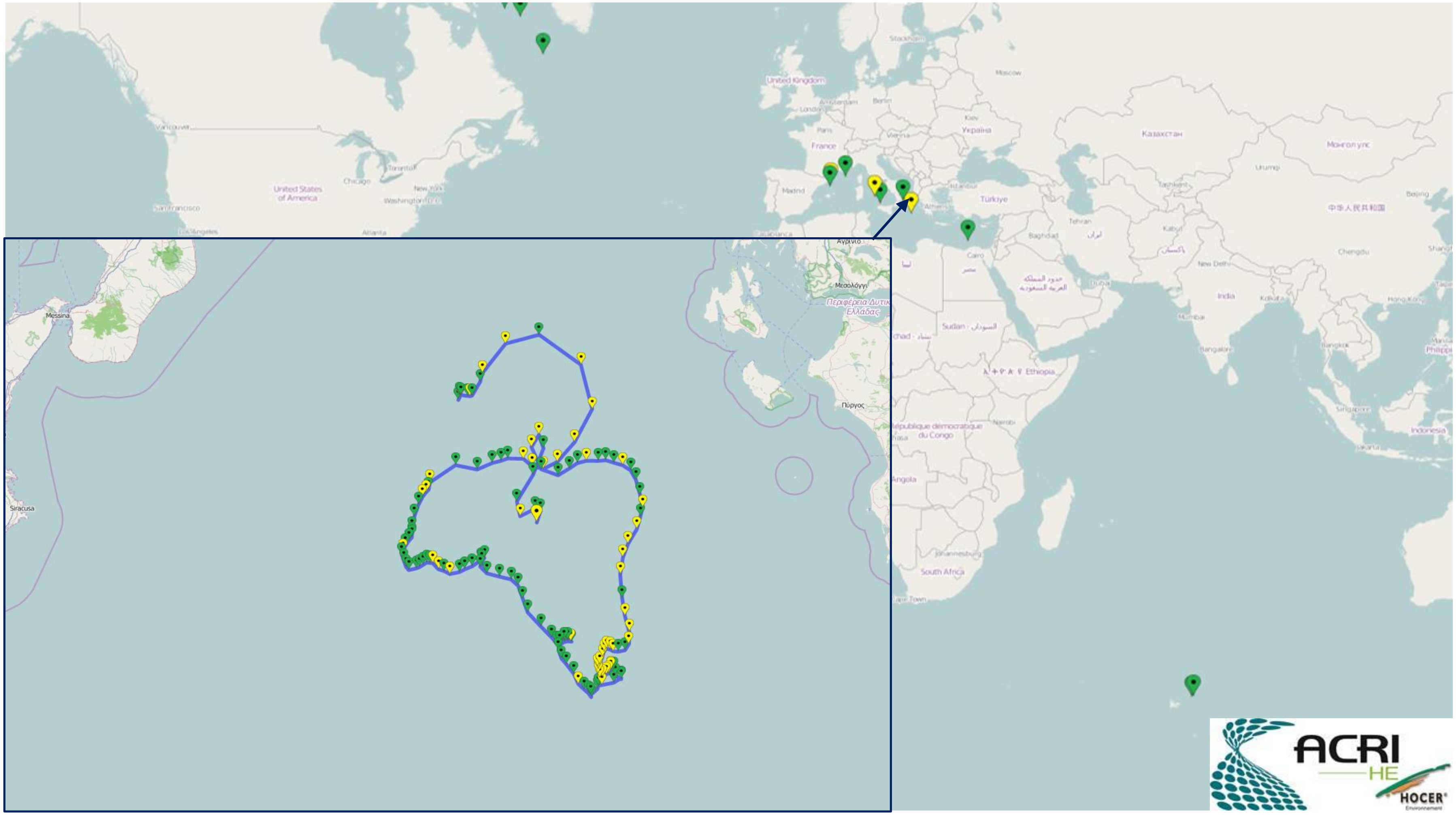

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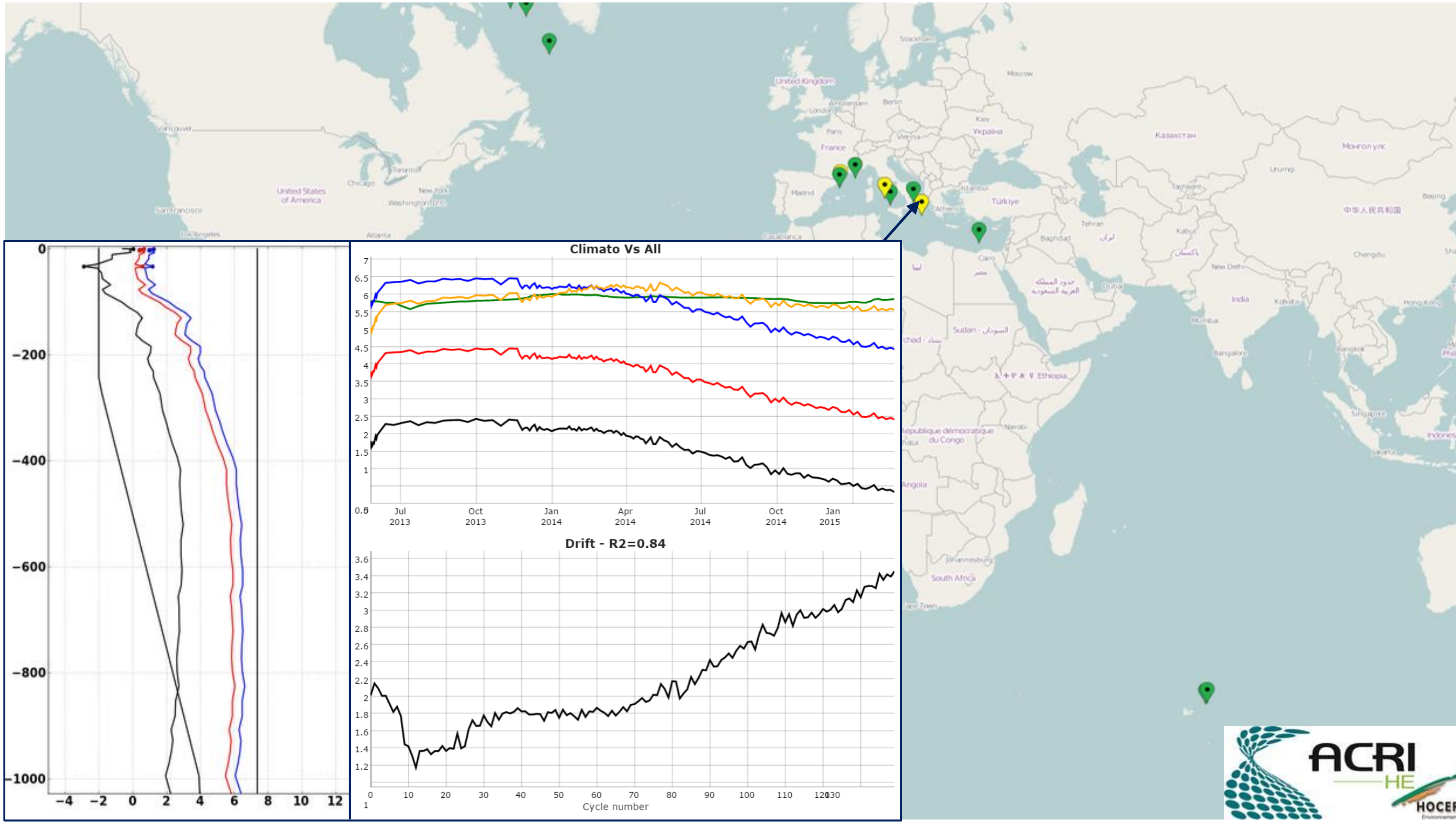

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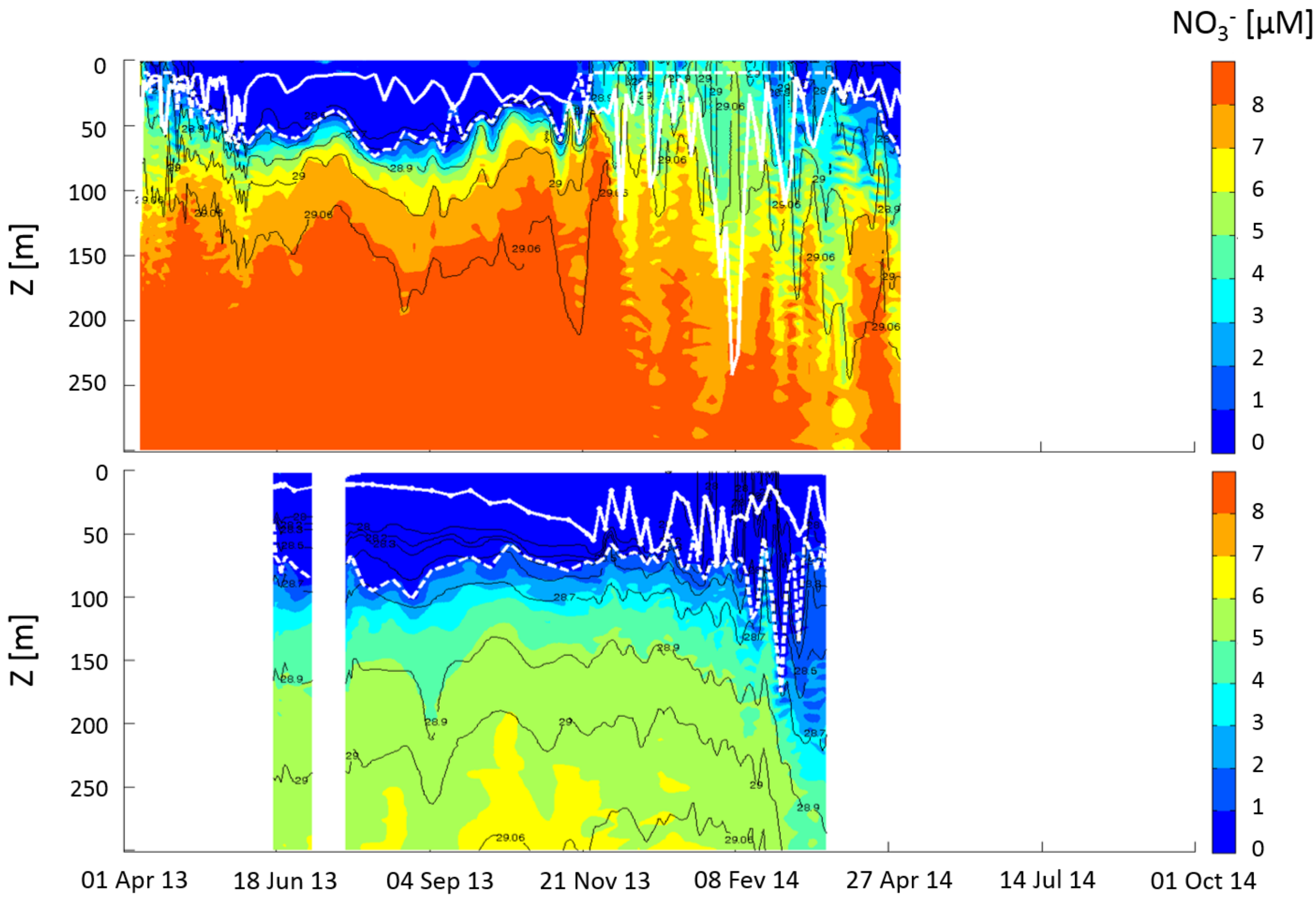
Results

The $[NO_3]$ field at high temporal resolution: 2013-2014 period



NW Med

$\overline{Z_{NO3}}s = 57m$

$\overline{MLD}_W = 70m$

$MLD_{max} = 242m$

TYR

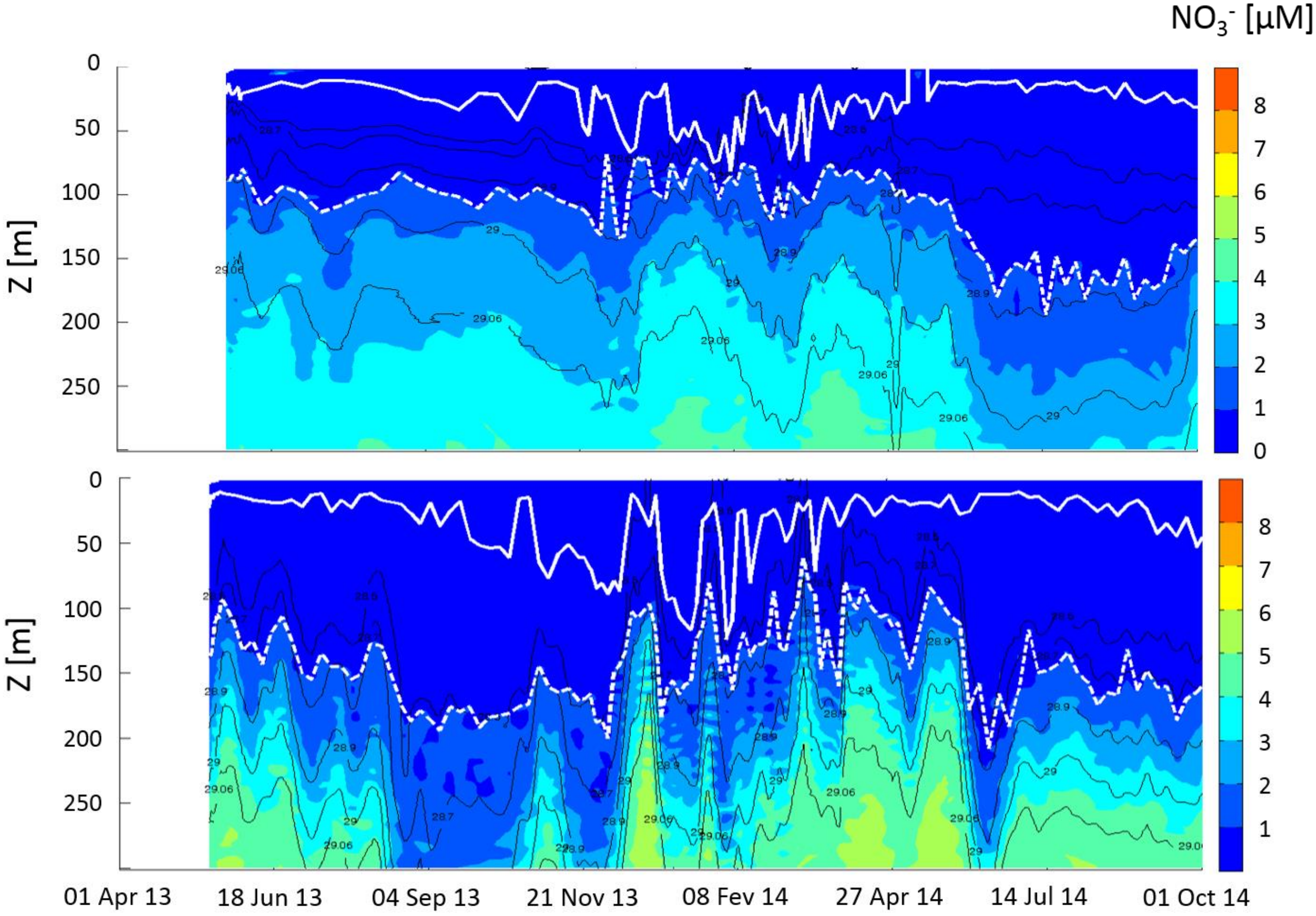
$\overline{Z_{NO3}}s = 84m$

$\overline{MLD}_W = 38m$

$MLD_{max} = 75m$

Results

The [NO_3] field at high temporal resolution: 2013-2014 period



ION

$\overline{Z_{NO3}}\,s = 138m$

$\overline{MLD_W} = 45m$

$MLD_{max} = 82m$

LEV

$\overline{Z_{NO3}}\,s = 151m$

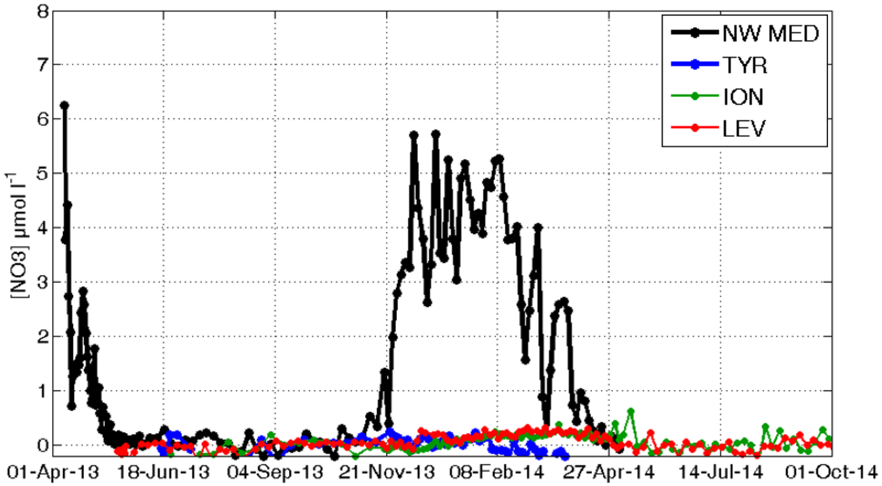
$\overline{MLD_W} = 65m$

$MLD_{max} = 124m$

Results

Float time-series

Surface values



- Seasonal cycle in the NW Med
- $[NO_3]_{surf}$ reaches 5µM
- $[NO_3]_{surf}$ around 0µM in the other areas

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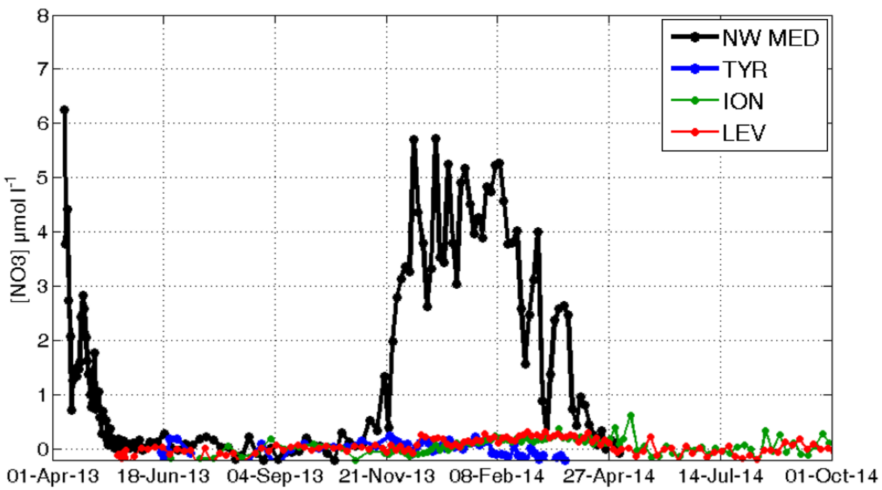
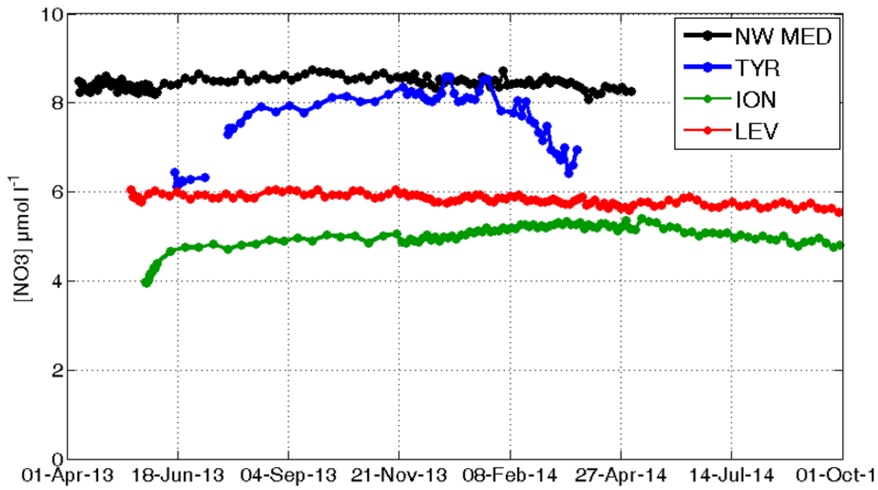


Deep values

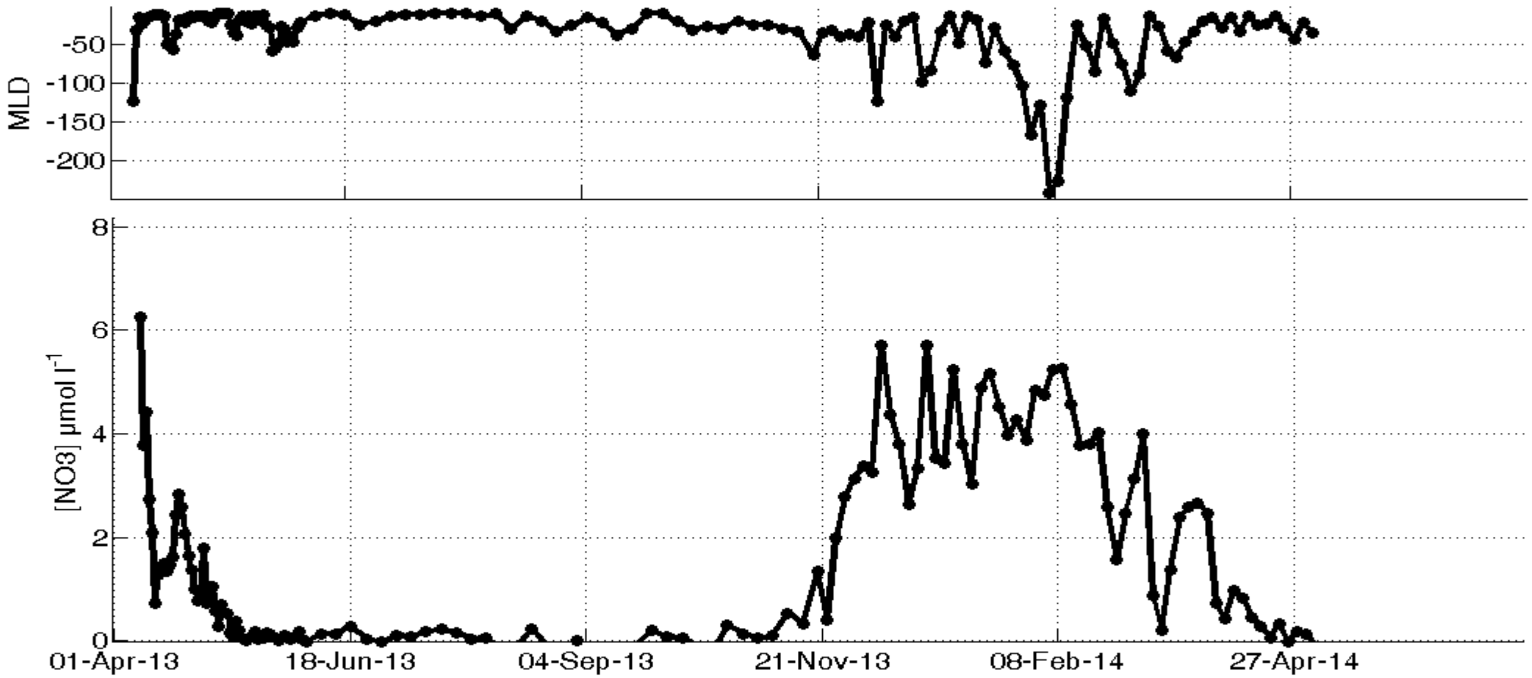


- Seasonal cycle in the NW Med
- $[NO_3]_{surf}$ reaches 5µM
- $[NO_3]_{surf}$ around 0µM in the other areas

- Low variability (except in the TYR)
- West-to-east gradient of decreasing $[NO_3]$

Results

MLD deepening events in the NW Med



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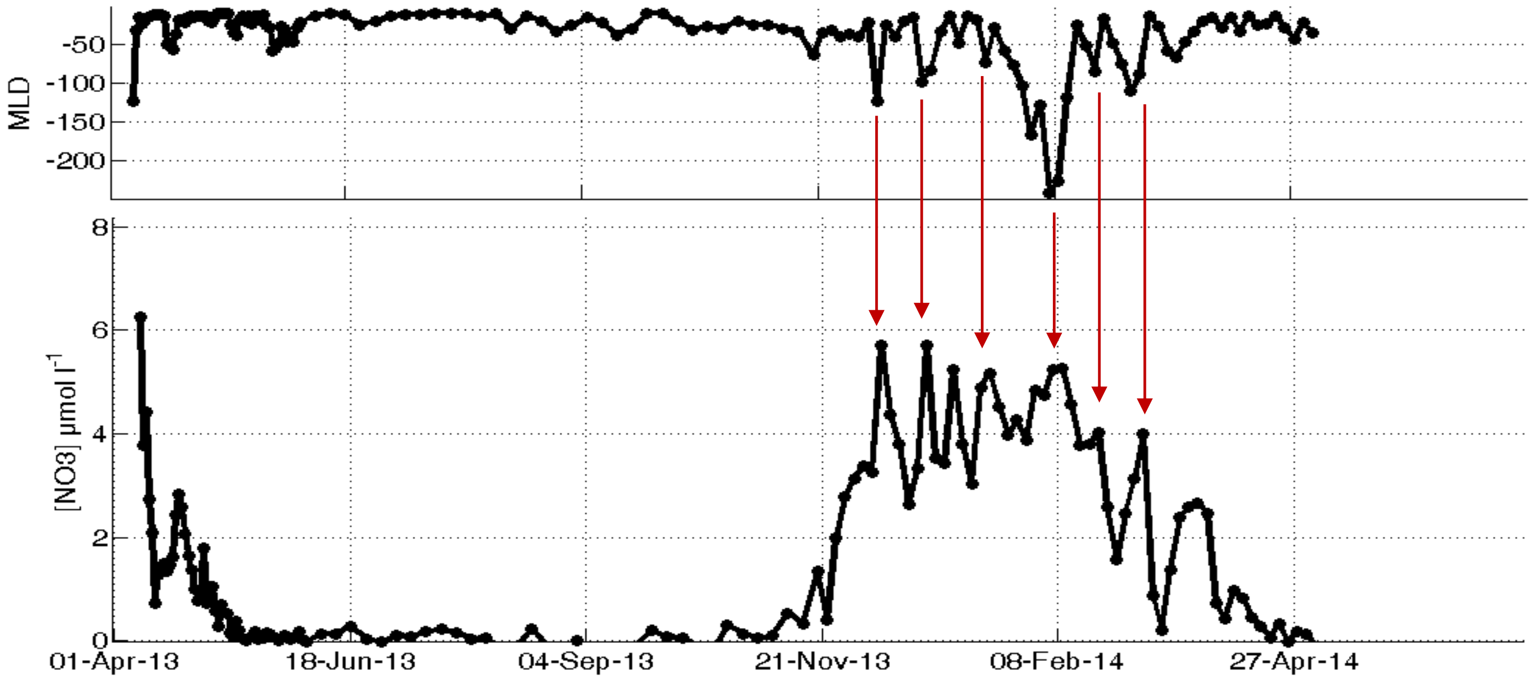

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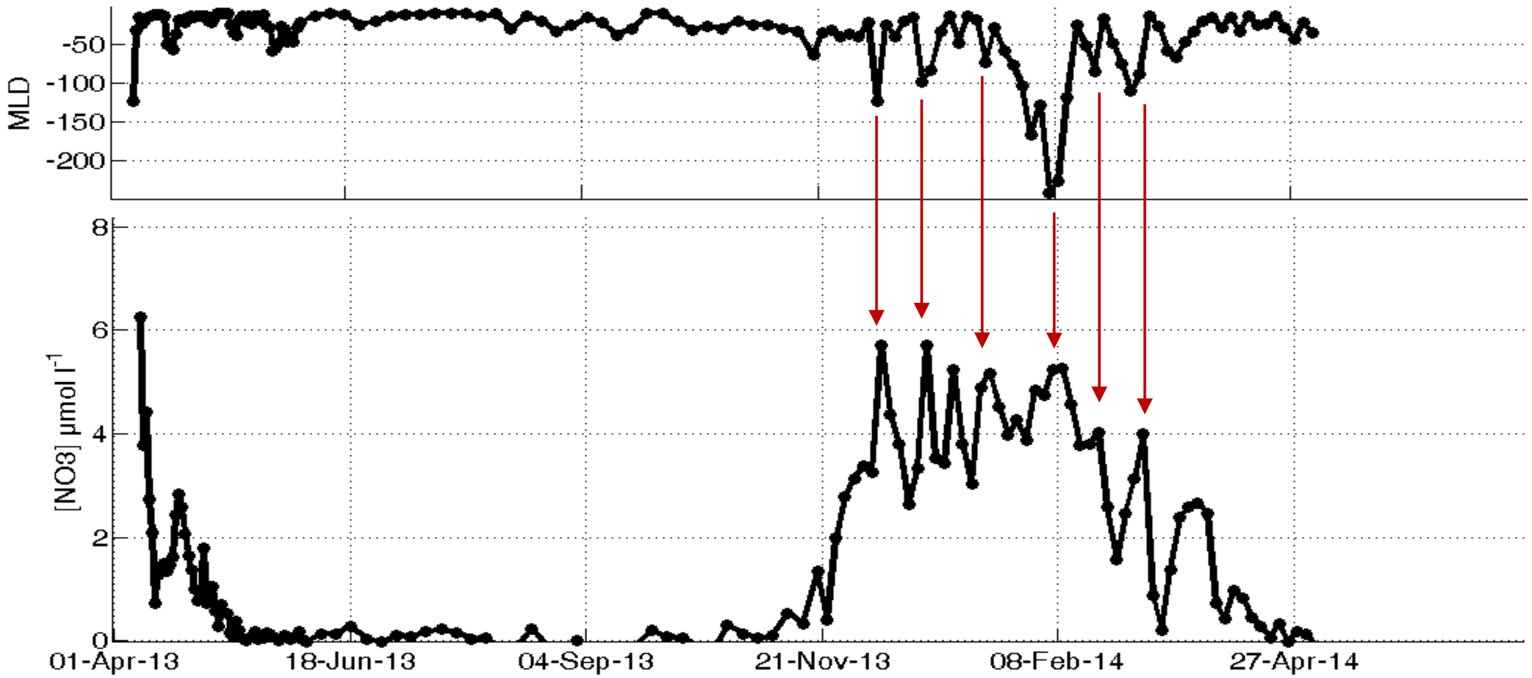

- ❖ High $[NO_3]_{surf}$ are measured since December, without deep convection
- ❖ The depth reached by the MLD poorly determine $[NO_3]_{surf}$
- ❖ $[NO_3]_{surf}$ often found > 4µM (15% of the profiles in the historical database)

Results

MLD deepening events in the NW Med

$$Nsup(t) = \left[\int_0^{MLD(t+\Delta t)} NO3(t,z)\, dz \;.\frac{Zeu(t+\Delta t)}{MLD(t+\Delta t)}\right] - \left[\int_0^{Zeu(t+\Delta t)} NO3(t,z)\, dz\right]$$

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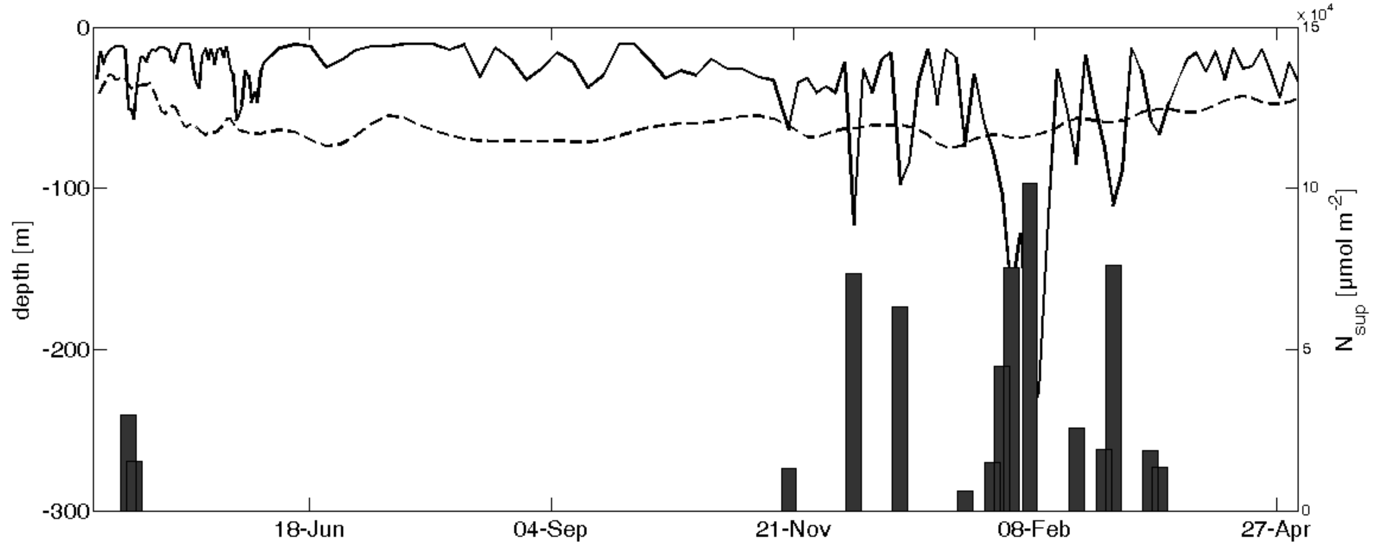

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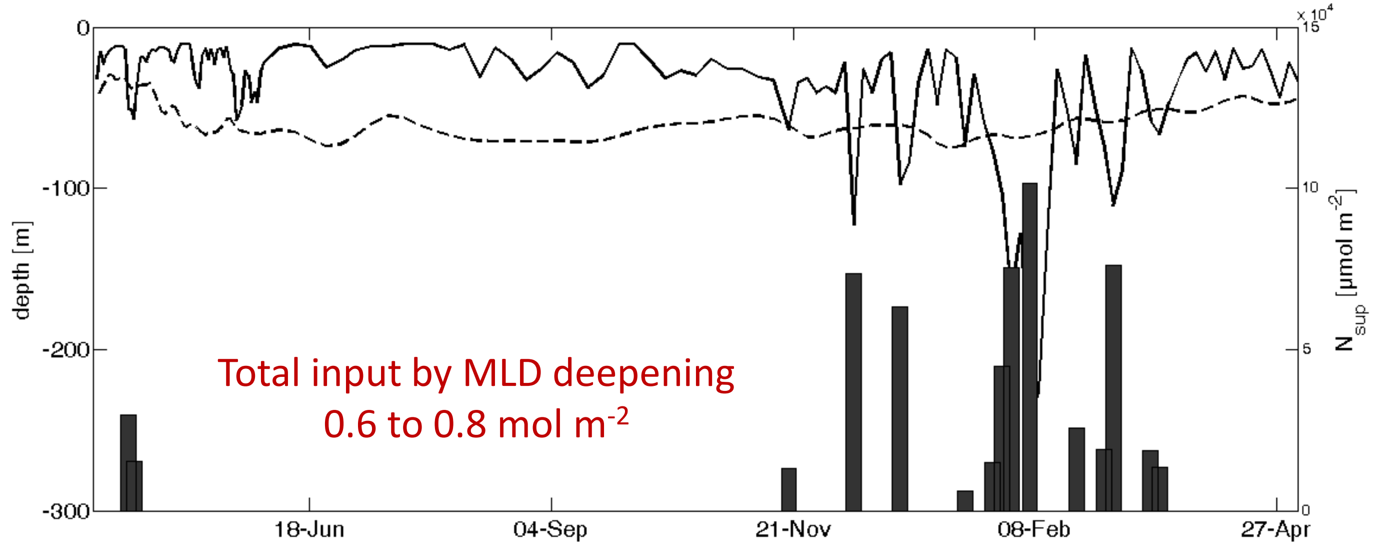

Results

MLD deepening events in the NW Med

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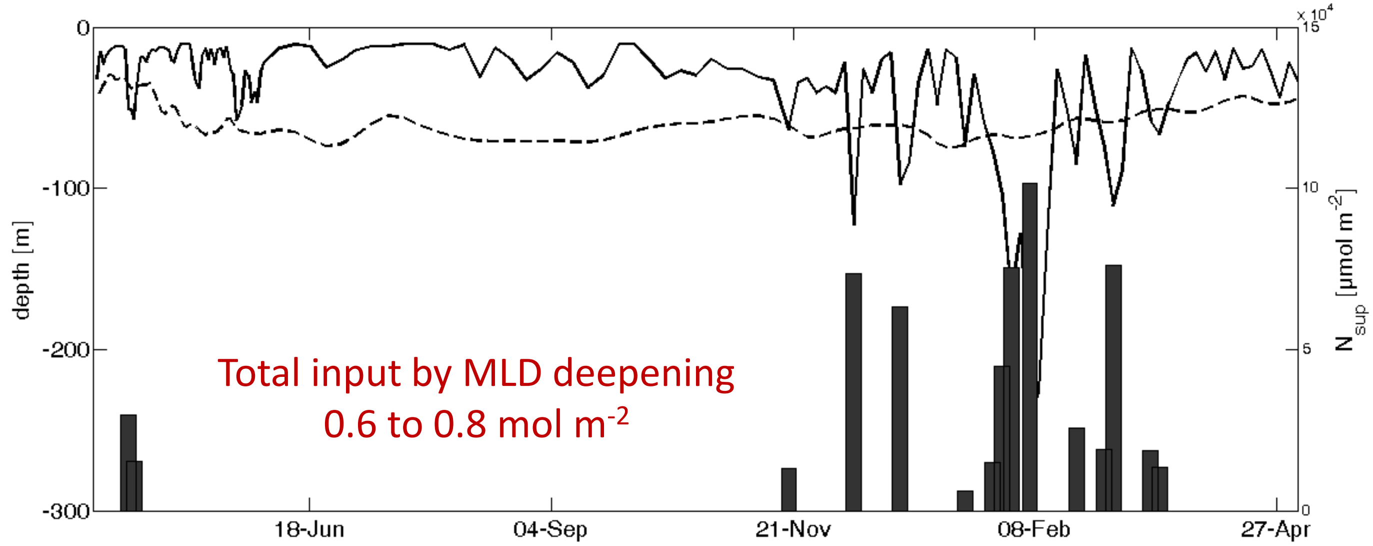

❖ May trigger a NP ranging from 49 to 67 gC m^{-2} (typical values for the area)

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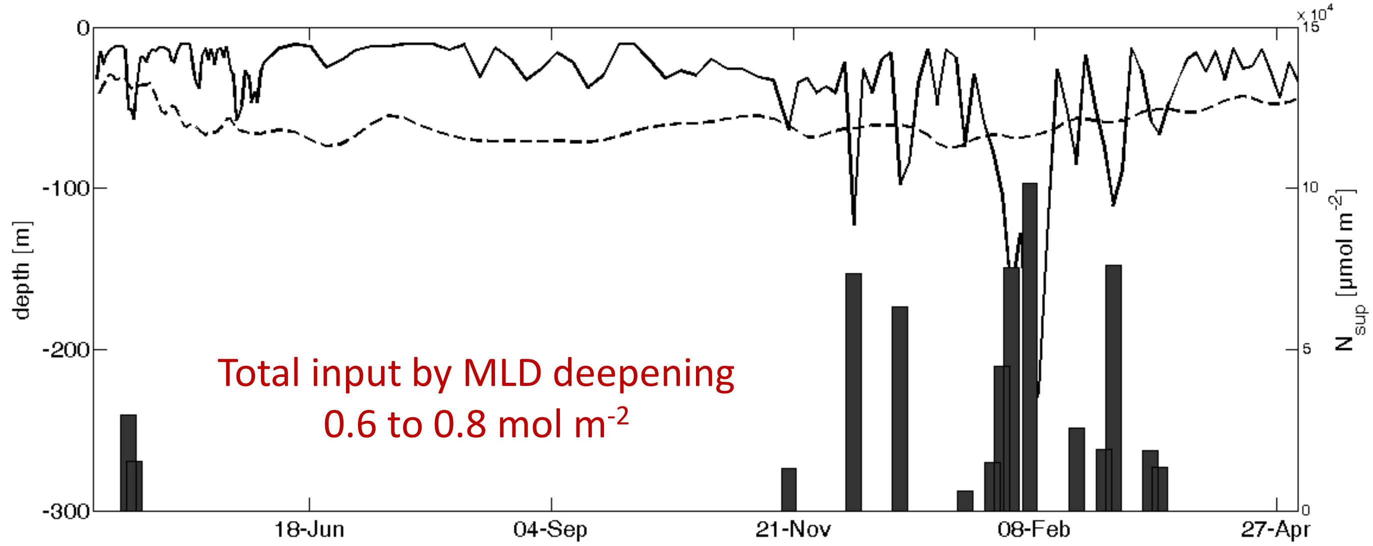

- May trigger a NP ranging from 49 to 67 gC m^{-2} (typical values for the area)
- 20-25 times higher than atmospheric inputs (Markaki et al., 2010)
- ~ 100 times higher than upward diffusion

Outline

I. Introduction
II. Database
III. Nitrate sensor calibration
IV. Results

V. Conclusion

Conclusion

<u>In summary</u>

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  - ✓ only one float moved from the initial bioregion.

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  - ✓ Decreasing [NO3] from west to east
  - ✓ Nitracline deepening from west to east

Conclusion

In summary

- Deployment strategy was successful
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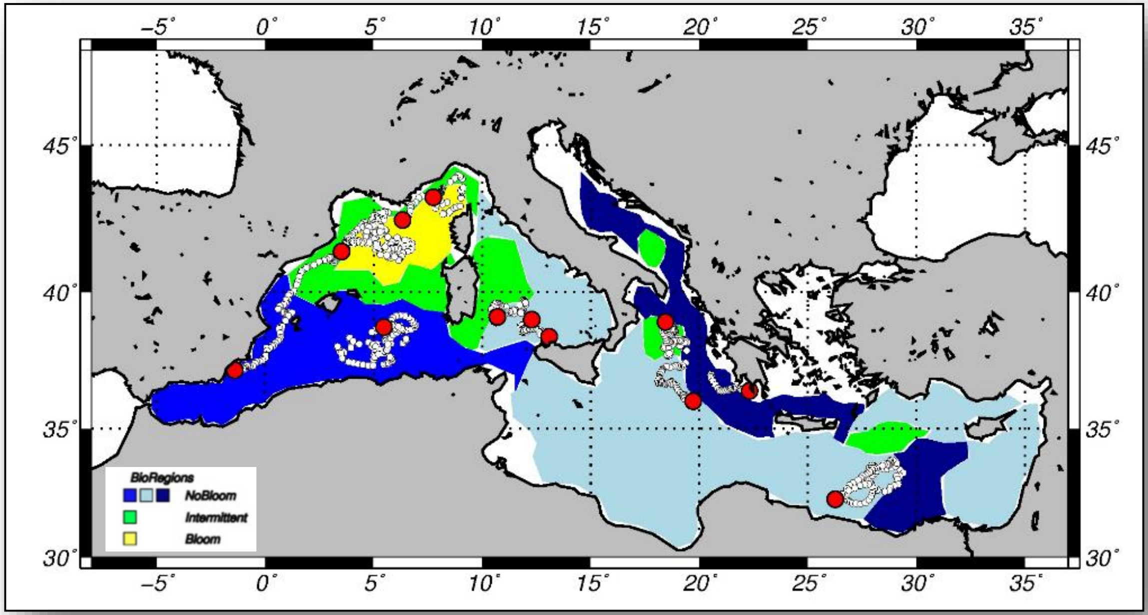
- Reliable [NO_3] which confirm the classical view of the basin
  - ✓ Decreasing [NO3] from west to east
  - ✓ Nitracline deepening from west to east
- Monitoring of a complete annual cycle
  - ✓ MLD and nitracline never cross in the TYR, ION and LEV
  - ✓ NW Med is the single area where MLD cross the nitracline
  - ✓ Frequency, number of events etc. a least as important than the MLD depth

Conclusion

Outlook

❖ Next wave of NAOS deployments (14 floats) will be performed on a dedicated cruise (Bio-Argo-Med) in May 2015.
❖ All second wave floats equipped with $[NO_3]$ sensor
❖ Still active floats will be recovered



Interannual variability in $[NO_3]$ seasonal cycle
Confirm/refute some statements

Conclusion

Outlook

- Next wave of NAOS deployments (14 floats) will be performed on a dedicated cruise (Bio-Argo-Med) in May 2015.
- All second wave floats equipped with $[NO_3]$ sensor
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➡ Interannual variability in $[NO_3]$ seasonal cycle

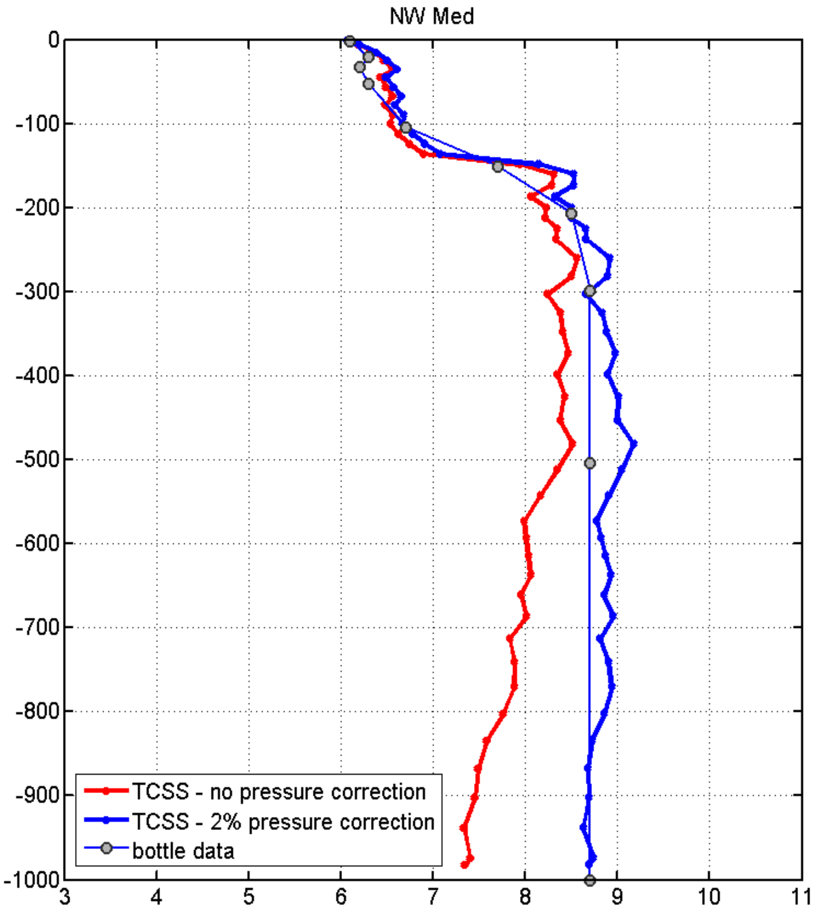
Thank you for your attention

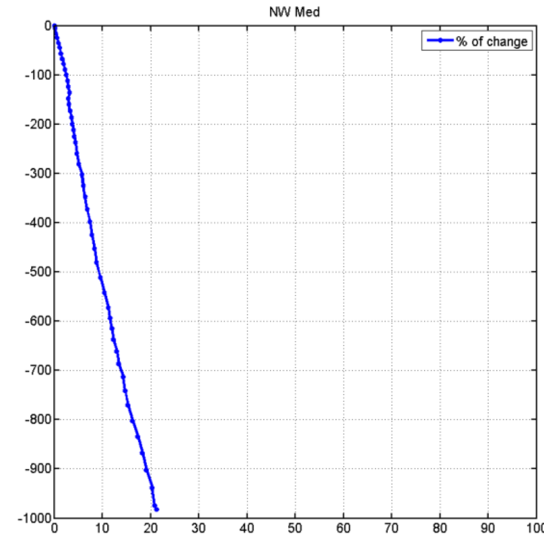
Introduction

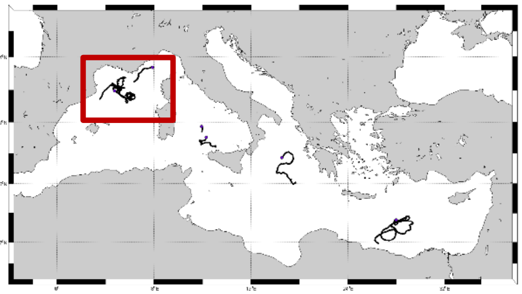
Climatological pattern

	NW Med		*TYR*		*ION*		*LEV*	
	$[NO_3]_{surf}$ >0.5µM	profiles available	[$[NO_3]_{surf}$ >0.5µM	profiles available	$[NO_3]_{surf}$ >0.5µM	profiles available	$[NO_3]_{surf}$ >0.5µM	profiles available
JAN	94%	18	15%	13	26%	34	0%	3
FEB	100%	13	33%	3	33%	3	14%	7
MAR	97%	33	0%	4	0%	1	66%	3
APR	0%	5	0%	5	0%	24	0%	17
MAY	0%	7	0%	19	0%	38	0%	1
JUN	0%	3	0%	11	-	0	0%	1
JUL	0%	3	0%	5	-	0	-	0
AUG	0%	8	-	0	-	0	0%	3
SEP	0%	36	0%	26	0%	14	0%	2
OCT	0%	10	5%	54	0%	9	0%	30
NOV	18%	11	-	0	0%	14	0%	9
DEC	29%	7	0%	7	0%	2	0%	1

Nitrate sensor calibration

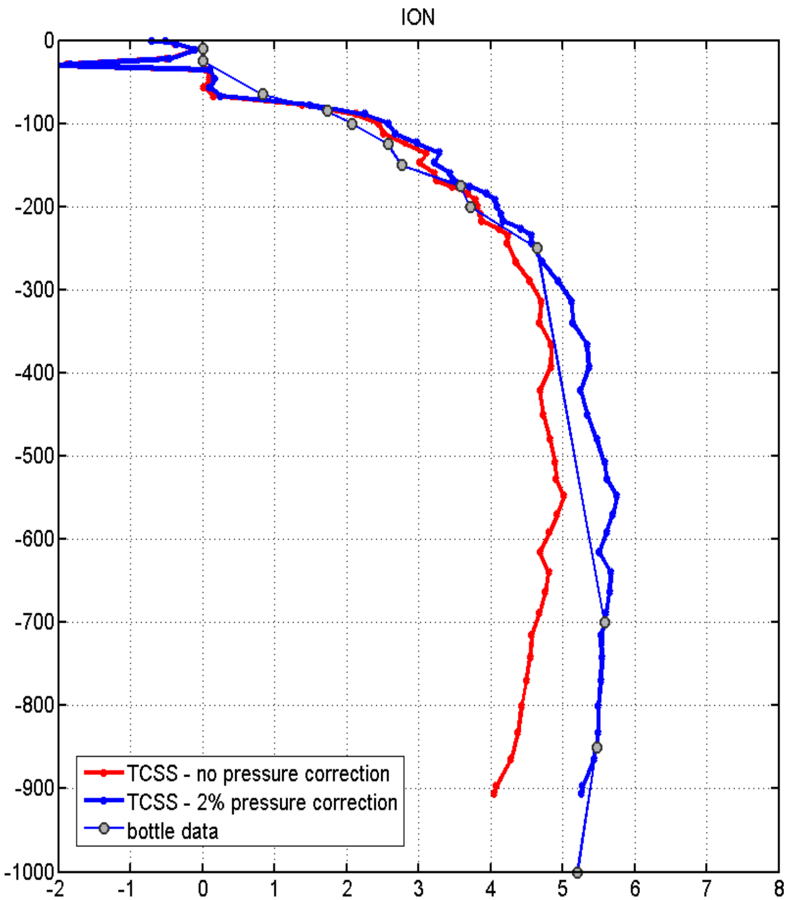


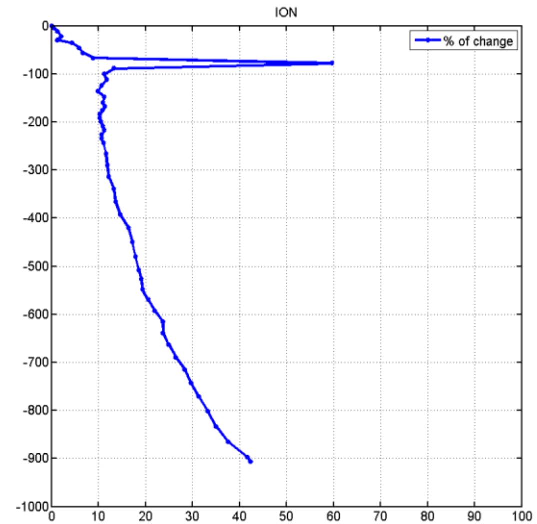


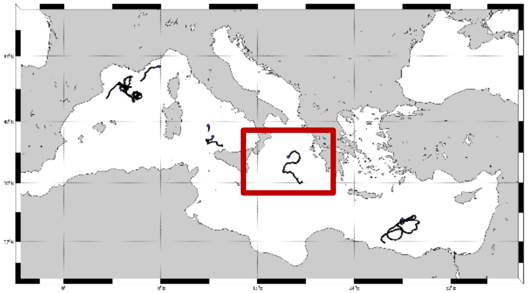


- Difference of 20% at depth (deep nitrate value ~ 8µM)

Nitrate sensor calibration

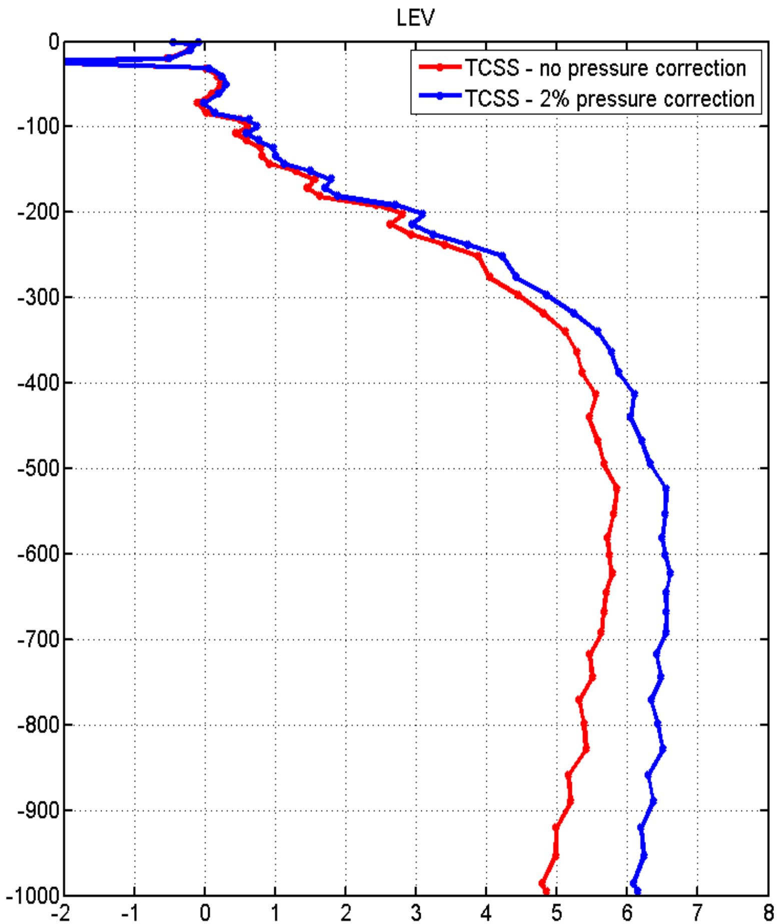


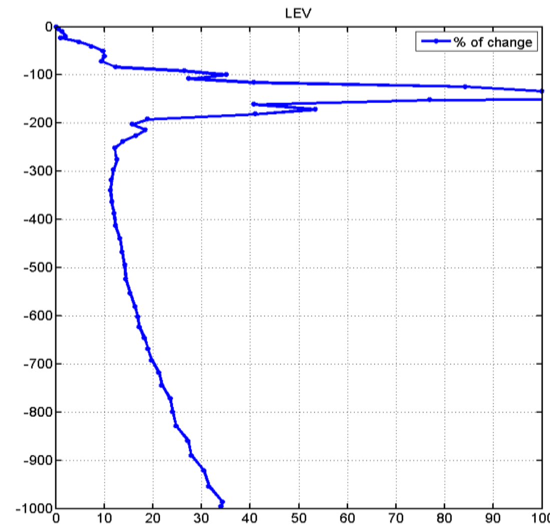


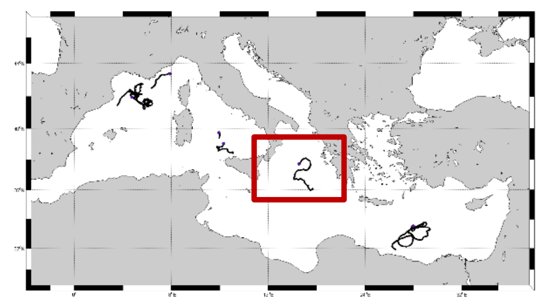


- ➢ Difference of 45% at depth (deep nitrate value ~ 5µM)

Nitrate sensor calibration



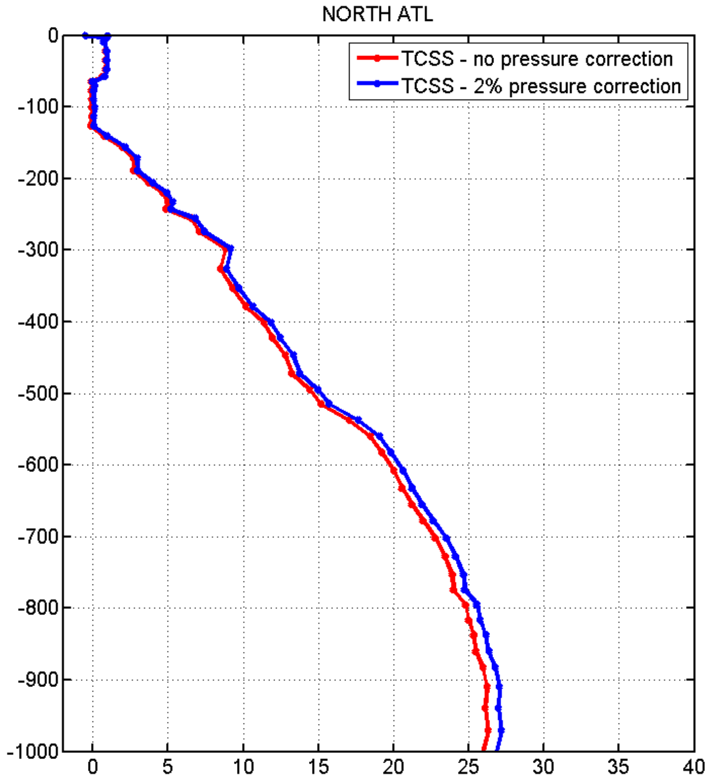


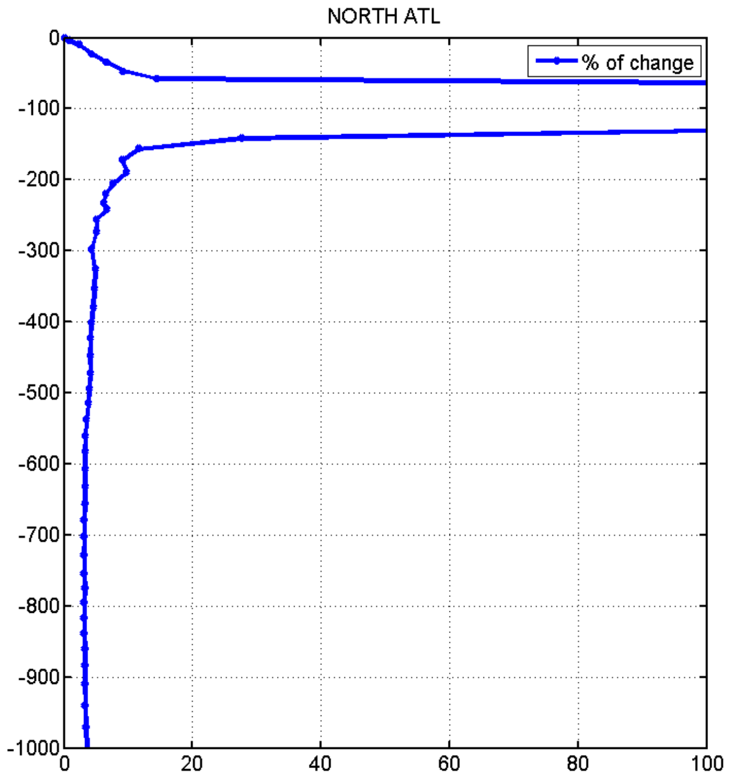


- ➢ Difference of 35% at depth (deep nitrate value ~ 6µM)

Nitrate sensor calibration

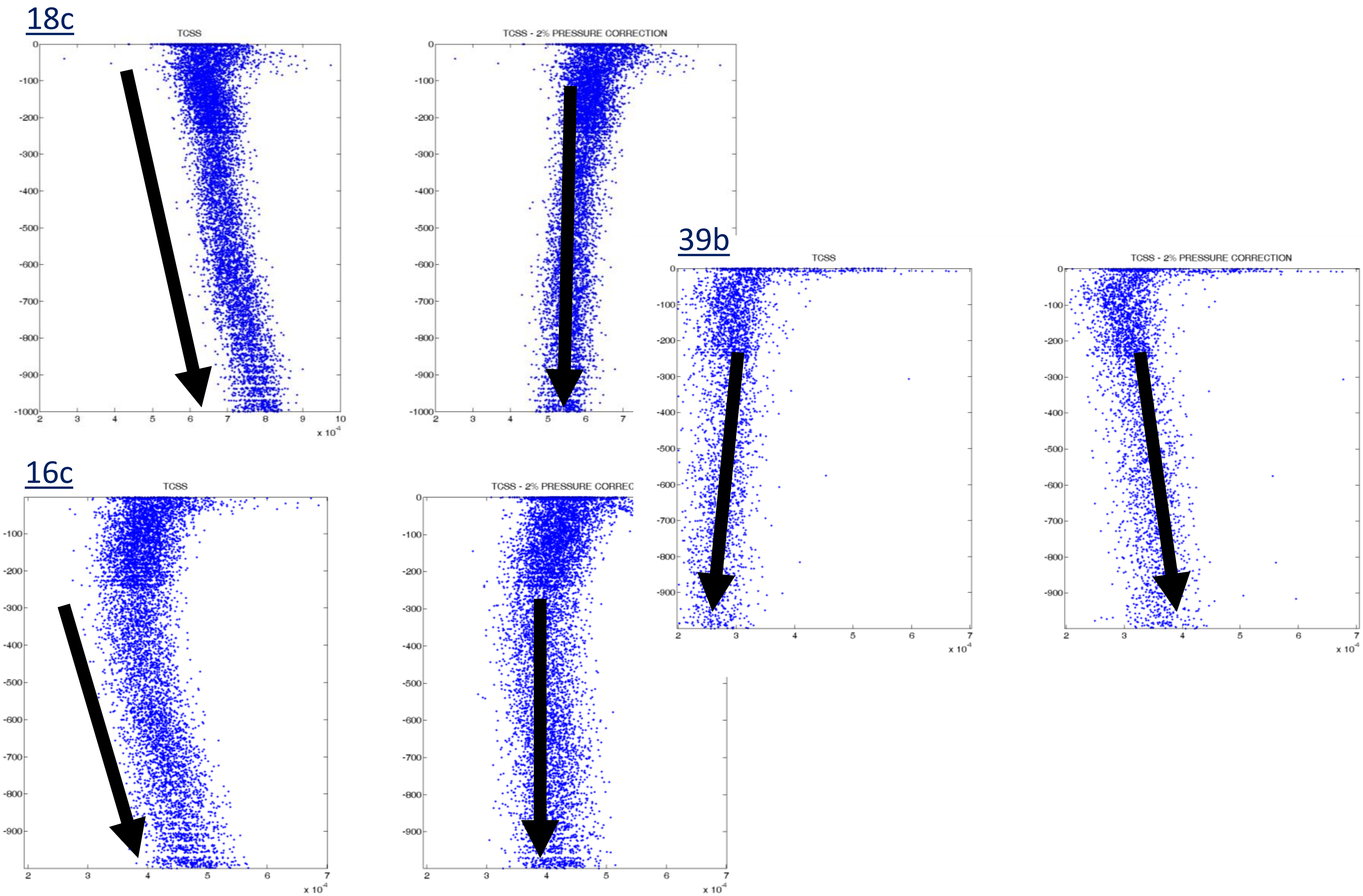
North Atlantic float





- Difference of 3% at depth (deep nitrate value ~ 25µM)

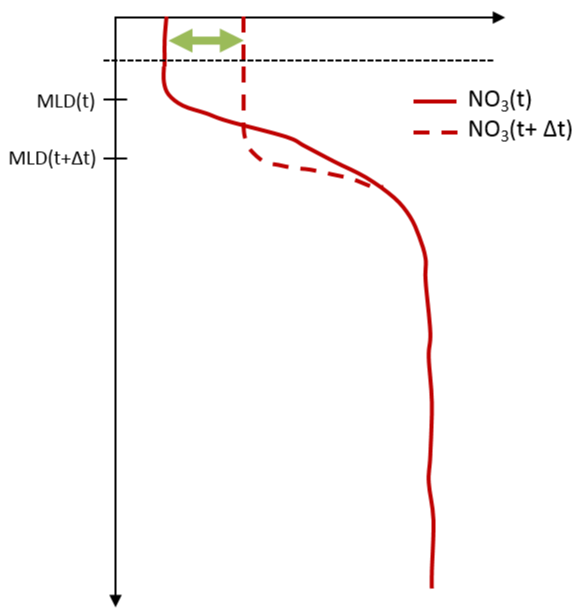
Nitrate sensor calibration



Results

Nitrate Input estimation

$$Nsup(t) = \left[\int_0^{MLD(t+\Delta t)} NO3(t,z)\,dz \,.\frac{Zeu(t+\Delta t)}{MLD(t+\Delta t)}\right] - \left[\int_0^{Zeu(t+\Delta t)} NO3(t,z)\,dz\right]$$



➡ Hypothesis

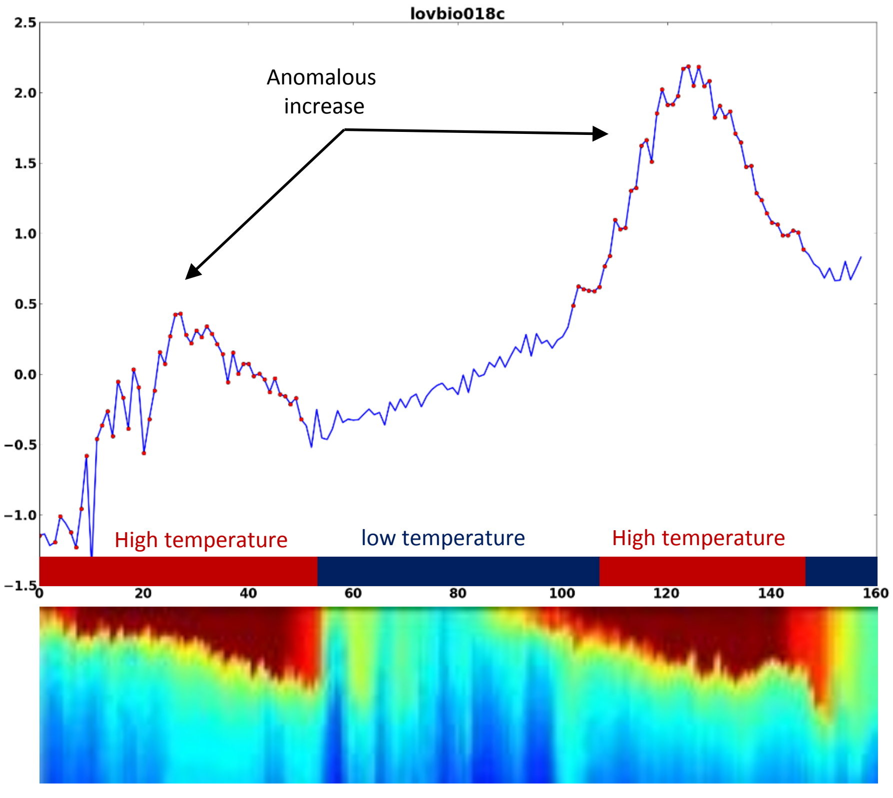
- MLD represents the depth reached by mixing
- Homogeneous nitrate concentration in the MLD

➡ Advantages :

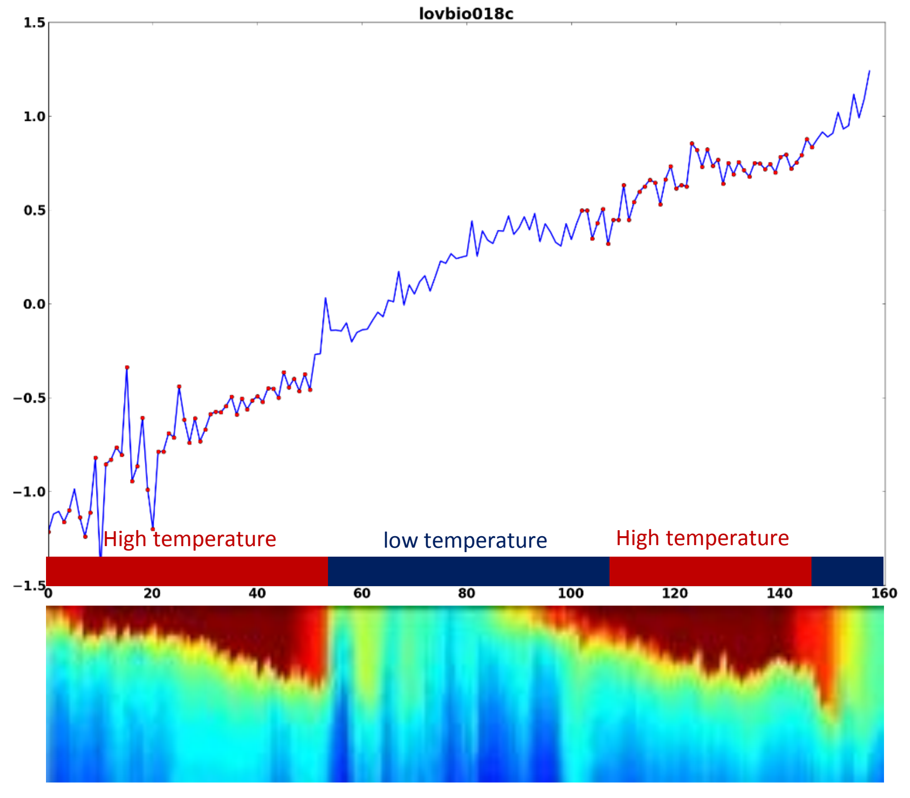
- Does not take directly into account the nitrate profile at time t+Δt
- No assumption on the consumption

Surface [NO3]
example of the float 018c (no drift and offset correction)

TCSS default parameter
wl = 210 nm



TCSS adjusted parameter
wl = 208.5 nm



Bias reaching 1.5µM in the eastern basin (i.e. 30% of the deep values)