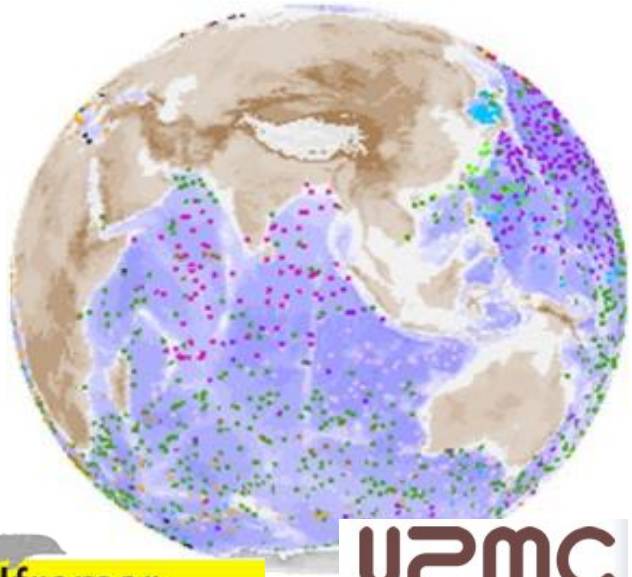
NAOS EQUIPEX Project

Global ocean observations for ocean and climate research and prediction: preparing the next decade of Argo

Mid-Term Evaluation Review - Paris, June 27, 2017

P.Y. Le Traon, F. D'Ortenzio
M. Babin, E. Leymarie, C. Marec, S. Le Reste, S. Pouliquen, V. Thierry



NAOS
Novel Argo Ocean observing System

www.naos-equipex.fr

Ifremer UPMC PARIS UNIVERSITAS cnrs ueb SHOM nke INSTRUMENTATION CLS

Outline

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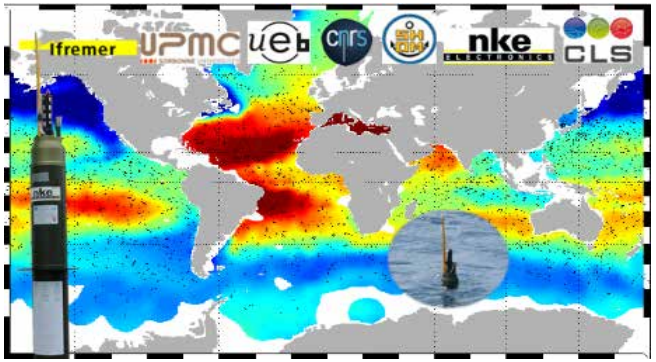
Context and project objectives

Developing the next generation of French Argo floats (WP2)

Use of equipment and scientific results (WP1, 3, 4 and 5)

Conclusions



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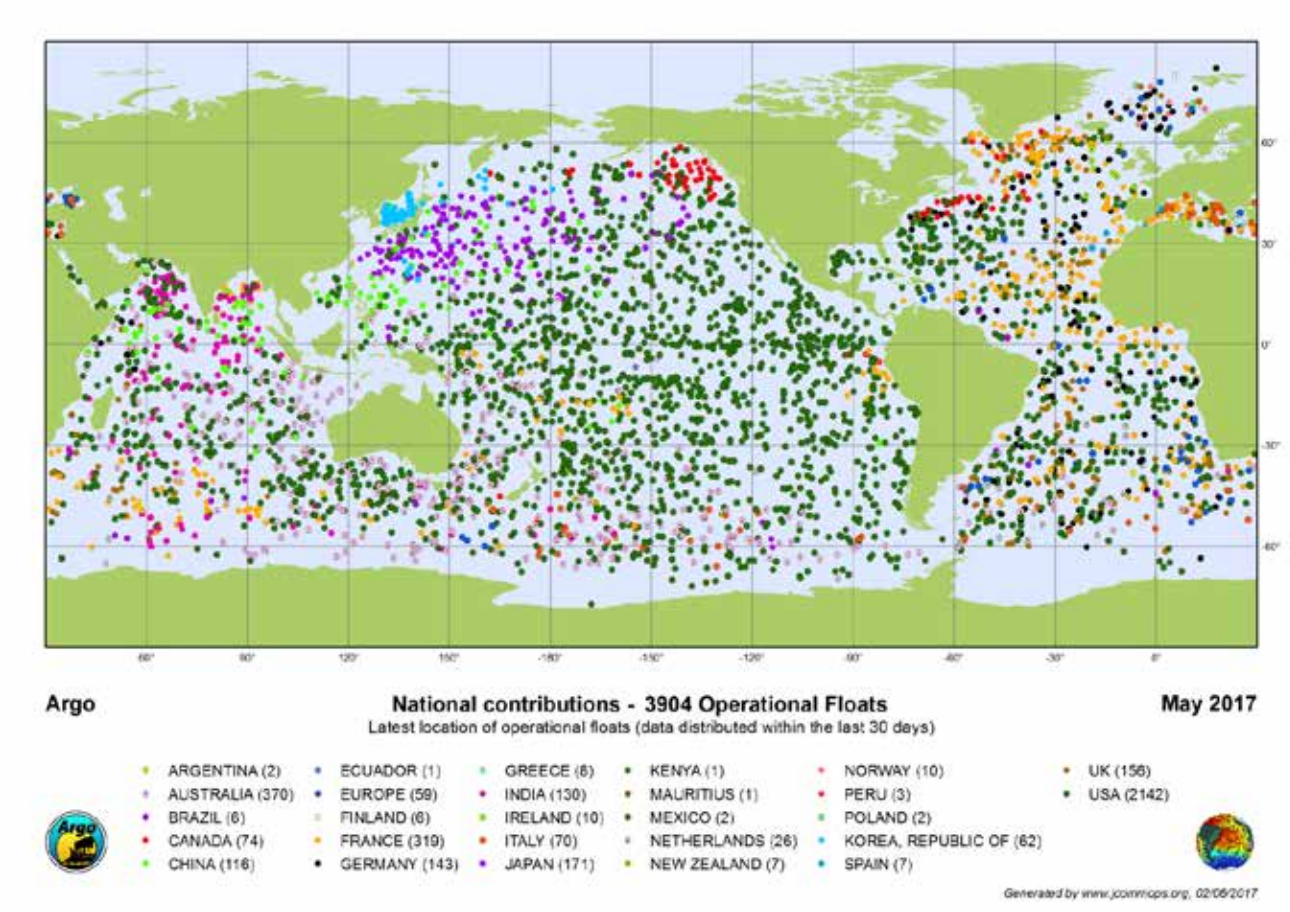
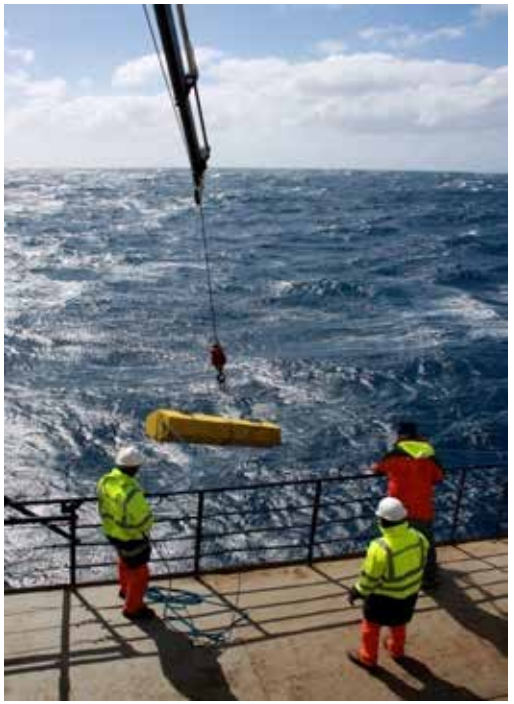
Context
and project objectives

Argo : a revolution in oceanography

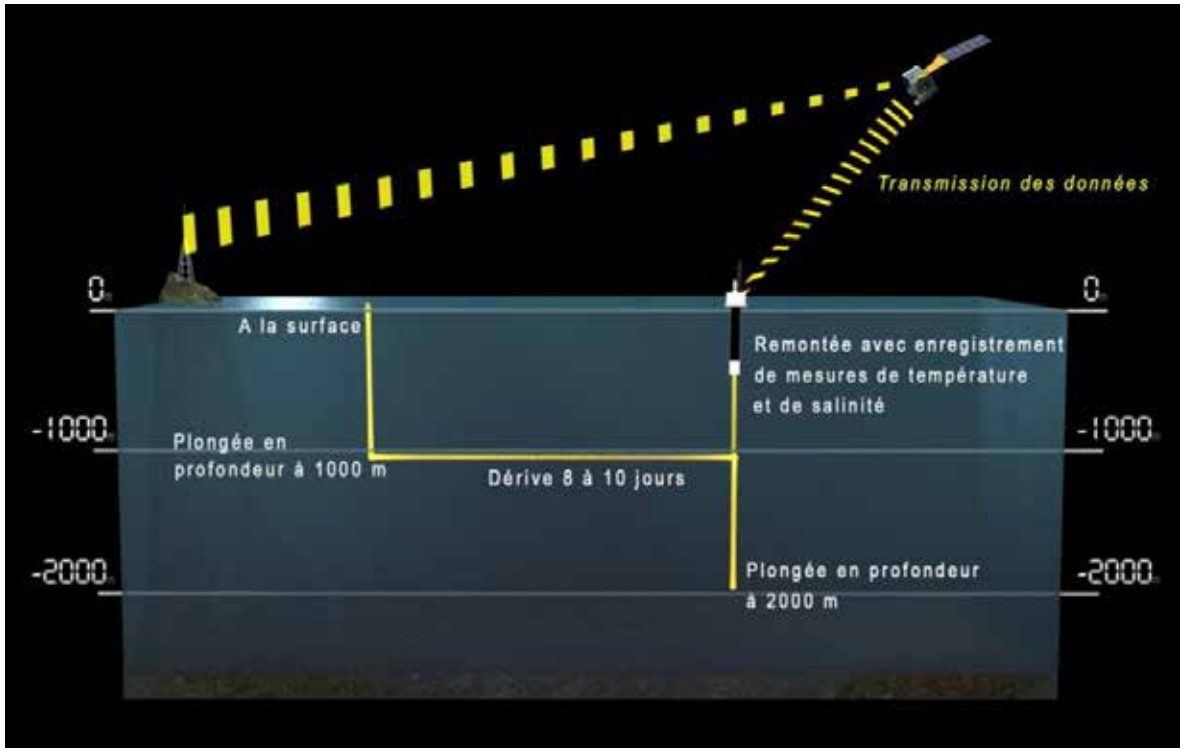
the first global real time in-situ ocean observing system

Almost 4000 profiling floats worldwide measuring the temperature and salinity to a depth of 2000 m. A major contribution to the global ocean and climate observing system.



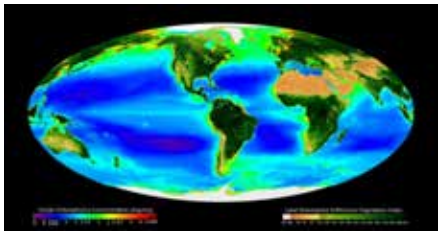


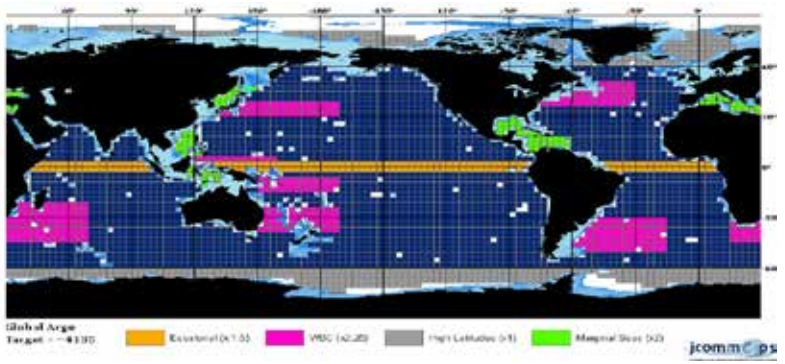
How does an Argo float work ?



Evolution of Argo for the next decade

- Proven concept. **Transition from research to sustained operational mode. 800 to 900 floats to be deployed per year .**
- Evolution of instrumentation (data transmission, hardware, lifetime)
- **The array needs to evolve over time. Extending the core mission. New scientific challenges.**
  - Under ice and high latitudes
  - Marginal seas
  - Sampling (e.g. WBC, tropics)
  - Deep ocean (Deep Argo)
  - New sensors and BioGeoChemical Argo (Oxygen, Chl-a, Nitrate, Carbon, pH)
- **Extension is on going** (pilot experiments – NAOS) and long term plans are prepared.

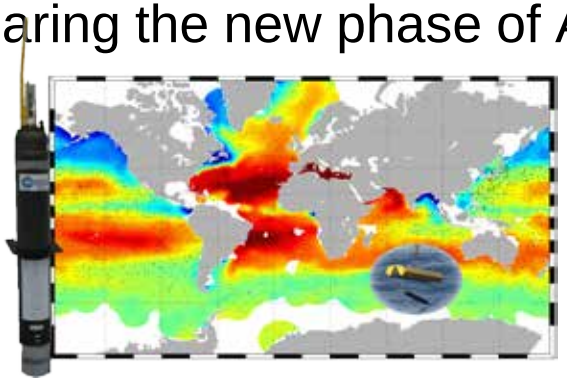




~4200 float array

Argo France : the French contribution to Euro-Argo research infrastructure and Argo international

- Argo France labelled as a TGIR by the French Ministry of Research
- Instrumentation (Provor and Arvor floats)
- At sea operation : 10% of the international efforts
- Data centers: one of the two global data centers
- Research: ocean, climate, biogeochemistry
- Operational oceanography: Mercator Ocean, Copernicus Marine Service
- European coordination: Euro-Argo ERIC hosted in France (Ifremer, Brest)
- Preparing the new phase of Argo : ERC Remocean, Equipex NAOS



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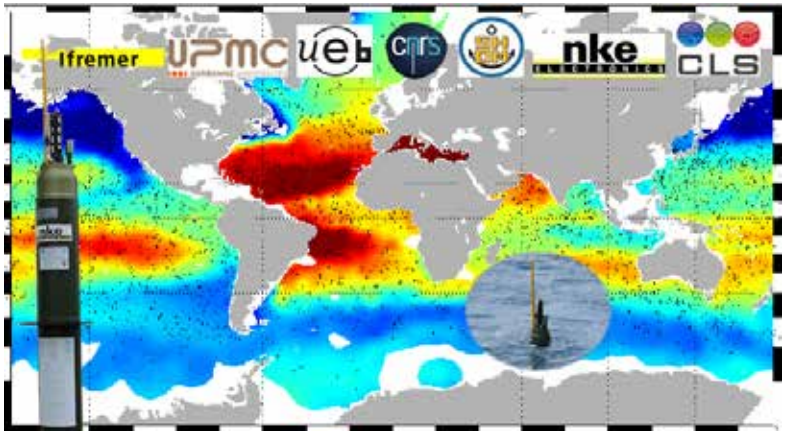
NAOS objectives : Consolidate and improve the French contribution to the international Argo program. A complement to Argo France and Euro-Argo.

The project has two main objectives:

1/ **to consolidate the French contribution to the Argo international array** deploying 10 to 15 additional floats per year from 2012 to 2019.

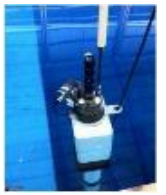
2/ **to develop and validate the next generation of Argo profiling floats**. New float capabilities include: improved performances, integration of biogeochemical sensors, deeper measurements and under-ice operations. **New floats deployed in three pilot areas: Mediterranean, Arctic and North Atlantic**.

Strong partnership *between IFREMER (coordinator), UPMC (co-coordinator), CNRS/INSU, UBO/IUEM (UEB), SHOM, CLS (satellite telecommunication) and NKE (industrialization/commercialization of French Argo floats).*



NAOS
Novel Argo Ocean observing System

Workpackages and Planning

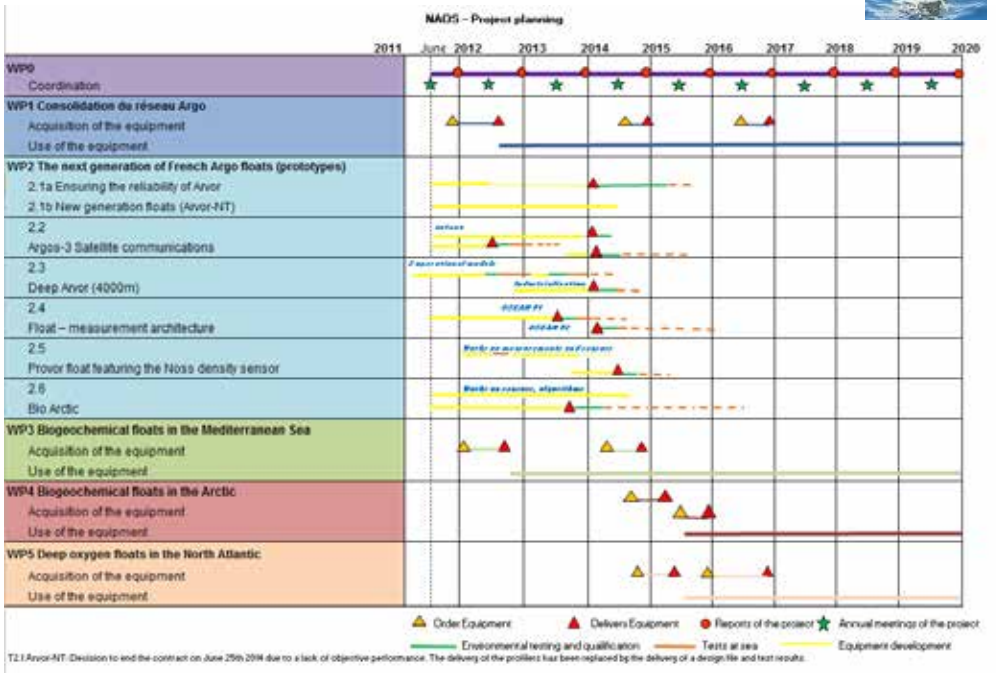


The project is structured into 5 main workpackages (WP):

- WP1: Consolidation of the French contribution to Argo (Lead: Ifremer).
- WP2: Development of the next generation of French Argo floats (Lead: Ifremer).
- WP3: Biogeochemical floats in the Mediterranean Sea (Lead: UPMC/LOV).
- WP4: Biogeochemical floats in the Arctic Sea (Lead: CNRS/UMI Takuvik).
- WP5: Deep oxygen floats in the North Atlantic (Lead: UBO/IUEM/LPO).

Project planning:

- June 2011 – December 2019, *Tranche 1* (development of equipment) (all WP2 activities and WP1, 3, 4 and 5 float orders) up to early 2017
- *Tranche 2* (use of equipment) from 2012 (start of WP1, WP3 in 2012, start of WP4 and WP5 in 2015/2016) to 2019.



NKE SME. NAOS main industrial partner

Float manufacturing and commercialization

Testing NAOS floats in Ifremer facilities (water tank, hyperbaric pressure tank)

NAOS is central to the development strategy of NKE. NKE objective wrt NAOS is to consolidate its market shares worldwide. Share of NKE floats increased from less than 10% (pre-NAOS) to more than 20% for the last 3 years.

NAOS WP2
Developing the next generation of French Argo floats

S. Le Reste, X. André, V. Dutreuil, C. Renaut, B. Moreau – IFREMER/RDT

E. Leymarie, C. Penkerc'h - Laboratoire Océanographique de Villefranche, UMR- UPMC-CNRS 7093

M. Le Menn - SHOM

J. Sagot, P. Brault, A. David, D. Malardé, C. Schaeffer, P. Hascoët – NKE Instrumentation

M. Guigue, S. Lauriol, J.P. Malardé - CLS

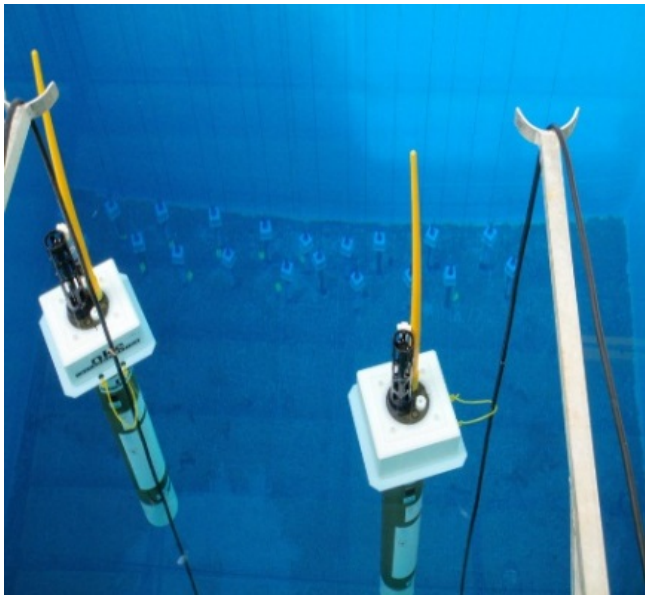
Six tasks identified to prepare the evolutions of instrumentation for the future needs of Argo

1. Improving standard Argo float reliability and reducing its cost (NKE).
2. Improving the Argos satellite transmission performance (Ifremer).
3. Reaching deeper depths (Ifremer).
4. Developing a modular electronics architecture (LOV).
5. Assessing a new density (salinity) optical sensor on an Argo float (NKE).
6. Developing a BioGeoChemical float for deployments in Arctic areas (LOV+Takuvik).

Instrumentation developed as part of NAOS WP2

T2.1 A new standard Argo float: Arvor NAOS

- Improving reliability of the float was obtained by improving sub-assemblies, manufacturing process, software robustness and userfriendliness.
- Reducing manufacturing costs was reached by simplifying hydraulic system.
- Validation at sea: 2 prototypes deployed in March 2015, still operating (88 of ten-day cycles performed over more than 2 years).



2 prototypes being tested at Ifremer pool

The NAOS Arvor : fully operational since 2016.

About 135 floats have been sucessfully deployed since 2016 (French & European fleet): after 6 months at sea, only 1 of them failed.

T2.2 Assessing the Argos-3 satellite transmission system to reduce the time spent at the surface, to transmit more data, and to control the float remotely

Development: specific transmitter and a bi-directionnal antenna on the Arvor float. Synchronisation of the float surfacing with the satellite pass.

Results at sea : The Argos 3 transmission was successfully tested: remote control of the float and transmission of data.

Deployment of Arvor float fitted with Argos3 system

Publication:


AMERICAN METEOROLOGICAL SOCIETY

AMS Journals Online

Argos-3 Satellite Communication System: Implementation on the Arvor Oceanographic Profiling Floats

Xavier ANDRE, Bertrand MOREAU, and Serge LE RESTE

Palma: WMO6901878, 205 cycles since July 2014

Chypre: WMO6901876 after 57 cycles Since July2015, grounded on turkish coasts

Golfe de Guinée: WMO6902682, after 65 cycles since août 2015

Madagascar/ Mozambique: 6902681/ 683, 109 cycles depuis août 2015

Significant progress: less than 5 mn needed to transmit one Argo profile, versus 8 hours with the current Argos-2 system. Transmission energy budget divided by 5.

T2.3 Reaching deeper (4000 m) depths

Deep Arvor development (from the lab to the manufacturer): prototypes designed to reach 4000m, developed at Ifremer and outsourced to NKE for serial manufacturing.

2011-2012: 2 prototypes developed/tested by Ifremer

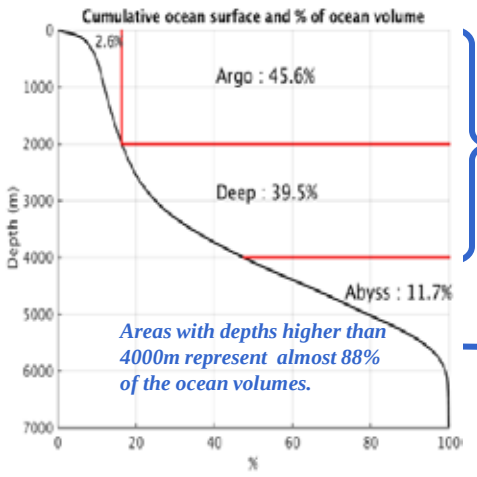
2013: Technical transfer to NKE and industrial process

2014: 2 industrial NKE prototypes tested at sea

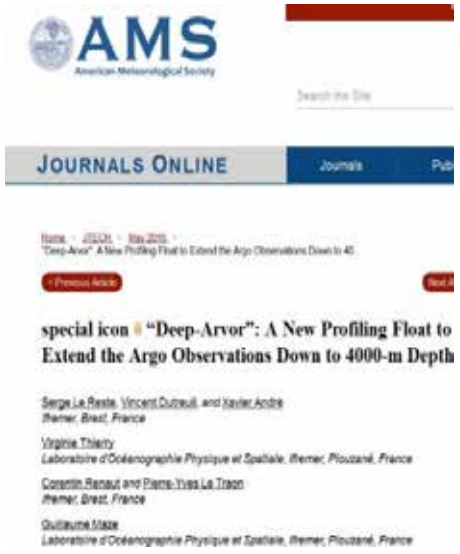
2015-2016: First serial of Deep-Arvor deployed (WP5)

Results at sea: behavior of floats very satisfactory: reaching the nominal depth, stabilizing at parking depth, etc…High quality scientific data collected.

The Deep Arvor is one of the best float in the range of a target depth of 4000m. Now manufactured and commercialized by NKE.



Publication


AMS
American Meteorological Society
JOURNALS ONLINE
special icon "Deep-Arvor": A New Profiling Float to Extend the Argo Observations Down to 4000-m Depth

Deployment of a Deep Arvor

T2.4 A modular electronics architecture to facilitate new sensors integration and to control the float behavior depending on measurements

Development: a float with dual electronics : one electronic board is dedicated to float motion, another one to data acquisition and retroaction in cas of events detection

Results at sea: the architecture was successfully tested in three applications: ocean color validation, acoustic recording and reversing float motion of the float when reaching the surface.

The Provor float fitted with dual electronics has demonstrated its capacity to embed several sensors and to react to reverse motion order in « Ice » detection application

Float control electronics

Protocole

retroaction

Measurements and events detection electronics

Sensor

Sensor

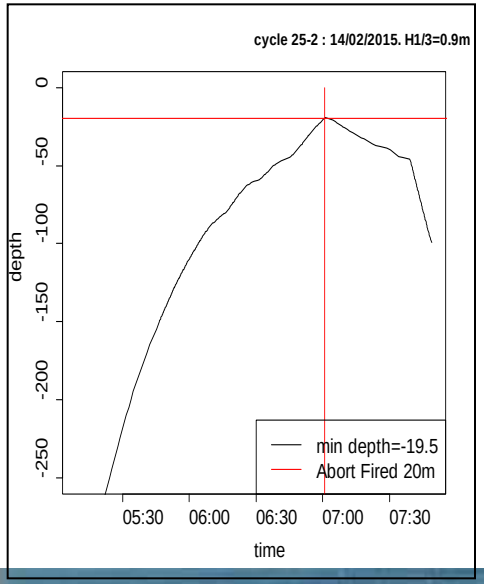
Sensor

Sensor

....

Provor CTS5: architecture

Graph of reversing motion of the float



T2.5 Assessing the NOSS (NKE Optical Salinity Sensor) on the Provor float

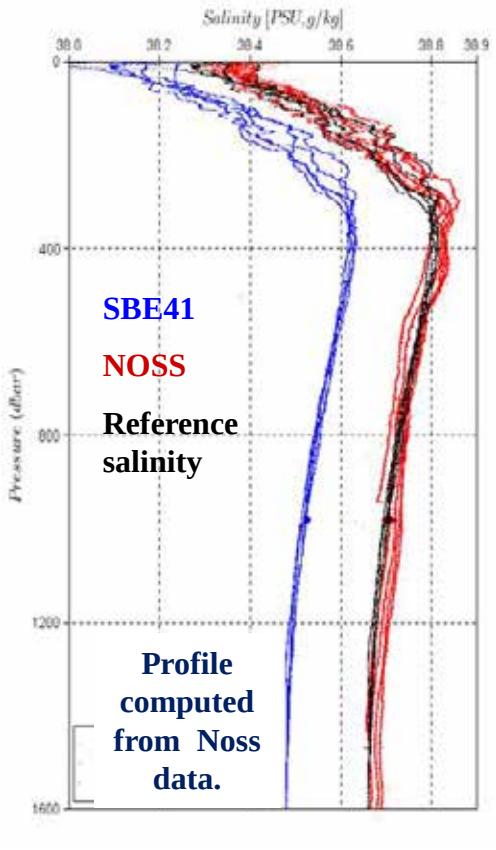
NOSS measures the deviation of a laser beam passing through a water sample. The refractive index allows computing absolute salinity.

Development: 2 sensors designed and housed in two Provor floats

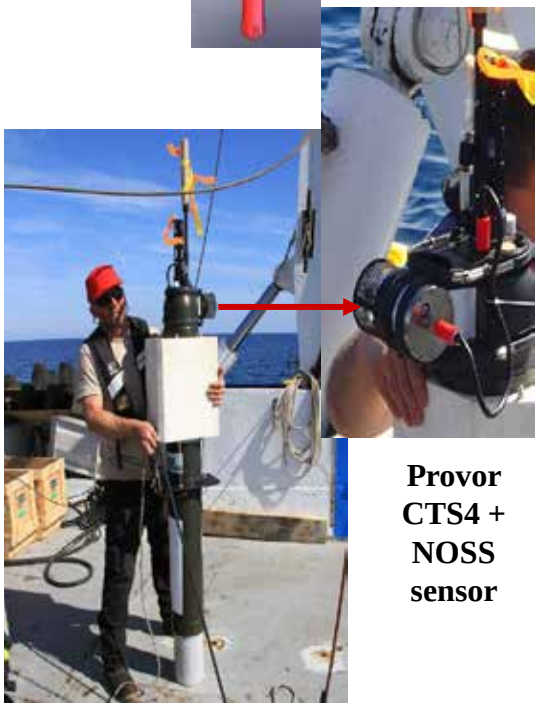
Results at sea: The 2 floats performed 10 profiles up to 2000m depth. Raw data retrieved of good quality (Sensitivity, S/N ratio).

Publication: Le Menn et al, I2M (Lavoisier)

The NOSS sensor has shown good raw data results during its first deployement at sea. Work remains to be done on the salinity estimation.



NOSS design (NKE)



Provor CTS4 + NOSS sensor

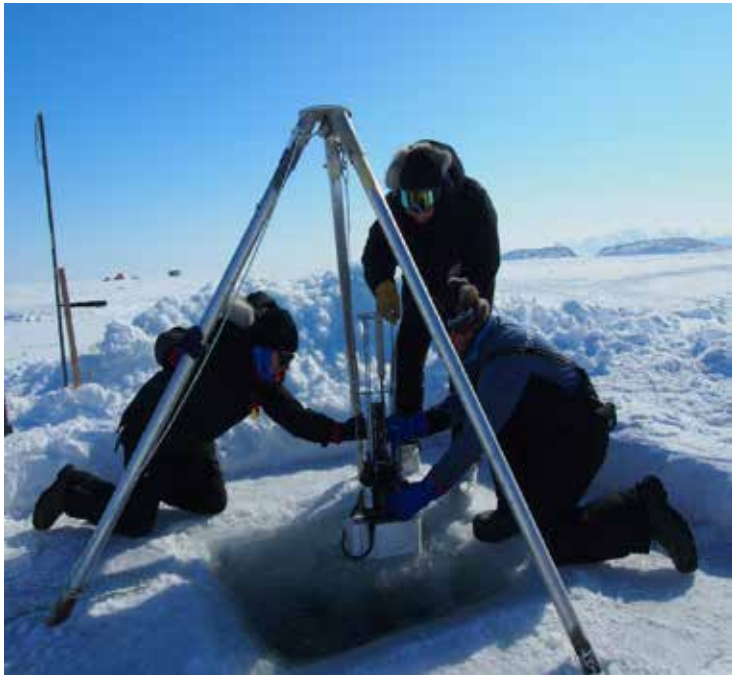
T2.6 Developing a BioGeochemical float for Arctic deployments

The “ProIce” float embeds the dual electronic system (T2.4): in case of ice detection, the float reverses its ascent to start another cycle and postpones the data transmission of profiles.

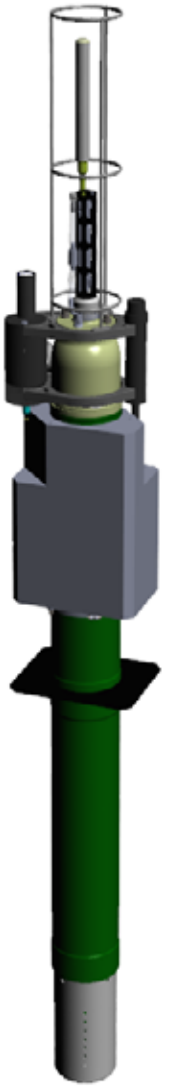
Development: the ProIce was fitted with Ice and Iceberg detections and sensors were validated in cold environment.

Results at sea: the prototypes were successfully deployed in the Labrador Area and the Baffin Bay, giving several hundreds of Biogeochemical data profiles.

The Pro-Ice float is available for production at NKE manufacturer. Serial production for WP4.



Pro-Ice float tested in cold and icy conditions in « captive » mode.



Pro-Ice float

Use of equipment and scientific results (WP1, 3, 4 and 5)

NAOS WP1
Contribution to the global Argo mission

S. Pouliquen (IFREMER)
N. Poffa, T. Carval, V. Bernard (IFREMER), N. Le Breton (SHOM), C. Schmechtig (UPMC/CNRS-LOV), J.P. Rannou (Altran)

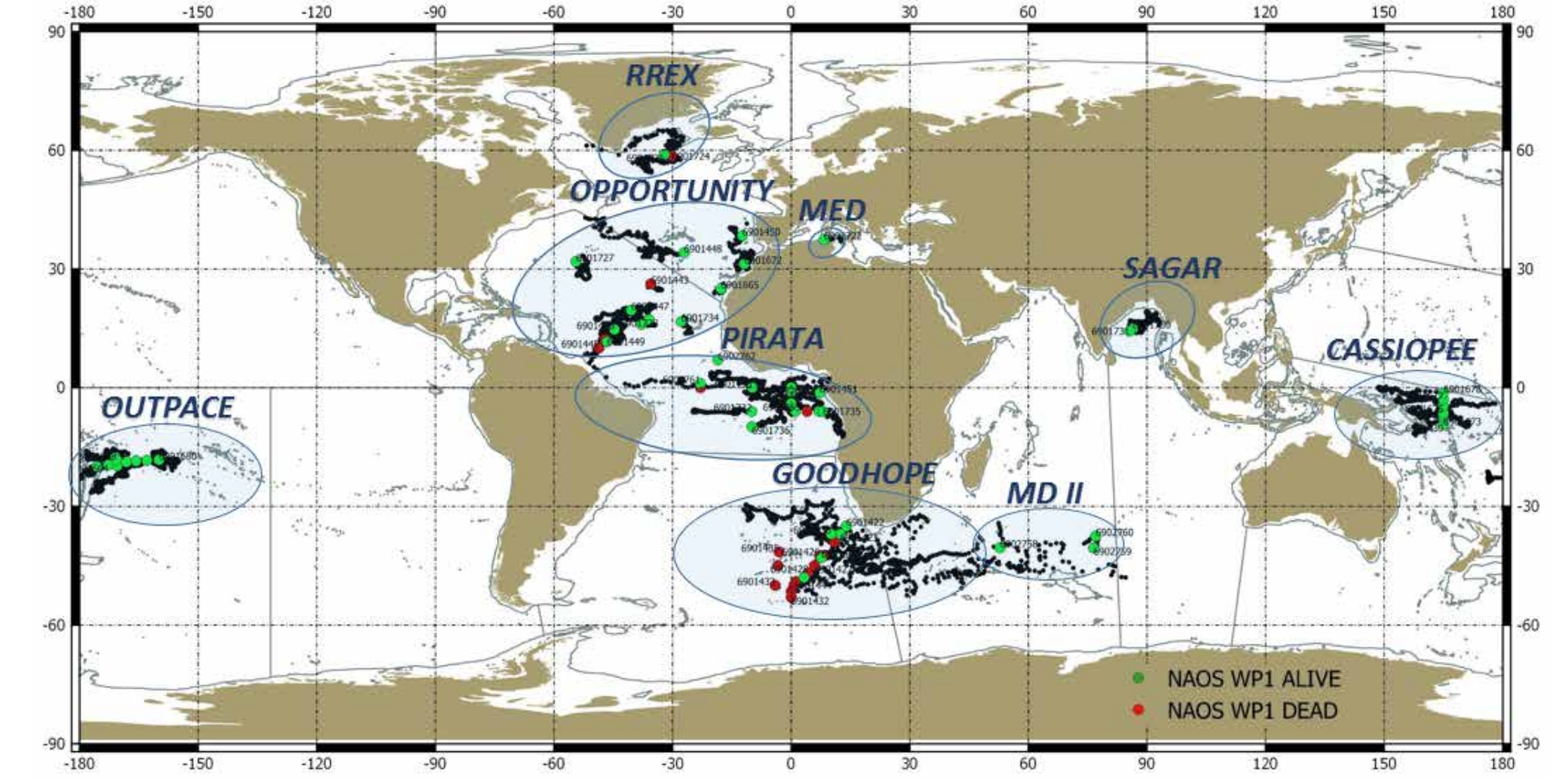
Argo France, Euro Argo, MOCCA, Argo ADMT, JCOMMOPS

WP1 Contribution o the global Argo Mission

- **Challenges: sustain the Argo network for next decades for ocean and climate change research and operational oceanography :**
  - deploy 800 floats per year to maintain the network in its present configuration (3° x3°, 0 to 2000 m, Temperature & Salinity)
  - Develop and maintain the Argo Data System up to date in order to serve both the operational users and the research community
- **WP1 objective is to reinforce the French contribution to Argo deploying** 10 to 15 floats per year to reach a target of 80 floats per year i.e. 10% of the international effort.
  - Deploying improved floats developed within WP2
  - Developing the operational capacity to operate and process the new NAOS floats (WP3-WP4 -WP5)

NAOS WP1 floats

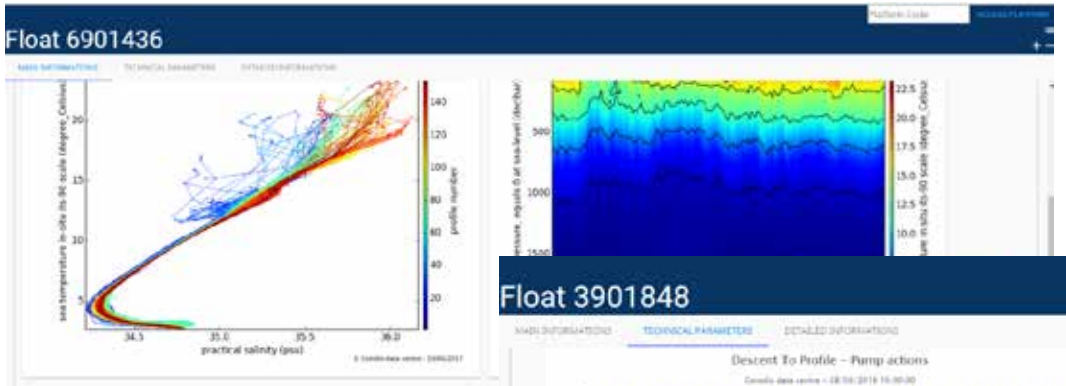
76 floats performed 5360 vertical profiles since November 2012

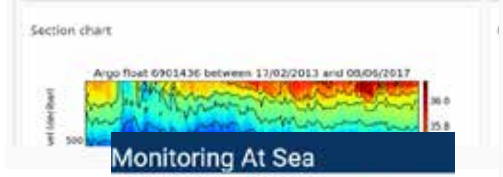


Data Centre Improvements

- Processing chain have been updated to distribute the data in the new recommended format (V3.1) that allows recording:
  - Change in mission configuration via iridium link
  - BGC parameters
  - Enhanced trajectory information for deep current estimation
  - The matlab processing chain for NKE floats has been shared with the Argo community (http://dx.doi.org/10.17882/45589).
- Real Time QC procedures for BGC parameters validated at Argo International have been turned to operation
- Based on the expertise developed by Ifremer within NAOS, Ifremer also collaborates with the European Research Infrastructure Euro-Argo ERIC to set up a suite of tools that will allow an at sea monitoring of the European Argo fleet and of the national Argo fleets.

At sea monitoring
A first prototype for Arvor fleet





NAOS WP3
Pilot array of Biogeochemical floats in the Mediterranean Sea

F. D'Ortenzio (UMPC/CNRS, LOV)
A. Poteau, E. Leymarie, V. Taillandier, C. Penkerc'h, C. Schmechtig, H. Claustre, L. Prieur, C. Migon, A. Dufour, L. Coppola, L. Féré, C. Poutier, N. Mayot, H. Lavigne, O. De Fommervault, C. Fontana, R. Sauzède, H. Bittig, N. Briggs

UPMC, INSU, CNES, Argo France

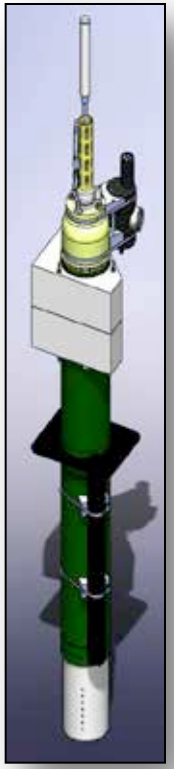
Argo Italy, Euro Argo, Argo International Science Team, Argo ADMT
Chantier Méditerranée (INSU)

Operational Objective

Defining, implementing and maintaining a network of BGC-Argo floats at basin scale

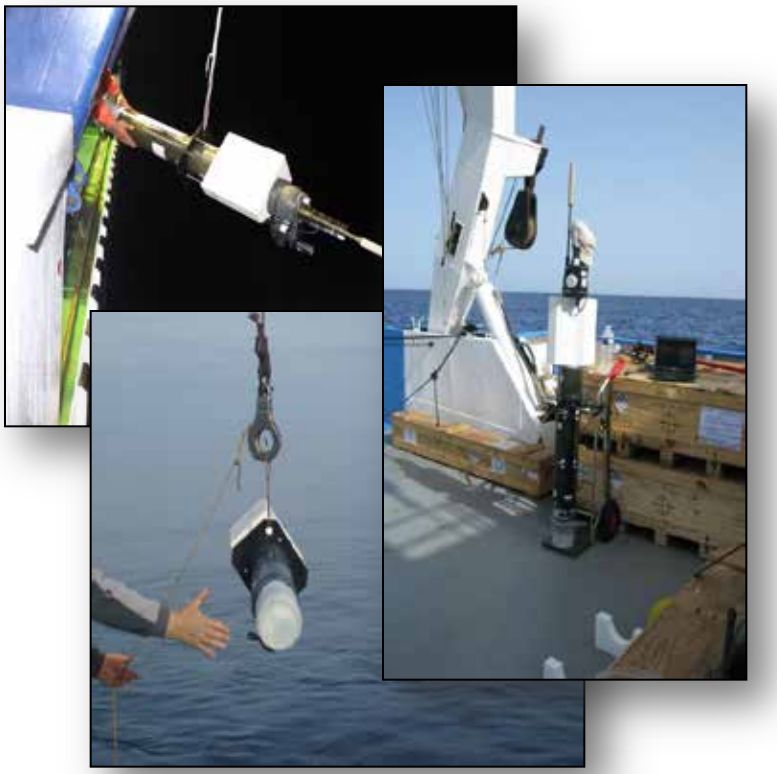
Scientific Objective

Contributing at the characterisation of the biogeochemical and ecosystem dynamics of the Mediterranean



The PROVBIO-V2

- The French version of BGC-Argo
- Fully matching international requirements
- Developed in the framework of ERC Grant ”remOcean” (coll. LOV-IFREMER-NKE) anterior to NAOS
- A robust, solid and efficient platform, with capability to be recovered
- Before NAOS, ready to be used in network (main objective of NAOS WP3)



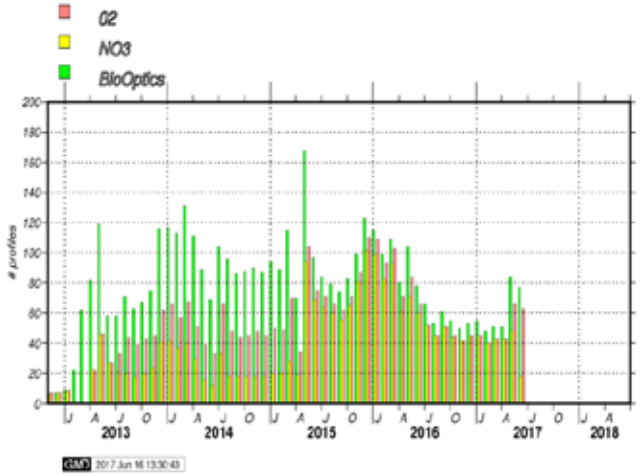
Deployment of NAOS WP3 floats

Operational Objective: Defining, implementing and maintaining a network of BGC-Argo floats at basin scale

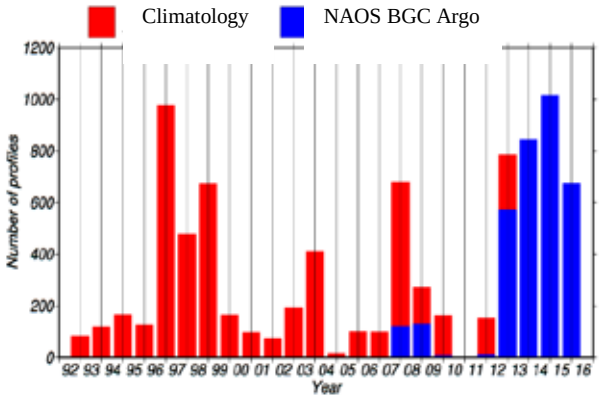
Main results :

- **25 BGC Argo** deployed in two **successive waves** (2010 and 2015)
- **9** Floats out of order BUT **12** recovered -> **A third wave NOT initially planned will be carried out in 2018**

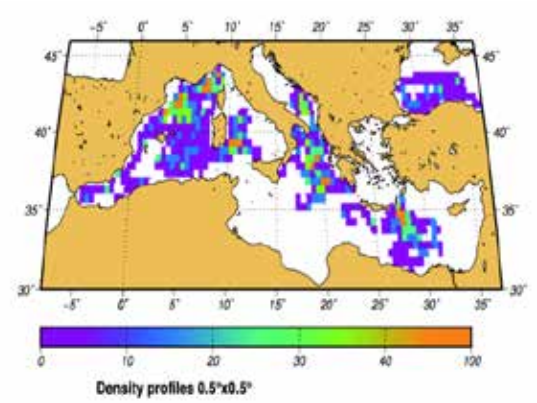
- More than **4000 profiles** in 7 years



NAOS Med # Profiles by month



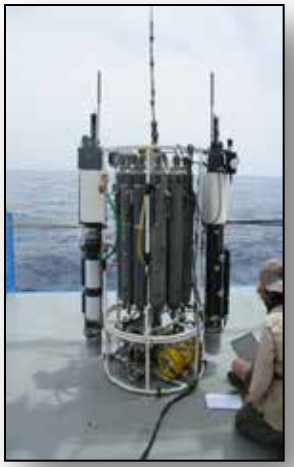
Chl profiles in historical data bases versus NAOS data



Scientific Objective: Contributing at the characterisation of the biogeochemical and ecosystem dynamics of the Mediterranean

- **18 Rang A papers**
  - Lavigne et al. 2013, JGR
  - DeFommervault et al, 2014,DSRI
  - D'Ortenzio et al. 2014,GRL
  - Lavigne et al. 2014,Biogeosciences
  - Sauzade et al, 2015,EESSD
  - DeFommervault et al, 2015,DSRI
  - **DeFommervault et al, 2016,JGR**
  - Organelli et al., 2016,JAOT
  - Mayot et al. 2016,Biogeosciences
  - Bosse et al. 2015, JGR
  - Estournel et al. 2015, JGR
  - Sauzade et al. 2016,JGR
  - Houpert et al. 2016,JGR
  - Roesler et al. 2017, L&O
  - Mayot et al. 2017a, JGR
  - Mayot et al. 2017b, JGR
  - Organelli et al. 2017, JGR
  - Xing et al. 2017
- **2 submitted papers**

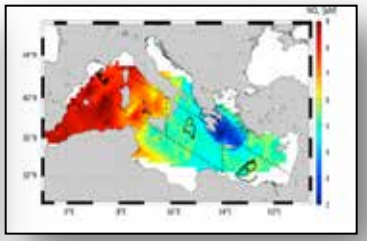
- **Positioning in the Mediterranean community**
  - **France: "Chantier Mediterranée" INSU CNRS**
  - **Italy: Argo-Italy**
  - **Spain/Greece/Turkey: collaborating projects**
- **Enhancing QC Methods**
  - **Mediterranean : dedicated Cruise (BioArgoMed)**
  - **Global: participating to BGC-Argo Working group**



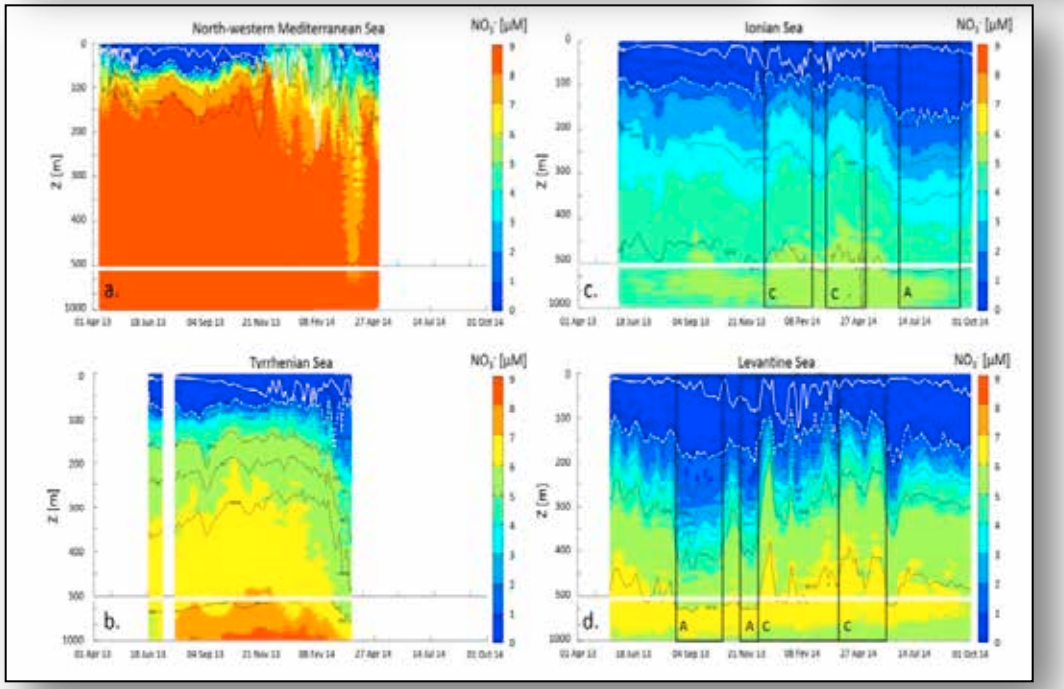
DeFommervault et al, 2016, JGR-Oceans

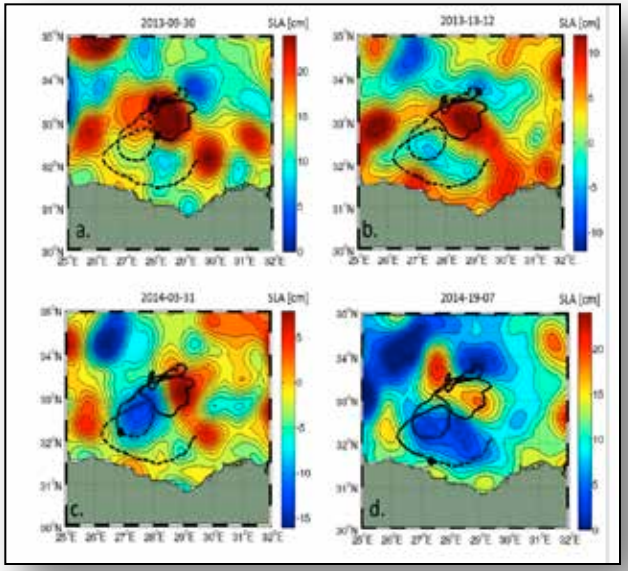
Seasonal variability of nutrient concentrations in the Mediterranean Sea: Contribution of Bio-Argo floats

Orens Pasqueron de Fommervault[1,2,3], Fabrizio D'Ortenzio[1,2], Antoine Mangin[3], Romain Serra[3], Christophe Migon[1,2], Hervé Claustre[1,2], Héloïse Lavigne[4], Maurizio Ribera d'Alcalà[5], Louis Prieur[1,2], Vincent Taillandier[1,2], Catherine Schmechtig[1,2], Antoine Poteau[1,2], Edouard Leymarie[1,2], Aurélie Dufour[1,2], Florent Besson[1,2], and Grigor Obolensky[1,2]



- Colocalized nitrate profiles and altimetry maps
- Assessment of the impact of mesoscale dynamics on biogeochemical fields





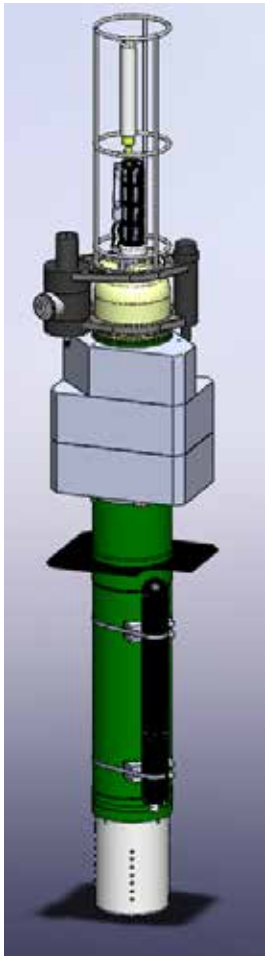
NAOS WP4
Biogeochemical floats in the Arctic

M. Babin (UMI CNRS Takuvik)

C. Marec (LOPS/ Takuvik), E. Leymarie, C. Penkerc'h (UPMC/CNRS-LOV), J. Lagunas, X. Xing, E. Rehm (UMI CNRS Takuvik)

WP4: BIOGEOCHEMICAL ARGO FLOATS FOR ARCTIC SEA
PRO-ICE Floats part 1: 2011-2016

TAKUVIK



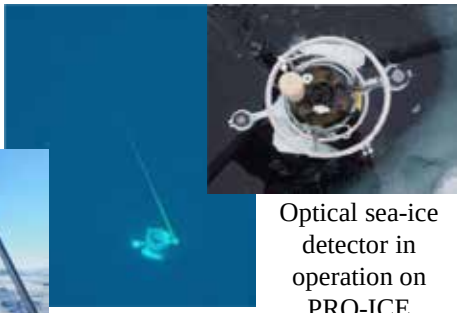
- **KEYWORD**: Ice bloom studies in Baffin Bay - **PRO-ICE float**: a complementary tool to remote-sensing observations and to oceanographic cruises.
- The **WP4** (conducted by Takuvik) is dedicated to the deployment of biogeochemical floats in the Arctic Ocean to study the dynamics of ice-edge spring phytoplankton blooms and to specify sources of nutrients.
- Strong links with the **GREENEDGE** scientific project (major international joint project : 20 labs involved, PI M.Babin)
- 20 Argo floats equipped with a biogeochemical payload (dissolved oxygen sensor, spectroradiometer (ED380, 412, 490nm+PAR), Fluorometers (Chla and CDOM), particle backscattering sensor, nitrate sensor (Suna).
- 11 funded by Equipex NAOS + 9 funded par CFI (Canadian Foundation for Innovation)

WP4: BIOGEOCHEMICAL ARGO FLOATS FOR ARCTIC SEA
PRO-ICE Floats part 1: 2011-2016

TAKUVIK

Work of Takuvik (2011-2016)

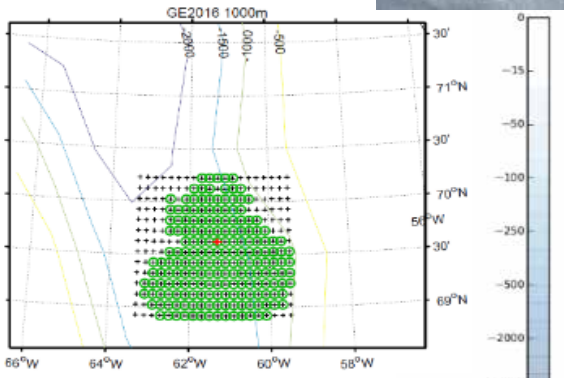
- Initial WP4 activities linked to WP2.6 (sea-ice detection techniques):
  - ü For ISA (ICE Sensing Algorithm) collection of CTD data / ice concentration to adapt ISA threshold to the Baffin Bay.
  - ü Development of the optical sensor for ice-detection (lidar) (depolarizing signature of sea-ice) à thin ice detection.
  - ü Trials in cold conditions (PRO-ICE & payload) in a frozen lake & trials in Arctic conditions in Qikiqtarjuaq (Nunavut)

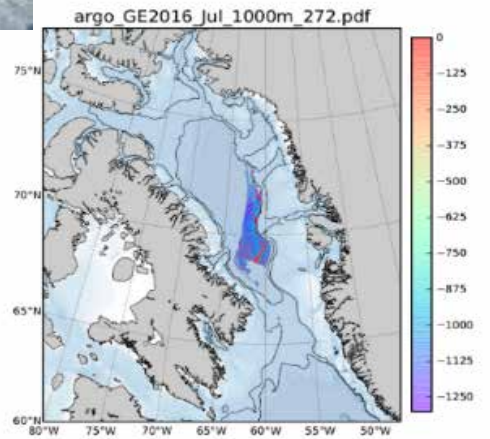


Optical sea-ice detector in operation on PRO-ICE

- Preparing the deployment strategy for Baffin Bay:
  Constraining « game zone »: Bathymetry,
  Circulation (cyclonic circulation),
  Ice cover (ice climatology & daily ice maps)

Determine best dropping zones so that floats are not ejected from Baffin Bay by currents via Davis Straits





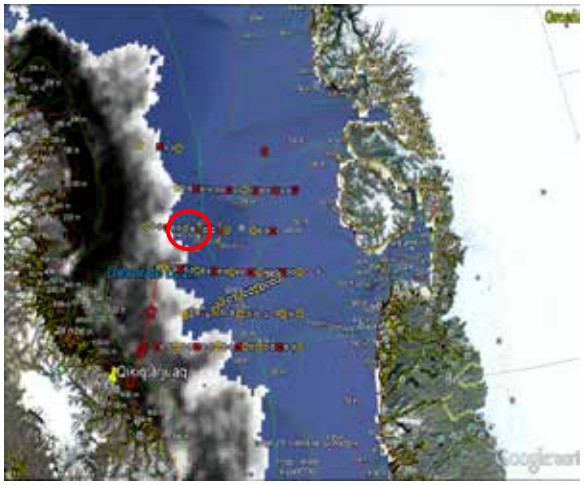
Drift simulation from a theoretical zone of deployment (E.Rehm, Takuvik)

WP4: BIOGEOCHEMICAL ARGO FLOATS for Arctic Sea: PRO-ICE Floats 2011-2016

Work of Takuvik (2016)

Deployment of 5 PRO-ICE (1 in Labrador Sea/WP2) and 4 in Baffin Bay during the 42 days cruise (Green Edge onboard icebreaker Amundsen). Deployment at the ice edge on July, 9th 2016

Trajectories of the 4 floats between deployment July, 9th and last surfacing (October 30th) before ice covers the sea.



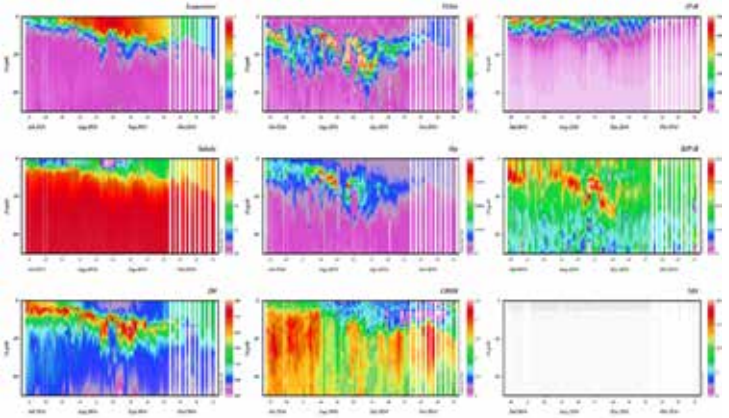
takapm009B (WMO 6902667)
lat: 69°30.062'N / Long 60°08.815'W
Bathymetrie 1547m . Complete payload

takapm013B (WMO 4901802)
lat: 69°30.029'N / Long 61°00.658'W
bathymetry 1785m . Complete payload

takapm05B (WMO 4901803)
lat: 69°19.341'N / Long 60°58.997'W
bathymetry 1800m . payload except Suna

takapm014B (WMO 6902668)
lat: 69°20.209'N / Long 60°13.251'W
bathymetry 1627m. Payload except Suna remplaced by
Optical sea-ice detector developed by José Lagunas (Takuvik)

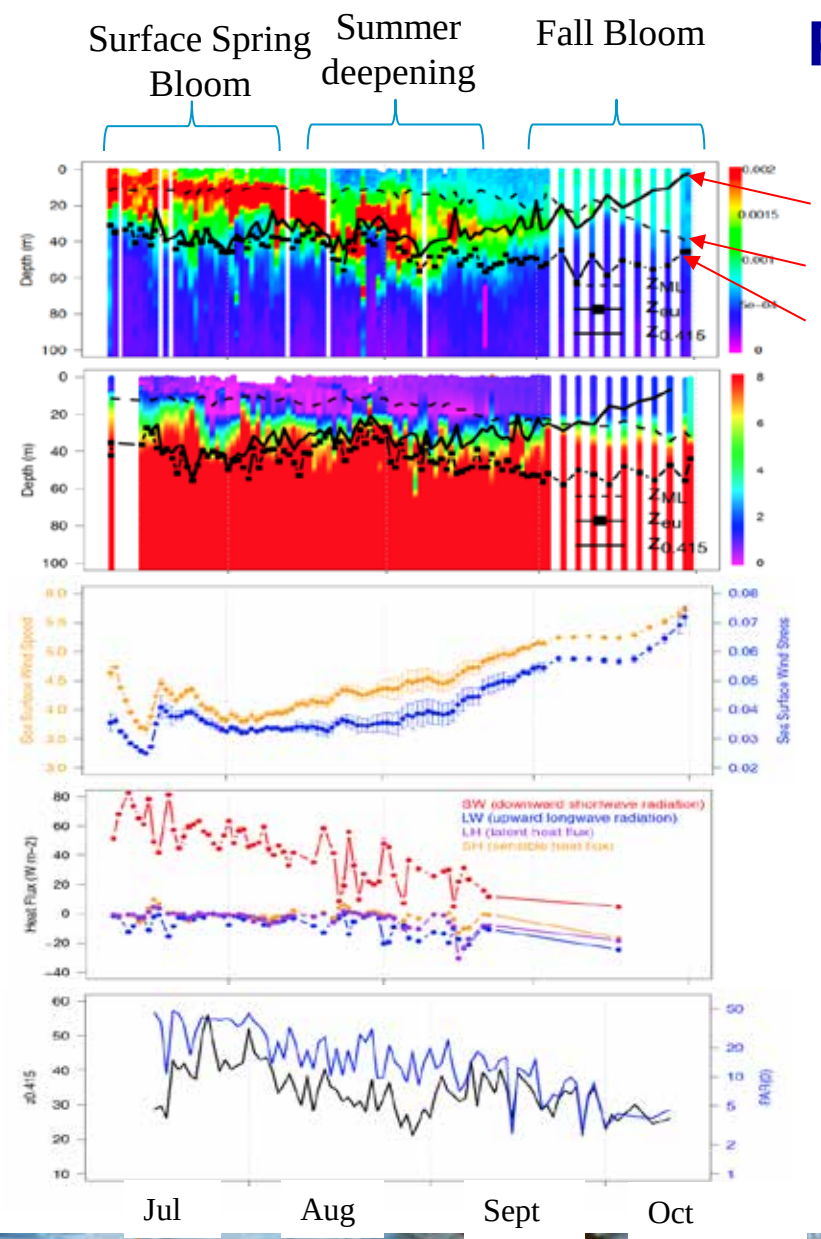
Greenedge cruise stations and PRO-ICE dropping zone with ice cover on July, 9th 2016



Data processing and quality control by Dr X.Xing (invited professor in Takuvik)

Preparing plans & floats for Summer 2017 deployments (7)

Phytoplankton seasonal cycle in Baffin Bay



TAKUVIK

1. Surface deplenishment of nitrate leads to a deepening of biomass in July, above $Z_{0,415}$
2. A mixing event leads to an increase in surface nitrate and a Fall bloom at surface
3. The Fall bloom is possible until $Z_{0,415}$ reaches the surface because incident irradiance decreases before winter
4. Vertical mixing is driven by wind and/or thermal convection

NAOS WP5
Deep oxygen floats in the North-Atlantic

V. Thierry

G. Maze, H. Mercier, C. Cabanes, V. Racapé, C. Lagadec

LOPS - UMR 6523 CNRS / IFREMER / IRD / UBO–IUEM

WP5: Scientific and technological objectives

- **Deployment of 23 Deep-Arvor floats with oxygen sensor in the North-Atlantic Ocean**
- **Implement a pilot experiment for O2 and deep data**
  - Deploy Argo-O2 floats and Deep-Arvor floats in the North-Atlantic Ocean
  - Implement the corresponding data stream at international level
  - Prepare the future international Deep-Argo and Argo-O2 array

- **Technological objective:** Demonstrate the capacity of the Deep-Arvor float at acquiring deep (below 2000m depth) and oxygen data of high-quality
- **Scientific objective** : Investigate deep convection and water mass ventilation in order to investigate the input and propagation of climatic anomalies within the ocean interior

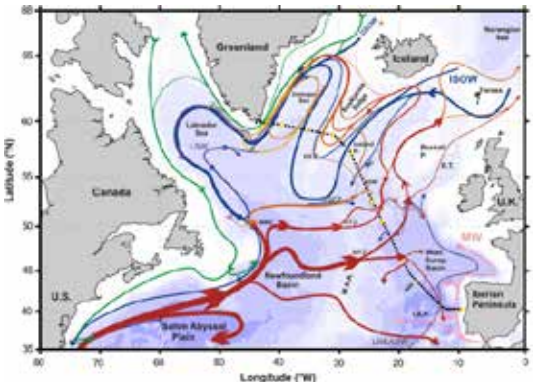
National and international context

Project conducted in relation with European and international partners

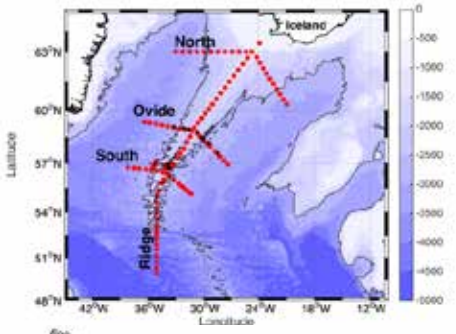
- Contribution to Euro-Argo strategy document
- Contribution to define the extension of the Argo program (Riser et al, 2016)
- AtlantOS: Optimising and Enhancing the Integrated Atlantic Ocean Observing Systems

NAOS complements and builds on other scientific projects

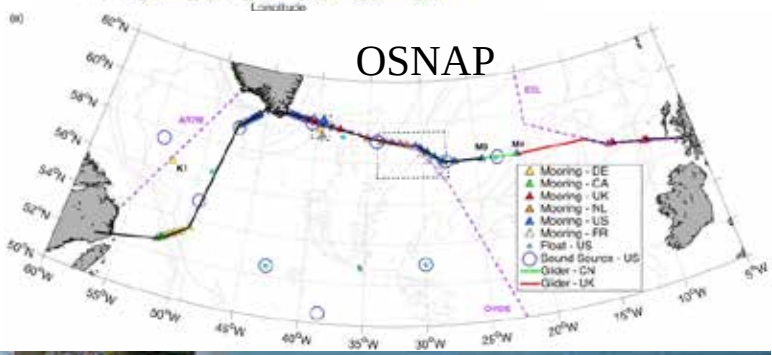
- OVIDE: to document and understand the variability of the circulation and water mass properties in the northern North Atlantic
- RREX: to investigate the interactions of the ocean currents with the Reykjanes Ridge
- OSNAP: understand the linkage between the meridional overturning circulation and deep water formation



OVIDE



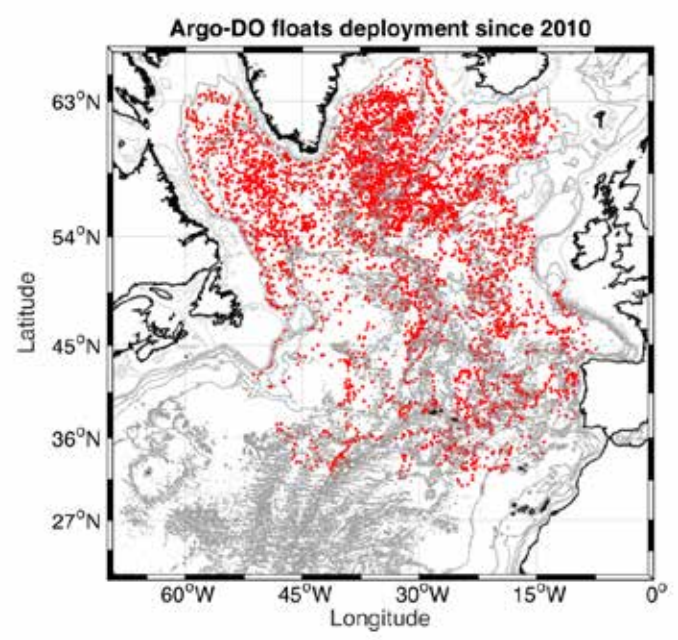
RREX

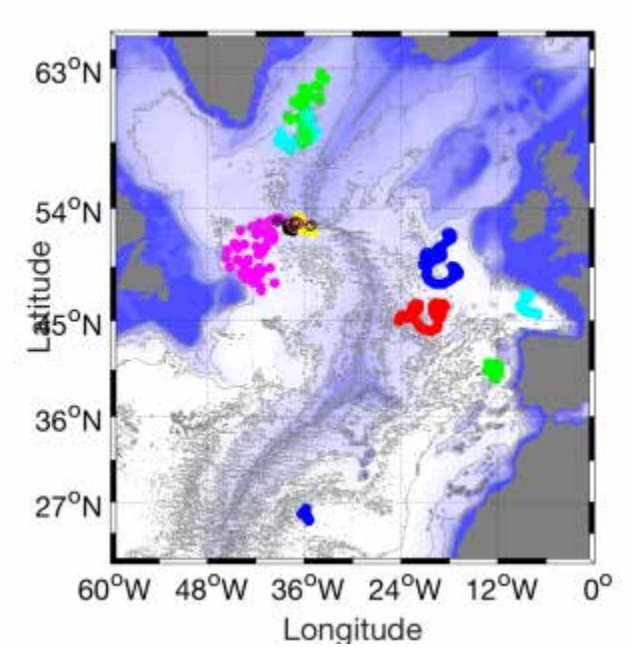


OSNAP

Pilot experiment for O2 and Deep-Argo data

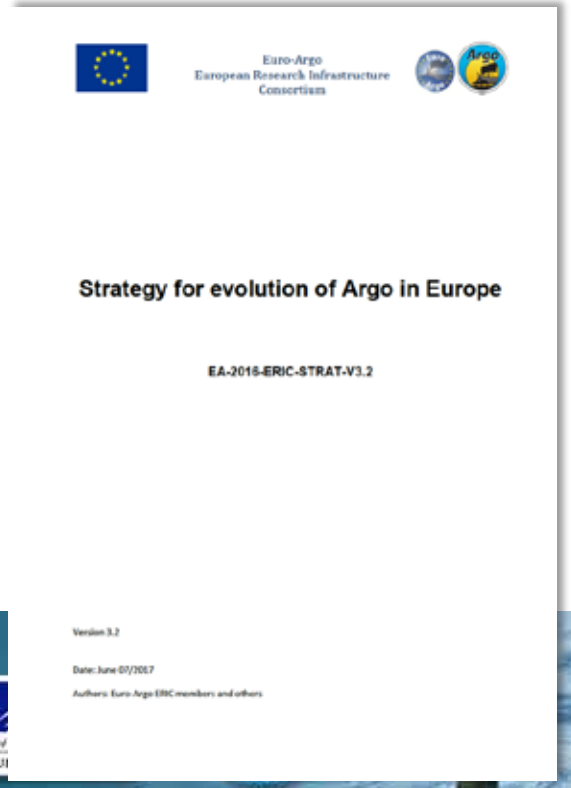
- **Float deployment**
  - 10 Deep-Arvor floats with O2 sensor deployed in the North-Atlantic Ocean
  - More floats will be deployed in the coming years (remaining NAOS floats and floats funded by CPER Euro-Argo over 2018-2021)
  - Those data complement Argo-O2 floats deployed in the North-Atlantic since 2010

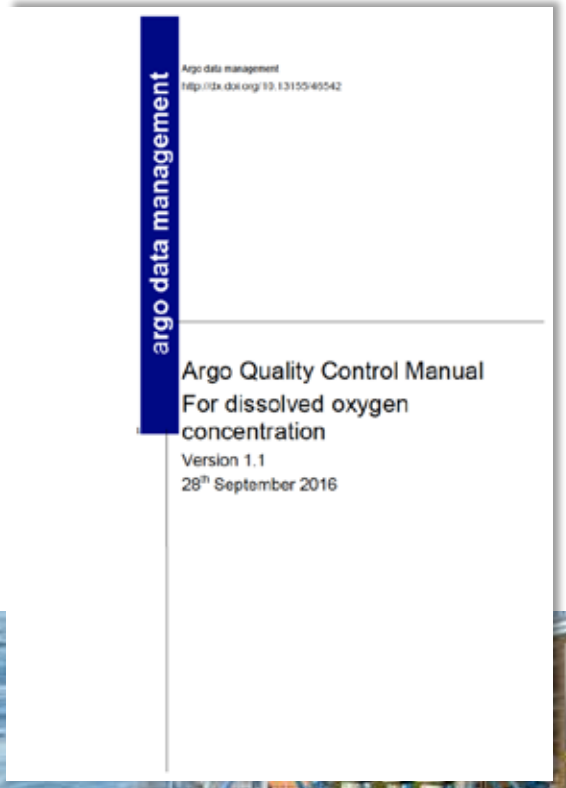


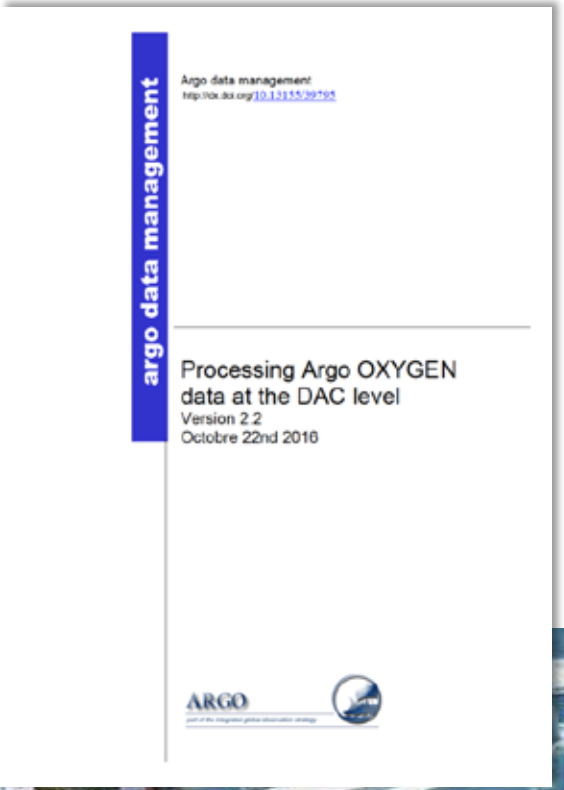


Pilot experiment for O2 and Deep-Argo data

- **Data stream and deployment strategy**
  - We established the data management procedure for O2 data from decoding to qualification
  - We contribute to establish the European strategy regarding the Deep-Argo and Argo-O2 arrays in agreement with European partners and the international Argo program

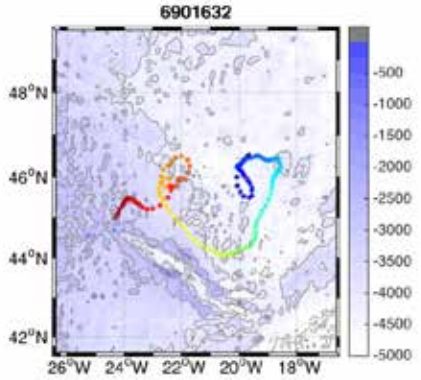


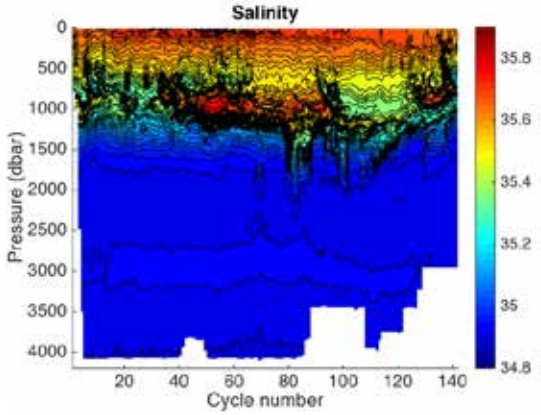


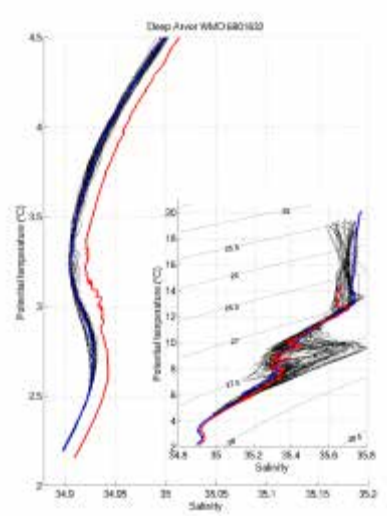


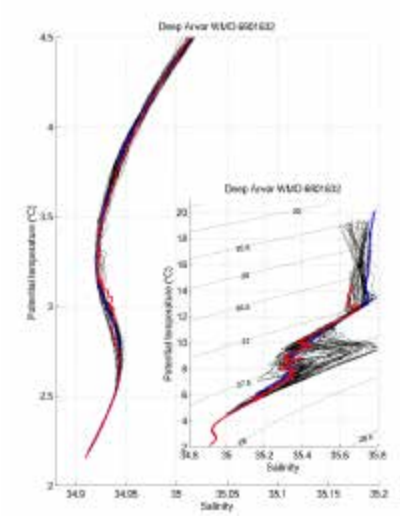
Demonstrate the capacity of the Deep-Arvor float at acquiring deep (below 2000m depth) and oxygen data of high-quality

- Ø The Deep-Arvor float is able to achieve more than 140 cycles
- Ø Owing to the measurements below 2000m, the Deep-Arvor floats revealed that a fresh bias was present in the classical Argo floats. Such bias is easily correctable and has been resolved by enhanced quality checks before deployment and a modification of the storage procedure









Conclusion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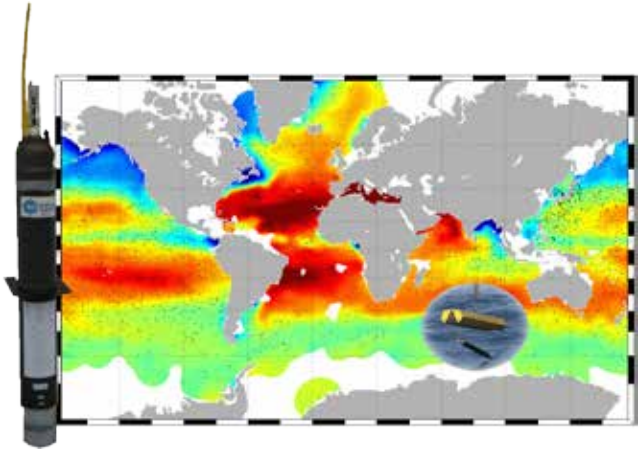
NAOS

Summary of achievements

The development and tests at sea of all of our prototypes have been successfully completed (WP2). All industrial series of present and new generation Argo floats (WP1,3,4&5) have been delivered.

The scientific experiments are running very well. French contribution to Argo significantly improved (> 100 NAOS standard Argo floats deployed by end of 2017) (WP1). Unique BGC observations have been collected in the Med Sea (WP3). Experiments in the Arctic (WP4) and in the North Atlantic (WP5) are already showing promising results.

NAOS directly contributes to Argo France and NAOS activities are fully integrated in European (Euro-Argo) and international (Argo) ones. They are also included in several major international research programmes (e.g. Greenedge, Mistral, Ovide/RREX)



Data from NAOS floats are freely disseminated to the scientific and operational communities (Argo data policy). This allows a much better scientific/operational uptake of the data and is key for long term sustainability.

On-going work to ensure sustainability of NAOS = preparing & implementing the new phase of Argo in France, Europe and at international level

- NAOS has successfully developed and tested the technology required to launch a new phase of Argo (Deep Argo, BioGeoChemical Argo).

- **Within this context the proposal is to start a new phase (2018-2023) of the TGIR Euro-Argo as the French contribution to the evolution of Euro-Argo and Argo international**

  New phase: continuation of the core Argo mission and extended mission following NAOS pilot experiments. French contribution of 70 to 80 floats/year with 30 T&S floats, 15 deep floats, 15 floats with oxygen sensors and 15 floats equipped with BGC sensors.

- **Funding issues.** Brittany region CPER Euro-Argo project = funding of deep and oxygen floats for 2018-2021. BGC floats for 2018-2023 will only be (very) partially financed by a PACA region CPER project and by CNES R&D funding. New sources of funding need to be found. A letter of intent for the French PIA-3 (*Plan d'Investissement d'Avenir*) jointly prepared by Ifremer, CNRS and SHOM was recently submitted to the French ministry of research (evaluation A+ by AllEnvi).

Thank you !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NAOS

Supplements

Project governance and project team

- **A steering committee (SC)** comprised of WP leaders is in charge of the scientific coordination and the management of the project. The SC is supported by a project office. The SC meets between 3 to 4 times a year and 18 meetings have been held since the start of the project.

- **A governing board (GB)** composed of directors or their representatives of the main institutions involved in NAOS is the decision making body. The GB meets at least once per year. 8 GB meetings have been held so far.

- **Project team**: about 12 full time equivalent people for the first 4 years followed by 6 full time equivalent people up to the end of the project). Human resources required by the project (in kind contribution of partner institutions to the project) are monitored by the project office and presented every year to the governing board. They agree with initial plans. General meetings with all project partners are held every year. First half of meetings are open to the wider scientific community to present and discuss NAOS results and achievements. Second half of meetings are restricted to project partners.

Overall WP2 achieved all its initial objectives. All planned prototypes were developed and tested at sea. Highly valuable results have been obtained:

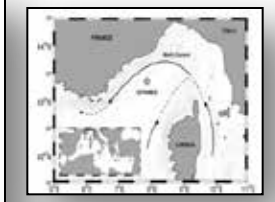
- An optimized Arvor float for standard 2000m depth Argo application,
- A demonstration to house the Argos 3rd satellite transmission system into the Arvor float,
- A new float able to reach 4000m depth, for Deep Argo future needs,
- A new electronics architecture offering higher performance for multi-sensors floats,
- A demonstration of the new sensor Noss as an alternative way for salinity measurements,
- A new biogeochemical float dedicated to high latitudes.

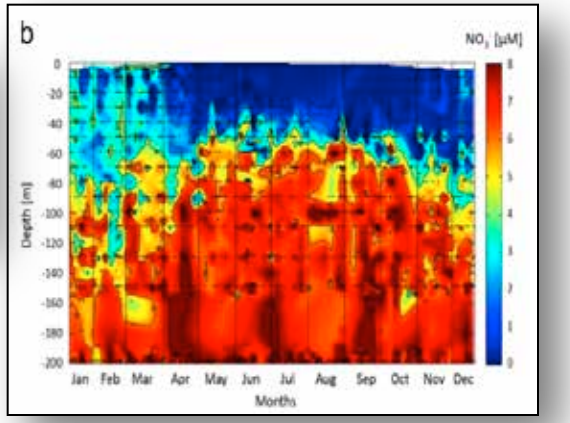
Mediterranean Nutrient dynamic


Deep-Sea Research I

Temporal variability of nutrient concentrations in the northwestern Mediterranean sea (DYFAMED time-series station)

Orens Pasqueron de Fommervault, Christophe Migon, Fabrizio D'Ortenzio, Maurizio Ribera d'Alcalà, Laurent Coppola



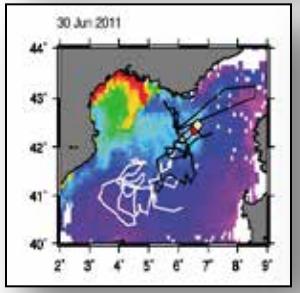


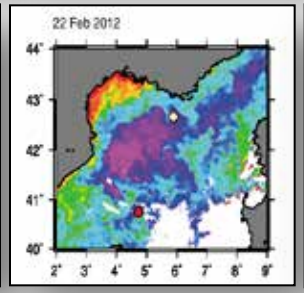

Geophysical Research Letters

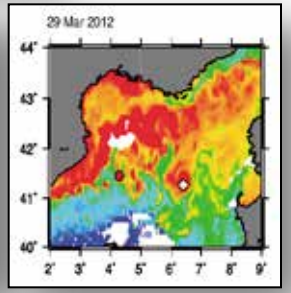
RESEARCH LETTER

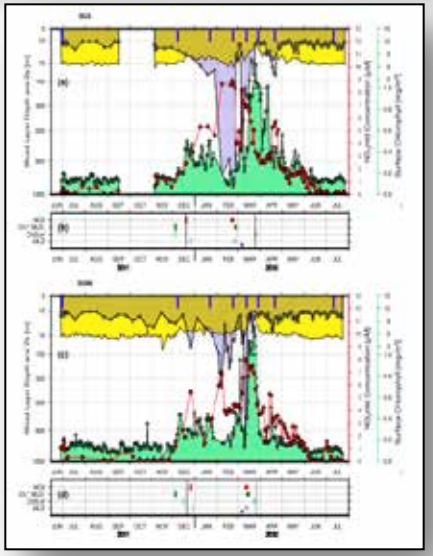
Observing mixed layer depth, nitrate and chlorophyll concentrations in the northwestern Mediterranean: O_3 profiling floats experiment

Fabrizio D'Ortenzio, Hélène Lavigne, Florent Besson, Hervé Claustre, Laurent Coppola, Nicole Garcia, Agathe Laës-Huon, Serge Le Reste, Damien Malarté, Christophe Migon, Pascal Morin, Laurent Mortier, Antoine Poteau, Louis Prieur, Patrick Raimbault, and Pierre Testor



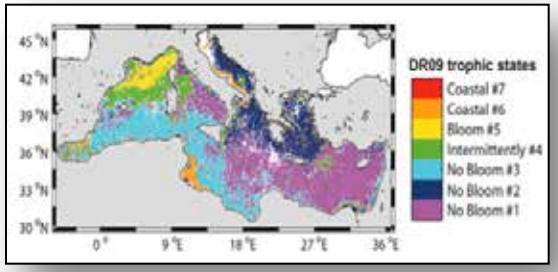


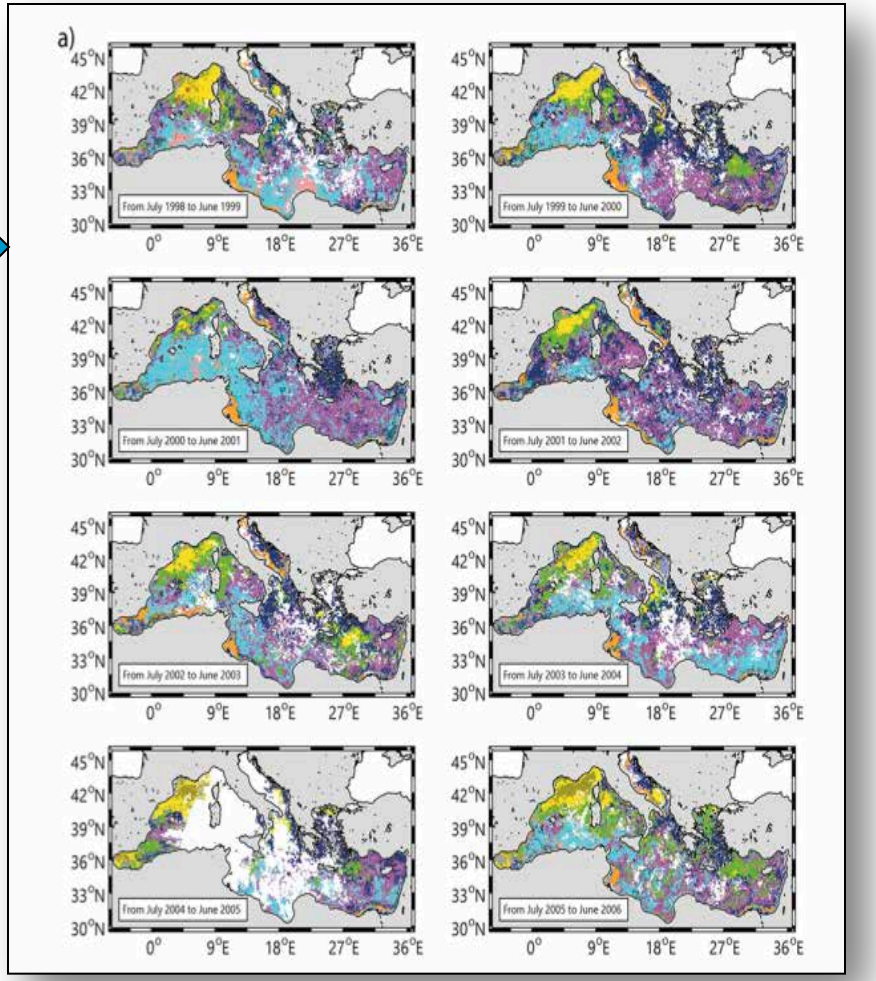




Interannual Satellite derived Bioregions

A tool to contextualize the WP3 BGC-Argo array

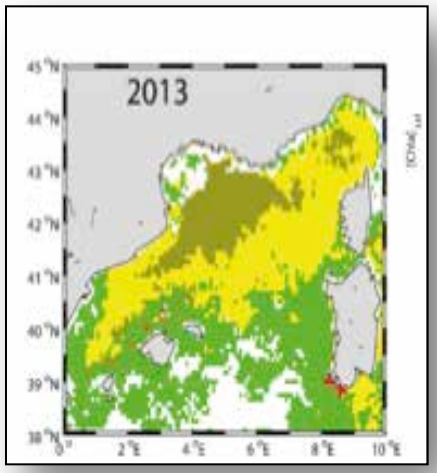


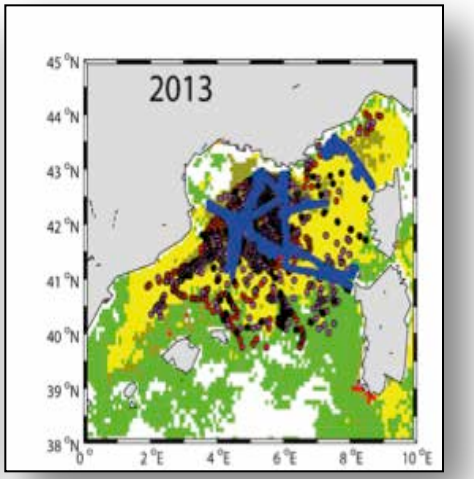


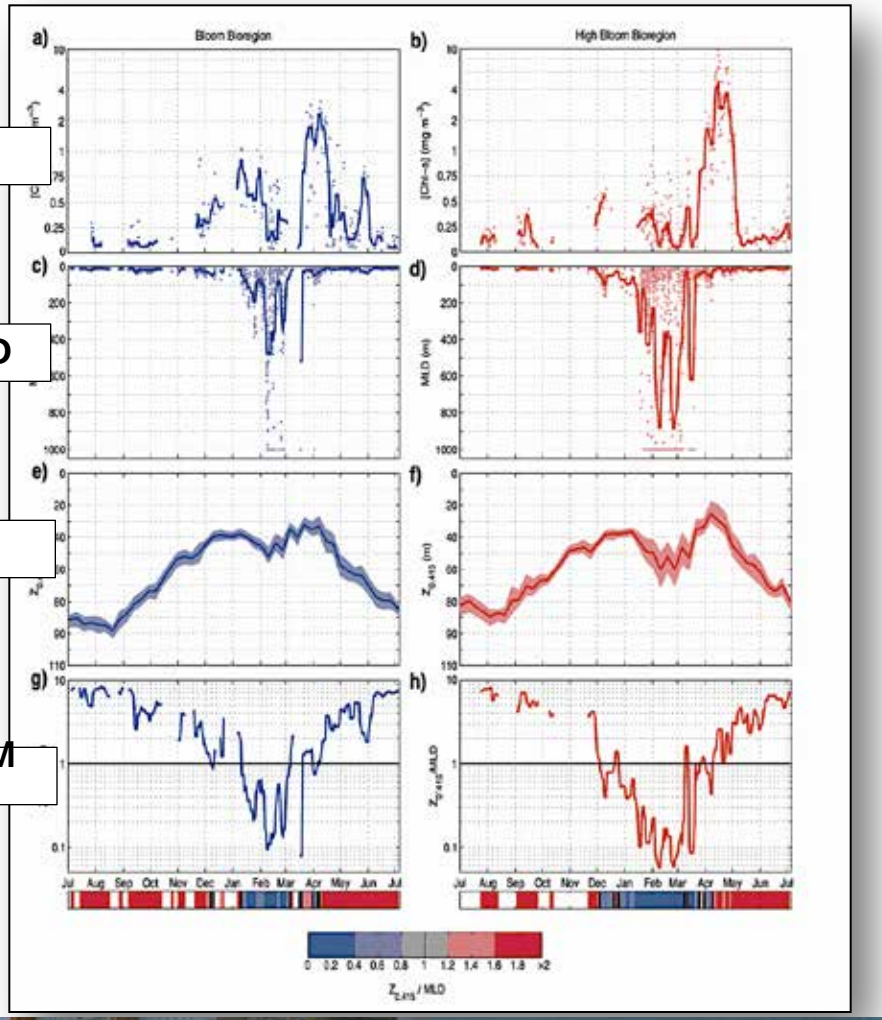
Mayot et al., 2015, BGS

Interannual Satellite derived Bioregions

A tool to contextualize the WP3 BGC-Argo array

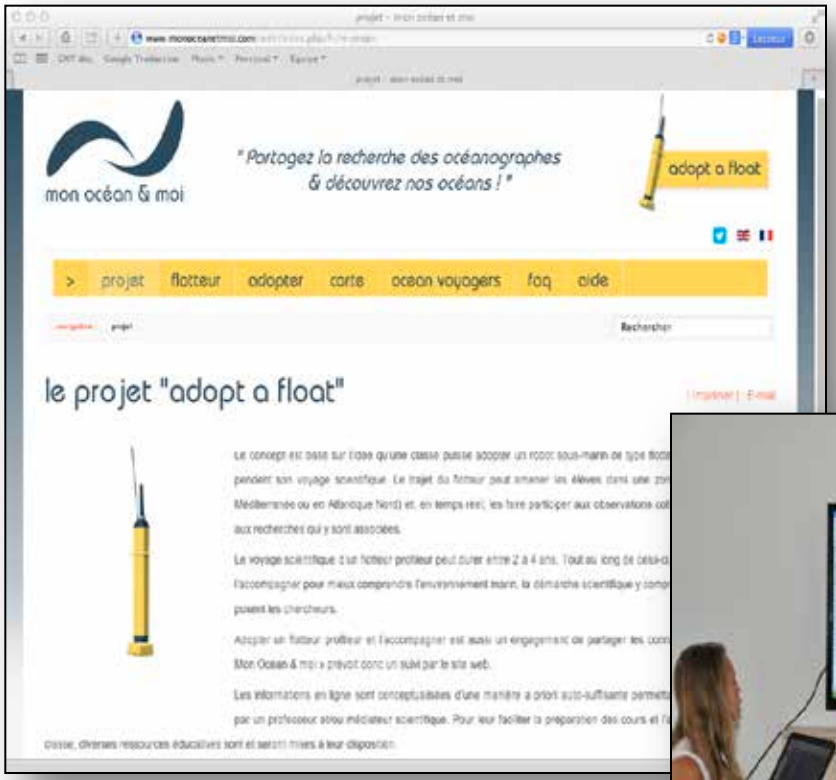






Mayot et al., 2016, JGR

Adopt a float

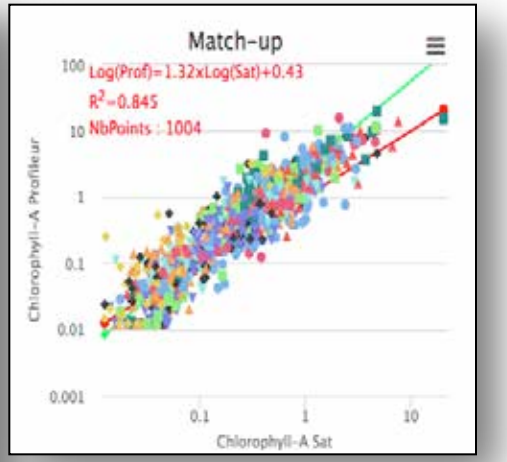


- 2 NAOS WP3 Floats « adopted » by scholars of Vlfr region in the framework of the « Adopt a float » project

Synergies with remote sensing

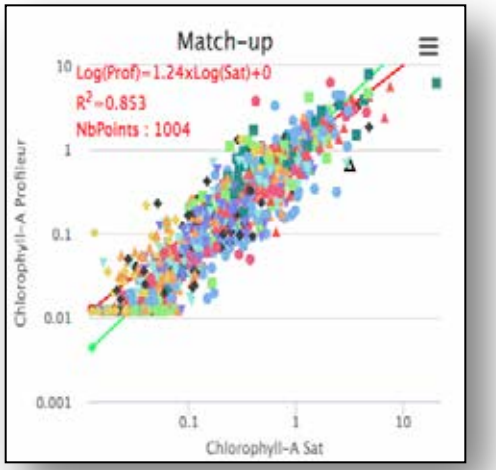
Seasiderendezvous tool for DM

http://seasiderendezvous.fr



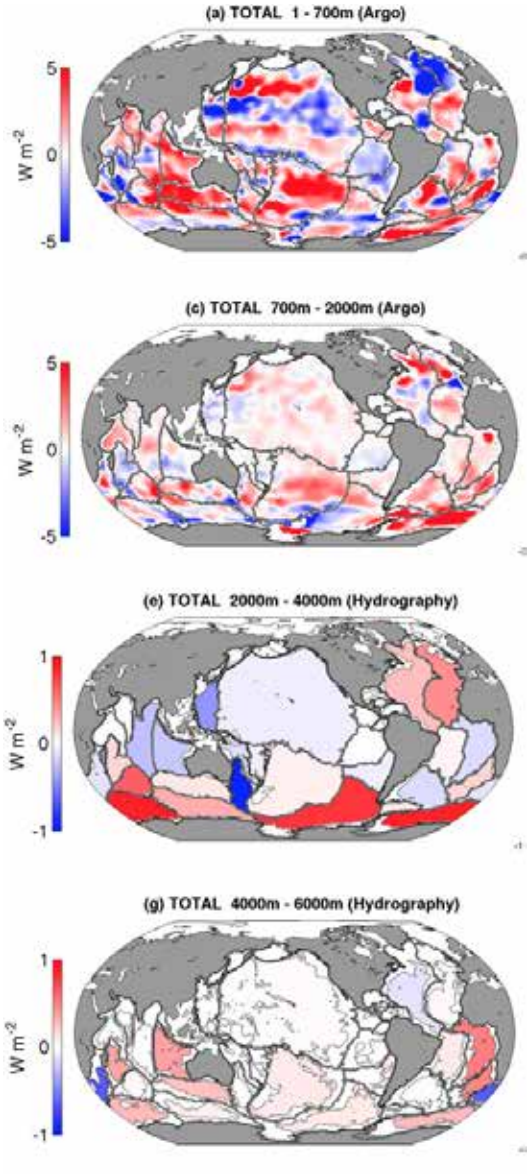
Using factory calibrations

Intercept = 0.43



Using scale factor of 2.5 on in situ data :
Intercept = 0.01

Organelli et al., 2016, JGR



Main drivers

Ocean and climate change research

- Improvement of global heat and freshwater budget
- Improvement of regional sea level budget and quantification of the causes of sea level changes

Operational applications

- Improve global ocean reanalysis, ocean and coupled ocean-atmosphere forecasting systems below 2000 m

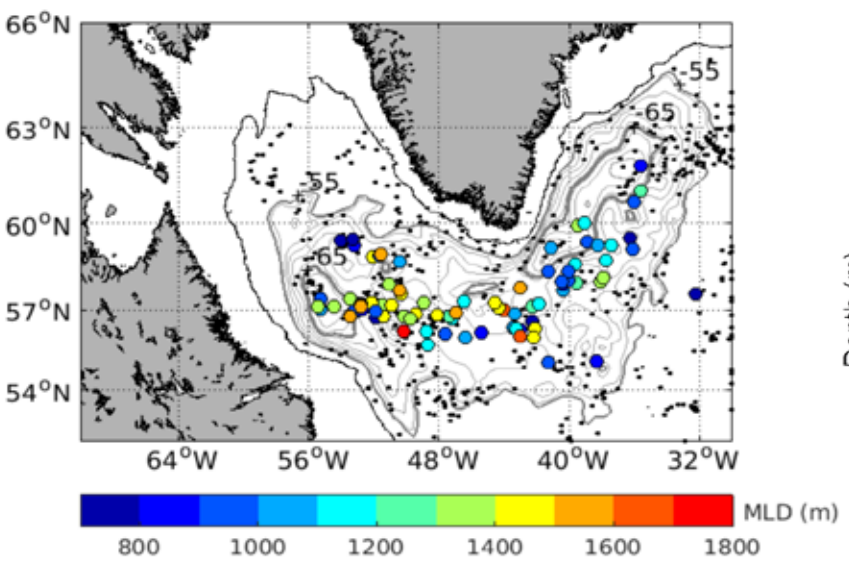
Other research topics

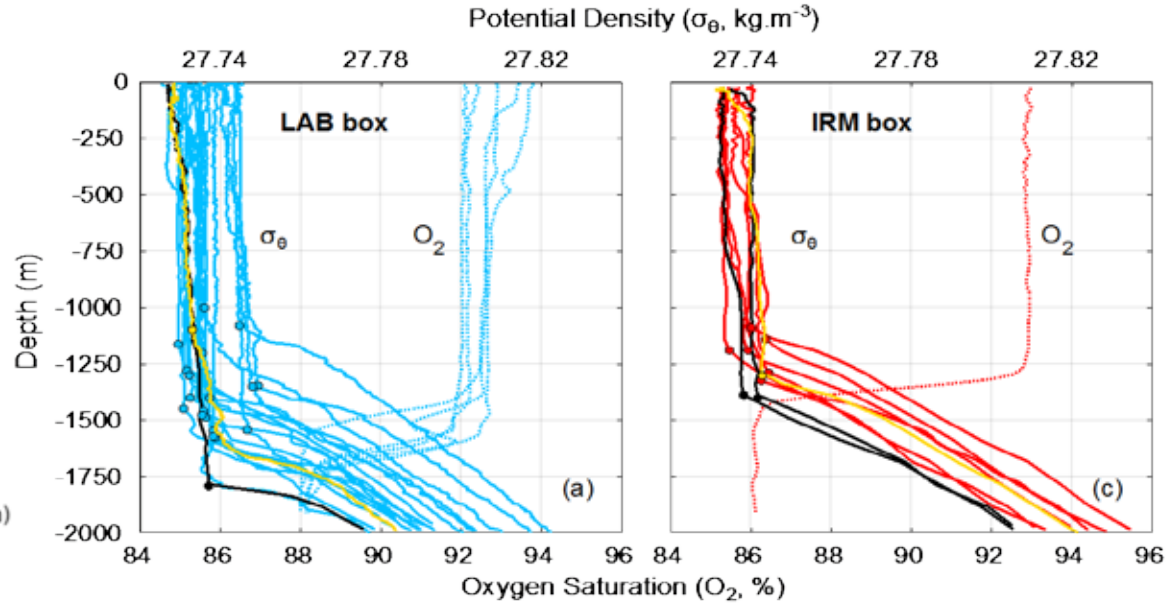
- Quantify mean state and variability of deep ocean circulation
- Investigate relationship between circulation and topography
- Deep mixing and convection

Heat content trend (W m^{-2}) 2006-2014
Desbruyères et al, 2017

Scientific analyses

q Investigate deep convection in the Irminger Sea and document an exceptionnal deep convection event that occured at basin scale during winter 2014-2015: PhD thesis A. Piron (Piron et al, 2016, 2017)

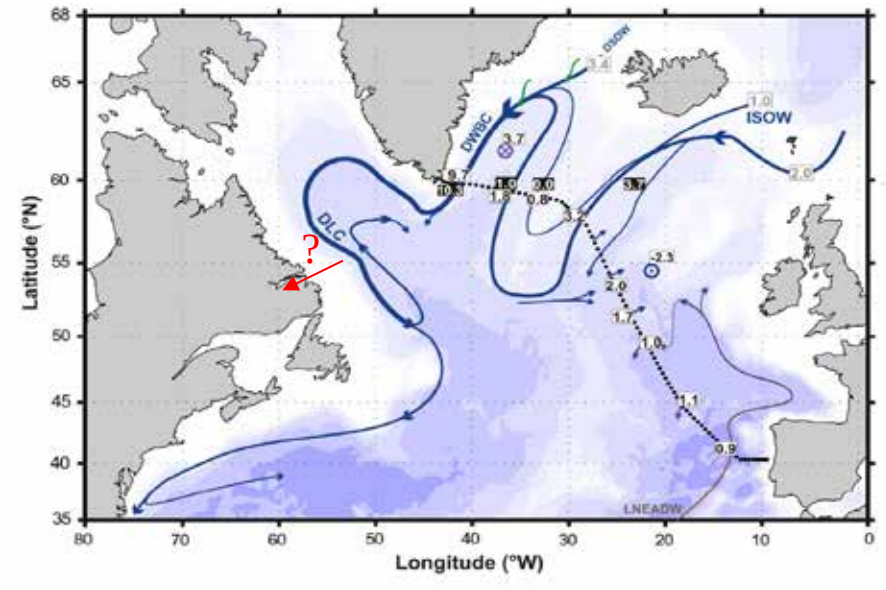


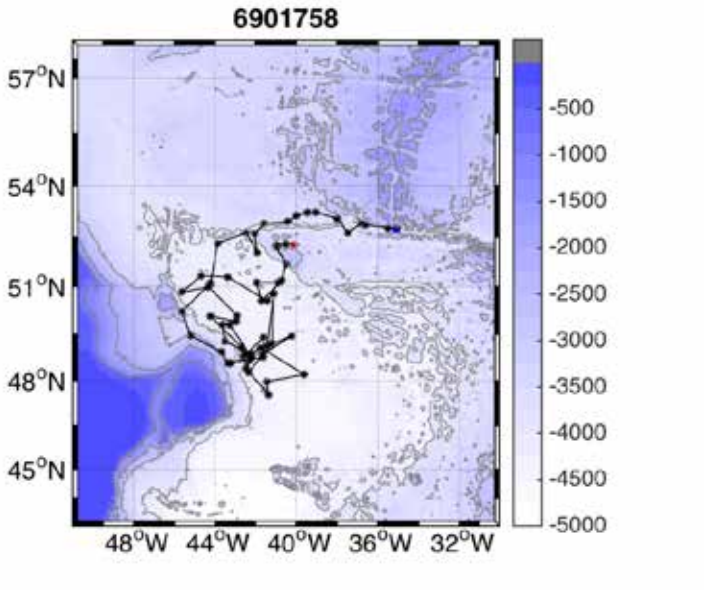


Due to exceptionnal winter heat loss, the mixed layer observed in March 2015 in the Imringer Sea are the deepest mixed layer ever observed in this basin.

Scientific analyses

- **Investigate new pathways for the deep water masses as revealed by Deep-Arvor float trajectory and their connection with the surface circulation. Post-doc V. Racapé**





Draft 9 June 2016

The Rationale, Design and Implementation Plan for Biogeochemical-Argo

The extension of the Argo array of profiling floats to include biogeochemical sensors for pH, oxygen, nitrate, chlorophyll, suspended particles, and downwelling irradiance

biogeochemical Argo

Euro-Argo
European Research Infrastructure
Consortium

Strategy for evolution of Argo in Europe

Version 2.0
Date 23/12/2015
Authors: Euro-Argo ERIC members and others

Communication/Outreach activities

Communication activities include presentations of NAOS results in conferences and in national (Argo France), European (Euro-Argo ERIC) and international (international Argo steering team) meetings.

NAOS publishes every year (in French and in English) a newsletter that is widely disseminated. Scientific publications on NAOS float prototypes and scientific results have been prepared (> 20). A scientific film for TV is now prepared to illustrate the main mid-term achievements of NAOS.

Major efforts have been carried out to develop European projects so that new NAOS Argo floats can also be tested and used by our European partners (E-AIMS FP7 and Atlantos H2020 projects). A DG MARE proposal (MOCCA) led by the Euro-Argo ERIC also organized an open procurement of 150 standard Argo floats. Our industrial partner NKE was selected.

Some of the floats of NAOS have been "adopted" by scholar classes, in the framework of an educational LOV project “Adopt a float”.

Socio-economic impact

NAOS is central to the development strategy of our main industrial partner NKE. NKE objective through NAOS is to consolidate and expand its market shares and leadership in Europe but also worldwide.

In terms of number of floats produced or deployed per year, **NKE is now the second manufacturer in the world.** Share of NKE floats (Arvor, Provor) increased from less than 10% (pre-NAOS) to more than 20% for the last three years. There is **thus a highly satisfactory increase of NKE market share over the past couple of years**.

NAOS is also part of the development strategy of CLS. The Argos system was designed 30 years ago by CNES and since then the French Space Agency has continuously invested on this system to improve its performances. NAOS has provided very valuable user feedback for the next evolution of the Argos system.

Users of the Equipex

Data from NAOS floats (WP1, WP3, WP4 and WP5) are freely disseminated to the scientific and operational communities (data policy of the international Argo program). This allows a much better valorization of the data.

It is estimated that between 100 to 200 scientists are directly using Argo observations in France and between 1000 to 2000 scientists at international level. Many more ocean and climate researchers benefit from Argo observations or are using products elaborated from Argo observations. Argo data are, in particular, assimilated in ocean analysis and forecasting centers (Mercator Ocean, Copernicus Marine Environment Monitoring Service), which can offer better service to their institutional and private users (up to 10000 users are now subscribers to the Copernicus Marine Service coordinated by Mercator Ocean via a delegation from the European Union).

Budget status 2011-2017

Expenses (2011 – 2017)

NAOS EXPENSES	2011	2012	2013	2014	2015	2016	2011+2012+2013+ 2014+2015+2016	2017	Total	Status June 2017
IFREMER										
Tranche 1	378 010 €	926 606 €	120 185 €	727 066 €	363 387 €	661 461 €	3 176 714 €	94 034 €	3 270 748 €	99%
Tranche 2		63 227 €	55 733 €	73 733 €	113 787 €	56 732 €	363 213 €	117 000 €	480 213 €	59%
UPMC										
Tranche 1	7 390 €	564 546 €	341 010 €	805 189 €	659 206 €	46 554 €	2 423 894 €	80 000 €	2 503 894 €	100%
Tranche 2		53 918 €	101 123 €	124 829 €	178 822 €	79 783 €	538 475 €	116 000 €	654 475 €	74%
CNRS										
Tranche 1		9 744 €	34 272 €	16 435 €	0 €		60 451 €		60 451 €	96%
Tranche 2				6 928 €	35 097 €	49 562 €	91 586 €	68 000 €	159 586 €	54%
SHOM										
Tranche 1	1 916 €	24 987 €	3 150 €	3 151 €	3 028 €	1 231 €	37 464 €		37 464 €	94%
CLS										
Tranche 1	16 091 €	41 600 €	22 646 €	0 €	0 €		80 337 €		80 337 €	100%
Done Tranche 1	403 407 €	1 567 482 €	521 262 €	1 551 841 €	1 025 622 €	709 246 €	**5 778 860 €**	174 034 €	5 952 894 €	99%
Done Tranche 2	0 €	117 145 €	156 856 €	205 490 €	327 706 €	186 077 €	**993 274 €**	301 000 €	1 294 274 €	65%
TOTAL DONE	**403 407 €**	**1 684 628 €**	**678 118 €**	**1 757 331 €**	**1 353 327 €**	**895 323 €**	6 772 134 €	475 034 €	7 247 168 €	85%

Compared to initial plan, delay of a few months for WP2 prototypes and delay for the order of WP3, WP4 and WP5 series of about 6 months.

June 2017: 99% of planned budget used for Tranche 1 (completed) and 65% of the Tranche 2 budget used.

Human Resources

Human Resources (2011-2016)

Partner institutions contribute in kind to the project with about 12 Full Time Equivalent (FTE) that were mobilized for the first five years of the project (*Tranche 1*) and then with about 6 FTE (*Tranche 2*) up to the end of the project. Human resources are monitored by the project office and presented every year to the governing board. They agree with initial plans.

3 FTE over 3 years in short term contracts (CDD) have been funded by ANR for WP2.

	Prévisionnel (proposition)				Réalisé 2011 (sur 6 mois)		Réalisé 2012		Réalisé 2013		Réalisé 2014		Réalisé 2015		Réalisé 2016		Réalisé 2011-2016	
	Homme/mois / 6 mois (indicatif)	Homme/mois / 1 an (indicatif)	Homme/mois/ 2011-2015	Homme/mois/ durée totale projet	Homme/ mois	Dont CNRS	Homme/ mois	Dont CNRS	Homme/ mois	Dont CNRS	Homme/ mois	Dont CNRS	Homme/ mois	Dont CNRS	Homme/ mois	Dont CNRS	Homme/ mois	**Dont CNRS**
IFREMER	30,89	61,78	**185,33**	340,50	23,00		102,25		42,42		43,11		34,34		17,55		**262,67**	
UPMC	20,17	40,33	**121,00**	177,00	20,90	15,40	44,00	29,50	38,00	28,00	40,00	20,50	48,30	30,30	32,30	22,30	**369,50**	**146,00**
CNRS	4,00	8,00	**66,00**	138,00	9,30		12,29		16,23		18,99		14,00		4,50		**75,31**	
SHOM	0,50	1,00	**3,00**	3,00	0,14		2,61		1,06		2,00		2,08		1,65		**9,54**	
UBO	2,50	5,00	**10,00**	30,00	0,50		0,50		0,50		0,00		1,00		1,00		**3,50**	
CLS	2,30	4,60	**6,90**	6,90	0,75		1,50		2,50		0,40		0,20		0,00		**5,35**	
NKE	7,50	15,00	**45,00**	45,00	6,79		18,90		17,61		10,24		9,32		2,34		**65,18**	
TOTAL			**437,23**	**740,40**	**61,37**		**182,05**		**118,31**		**114,74**	**20,50**	**109,23**	**30,30**	**59,34**	**22,30**	**791,04**	

Argo is a long-term global array integrated with other elements of the climate observing system to:

- **detect climate variability from seasonal to decadal scales and provide long-term observations of climate change in the oceans.** This includes regional and global changes in temperature and ocean heat content, salinity and freshwater content, sea level and large scale ocean circulation.
- provide data to **constrain global and regional ocean analysis and forecasting models**, to **initialize seasonal and decadal forecasting ocean/atmosphere coupled models** and to **validate climate models.**
- provide information necessary for the **calibration and validation of satellite data**

The Euro-Argo European Research Infrastructure

- **Objective: ensure a long term European contribution to Argo**
- **Europe establishes an infrastructure for ¼ of the global array**
  - Deploy about 250 floats per year to contribute to the Argo core mission including regional enhancements (Nordic seas, Mediterranean&Black seas) (maintain an array of 800 floats).
  - Prepare and contribute to the extension of Argo (e.g. marginal seas, biogeochemistry, deep ocean, polar regions).
  - Users and applications: ocean and climate research and operational oceanography (Copernicus Marine Service).
- **A new European legal structure (Euro-Argo ERIC) set up in May 2014 that will allow European countries to consolidate and improve their contribution to Argo international.**