

NeXOS - Next generation, Cost-effective, Compact, Multifunctional Web Enabled Ocean Sensor Systems

Simone Memè, Eric Delory, Matthieu Felgines

Plataforma Oceánica de Canarias
PLOCAN
Telde, Gran Canaria, Spain
{simone.meme, eric.delory, matthieu.felgines.ext}@plocan.eu

Jay Pearlman, Françoise Pearlman

IEEE France
Paris, France
jay.pearlman@ieee.org; jsp@sprintmail.com

Joaquin del Rio, Enoc Martinez, Ivan Masmitja

Universitat Politècnica de Catalunya
Vilanova i la Geltrú, Spain
{joaquin.del.rio, enoc.martinez, ivan.masmitja}@upc.edu

Johan Gille

ECORYS
Rotterdam, Nederlands
johan.gille@ecorys.com

Jean-Francois Rolin

IFREMER
Plouzane, France
jean.francois.rolin@ifremer.fr

Abstract—Ocean processes are of biological, geological, chemical or physical nature, occurring at micro - to kilometer scales, from less than seconds to centuries, turning the understanding and the sustainable management of the ocean into a multi-scale and multi-disciplinary effort. To address this variability with a cost-effective solution, the European FP7 project NeXOS has developed a new generation of multifunctional, compact, interoperable and Web enabled optical and acoustical sensor systems as well as sensors for fisheries management. These sensor systems have been designed, built, tested and validated in a number of platforms using scenarios that are demonstrations of applications for long-term implementation. The performance validations have been carried out during 2017 and the most updated results are provided in this paper.

Keywords—*Multifunctional ocean sensors, Compactness, Cost-efficiency, Interoperability, Marine GEOSS, GOOS, Optical sensors, Biogeochemistry, Polycyclic Aromatic Hydrocarbons, Underwater sound, Hydrophones, Acoustics, Fisheries management, RECOPESCA, Smart interface, Sensor Web*

Lars Golmen

Norsk institutt for vannforskning
NIVA
Bergen, Norway
lars.golmen@niva.no

Nils Roar Hareide

Runde Environmental Centre
Runde, Norway
nilsroar@rundecentre.no

Christoph Waldmann

MARUM, Universität Bremen,
Bremen, Germany
waldmann@marum.de

Oliver Zielinski

ICBM, University Oldenburg
Oldenburg, Germany
oliver.zielinski@uni-oldenburg.de

I. INTRODUCTION

Oceans regulate the Earth's climate and are integral to all known sources of life. Ocean processes are of biological, geological, chemical or physical nature, occurring at micro- to kilometer scales, from less than seconds to centuries, turning the understanding and the sustainable management of the ocean into a multi-scale and multi-disciplinary effort. Most chemical sampling methods are still experimental and expeditionary, i.e. based on costly laboratory analysis and discrete field campaigns. These can also only harvest data for a limited time - space window, resulting in the problem of insufficient sampling resolution, spectral aliasing and consequently incomplete information. To address this, new interoperable sensor systems are needed, which can measure several parameters with vested quality while at the other end of observation strategies, real-time or near real-time permanent ocean observations need to be more cost- effective and reliable. Also, reducing the frequency of sensor maintenance and implementing a remote management of sensors are important targets for cost- reduction. The new sensors should interact with a wide range of in-situ ocean observing platforms, which provide power and information transmission capability for

sensors. These ocean observing platforms can be mobile, such as ships, autonomous underwater vehicles, drifters and profilers, or fixed, such as buoys, moorings and cabled observatories.

To this end, a number of challenges need to be overcome related to the establishment of agreed upon best practices on sensor preparation, an effective concept of operations, and the high cost and accessibility of data. The general priority for all observing systems, monitoring strategies and sensor technologies is therefore to create mechanisms and technologies such that data has greater scientific value, and the overall life cycle cost of sensors and observing systems is reduced. This must be achieved by innovations in sensor technologies, data accessibility, reliability, interoperability and multi-functionality for the key ocean variables.

The European FP7 Project for Next generation, Cost-effective, Compact, Multifunctional Web Enabled Ocean Sensor Systems, called “NeXOS” for short, addresses the challenges above by answering to the key environmental descriptors identified by the European Marine Strategy Framework Directive (MSFD) [1]. Cost-efficiency is improved through specific innovations of broad spectrum, robust, complementary measurement technologies that can be hosted by existing in-situ observing systems, including mobile platforms (drifters, gliders, vessels) and fixed platforms (buoys, moorings, seafloor stations, cabled observatories).

NeXOS has built a new generation of multifunctional optical and acoustical sensor systems as well as sensors for fisheries applications. To increase the reliability of optical sensors in particular, a new antifouling system has been developed to work with the sensors. These sensor systems have been designed, built, tested and validated for specific technologies and monitoring strategies. They have common interface with Platforms (PUCK plug and play capability) and data interface and transmission protocols (SWE sensor web enablement that addresses the flow of information from sensor to user). The NeXOS compact and cost-efficient multifunctional optical sensor systems are for monitoring marine hydrocarbons and other components of the carbon cycle.

This includes:

(1) Two acoustic sensors: A1 - low-power multi-functional acoustics sensor and A2 – real time waveform streaming passive sensor system.

(2) Three types of optical sensors: O1 - multi-wavelength fluorescent sensor; O2 - hyperspectral absorption sensor; and O3 - multifunction carbon sensor.

(3) A low-cost sensor system measuring oxygen and chlorophyll-a, as well as physical parameters (T, S, Depth) to provide improved ecosystem knowledge for fisheries management

Interfaces of these sensors for sensor control and data retrieval are through Smart Sensor Interfaces. Hardware and software interface implementation is based on new CORTEX architectures [2] for a miniaturized low power modular design with controllable variable frequency clocks ensuring low

power consumption or high performance when needed. This includes implementation of PUCK protocol for instrument discovery and identification in point-to-point or networks communications and implementation of PTP (Precision Time Protocol IEEE Std. 1588) for time synchronization. Open Source software development tools facilitate reprogramming or reconfiguring sensor interface. The new interface capabilities allow real-time data collection without the need for a specialist at the monitoring location. Antifouling system has been developed with the objective to increase reliability of optical sensors and underwater cameras.

Validation of sensor performance has been done on a number of platforms using scenarios that are demonstrations of applications for long-term implementation. These include:

- Scenarios 1 – detection and quantification of hydrocarbons leakage by a combination of sensors in a mobile platform.
- Scenario 2 – ecosystem demonstrations on fishing vessels with EAF sensors and observe impacts.
- Scenario 3 – characterization of sounds and noise of species of interest.
- Scenario 4 – quantification of complete carbon system in seawater (e.g. pH, inorganic carbon, carbonate ions, partial pressure CO₂).
- Scenario 5 – Detection and characterization of phytoplankton blooms.

The performance validations have been carried out during 2017 and this paper summarizes final developments and provides the most updated results on validations and demonstrations.

II. VALIDATIONS AND DEMONSTRATIONS

Progresses within the NeXOS project have been made by implementation of six main scientific and technical innovations: three innovations specific to the chosen observation frameworks (optics, acoustics, EAF) and three of which are transversal and will increase reliability, sensor and data interoperability for integration with GOOS, GEOSS and other initiatives. A comprehensive description of each development has been provided in [3].

Validation and demonstration of sensors are important activities within NeXOS. Validation is about the functionality, operability and data quality of a sensor on a specific platform. In any program, depending on its objectives and the desired maturity of the sensors and systems, there are varying levels of validation that are considered appropriate. As a research and development program, NeXOS targeted Technical Readiness Levels (TRL) that are transitions between development and operation capabilities (TRL 6 or 7). For operational systems the emphasis is on “full” validation, but for development systems, a partial validation may be considered. [4]

User scenarios (also termed “Integrative Scenarios”) for the different sensor types formed are part of the background for the validation and the demonstration plans. For NeXOS, these are:

- Hydrocarbon observations with gliders
- Passive acoustic monitoring and characterization of underwater sounds and bioacoustics with gliders, profiling floats ad buoys.
- Observations for sustainable fisheries using selected fishing vessels equipped with EAF sensors
- Carbon cycle and carbon sequestration monitoring mounted on ferries
- Detection and characterization of phytoplankton blooms with gliders,

Validation and demos were carried out in three different ocean environments: Mediterranean Sea, Central Atlantic and Northern Europe. These were chosen because they represent important diversity in both ecosystems and ocean applications. In practice the actual location for demonstrations are the Canary Islands (co-ordinated by PLOCAN), the coast off SE

A1	A2	O1	O2	O3	EAF	PLATFORM	DEMO SITE
Med1						Beacon	
				MED3		Fishing Vessel	MED SEA
	MED2					OBSEA	
NOR1		NOR2				SEA EXPLORER	
			NOR3			SAIL BUOY	
		N O R 4	NO R 4	NOR5		FERRYBOX	NORWAY
					NOR6	FISHING VESSEL	
CAN1		CAN2				WAVE GLIDER	
CAN3						PROVOR	
CAN4						ESTOC TB	CANARY ISLANDS

Fig. 1. Validation and demonstration environments for NeXOS sensor systems.

Spain (co-ordinated by UPC), the northern Adriatic Sea (coordinated by CNR-ISMAR) and the North Sea (coordinated by REC and NIVA). Each combination for demonstration has been given a name as visible in Fig. 1. In all of the validation/demonstration environments, data streams are accessible through the Internet in standard formats. This is consistent with the end-to-end approach of NeXOS in support effective use in a broad range of applications.

Only available results from validation/demonstrations missions will be summarized in this section; however other mission are still underway and will continue through the summer of 2017.

A. Passive acoustic sensors

During February 2017, passive acoustic sensors A1 and A2 were submitted to calibration and optimization both in air and tronco-conical tank of up to 10m depth at CTN partner's facilities. Directivity, sensitivity and self-noise were calibrated according to IEC 60565:2006 standard.

Functional validation process of A1 is currently in progress at PLOCAN facilities by emulating field conditions in a tank using a reference system. Noise processing validation includes comparison with reference low-noise hydrophone and acquisition system (RTSYS + Reson 4032), processing via MATLAB. Bioacoustics processing is being validated by means of PAMGUARD software, broadly used in the bioacoustics community. Preliminary results from hardware and software test showed successful results for relevant raw data storage, sampling frequency, dynamic range, linearity and power consumption; real-time processing is under verification as it showed that when real-time is no longer possible due to processing speed reduction, some data stream chunks appear to be discarded. Acoustic data products such as click and whistle detection are being validated and the preliminary results for ambient noise level within 1/3 octave bands 63 and 125 Hz show that the system behaves coherently with correct results for RMS, with different gain configurations. Some differences from expected levels are attributed to system set-up and interferences (to be confirmed).



Fig. 2. A1 sensor integrated in several platforms for demonstration

A1 is being field validated on several platforms in three geographic locations as indicated in Fig. 1. The main objective of these missions respond to the User Scenario of Characterising the underwater soundscape with emphasis on areas where human activities such as fishing, boat traffic and ocean energy conversion, are taking place. Fig 4 represents a snapshot of the data flow to SOS server for the CAN3 mission while fig. 2 shows pictures of on-going/upcoming demonstrations.

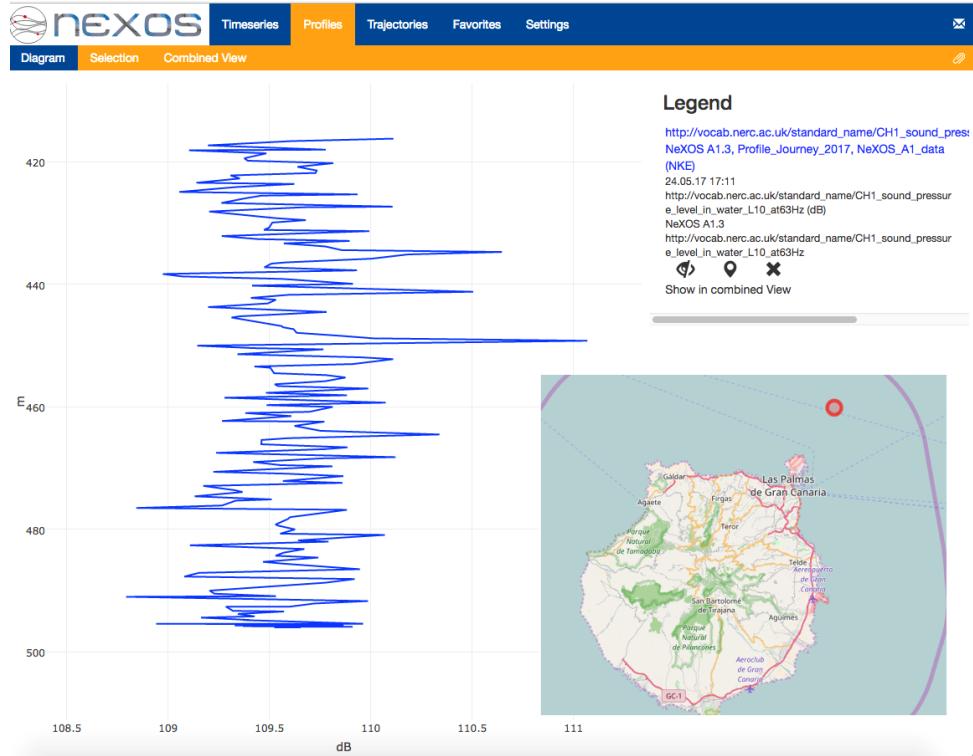


Fig. 4. A1 dataflow recorded with the NKE PROVOR off-shore PLOCAN at Canary Islands. Values currently under verification for potential sensitivity adjustment.

Validation of A2 system is taking place at Obsea cabled observatory, in Vilanova i la Geltru, Barcelona (Spain). The depth of the observatory is 20m (Fig. 3 and Fig. 5). The duration of the validation is planned for two months from June 2017 and a follow-on demonstration will start in August 2017. This validation will verify the proper functionality of the hardware system, communications, synchronization, robustness of the system, and embedded processing capacity (Direction of Arrival via PTP synchronisation). In order to verify these characteristics of the system, the main algorithm executed by the A2 system is devoted to estimate the angle of arrival of a sound source. A specific sound is generated around the system, at different locations, using an underwater speaker. Hardware and software validation consisted in a general communication and functionalities check after the integration to the Obsea station. During the first field tests it was possible to validate the synchronization between the 4 hydrophones of the array so that it was possible to calculate the direction of the arrival of the sound. A second field test is continuing at the end of July that to further validate the full data flow from the sensor to the SOS server.

B. Optical sensors

The first validation campaign for optical sensors, in this case the O1 MiniFluo, was carried out in a series of measurements at the end of 2015 and throughout 2016. The locations were offshore Marseille in France and at the Troll oil field in Norwegian waters. The O1 MiniFluo sensor integrated in the Seaexplorer glider from ALSEAMAR. In the first campaign, the glider was towed in sub-surface and 4 water samples were collected along the path. These samples were

analysed in laboratory and their total Phe concentration (main compounds + alkylated derivatives) was determined by gas chromatography coupled with mass spectrometry (GC-MS) analysis. These measurements were used to determine an in situ calibration constant (slope of the linear fit between MiniFluo output signal and compound concentrations), and from which the full Phe-like (Phenanthrene) time series is derived (Figure 6). These results showed a good fit between lab tests and campaign measurements.

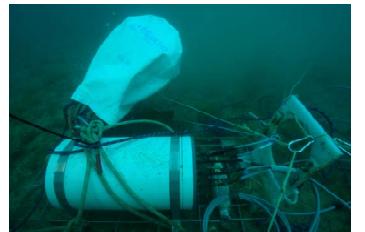


Fig. 3. A2 master unit at Obsea

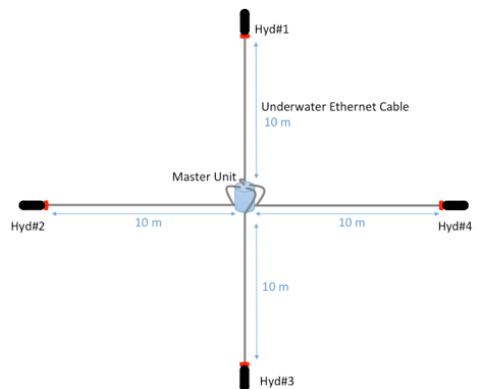


Fig. 5. A2 geometrical set up of the array

The second campaign in Norwegian waters showed that coherent patches of water with different properties were successfully mapped. The measured concentrations of organic constituents were low and their origin (natural or due to offshore activities) uncertain.

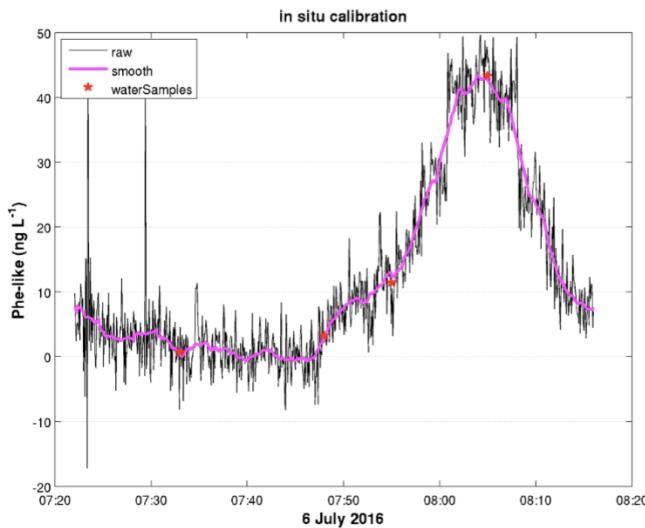


Fig. 6. Inter-comparison between glider-mounted MiniFluo sensor and GC-MS laboratory measurements for the glider mission offshore Marseille. Raw (0.25 Hz) MiniFluo measurements (black line) have been smoothed using a 1mn running mean (magenta line). Water samples were GC-MS analyzed (red stars) and used for in situ calibration and validation of MiniFluo data.

Discrepancies between fluorescence-derived concentrations

and GC-MS measurements are especially important for Naphs, where the MiniFluo overestimated near-surface concentrations by more than a factor 5 (Fig. 9, left panel). This overestimation is reduced when the raw data set is corrected for environmental blank value [5], which is when the minimum value of the relative-unit dataset is subtracted (dashed lines in Fig. 9).

Also, Naphs have the same excitation/emission wavelengths ($\lambda_{\text{Ex}}/\lambda_{\text{Em}}$: 275/340nm) than the Tryptophan, an amino-acid naturally found in water and associated with microbial processes. In the absence of strong hydrocarbon signal (e.g., a significant spill), it is possible that part of the overestimation of Naphs by the MiniFluo is linked to a Tryptophan fluorescence signal. This might explain the overestimation observed in fluorescence-derived Naphs concentrations. Surface Phes concentrations derived from the MiniFluo match surprisingly well those measured by GC-MS (Figure 9, right panel). The latter are however suspicious, especially the near-zero concentrations measured near 10 and 40m. While the fluorescence profile is smooth, discrete GC-MS measurements are rather spiky. Nevertheless, even without a proper calibration on Troll crude oil, MiniFluo captured the bulk part of the Phes signal in the region. Finally, on the 15th of June 2017 the O1 MiniFluo has started its demonstration mission in Norwegian water with the SeaExplorer glider (Fig. 7)



Fig. 7. NOR1-2 mission

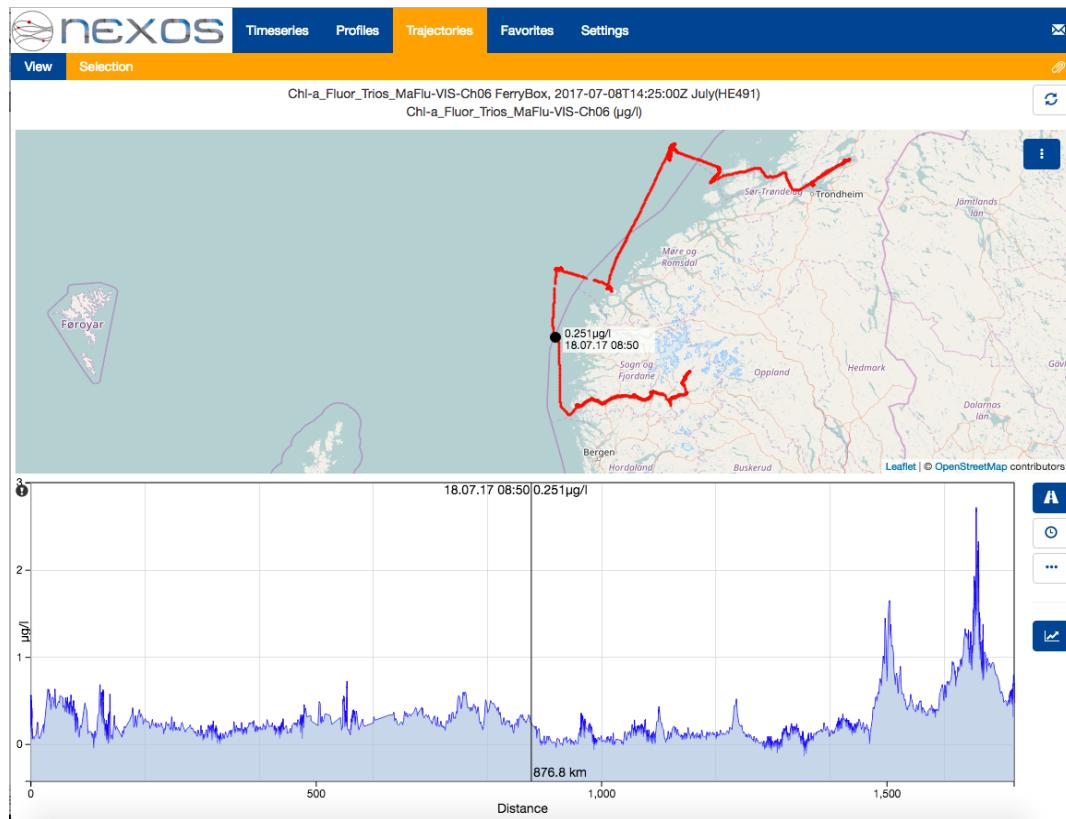


Fig. 8. NOR4 demonstration mission data from O1 MatrixFlu sensor

(equipped also with A1 sensor), following the requirements of the user scenario for Hydrocarbons detections.

O1 MatrixFlu is currently under validation and demonstration on the NOR4 Heincke cruise in Norway that took place in July/August timeframe. A dataflow example of the sensor output to the SOS server can be seen in fig. 8. Experiments regarding the validation of the optical absorption sensor developments O2 were performed during a cruise in the German Bight area of the North Sea In May/June 2017. Both integrating cavity instruments, the OSCAR (TriOS) and the HyAbS (HZG) were operated in flow-through mode and data were obtained continuously in time intervals of 20 and 5 seconds, respectively. Sample water was provided by a FerryBox installation, which was considered as platform for the integrating cavity instruments during the validation and demonstration phases.

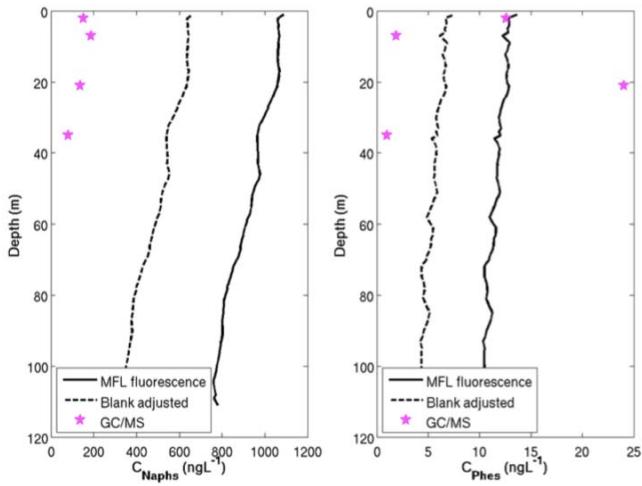


Fig. 9. Comparison between PAHs concentrations derived from MiniFlu measurements and Gas Chromatography / Mass Spectrometry (GC-MS) analyses. Left: Naphthalenes concentrations. Right: Phenanthrenes concentrations. Concentration profiles derived from uorescence using laboratory calibration on water accommodated fraction (WAF) of Maya petroleum are drawn in solid black.

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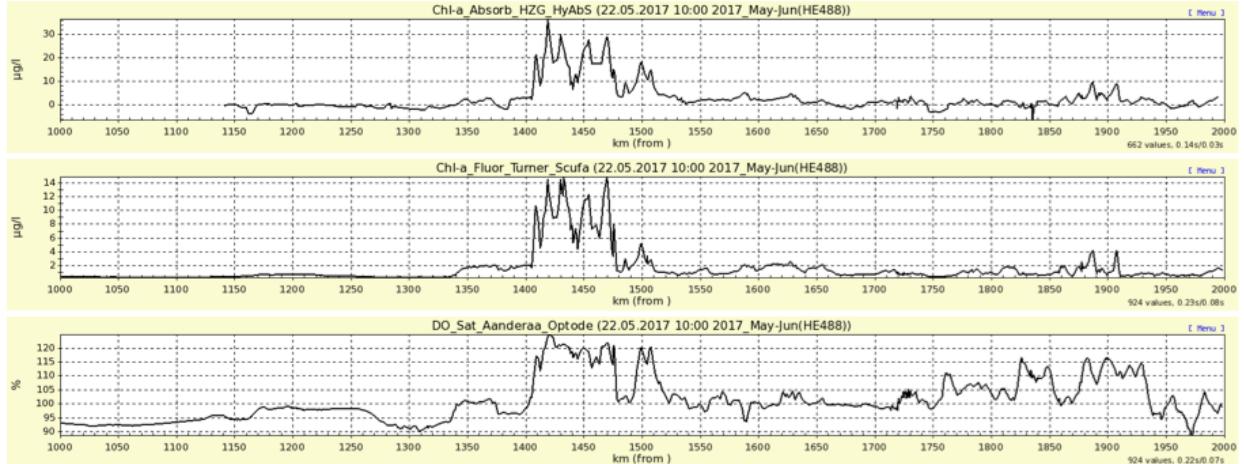


Fig. 10. Chlorophyll-a estimated on the basis of absorption spectra measured by the HyAbS (upper panel) and chlorophyll-a fluorescence (mid panel). The lower panel shows the saturation of the water with oxygen, indicating also the presence of primary producer biomass.

OSCAR was calibrated manually once a day using nigrosin dye solution. The HyAbS was running completely autonomous, performing solid standard calibrations automatically approximately every 60 min. Only the container with the reference solution (purified water) had to be refilled once a day. As proposed during the planning of the validation, the data from OSCAR were stored internally and then processed following the cruise. The HyAbS data were stored within the instrument itself, but the biological relevant parameters (chl-a, total suspended matter, phytoplankton group information) that were derived from the calculated absorption coefficient spectra were in addition successfully transferred to the FerryBox. From there, these data together with the other FerryBox data were transferred as 3 min averages in real-time to the FerryBox database at HZG via satellite communication. Data could be visualized via the SOS server after transferring the data from the incoming survey database to the FerryBox database for fixed routes connected to the SOS-server. To the time of this report, the data of the validation cruise are being evaluated. Only observations made on the non-quality controlled data directly transferred to the database are available. As visible in the figure 10, the absorption-based estimation of chl-a was in qualitative accordance with fluorescence-based measurements and oxygen measurements from sensors mounted in the FerryBox, at least in areas with high biomass. In lower biomass areas, the absorption-based chl-a concentrations were occasionally negative. This was the result of an unexpected error in the HyAbS software, which occurred especially at low concentrations of absorbing material. The high biomass areas were according to preliminary microscopic investigation often dominated by the colony-forming haptophyte *Phaeocystis* sp. At least in the core areas of the blooms, the phytoplankton identification algorithm implemented in the HyAbS software also found this phytoplankton group. Although a real validation of the performance of the algorithm requires a comparison with the microscopic data, these preliminary results can be considered as promising. Fig. 11 shows a snapshot of the O2 data sent to the SOS during the on-going demonstration mission in Norway on-board of the FerryBox Heincke Cruise.

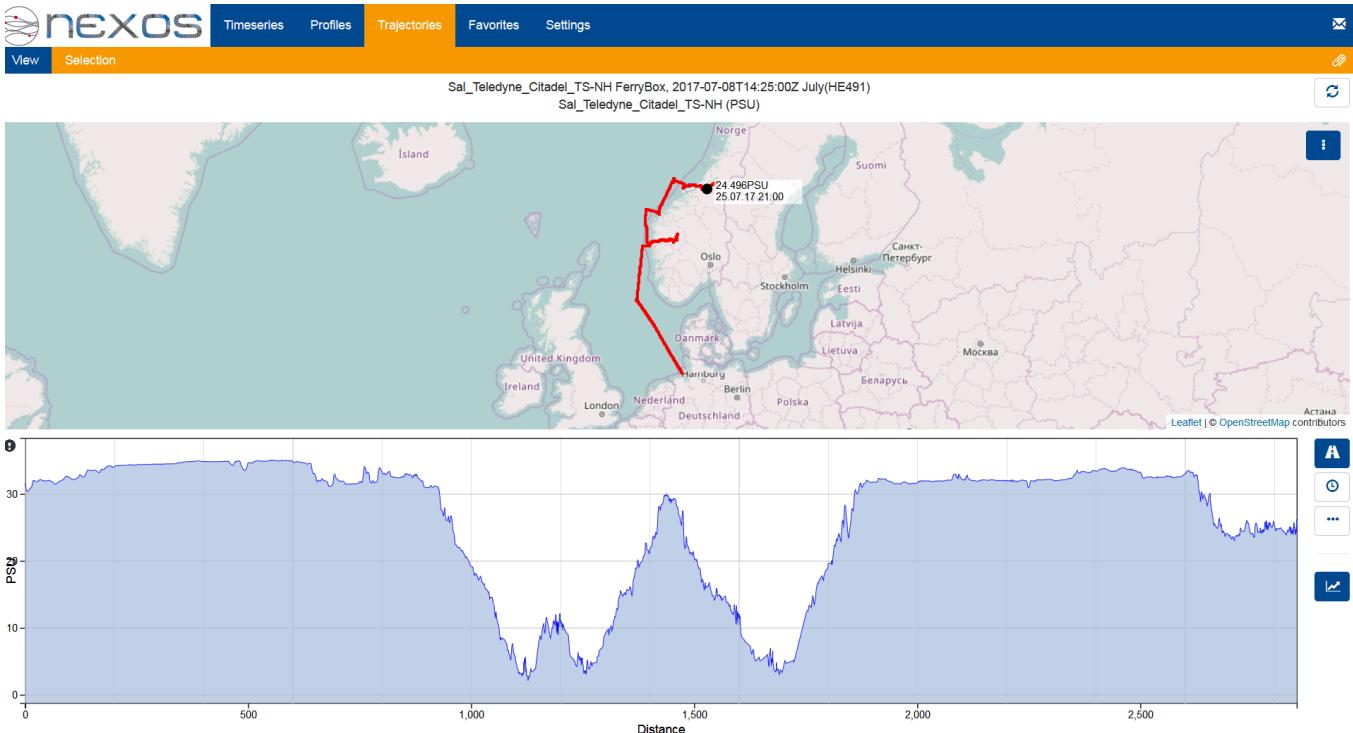


Fig. 11. NOR4 demonstration mission ongoing results for O2 sensors

O₃ Cbon2-sv sensor mounted on a CMR Sailbuoy was validated in Norwegian waters in April 2017 in the Vestrepollen near Hjellestad, an inlet off the ocean. The testing was run for about three hours and data of both pH and pCO₂ were collected (Fig. 12). Data measured were compared with discrete samples taken in situ, DIC/TA analysis with analytical laboratory. During the measurements there were rapid and intense changes in the weather that may have impacted the locally measured values. The intake for the sensor was near the surface but it should be located at the bottom of the keel for a more stable sampling environment. Experience is showing that

the system needs warm-up because it operates at a temperature set point. In addition to the sampling of the NeXOS sensor, water samples were taken for comparison and calibration. O₃ sensor provided a reading of pH=8.159 reported at S=27.8 psu and 8.33 °C, that was the temperature inside the cuvette. In situ T was 7.1 °C,

Total Alkalinity: 1913.8 μmol/kg and Dissolved Inorganic Carbon: 1746.2 μmol/kg. DIC report pH to 7.1 °C (in situ temperature) and obtain in situ pH: 8.178±0.003. O₃ sensor

provided a reading of pCO₂=192±2 ppm. Measures were taken within an area dominated by coastal runoff (S<30) and, likely, with heavy influences by organic alkalinity. The instrument measured pH outside the salinity range (Cbon2 is rated for 40psu>S>30 psu) and pH data were reported to in-situ salinity using the pK of the indicator provided by literature. Using measured DIC from discrete sample and measured pH from O₃, with the same equations used above, TA=1906.3 μmol/kg. O₃ Measured TA is in excess of 7.5 μmol/kg. According to [6] in a controlled mesocosm experiment, a mean value of 10 μmol/kg contribution from organic alkalinity was estimated. Regarding the pCO₂, the value reported to 7.1 °C is 244.8, further higher than the one measured. The reasons of this shift are currently investigated with a copy of the sensor that was deployed. Fig. 13 shows the dataflow to the SOS server during the validation mission.



Fig. 12. O₃ validation mission, April 2017



Fig. 16. EAF sensor installed in the FOOS

C. EAF sensors

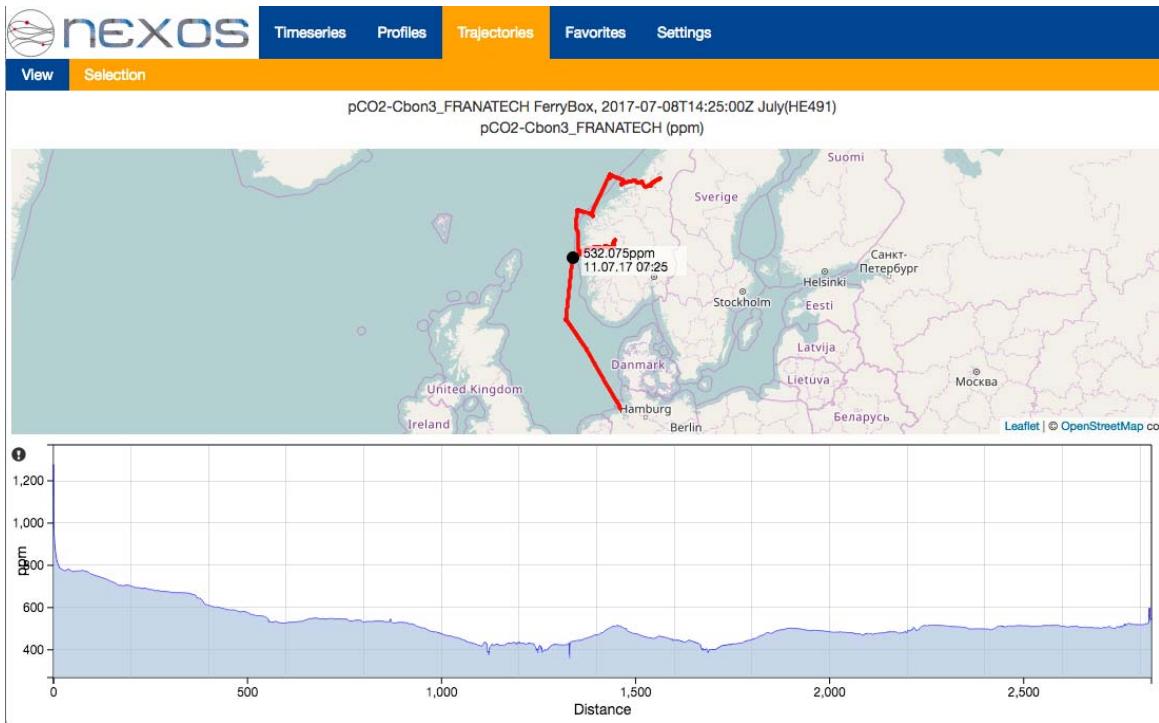


Fig. 13. O3 dataflow to SOS server during validation mission

Validation tests were carried out by CNR ISMAR on-board of the research Vessel Dallaporta in December 2016 in the Adriatic sea (Mediterranean sea) during an oceanographic cruise, in order to make a validation through comparison with

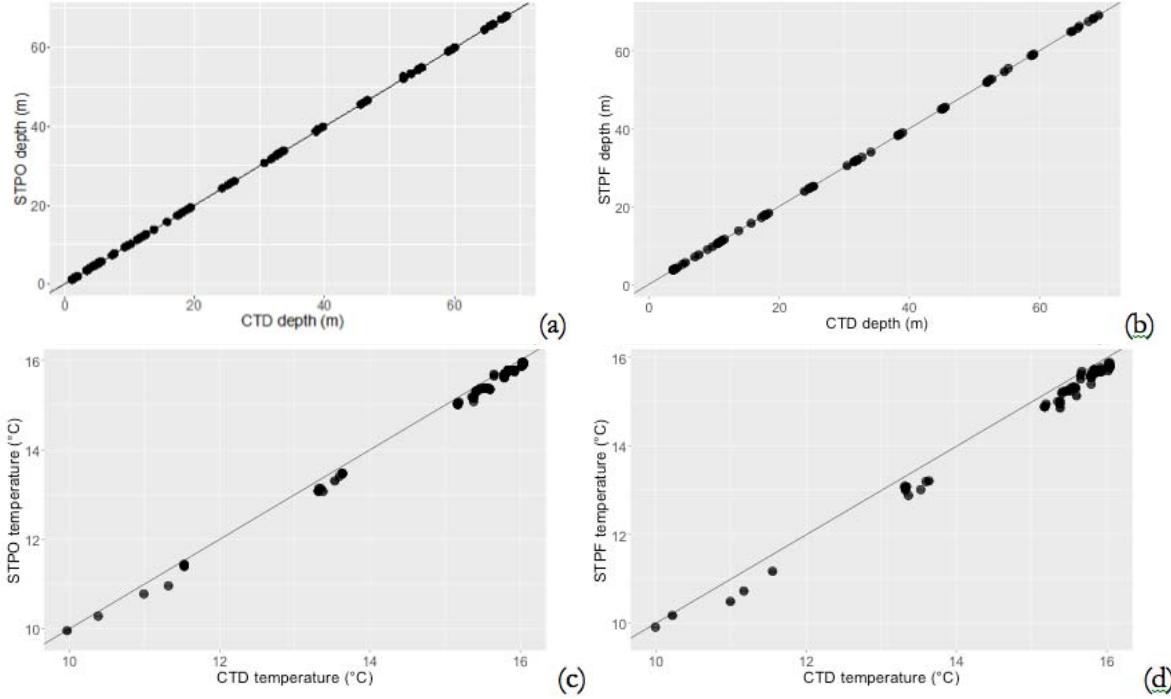


Fig. 14. Comparison between the depth values of sensor NKE in comparison with the closest values recorded by CTD: in (a) the comparison pertinent to the oxygen measurements (STPO), in (b) the comparison pertinent to the fluorescence measurements (STPF). In (c) and (d), the comparison between the temperature values of the NKE sensor and CTD at the depths shown in (a) and (b). In all the plots, the solid line represents the identity $y=x$.

commercial sensors by parallel profiling of the water column. During the cruise, two prototypes were simultaneously tested with a calibrated CTD instrument (Conductivity Temperature Depth) for 7 times following [7]. Data on the water column characterising parameters were collected by means of a SeaBird Electronics SBE 911-plus CTD equipped with a SeaBird SBE43 oxygen sensor, Wetlabs ECO NTU turbidity sensor (Nephelometric Turbidity Unit-NTU) and Wetlabs ECO-AFL fluorimeter. The 24 Hz CTD data were processed according to UNESCO (1988) standards, and pressure-averaged to 0.5 db intervals.

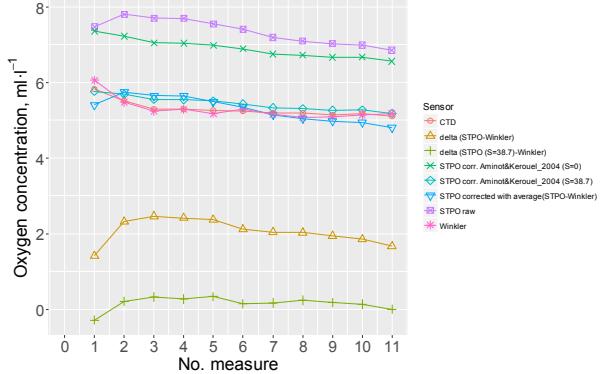


Fig. 15. Comparison between the O_2 of the different sensor reading (STPO, CTD) and Winkler measurements. The values of the raw O_2 reading of STPO were also corrected according to the eq. of Amino and Kerouel (2004) for salinity =0 and =38.7. Some deltas, i.e. reading differences, are also shown.

Water samples were collected on the upcasts by means of a SeaBird Carousel rosette water sampler equipped with 10-l Niskin bottles (25 water samples were collected and analysed for chlorophyll concentration, 13 samples were collected and analysed for oxygen concentration at suitable depths). Dissolved oxygen was directly analysed on board according to [8], and samples were immediately fixed and stored in the dark and analysed within 24 h using the potentiometric method [8].

Chlorophyll-*a* was measured by filtering 1-3 liter samples through 47 mm GF/F filters and immediately extracted with 5 ml of acetone at -22°C . The analyses were carried out in the CNR ISMAR laboratory with a Dionex UHPLC equipped with a UltiMate 3000 RS pump, a PDA100 Photodiode Array Detector (wavelength range: 190–800 nm), a RF 2000 Fluorescence Detector (wavelength range: 200–650 nm), a C18 reversed phase column (4.6 mm x 150 mm, 3 μm particle size), an ACC3000 Autosampler and a 100 μl sample injection loop. Cholorophyll *a* concentrations were determined using a modification of the procedure [8]. To properly compare the oxygen and fluorescence data measured by the two prototypes with the measurements obtained by means of CTD and of analytical methodologies, an alignment of the data respect to depth was necessary. Measurements for comparison were therefore chosen taking into account that the depth value was as close as possible for the 3 techniques (e.g. not always the recorded values were collected exactly at the same time by the instruments, due to different response time/setup).

In Fig. 14a and 14b, the plot of measure depths of sensor

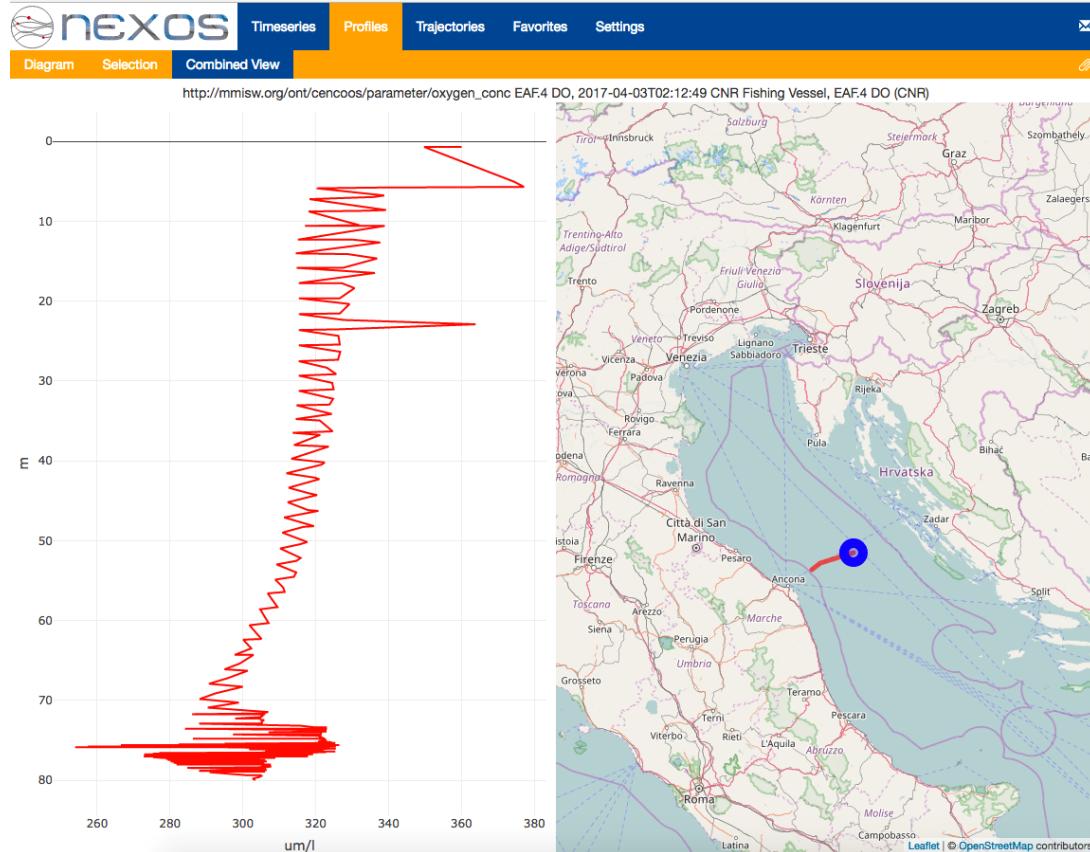


Fig. 17. NeXOS SOS screenshot from EAF demo mission

NKE as function of the relative CTD depths is shown. The agreement is very good and slight offset can be instead observed for the temperature reading between the NKE and CTS sensor, Fig. 14c and 14d. By default, the O₂ measure of the NKE sensor are calculated for a salinity=0. However, when a value of salinity of 38.7 is used, which is an average value for the Adriatic Sea salinity, the NKE reading is much closer to the CTD reading and Winkler measurements, as can be seen in Fig. 15. This validation process was crucial to prepare for the demonstration phase that started in May 2017, in which the EAF sensors integrated in the Fishery and Oceanography Observing System (FOOS) (Fig. 16) worked automatically, recording and sending near real time data to the NEXOS datacentre during every fishing day until the end of the project (Fig. 17). Complementary demonstration activities are ongoing in a Norwegian fishing vessel offshore the Norwegian coast.

D. Antifouling Technology

To demonstrate the antifouling system, an underwater station has been developed and has been deployed on the seabed in St-Anne-du-Portzic bay close to the Ifremer Bretagne Centre. The deployment has been performed at a depth around 20 meters and sea temperature range from 8°C up to 17 °C. The demonstration structure is equipped with 4 fluorometer sensors TriOS MicroFlu-chl, one D-Link camera and one biofilm sensor A10KSU from ALVIM. The fouling protection efficiency was monitored during at least 3 months and was “measured” up to the fluorescence measurement produced by the fluorometer sensors (presence or not of a shift or bias), by the camera observation and by periodic divers observations. A final inspection (photos) shows as well the antifouling efficiency. The ALVIM efficiency was measured in terms of energy economy obtained by the reduction of the rate of active antifouling cycles. After 4 months of testing (from July to November 2016) at sea, the results obtained in terms of biofouling protection are very promising and in accordance with the preliminary tests run at IFREMER. As shown in the figure 18, the windows remain clean and fully operational for proper fluorescence measurement as long as the SnO₂ coating is properly operated. During the same period, the unprotected sensor shows fouling progress all over the transducing interface. One can notice that the design of the flat porthole with optical windows on the same plan as the enclosure should be done very careful. Indeed on the figure, it is possible to see slight fouling development on the edge of the porthole. It confirmed that fouling is developing more easily on mechanical edge and holes rather than on flat surfaces. The ALVIM biosensor has allowed a reduction by 6 of the energy needed to get a total antifouling protection.



Fig. 18. Antifouling system applied to optical sensor submerged in natural seawater for 4 months in France. Left – unprotected; Right - protected

III. CONCLUSION

The NeXOS Project developed different innovative sensor technologies that allow improvements of the temporal and spatial resolution of the marine environment. Results of the Project offer significant advantages over existing systems, not only from the perspective of performance, but also from the capability to be easily integrated into a wide variety of platforms. The platforms during the validation phase include research ships, ferries, profiling floats, gliders, wave gliders, fixed buoys and SailBouys. Each of the interfaces is slightly different, but the use of a programmable interface, PUCK, and a smart sensor interface common to all new NeXOS sensor systems are key to improved adaptability. This interoperable standard interface is reconfigurable to respond to sensor specificities and monitoring strategies, with connectivity envisioned to the majority of ocean observing platforms.

Initial results of validation and demonstration have been reported in this paper and provision of the data is planned for contribution to a sustainable archive to have a reference for further development and production systems.

ACKNOWLEDGMENT

Work represented was funded by project NeXOS (Grant Agreement No. 614102) under the call FP7-OCEAN-2013.2 from the EU Commission as part of the 7th Framework Program, “The Ocean of Tomorrow” topic 2. The authors acknowledge and thank the many partners on the NeXOS project who have contributed to the successful outcomes.

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