We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900
Open access books available

185,000
International authors and editors

200M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com



2

New Technological Developments for Oceanographic Observations

Marco Marcelli, Andrea Pannocchi,
Viviana Piermattei and Umberto Mainardi
University of Tuscia, Laboratory of Exerimental Oceanology and Marine Ecology
Italy

1. Introduction

Measurement is the foundation of any branch of science, and no less so in oceanography (Thorpe, 2009).
Radical changes in early instruments that were largely mechanical, have been realized due to electronic, computing and data transmission advances.
These advances produced new ways in oceans observing and monitoring which improve operational and forecasting oceanography to better understand the oceans.
Operational forecasting of marine physical and biochemical state variables is now becoming an important tool for modern management and protection of the oceans and their living resources (Marcelli et al., 2007).
Despite all these rapid advances in ocean measuring capabilities, the number of variables necessary to solve oceanographic problems is still big and increasing, generating a continuous gap between the available instruments and what we want to measure.
In addition, the time and space scales of key processes span over ten orders of magnitude; to solve the risk of undersampling it is necessary to expand the rates of data acquisition, temporal coverage and spatial coverage.
The recent advances in ocean monitoring system and new sampling strategies will going to face all these problems. This modern approach is based on the use of in situ autonomous sampling together with satellite observations, integrating SOOP (Ship Of Opportunity) monitoring programs. Moreover, programs like the Pan European Seadatanet (www.seadatanet.org) are set up to promote the use of common vocabularies in datasets in order to allow interoperability and data exchange.

2. State of the art

Oceanographic investigations, traditionally, are both limited and strictly dependent by time and space scales and by sensors technological developments (Dickey & Bidigare, 2005).
To observe oceanographic phenomena and processes, several and different methods can be utilized providing different results.
Even if some methods still have remained almost unvaried, even if they have been improved and perfectioned (as for example the continuous plankton recorder, CPR), in many cases, technological developments lead us to a noteworthy advancing of the knowledge of processes and phenomena, formerly undetectable and just intuitable.

2.1 Platforms and sensors

Relating to a defined phenomena, observation has to be carried out with the appropriated method in order to detect processes and trends of such phenomena. To this aim, platforms and sensors have to be choose as in respect to the time and space scale of the phenomena, as taking into account the nature (e.g. chemical, physical or biological) of what we are looking to (Dickey & Bidigare, 2005). The environment (e.g. shallow water, deep sea or coastal areas) is also fundamental to the choice of the adequate sampling sensors and operative methods.

Many physical, chemical and biological aspects can be described by means of punctual observations, e.g. stand alone moored instruments or oceanography buoys and multi-purpose platforms. Also, dedicated oceanographic surveys can be set up in order to study a particular aspect of a defined marine area.

In order to reduce operative costs and to enhance spatial resolution of data for water column characterization, towed vehicles can be utilized to continuous measure of physical, chemical and biological variables, along water column and along horizontal trajectories. Also the use of expendable probes and the ship of opportunity, are fundamental to this aim.

From an operative point of view, observation platforms can be divided basically into the following categories:

Ships (Research Vessels RV);

Mooring;

Underwater vehicles and lowered devices (Remote Operated Vehicles ROV; Towed Vehicles; Crewed Deep Submersible Vehicles; Autonomous Underwater Vehicles; Gliders; Lagrangian buoys; Expendable probes; Drifters)

Voluntary Observing Ships (VOS);

Remote sensing platforms (Airplains and Satellites);

2.1.1 Ships

Oceanographic research vessels can be considered shipborne platform as they can be utilized to conduct many kind of scientific investigations, such as mapping and charting, marine biology, fishery, geology and geophysics, physical processes, marine meteorology, chemical oceanography, marine acoustics, underwater archaeology, ocean engineering, and related fields (Dinsmore, 2001 in Thorpe, 2009).

The United Nations International Maritime Organization (IMO) has established a category of Special Purpose Ship which includes ships engaged in research, expeditions, and survey. Scientific personnel are also defined as "persons who are not passengers or members of the crew, who are carried on board in connection with the special purpose" (www.imo.org).

The design of a modern Research Vessel can vary significantly in respect to the research activities. Typical caracteristics can be as follow described:

a. RV have to be as general as possible in order to allow multidisciplinary studies and researches;
b. the size is determined by the requirements, but the length-over-all should not exeed 100 m LOA;
c. speed of 15 knots cruising should be sustainable through sea state 4 (1.25–2.5 m) and the seakeeping should be able to maintain science operations in the following speeds and seastates:

- 15 knots cruising through sea state 4 (1.25– .5 m);
- 13 knots cruising through sea state 5 (2.5–4 m);
- 8 knots cruising through sea state 6 (4–6 m);

- 6 knots cruising through sea state 7 (6–9 m).

d. Work environment: lab spaces and arrangements should be highly flexible to accommodate large, heavy, and portable equipments.
e. Suite of modern cranes, in order to reach all working deck areas and offload vans and heavy equipment, and in order to work close to deck and water surface.
f. Oceanographic winches permanently installed should provide a wire monitoring systems with inputs to laboratory panels allowing local and remote data and operational controls.

The above general characteristics, can be modulate relating to the particular purpose of the vessels itself.

Therefore it is more convenient and appropriate divides RV in the following categories:

General Pourpose Vessels

Multidiscipline Ships represent the classic oceanographic research vessels and are the dominant class in terms of numbers today. Current and future multidiscipline oceanographic ships are characterized by significant open deck area and laboratory space. Also accommodations for scientific personnel are greater than for single purpose vessels due to the larger science parties carried. Flexibility is an essential feature in a general purpose research vessel.

Mapping and Charting Vessels

These group of ships were probably the earliest oceanographic vessels, traditionally involved in exploration voyage. Surveys were carried out using wire sounding, drags, and launches. Survey vessels are also characterized by less deck working space than general purpose vessels. Modern survey vessels, however, are often expected to carry out other scientific disciplines. Winches, cranes and frames can be observed on these ships.

Fisheries Research Vessels

Fisheries research generally includes studies on environment, stock assessment, and gear testing and development.

The first of these are carried out by traditional surveys to collect biological, physical, and chemical parameters of sea surface and water column as well as geological informations. These surveys can be accomplished from a general purpose oceanographic research vessel.

Geophysical Research Vessels

The purpose of marine geophysical research vessels is to investigate the sea floor and sub-bottom, oceanic crust, margins, and lithosphere ranging from basic research of the Earth's crust to resources exploration. The highly specialized design requirements for a full-scale marine geophysics ship usually precludes work in other oceanographic disciplines.

Polar Research Vessels

Polar research vessels are defined by their area of operations. The special requirements defining a polar research vessel include increased endurance, usually set at 90 days, helicopter support, special provisions for cold weather work, such as enclosed winch rooms and heated decks, and icebreaking capability.

Support Vessels

These include vessels that support submersibles, ROVs, buoys, underwater habitats, and scientific diving.

Other Classes of Oceanographic Research Vessels

Into this category it can be include research ships which serve other purposes as ocean drilling and geotechnical ships, weather ships, underwater archaeology, and training and education vessels.

2.1.2 Moorings

Much of what we know about the oceans processes is the result of ship-based expeditionary science, dating back to the late 19th century.

It is clear that, to answer many important questions about oceans and Earth science, it is necessary a co-ordinated research effort based on long term investigations (Favali & Beranzoli, 1996).

One of the most important aspect of sea investigation, in fact, deals with the possibility to obtain continuous data from fixed stations or from a net of fixed stations, fundamental for forecasting systems (coupled with meteorological data and time data series).

Mooring platforms, both for upper and deep water, allow continuous observations of phenomena of very different disciplines like geophysical and biological once. World wide initiatives and programs, such as European Seafloor Observatory Net (ESONET NoE) and the European Multidisciplinary Seas Observatory (EMSO) have been developed in order to increase the capacity in the research, with the purpose of better understanding of physical, geological, chemical, ecological, biological and microbial processes, that take place in the oceans: from the surface down to the highest depth.

Much of our latest knowledge, infact, stems from studying the seafloor: its morphology, geophysical structure, and characteristics, and the chemical composition of rocks collected from the ocean floor.

Furthermore, in the late 1970s, at the midocean ridge (MOR) crest, deep sea biological observations led to the discoveries of deep sea 'black smoker' hydrothermal vents and to their chemosynthetic-based communities.

Such discovery changed the biological sciences, provided a quantitative context for understanding global ocean chemical balances. Deep sea observatory are also fundamental in the study of the physical oceanography of the global ocean water masses and their chemistry and dynamics (Moran, 2009 in Thorpe, 2009).

Traditionally, fixed platforms consist of one surface buoyant unit moored on sea bottom by means of an instrumented chain. Most often surface unit is equipped with meteorological sensors, while along the chain (from the surface till the bottom) are mounted many different sensors in order to collect water column variables.

A mooring design can vary relating both to the kind of investigation and to physical characteristics of the environment of destination (coastal or open ocean).

Fixed measurement platforms have the following features and play the following roles:

1) Stand alone data collecting system allowing real time or quasi-real time data acquisitions and transmission

Surface platforms are traditionally able to store sampled data into an internal storage devices, and most often they are equipped with a communication system that allows data transmission to data centers. Typical systems involve satellite (open ocean), GSM or H3G phone systems but also radio, ethernet or LAN communication can be utilized.

2) Operational forecasting system

Continuous data coming from a buoy or a buoy network provide fundamental input for ocean and weather forecasting models.

3) Remote sensing calibration system

In situ data can represent the sea-truth for remote sensing as they are provided from standard and calibrated instruments. Because of the high maintenance possibility and the continuos data control, fixed platforms and mooring buoys can serve successfully to this aim. The calibration of a moored buoy, for example, can be ongoing, with retrieval at certain intervals to check sensor degradation and biofouling.

4) Data network

The importance of realizing a network of buoys is related to the possibility to put all the information of each platform together, in order to provide an even more rich data base. It is necessary not only for the oceanographic research and monitoring, but also for climate and global change investigations.

Following there are reported some of important buoy networks.

a) An important example is represented by the United States National Data Buoy Center (NDBC). In the 1960's, there were approximately 50 individual United States programs conducted by a variety of ocean-oriented agencies. These programs were consolidated into the National Data Buoy Center under the control of the US Coast Guard. Nowadays the United States NDBC manages the development, operations, and maintenance of the national data buoy network. It serves as the NOAA focal point for data buoy and associated meteorological and environmental monitoring technology. It provides high quality meteorological/environmental data in real time from automated observing systems (www.ndbc.noaa.gov).

It also manages the Volunteer Observing Ship (VOS) program to acquire additional meteorological and oceanographic observations supporting the NOAA National Water Service (NWS) mission requirements. It operates the NWS test center for all surface sensor systems. It maintains the capability to support operational and research programs of NOAA and other national and international organizations.

b) The Australian National Moorings Network of the Integrated marine Observing System (www.imos.org.au) comprises a series of national reference stations and regional moorings designed to monitor particular oceanographic phenomena in Australian coastal ocean waters.

Nine national reference stations are located around the Australian coasts in order to provide a baseline informations, decadal time series of the physical and biogeochemical properties of Australia's coastal seas, to inform research into ocean change, climate variability, ocean circulation and ecosystem responses.

Each National Reference Station consists of a mooring with sensors for conductivity, temperature, depth, fluorescence, dissolved oxygen, photosynthetically available radiation (PAR), fluorescence and measurement of turbidity at three depths: the surface, seabed and an intermediate depth. On the seafloor, acoustic doppler current profilers (ADCPs) are also deployed. All reference stations telemeter a reduced data set via Iridium satellite for real time monitoring. Boat-based water sampling is also undertaken at each of the reference stations on a monthly basis. These samples are analysed for nutrients, plankton species, both visibly and genetically, and pCO2.

A number of the National Reference Station moorings are also equipped with passive acoustic listening arrays, containing sea noise loggers to record sounds in the ocean. Furthermore, three National Reference Stations are equipped with three instruments determining surface CO2, dissolved oxygen, temperature and salinity.

Regional moorings can measure physical, chemical and biological parameter of sea water. These moorings can hold a range of instrumentation including acoustic doppler current profilers (ADCPs), Water Quality Meters (WQMs), fluorometers, instruments to measure turbidity, dissolved oxygen, photosynthetically active radiation (PAR), nutrients, pCO2, dissolved inorganic carbon, total alkalinity, as well as imaging flow cytometetry, spectroradiometry, profiling conductivity-temperature-depth instrumentation, laser In- situ scattering and transmissometry.

The regional moorings monitor the interaction between boundary currents and shelf water masses and their consequent impact upon ocean productivity and ecosystem distribution and resilience. Operation of the moorings network facility is coordinated nationally and distributed between several sub-facilities.

d) The Italian National Mareographic Net (RMN) was set up by the National Mareographic System. It consists of 33 measuring stations uniformly positioned throughout the entire national seas.

The main feature of Italian RMN is the measure of sea level. Each buoy is equipped with a sea level microwave sensor coupled with another one level sensor with back-up function. In addiction there is the traditional ultrasound hydrometric sensor working since 1998. Each buoy also carries a meteorological station and a sea water temperature sensor. Ten buoys are equipped with a multiparametric probe in order to measure temperature, pH, conductivity and redox parameters.

All data collected are available for historical series updates, real time observations, astronomical tides forecast and for scientific investigations. (www.mareografico.it).

Other important examples are represented by the deep sea observatories.

a) The Circulation Obviation Retrofit Kit (CORK) is a seafloor observatory that measures pressure, temperature, and fluid composition, important parameters for the study of the dynamics of deep-sea hydrologic systems. CORKs are installed by the International Ocean Drilling Program (IODP) for measurements over long periods of time (months to years) (Moran, 2009in Thorpe, 2009)

b) The MARS Observatory of Monterey Bay Aquarium Research Institute (MBARI) is the first deep-sea ocean observatory offshore of the continental United States and cosists of a metal pyramid on the seafloor off the coast of Central California at 900m depth. Working since 2008, it is involved in the FOCE experiment (Free-ocean carbon dioxide enrichment) to study the effects of increased carbon dioxide concentrations in seawater on marine animals (www.mbari.com). The heart of observatory consists of two titanium pressure cylinders packed with computer networking and power distribution equipment. These cylinders are nested within a protective metal pyramid on the deep seafloor. This central hub is connected to shore by a 52-kilometer-long cable that can carry up to 10,000 watts of power and two gigabits per second of data. Most of the cable is buried a meter below the seafloor.

c) The Ocean Observatory Initiative (OOI), a project funded by the National Science Foundation, is planned as a networked infrastructure of science-driven sensor systems to measure the physical, chemical, geological and biological variables in the ocean and seafloor (www.oceanobservatories.org). The OOI will be one fully integrated system collecting data on coastal, regional and global scales. Three major Implementing Organizations are responsible for construction and development of the overall program. Woods Hole Oceanographic Institution and its partners, Oregon State University and Scripps Institution of Oceanography are responsible for the coastal and global moorings and their autonomous vehicles. The University of Washington is responsible for cabled seafloor systems and moorings. The University of California, San Diego, is implementing the cyberinfrastructure component. Rutgers, The State University of New Jersey, with its partners University of Maine and Raytheon Mission Operations and Services, is responsible for the education and public engagement software infrastructure.

The OOI will consist of six arrays with 56 total moorings and 763 instruments. Moored platforms (Fig.1) provide oceanographers the means to deploy sensors at fixed depths

between the seafloor and the sea surface and to deploy packages that profile vertically at one location by moving up and down along the mooring line or by winching themselves up and down from their point of attachment to the mooring.
An oceanographic mooring is anchored to the sea floor by a mooring line extending upward from the anchor to one or more buoyant floats, which can be located in the water column or at the sea surface.

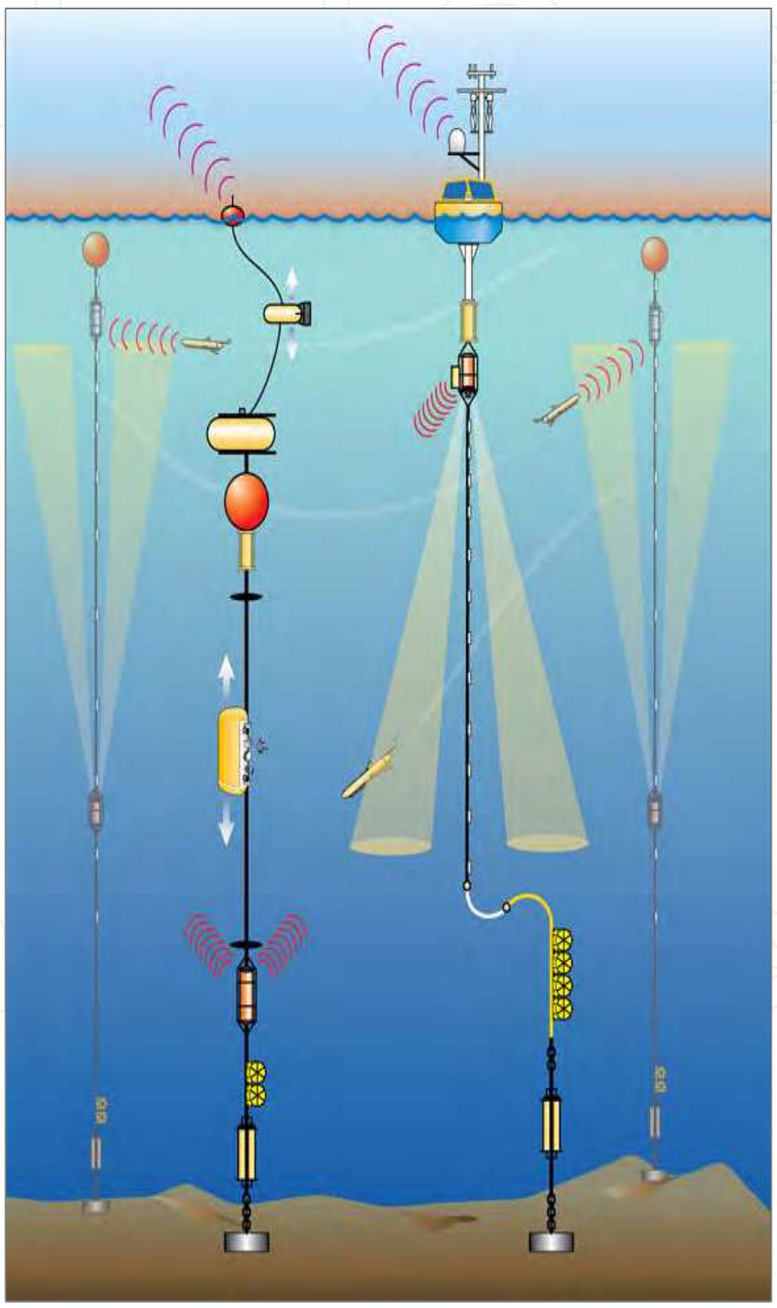


Fig. 1. Ocean Observatory Initiative moored platforms. (Credit: Jack Cook, Woods Hole Oceanographic Institution)

2.1.3 Underwater vehicles and lowered devices

Underwater vehicles can be considered as platforms that combines the advantages of a ship-mounted instruments collecting data while moving, and a lowered device that profiles the water column.

Underwater Vehicles can be divided into three categories related with their moving capabilities: towed, remoted operated and autonomous. Traditionally they are called Towfish or Towed body, ROV and AUV respectively.

Towed vehicles

A towed vehicle system has three main components: the vehicle, the tow cable and a winch. Vehicles, with their instrument payload, represent the measurement platforms. The cable, whenever double-armored (electromechanical) can be considered the principal part of the towfish. Cable is responsible for power and data trasmission, but, above all, because of its total cross sectional area, cable drag dominates the performance of the system.

Towed-vehicle systems using electromechanical cables usually require a special winch with accurate spooling gear and slip-rings to make the electrical connection to the rotating drum. The faired cable has a large bending radius and can only be wound onto the winch drum in a single layer. If the towed vehicle system uses wire rope for the tow cable, then the winch can be a standard type (Helmond 2001, in Thorpe, 2009).

Towfish payload can be different one to each other relating to the field of investigation.

Typical instrument payloads can be CTDs added with specific sensor (i.e. pH and fluorometer) required for traditional hydrological studies. Acoustic devices and biological sampler can be mounted on "ad hoc" designed towed body.

One of the most important towed vehicle for biological sampling was designed by Sir Alister Hardy in 1925, and until now it is remained relatively unchanged in its sampling mechanism (Richardson et al., 2006). Called Continuous Plankton Recorder, (CPR) this towfish is able to collect and stock zooplankton samples continuously while it is towed from a ship (Fig. 1a.).

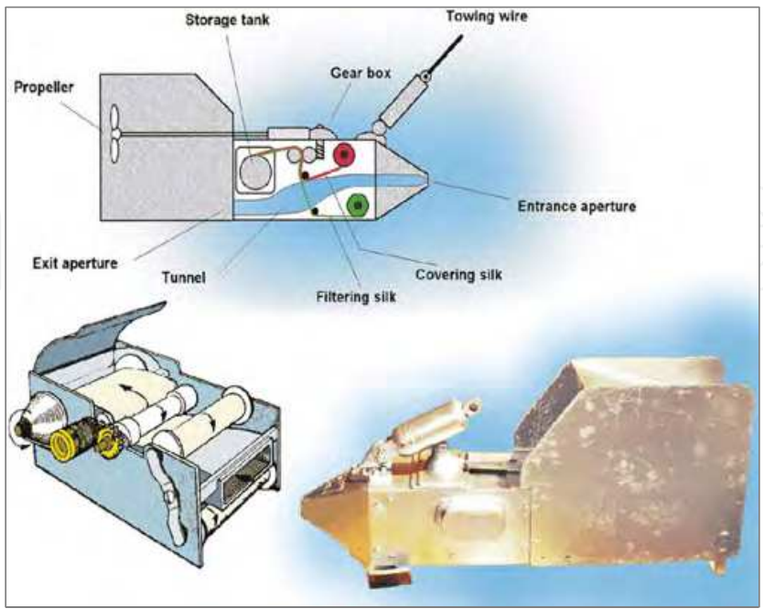


Fig. 1a. Continuous Plankton Recorder (Richardson et al., 2006).

The continuous plankton recorder (CPR) survey is the largest multi-decadal plankton monitoring programme in the world (Richardson et al., 2006). Since the prototype was deployed, until 2004, over 4 000 000 miles of towing have resulted in the analysis of nearly 200 000 samples and the routine identification of over 400 species/groups of plankton, used to study biogeography, biodiversity, seasonal and interannual variation, long-term trends, and exceptional events (John 2001, in Thorpe, 2009). Another and notably CPR most important aspect is the ability to collect hundreds of samples throughout an ocean basin because it is can be towed behind ships of opportunity (SOOPs) at their conventional operating speeds of 15–20 knots.
Recently, at the Woods Hole Oceanographic Institution (WHOI), was designed and realized a Bio-acoustic system, the BIOMAPER II (Wiebe et al. 2002). In its original conception BIOMAPER II (Fig.1b) was designed primarily for acoustic monitoring of plankton and includes both up- and down-looking acoustic transducers of different frequencies, as well as a suite of conventional environmental sensors (including conductivity, temperature, pressure, chlorophyll fluorescence and beam transmission). The upgraded vehicle has been integrated with a pair of dual path absorption and attenuation meters (AC-9, Wet Labs, Inc.), one for whole water and the other for a filtered fraction (0.2 Pm), and two spectral radiometers (OCI/OCR-200 series, Satlantic, Inc.) for measuring downwelling irradiance and upwelling radiance. The BIOMAPER II is particularly well suited to assessment of apparent optical properties during towed operation because the vehicle is designed to maintain a horizontal attitude regardless of flight pattern.

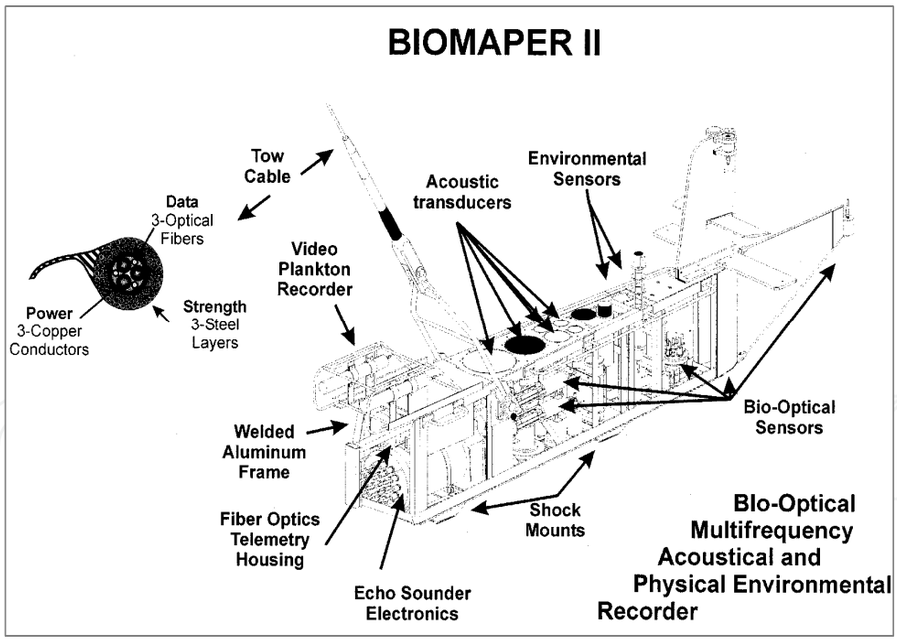


Fig. 1b. BIOMAPER II (Wiebe et al. 2002)

During the 1970s the firsts undulating vehicles were realized at the Bedford Institute of Oceanography (BIO), Canada and the Institute of Oceanographic Sciences (IOS of National Oceanography Centre, Southampton, UK). The BIO Batfish was a variable-depth towed body equipped with a CTD and various other sensors used for rapid underway profiling of the upper layers of ocean.

Its evolution is the SeaSoar (Fig.1c) developed by Chelsea Technologies Group from the original design of IOS. It is a versatile towed undulating vehicle used to deploy a wide range of oceanographic monitoring equipment. Its typical instrumentation payload is a combination of: CTD, Fluorimeter, Transmissometer, Turbidity, Bioluminescence, Irradiance meter, Nitrate/Nitrate sensor, Plankton Sampler, and SeaWifs bands sensors.



Fig. 1c. SeaSoar (www.chelsa.co.uk)

In 1990 the italian underwater undulating vehicle SARAGO (Bruzzi & Marcelli, 1990) (Fig. 2) was planned at ISMES Laboratories in collaboration with University of Tor Vergata, Rome, Italy. Its main objective was to provide quasi-synoptic measurements of ecological and physic-chemical variables in marine environment. Its main application were the basic scientific research, the environmental monitoring and the assessment of biological resources. Therefore it was created a modular system capable to support different instruments and to expand its own working operating capabilities.
SARAGO characteristic payload consists of a SBE 19 CTD for physical variables and a pressure transducer to control depth separately from CTD sensors and a double impulse fluorometer called Primprod 1.11, created in collaboration with the Biophysics Institute of Moscow University. With this configuration, the SARAGO was used in the project PRISMA2 CNR from 1995 to 1998, to continuous measure photosynthetic efficiency and PAR, and to compute high resolution estimations of phytoplankton primary production (Piermattei et al., 2006).

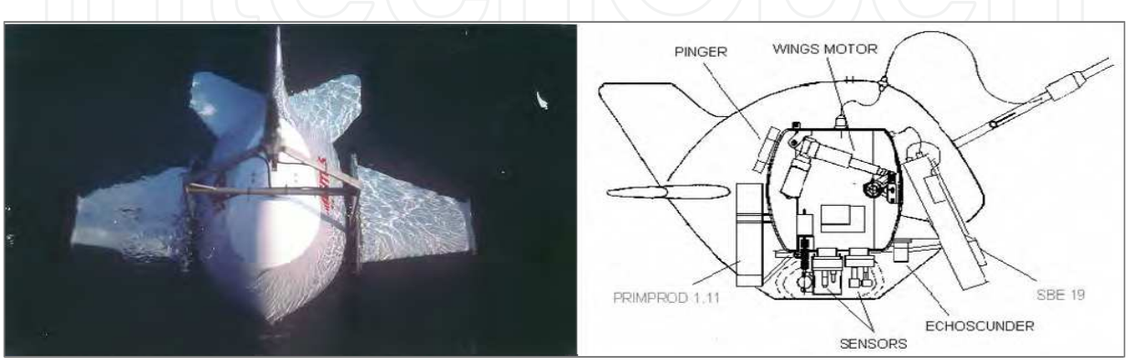


Fig. 2. SARAGO

SARAGO paths are checked by means of a pressure transducer for the wings and a Sonar. The pressure transducer allows to control depth separately from CTD sensors. The sonar works both as a path controller (in case SARAGO is programmed to navigate at constant distance from the bottom) and as a bottom alarm (Marcelli & Fresi, 1997)

A different approach was taken by the researcher of Institute for Marine Environmental Research (IMER), Plymouth, UK. They targeted ships of opportunity with the robust and compact Undulating Oceanographic Recorder. Unlike its predecessors the UOR did not require a multi core tow cable all power being generated by an onboard impeller/alternator thus removing the need for a dedicated research vessel.

The Undulating Oceanographic Recorder UOR Mark 2 is a self-contained, multirole, oceanographic sampler. It is independent of the vessel for any service and can undulate from research vessels and merchant ships at speeds up to 13.5 m. s−1 (26 knots) between the surface to depths of 55 m (at 4 m.s−1) and 36 m (at 10 m.s−1) with a preset undulation length between 800 and 4000 m.

It can record (internally on a miniature digital tape recorder, resolution 0.1% full scale) measurements by sensors for temperature, salinity, depth, chlorophyll concentration, radiant energy, or other variables (Aiken J., 1985).

Since emerging oceanographic programmes demanded large synoptic data sets over extended periods of time with inherent reliability and high data recovery, so new towed vehicles are required to accommodate larger payloads, be highly versatile yet meet or exceed the performance of existing vehicles. Improved production techniques should also reduce the manufacturing cost.

One example is represented by the ScanFish MK II (Fig. 3) of Graduate School of Oceanography, University of Rhode Island. ScanFish is a towed undulating vehicle system designed for collecting profile data of the water column in oceanographic, bathymetric and environmental monitoring applications at either fixed depth or to pre-programmed undulating flight path. The ScanFish MK II is an active unit, which generates an up or down force in order to position the tow-fish in the water column. This instrument may carry on a number of sensors measuring parameters like conductivity (salinity), temperature, pressure, fluorescence, photosynthetically active radiation (PAR) and other parameters.



Fig. 3. ScanFish (www.eiva.dk)

ROV, AUV and GLIDERS

The technology of underwater vehicles focus on seafloor research or/and deep sea observation using human occupied submersibles (i.e. Alvin) or remotely operated vehicles

(ROVs), and most recently, autonomous underwater vehicles (AUV). Despite AUVs represent the ultimate advances of oceanographic platforms, they are very expensive due to involved technologies and deployment systems.

GLIDERS, are the most recently developed class of underwater vehicles. Due to their autonomous capacity to perform saw-tooth trajectories driven by changes of buoyancy, they can be consider as low cost AUVs (Eriksen 2009 in Thorpe, 2009)

The first modern deep *Human occupied vehicles*, was the William Beebe bathysphere able to dive down to 923 m depth.

Realized in 1934, the bathysphere was a small spherical shell made of cast iron, 135 cm in inside diameter designed for two observers.

The second generation of deep submersibles began in 1964 with Alvin (Fig 4a). It was funded by the US Navy under the guidance of the Woods Hole Oceanographic Institution (WHOI). Alvin was a three-person, self-propelling, capsule-like submarine about 8 meters long that could dive up to 3.600 meters. It was equipped with underwater lights, cameras, a television system, and a mechanical manipulator.

In 1975, scientists of Project FAMOUS (French-American Mid-Ocean Undersea Study) used Alvin to dive on the Mid-Atlantic Ridge for the first direct observation of seafloor spreading. Alvin has allowed the discovering of the hot springs and associated sea life that occur along the East Pacific Rise. Moreover, it provided early glimpses of the Titanic wreck site in 1985. Since Alvin, other manned submersibles have been used successfully to explore the ocean floor.

Remotely operated vehicles (ROVs) (Fig 4b) are underwater platforms remotely controlled from the surface by a cable that provides power and control communication to the vehicle. ROVs can be divided into three main types of vehicle:

a. free-swimming tethered vehicles have thrusters that allow manoeuvring along the three axes, and provides visual feedback through onboard video cameras. Generally their use is for mid-water or bottom observation or intervention;
b. bottom-crawling tethered vehicles move with wheels and can only manoeuvre on the bottom. Visual feedback is provided by onboard video cameras. Their mainly use is for cable or pipeline works;
c. towed vehicles are carried forward by the surface ship's motion, and are manoeuvred up and down by the surface-mounted winch. Towed vehicles usually carry sonar, cameras, and sometimes sample equipment.

ROVs have been developed in the 1950s and have been used worldwide since the 1970s and 1980s to explore previously inaccessible underwater supporting scientific missions.

Autonomous underwater vehicles (AUVs) (Fig. 4c) are untethered mobile platforms, computer controlled, used for survey operations by ocean scientists, marine industry, and the military. Their main feature is the completely free/or very little human operator interaction while operating. This characteristic allow AUVs to access otherwise-inaccessible regions as for example under Arctic and Antarctic ice.

Despite the off-shore oil industry represents the main field of use of AUV platforms, since 1990s the oceanographic scientific community has adopted these autonomous vehicles for oceanographic investigation as they can provide, for example, the rapid acquisition of very distributed data sets (Bellinghman, 2009 in Thorpe, 2009).

Today a wide range of AUV are available for commercial use as well as for oceanographic surveys, and a large number of companies develop subsystems and sensors to install onboard AUVs.

AUVs are highly integrated devices, containing a variety of mechanical, electrical, and software subsystems that can be summarized as follow:

1. hardware and software components in order to program specific tasks;
2. energy storage to provide power;
3. propulsion system;
4. stability control system;
5. measurement instruments
6. communication devices;
7. locating devices;
8. emergency recovery system.

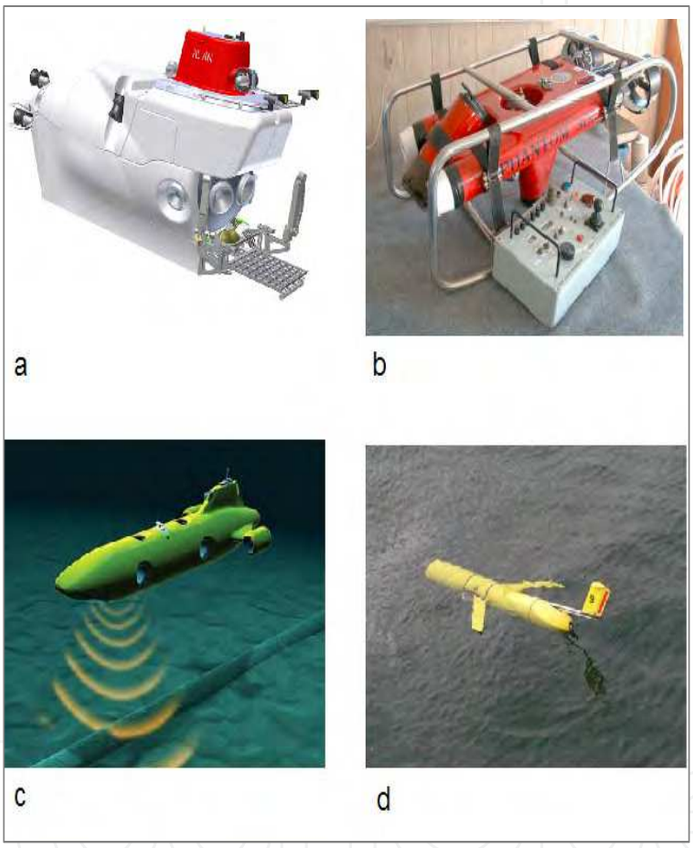


Fig. 4. a Alvin; b ROV; c AUV, d GLIDERS

Gliders (Fig. 4d) have been developed specifically to better investigate the main characteristics of mesoscale eddies, fronts, and boundary currents. The salient characteristic of gliders can be found in the realization cost that correspond to about few days of research vessel operation while they can be operated for a few months (Eriksen, 2009 in Thorpe, 2009).

Three operational gliders, Slocum (Webb Research Corp.), Spray (Scripps Institution of Oceanography and Woods Hole Oceanographic Institution) and Seaglider (University of Washington) were realized within the Autonomous Oceanographic Sampling Network program set up by the US Office of Naval Research (ONR) in 1995.

The four key technical elements of gliders are :

1. small reliable buoyancy engines;
2. low-power computer microprocessors;
3. GPS navigation system;
4. low-power duplex satellite communication.

The three operational gliders, are descendent floats and differ from drifter and lagrangian profilers essentially because of their characteristics: the wings that allow forward motion mainly while diving. During this gliding cycle gliders are fully autonomous, and at the surface they use GPS to determine next target direction.

Lagrangian devices, expendable probes and drifter

Traditional methods for oceanographic measures and observations are carried out through ad hoc surveys in order to collect data of specific areas, with the consequently limitation of time and costs.

To overcome this limitation, world oceanographic community, has developed different programs and methodologies.

Starting in the 1970s, a great number of surface *drifters* and subsurface neutrally buoyant floats have been developed, improved, and tracked in the ocean.

Drifters are able to provide worldwide maps of the surface and subsurface water velocity at a few depths. *Lagrangian profiling buoys* like WOCE floats and their successors Argo (Fig. 5a and 5b), are measuring and reporting in real time the temperature and salinity structure of the upper 2km of the ocean (Richardson 2009, in Thorpe, 2009). Drifters and floats provide fundamental surface and sub surface data allowing the description of world ocean's temperature and salinity structure, ocean circulation and its time variability.

The basic elements of a lagrangian drifter designed, for example, to track mean currents at a fixed depth beneath the ocean surface are: the drogue, the surface float and the connecting tether. The drogue is the draging element that locks the drifter to a water parcel.

The surface float contains the telemetry system, antenna, batteries, and sensors. The drifter position can be calculated by an installed GPS receiver. Data and position can be transmitted by Argos or Iridium systems to the data server.

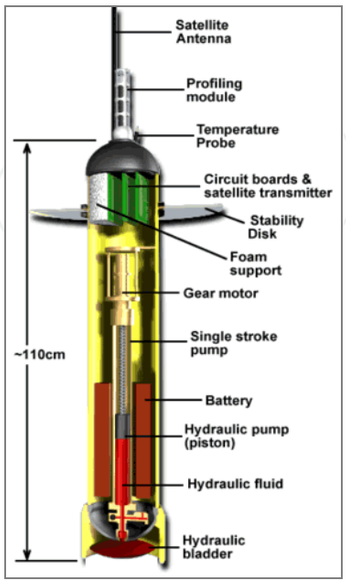


Fig. 5a. Argo (www.argo.net)

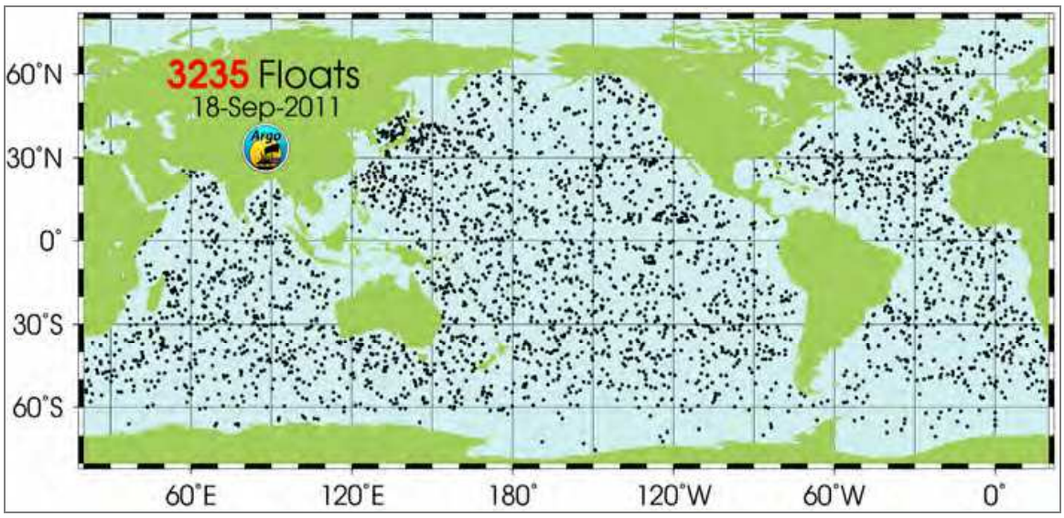


Fig. 5b. Argo distribution map (www.argo.net)

Autonomous WOCE and Argo float, usually drifts submerged for a few weeks. Periodically, when it rise up to the sea surface, transmit data and position by the Argos satellite system. After around a day drifting on the surface, the float re-submerges to its operative depth, in the upper kilometre of the ocean, and continues to drift for another few weeks. Around 100 round trips are possible over a lifetime up to 6 years.

Despite Argo floats can autonomously measure physical, chemical and some biological parameters, in practice this potential capability is limited by cost and power supply.

Recently, expendable probes like *eXpendable Bathy Termographs* (XBT) (Fig. 5c), have assumed particular relevance for the measure of physical variables. Their main future is the possibility to be launched directly from a moving ship, saving time and costs.

Despite all technological developments, the challenge of oceanography still remains the synopsis of data acquisition in order to observe high spatial and temporal variability phenomena such as oceans primary production. This variable is fundamental as it is strictly related with oceans water characteristics (physical, chemical and biological) and it is regulated by ocean dynamics (current and water mass properties).



Fig. 5c. XBT (www.earthobservatory.nasa.gov)

2.1.4 The JCOMM Ship Observations Team (SOT) programmes: VOS and SOOP

From the origin of the climate studies, oceanographic measures has been acquired by ships, the only available platforms to survey the oceans.

Although there are now several other platforms (i.e. satellites, drifting buoys, floatings and radar) ships still play a very important role providing sea truth for the calibration of satellite observations and because of they allow measurements not yet obtainable by other means, such as air temperature and dew point (www.bom.gov.au/jcomm/vos/).

The World Meteorological Organization (WMO) within Intergovernmental Oceanographic Commission (IOC) of UNESCO, the United Nations Environment Program (UNEP), and the International Council for Science (ICSU) sponsor the Global Ocean Observing System (GOOS) that is the oceanographic component of GEOSS, the Global Earth Observing System of Systems.

WMO members directly participate in the GOOS, providing in situ and satellite observations.

GOOS (www.ioc-goos.org) is designed to provide observations of the global ocean (including living resources), related analysis and modelling, supporting operational oceanography and climate change predictions.

Through Regional Alliances and dedicated linked programmes, GOOS allow all data to become accessible to the public and researchers by standard and simple shared methods to produce products useful to a wide range of users.

It is not solely operational, but includes work to convert research understanding into operational tools. In this way GOOS should sustain the management of marine and coastal ecosystems and resources, supporting human activities like mitigate damage from natural hazards and pollution, protect life and property on coasts and at sea and suggest scientific research activities.

Since 1999, the marine activities of WMO, as well as those of IOC, have been coordinated by the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM - www.jcomm.info).

The creation of this Joint Technical Commission results from a general recognition that worldwide improvements in coordination and efficiency may be achieved by combining the expertise and technological capabilities of WMO and IOC.

The Observations Program Area of JCOMM is primarily responsible for the development, coordination and maintenance of moored buoy, drifting buoy, ship-based and space-based observational networks and related telecommunications facilities.

In this framework it was created a Ship Observations Team (SOT) which coordinates two programs: the Voluntary Observing Ship Scheme (VOS) and the Ship of Opportunity Program (SOOP).

The WMO Voluntary Observing Ships (VOS) program

Developed about 150 years ago, VOS is the international scheme for taking and transmitting meteorological observations by ships recruited by National Meteorological Services (NMSs), comprising member countries of the World Meteorological Organization (WMO).

With a fleet strength, estimated in about 4000 ships worldwide, presently the VOS supports measures useful to comprehend and predict extreme weather events, climate variability, and long-term climate changes (www.vos.noaa.gov).

In this way, providing increasingly data to the global climate studies, VOS makes a highly important contribution to the Global Observing System (GOS) of the World Weather Watch (WWW).

The Ship-of-Opportunity Program (SOOP)

The SOOP is based on the possibility to use merchant ships that join to the programme, in routinely strategic shipping routes. At predetermined sampling intervals, Expendable Bathythermographs (XBTs) are launched to acquire temperature profiles in the open ocean in order to be assimilated into operational ocean models.

SOOP plays a relevant role as it serves as a platform for other observational programmes, communicating closely with the scientific community. In this way, SOOP assumes a big relevance to seasonal and interannual climate prediction.

The programme is managed by the SOOP Implementation Panel (SOOPIP). Along the strategic shipping routes, SOOPIP identifies and coordinates the measuring necessities in terms of type of instruments, their use modality and deployment.
So, thanks to the use of different instruments such as XBTs, TSGs, CPR, it is possible to obtain long measuring series of physical, chemical and biological parameters.
Moreover SOOP looks at new instrumental technological development and coordinates the exchange of technical information; in particular: functionality, reliability and accuracy, and recommended practices about relevant oceanographic equipment and expendables.
The main important aspect of VOS and SOOP programs deals with the possibility of collect data in a cost effective way.
VOS operates without ship cost, whilst the communication charges, the observing equipments and the consumables are furnished by the National Meteorological Services.
Within these programs (VOS and SOOP), many international initiatives are presently carried out in order to develop new observing devices and systems, suitable to be utilized from as many vessels as possible.
New expendable probes and devices (low cost and user friendly) represent the ultimate effort of oceanographic technological development in order to collect even more accurate measurements and to enhance the range of variables to be measured in automatic way, particularly for the biological ones.

2.1.5 Remote sensing platforms

Data from satellites allow us understanding and monitoring ocean processes at large spatial and temporal scale. Also if the same sensors payload equips airborne remote sensing, this platform is otherwise dedicated to the surface analysis of meso-scale processes, particularly to that of shallow waters and coastal environment.
Even if remote sensing can provide a unique synoptic view of phenomena such as chlorophyll concentration and sea surface temperature, however the measurement validation requires constant scrutiny and much sea-truth data as possible (Marcelli et al. 2007).
For this reason (and also to develop ecosystem forecasting models) the integration between field sampling and remote sensing technique should be improved. Actually this is a primary necessity also because of still a lack both of basin wide and of coastal ones, operational, multidisciplinary, in situ observing system.
In fact today, thanks to new satellites capabilities, there is the possibility of sampling on smaller scales to describe relevant phenomena, especially in the coastal zone where scales are considerably smaller than those in the open ocean.
To comprehend the complexity of physical and biological processes, the human activities impacts, the climate changes, and every process involving seas and oceans, it is not possible to use a single approach.
To face this problem, the best strategy seems to be the integration of data derived from different platforms.
For all these reasons, the oceanographic investigation needs more and more new instruments and sensors with well defined measurement characteristics also in order to calibrate the synoptic data providing by remote sensing observations.
Whilst the monitoring of physical variables is continuously improving, the biological ones still lack and furthermore they have to be observed in situ.

There are several empirical algorithms commonly used to assess primary production in the euphotic zone, based on data provided by satellites Coastal Zone Colour Scanner.
These models are parameterized both on water visible radiance (obtained by means of satellites), and other simple variables, and also on the knowledge of photoadaptive parameters, such as maximum photosynthesis which can be obtained only by in situ sampling (Balch & Byrne, 1994).

3. Requirements of oceanographic observations

One of the most important problem of operative and operational oceanography is related to the availability, quality and accessibility of the data.
To meet these needs it is necessary to acquire more data than possible, but, as already mentioned, data collection is often limited by survey costs. Moreover data distribution is often discontinuous and it does not allow a synoptic understanding of many dynamic processes.
As already mentioned, the ships of opportunity are fundamental, since they integrate the ocean surface temperature (from satellites) with water column data. So they contribute to the Marine Forecasting System capability of providing near real time analysis of the oceans.

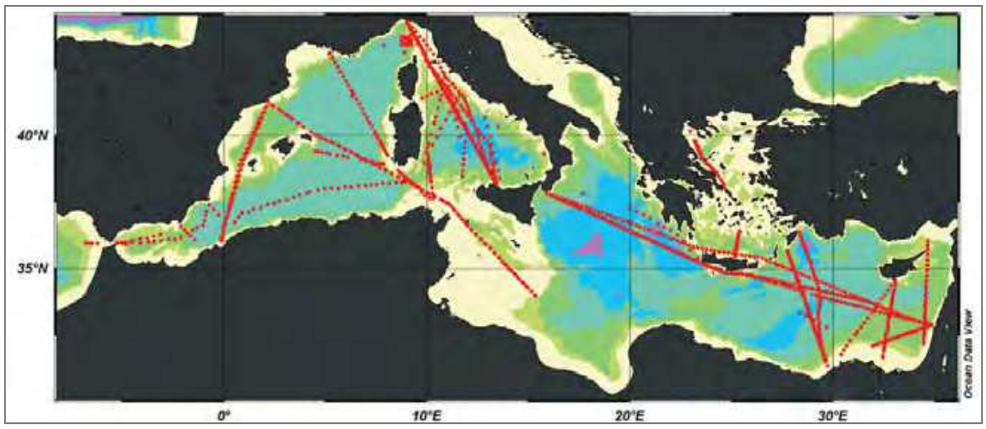


Fig. 6. Mean Mediterranean VOS acquisitions (MFSTEP Project)

As described in detail in par. 2.1.4, within the international projects knowledge necessities, it is fundamental the development of innovative technologies according to requirements of high performances, data quality and low-cost.
Even if data provided by models, by high resolution remote sensing and by the new autonomous sampling platforms are increasing temporal and spatial sampling capabilities (Dickey & Bidigare, 2005), however, there is still a lack of operational, multidisciplinary, in situ observing systems.
This fact is particularly related to the biological variables that need to be observed in situ more than the physical once. Especially in the mid-high latitudes, a complete upper layer observation of the water column is needed, because of the typical distribution of phytoplankton's biomass (Mann &Lazier, 1991).
Traditional methods (water sampling, storage and laboratory analysis) are too expensive and do not allow to have enough measures to describe variability of marine natural phenomena with sufficient temporal and spatial detail.

Therefore, bio-optical measures, used to study the main environmental characteristics, such as phytoplankton biomass, CDOM (Coloured Dissolved Organic matter), turbidity, can be integrated in new technological developments to give continuous measures.
In such a context our aim was to answer to all the above issues, developing new user friendly technologies, based on low cost materials and suitable to different configurations (Moored, stand alone, expendable, continuous and towed).
In order to face the necessity of the world oceanographic observations, we identified two main development necessities:

- - a new low cost flexible modular instrument, to be used like profiler, expendable, stand alone and instrumental payload;
- - a towed vehicle able to be used both in coastal and open oceans, capable to host the new low cost instrument

Low cost modular instrument
Expendable probes (see before XBT), represent an approach to ocean measurements in which the high accuracy of measurements may be sacrificed considering lower costs and operational expediency (Thorpe, 2009). Relating to operational oceanography, this kind of technology derives from the needs of adequate spatial sampling on timescales commensurate with temporal variability.
These probes can provide measures of temperature quickly as they can be used by a ship moving up to 20-30 knots. This technique also provides standard results and it became the central component of programmes such as the Global Ocean Observing System (GOOS).
Current expendable probe capabilities include also the measurements of sound speed, conductivity, ocean current and (most recently) optical irradiance and suspended particle concentration (Thorpe, 2009).
Such expendable measurements could be fundamental for satellite data calibrations and for programmes such as Marine Forecasting System (MFS).
With support from GOOS, GEO, POGO, IOCCG and Plymouth Marine Laboratory, the Chlorophyll Globally Integrated Network (ChloroGIN) was set up in order to provide a network of researchers with the aim of integrating in situ time series of chlorophyll measurements with satellite ocean colour-based observations. From these integrated measurements it is possible to provide maps of ocean chlorophyll and sea surface temperature, as indicator of the state of the ecosystem, and measures of light penetration to calculate primary production (Hardman-Mountford, 2008).
In addition to the prototypes made by Marcelli et al. (2007) during the MFS-TEP project, at now there are no expendable probes for the measurement of chlorophyll and other bio-optical variables.
This last feature is very important as it may concern in situ measurements of water optical property dealing directly with phytoplankton biomass and Coloured Dissolved Organic Matter (CDOM).
The measure methods currently available consist infact in expensive instruments, or they require expensive methods (sampling and laboratory analysis).
In this field, the maximum effort should be made to develop innovative tools looking to: economicity, flexibility and with a sufficient level of precision and accuracy.
They must be modular to be adapted to measure the widest number of variables and they must be flexible to be used by the largest possible number of measurement platforms, and also as expendable.

Towed vehicle

In order to increase our understanding of ocean processes it is necessary to have the most comprehensive and synoptic data sets.

Significant advances have been made in remote sensing from both satellite and aircraft, which nevertheless increase the requirement of in situ data for sea truth.

Methods of traditional oceanographic research and marine environment monitoring are limited to the time scale of the observer and therefore they cannot carry out synoptic observations (Marcelli & Fresi 1997).

The large coverage collection, of long term data sets or high resolution field studies, should require high costs.

The problem of monitoring of physical, chemical and biological parameters of the oceans, both for operational and forecasting, remains one of the most important issue that ocean science community is facing today.

It is commonly accepted that the most cost effective method for spatially and temporally monitoring is represented by the use of both towed instrumentation and expendable low-cost probes (Reseghetti et al., 2006) from ships of opportunity.

Towed vehicles, in use since the 1930s, in recent years have been advanced significantly becoming extremely robust and high reliable. Typical payloads are CTDs, that can be be interfaced with other sensors such as fluorometers, transmissometers, pH, dissolved oxygen, and other optical sensors dedicated to sea truth.

Undulating vehicle main feature is the capability to make continuous measurements along water column by moving ship, with a considerable operative time saving. Furthermore continuous measurements can resolve fine structures of high variability phenomena such as phytoplankton patchiness.

Distribution of phytoplankton biomass is characterized by a great variability. Its assessment is a fundamental issue since it modulates the carbon cycle. While primary production measurements are expensive for time and costs, phytoplankton biomass can be detected by in-vivo chlorophyll a measurements.

The possibility of using a continuous profiling probe, with an active fluorescence measurement, is very important in real time phytoplankton's study; it is the best way to follow the variability of sea productivity. In fact, because of the high time and space variability of phytoplankton, due to its capability to answer in a relatively short time to ecological variations in its environment and because of its characteristic patchiness, there isn't a precise quantitative estimation of the biomass present in the ocean (Piermattei et al., 2006).

Despite this fundamental aspect, the use of such towed vehicle often needs dedicated surveys or ships with ad hoc deploying and towing systems. However, towing vehicle will continue to have a key role if deployed from ships of opportunity looking to oceanic processes and it will become fundamental for the study of coastal high variability processes.

4. Material and methods

The first innovative probe that we present in this work is an expendable probe for chlorophyll a fluorescence and temperature measurements: the T-FLAP (Marcelli et al.2007). It represents an evolution of the XBT (eXpendable BathyThermograph), from which differs mainly for its electronic system and the and the addition of a fluorescence sensor.

The simple use of this probe and its low cost were the principles of its development, in order to realize an industrial production which will diffuse its employment by any ship who participates to the VOS (Voluntary Observing Ship) program.
The second is the Sliding Advanced VEhicle (SAVE) which allows a rapid and detailed physical and biological characterization of the water column. The system is composed by a depressor unit, towed at fixed depth, and an underwater instrumented vehicle able to slide along the towing cable.
The main features of the system are the cable drag reduction, that allows a higher velocity and the absence of the fairings (fundamental for the application of the system on board of ship of opportunity), and the electromagnetic induction data transmission system.
This towed vehicle consists in a "sliding unit" able to be used in shallow water and from small boats. The sliding system was chosen to reduce the "data anisotropy" deriving from the undulating and sinusoidal motion of the traditional towed vehicle.

4.1 Temperature Fluorometric Launchable Probe

In the framework of MFSTEP project (Manzella et al., 2003; Pinardi et al., 2003), and in the follow ADRICOSM-STAR Project we started to develop and realize a new low cost expendable probe able to measure fluorescence of Chl a, with sufficient accuracy to detect the main ecological structures in the water column (DCM).
The Temperature Fluorescence LAunchable Probe T-FLAP (Fig. 7), was charted in order to answer to the claim of a cost effective temperature and fluorescence expendable profiler, to be used on ships of opportunity. The development of the expendable fluorometer has followed similar concepts of the XBT, but differently the T-FLAP was developed with an electronic system which can be improved and adapted to several measure channels. T-FLAP (Marcelli et al. 2007) was tested during several oceanographic surveys (Fig.8).

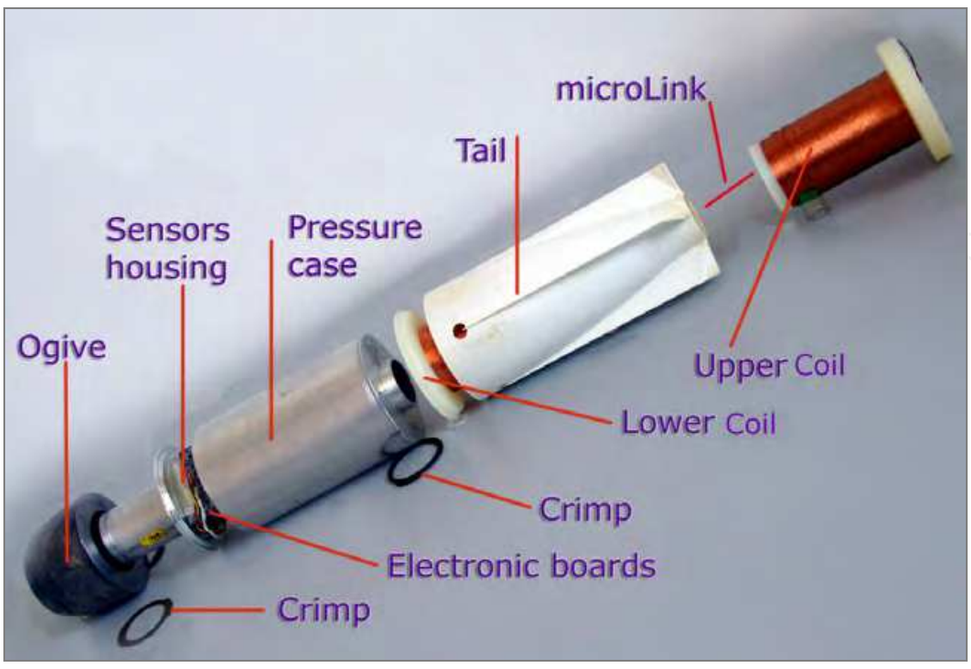


Fig. 7. T-Flap outline



Fig. 8. T-Flap Launched from a ship

The probe measurement cell is made of a tube where the water flows into, getting directly in touch with the sensors. The fluorescence sensor is composed by a light source (blue LEDs between 430nm and 470nm) and a photo-diode positioned orthogonally with respect to the light source.
The temperature sensor is build with a glass bulb micro sensor, with a high sensitivity to temperature variations (0.01°C).
Electronic and firmware for sensor management and data transmission are located inside the pressure case.
Digital data transmission is assured by a twin copper wire wrapped on two different reels: one in the probe tail, the other one is on board the moving ship and allows the connection with the pc till the signal interruption for wire break. The transmission frequency is about 5.6Hz and the falling velocity 4.5m/s.
To reach the aim of a low-cost probe, were utilized commercial components: a glass bulb temperature resistor for the temperature measurement, blue LEDs, a photo-diode and available selective glass filters, for the fluorescence measurement.
The measurement principle employed to detect phytoplankton biomass, is the active fluorescence. This method is an in vivo chlorophyll estimation, that can get the immediate biophysical reaction of phytoplankton inside the aquatic environment; it is a non-disruptive method which gives real time estimation and avoids the implicit errors due to the manipulation of samples.

4.1.1 Sensors

Fluorometer
The fluorometer is composed by:

- a source of light composed by 3 different wavelengths (blue LEDs);
- an optical filter which selects the blue wavelength from 430 to 480 nm positioned over the light source;
- an amplified semiconductor element (with electronics integrated) as sensitive receptor;
- an optical filter which selects the red light up to 600 nm over the sensitive receptor.

Temperature measurement

The temperature measurement is performed through a glass bulb micro sensor which comes out from the measure cell for 10 mm, the sensitive part is composed by resistive sensor inside a spherical glass bulb with the diameter of 1.5 mm. This sensor has a high sensitivity to temperature variations (0.01°C) and to the dynamic variations (0.05 ms).4.1.2.

4.1.2 Calibration

The calibration procedure is a very important step in the development of a fluorometer, especially if it is an expendable one. In vivo fluorescence (IVF) is commonly used to estimate Chl a (i.e., phytoplankton biomass) in natural waters (A. E. Alpine and J. E. Cloern 1985). The main problem of an expendable probe is that it is not possible to calibrate the instrument through in situ samples, because ships of opportunity does not stop to collect water samples like in a traditional survey.

Fluorometer calibration

Different solutions of Chlorella sp. measured with a calibrated fluorometer (PrimpProd 1.11) were used for the calibration of T-FLAP. Figure 9a shows the relation between fluorescence measurements of PrimProd and T-FLAP.

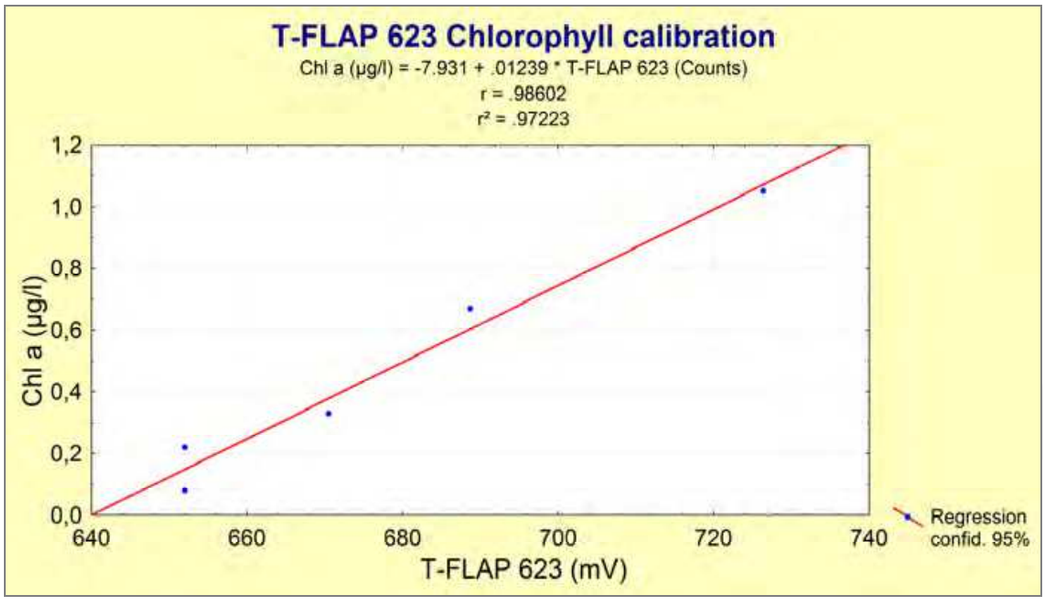


Fig. 9a. On X axis there is the Chl "a" measured by T-FLAP (millivolt) while on Y there is the Chl "a" from PrimProd 1.08 (µg/m3)

The fluorometer (PrimpProd 1.11) was calibrated by spectrophotometric analysis of the samples (Lazzara et al. 1990).

In order to acquire data simultaneously it was built a water circuit where the T-FLAP and the Primprod 1.11 were together in line.

The water flowed through the reference probe and through the T-FLAP thanks to a bulk insulated tube system connected to a circulation/feeder pump (0.7 bar, 5.7 l/min) which kept a constant flow.
In this way it has been possible to perform a dynamic calibration, which is necessary to test an instrument like T-FLAP, that descends at constant speed in the water column.
The probes were connected to the pc by a serial interface so that the values were available in real time.
Temperature calibration
The temperature sensor was calibrated using the same flow system employed for the fluorescence calibration.
The response of the temperature resistor is converted in a tension signal value. To find out the conversion law, which allows to transform the mV signal value in °C, the T-FLAP was immersed in temperature controlled water and the degree temperature value has been obtained by a reference temperature sensor.
The temperature measurement inside the calibration circuit was done by means of a OTM Falmouth temperature sensor with Platinum Resistance Thermometer which has got an accuracy of 0.003°C.
The probe is connected to the pc by the serial interface so that the values were available in real time.
When the water volume reached a stable temperature the T-FLAP acquisition got started and the output values were saved on the pc.
The calibration was realized in different correspondent temperatures, in a range of 0 to 25°C. For each of the temperature values, correspondent T-FLAP values were extracted from sensors and a regression analysis carried out. In Fig. 9b is represented the fit curve for the calibration of the temperature sensor of T-FLAP.

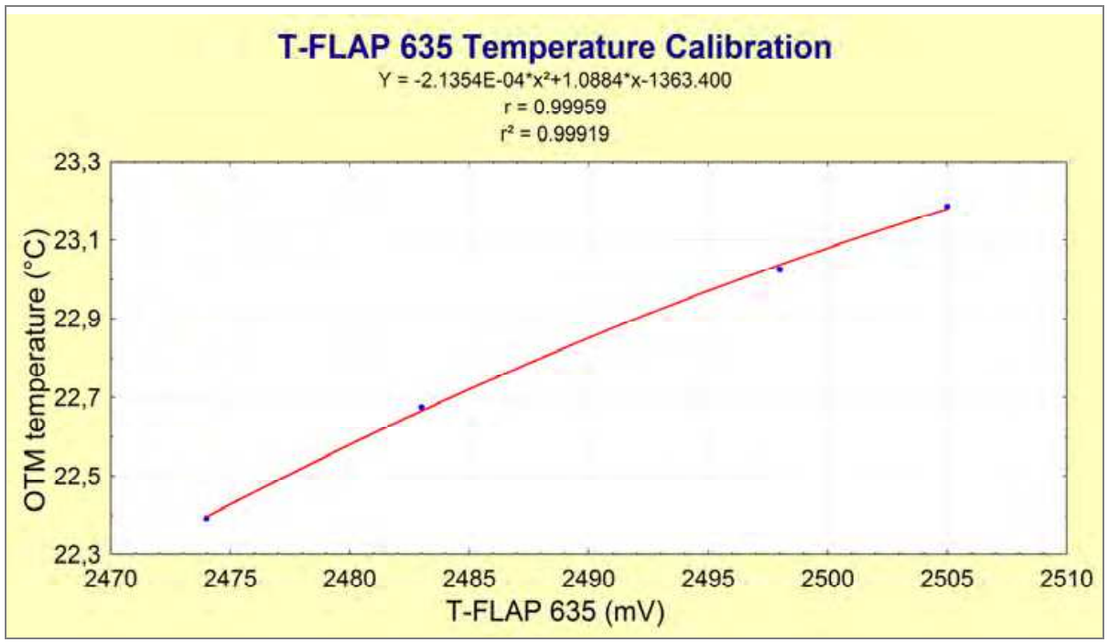


Fig. 9b. On X, temperature from T-Flap (mV); on Y temperature from OTM (°C).

4.1.3 Digital transmission system

The digital data transmission system is allowed by a twin copper wire (µlink) wrapped on two separate coils; one of these is mobile and positioned in the tail, while the other is fixed in the canister launcher, through which the probe is connected to the pc on board.

Data acquisition doesn't need specific software, it is enough to have a pc terminal as Windows ® HyperTerminal. The T-FLAP firmware provides an interactive menu, which allows different work activities including programming and controlling.

Coil's capacity

The mobile coil, inside the probe, has to contain a wire with a length as the maximum depth it could reach plus a tolerance length: the pre-serie has 700 meters wire.

Limits

Being subjected to a progressive hydrostatic pressure, the functional limits of T-FLAP, concerning to the implosion of the materials, has reached 500 dBar.

A second limit is the capability of the coils to host a longer or thicker couple of conductors: for each one it was prevented at the most a double length with the same diameter, or a bigger diameter with the present length.

4.2 Sliding Advanced Vehicle SAVE

SAVE was designed to carry out detailed and rapid profiles, in order to have quasi-synoptic measures of physical and biological variables.

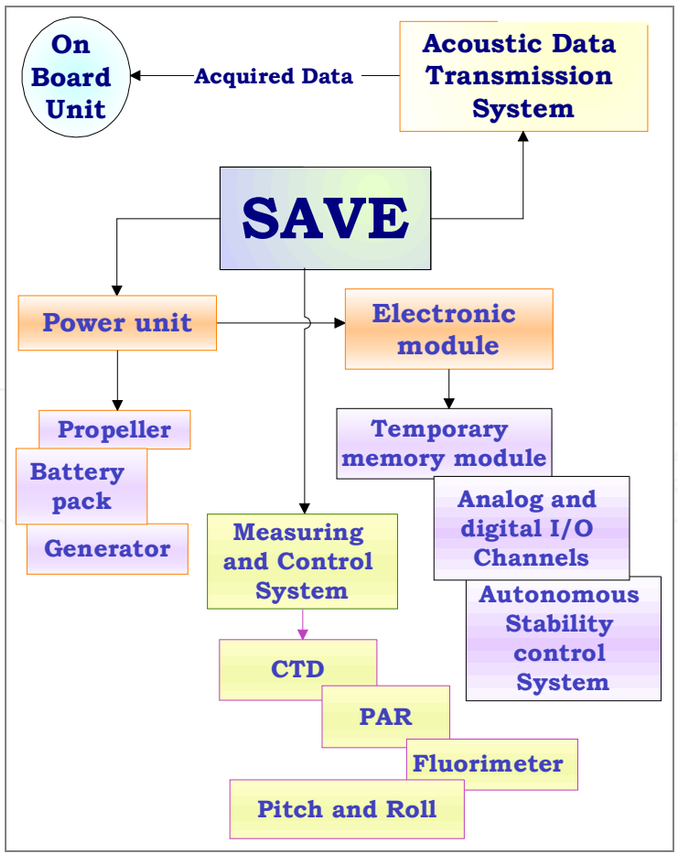


Fig. 10. Flux diagram of SAVE Architecture System

The system permits to perform a detailed characterization of the water column, following the phenomena dynamic evolution.
The system is composed by a depressor towed by a surface unit at fixed depth and an instrumented vehicle, that slides along a cable from the surface to the depressor. This approach starts from a previous development that was built in the mid-80s (Nomoto et al. 1986).
Numerical Model
In order to test all the system (Depressor and SAVE vehicle) a numerical analysis program, able to simulate the SAVE navigation, was developed.
The system is subdivided in:
- depressor
- SAVE vehicle
- cable

In this way the system can be improved with different operative conditions. A special attention was given to the definition of the geometry of the depressor and of the hydrodynamic control surfaces of the SAVE vehicle and of their moving, in order to obtain the expected performances at the different operative conditions.
For every solution the navigation limits were verified, in order to reach a compromise between system efficacy and subsystems measuring. We optimized the executive design of the single subsystems making it more effective.

4.2.1 Depressor unit

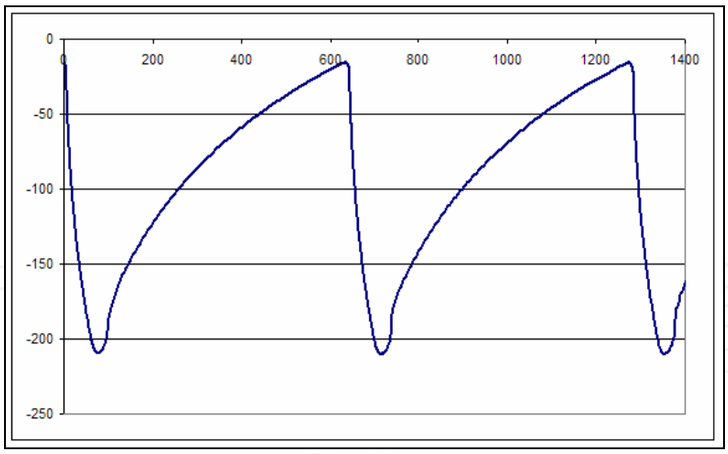
The depressor was designed to work between surface and 200m depth and between 2 and 8 knots speed. The model allowed to define the balance configuration of the depressor/cable system at different speeds.
The wing geometry was selected after a comparison between different NACA profiles efficiency. The results conduced to select NACA 4412 profile.
Extremity plates was applied to improve the profile, in order to reduce the fluid motions between the overpressure margin and the depression margin.
In order to control the behaviour during the navigation, the depressor lodges a miniature pressure transducer (Depth range 0-500 dBar, Depth resolution 0.1 dBar), a biaxial inclinometer (Roll angle ± 90 degrees, Pitch angle ± 90 degrees, Angles resolution 1 degree) and a data acquisition board (Rate 1 sample/second, Storage up 4000 samples, Serial com 0.5 sample/second).

4.2.2 Underwater vehicle

The SAVE vehicle is constituted by an instrumented pressure hull; the guide system is located on the front side of the vehicle and is composed by pulleys connected to the cable.
The vehicle was designed to work up to the maximum depressor depth and between 2 and 12 knots. The model provided the vehicle movement with different towing speed. In figure 11 is represented the result at 4 Kn speed (Fig.11).

4.2.3 Sensors

The temperature and the conductivity measurement are effectuated through a CT double sensor, that includes a ceramic type inductive conductivity cell and a high stability platinum resistance temperature device (RTD) temperature sensor.



V = 4 kn

Fig. 11. Model results of vehicle movement at 4 kn speed. On X is represented the distance in m; on y is represented the depth in m.

Specification of the Conductivity sensor:
- range 0->64 mmho/cm (0->6.5 S/m)
- accuracy: ± .025 mmho/cm (.0025 S/m)
- stability: ± .005 mmho/cm/month (.0005 S/m)

Specification of the Temperature sensor:
- range -5°->35° Celsius (ITS-90)
- accuracy: ± .050° Celsius
- stability: ± .002° Celsius/month

The CT sensor electronics is contained on a single printed circuit board, that provides two high level analog output signals 0-5 VDC.
The pressure measurement is effectuated through a 50 Bar pressure transducer supplied by a stabilized reference voltage (5V). A type Butterword (12dB/octave) low-pass filter is present In cascade to the amplifier, in order to eliminate the noise component induced by the water flux on the membrane.

4.2.4 Cable

The cable is one of the main elements of the system, because it sustains the weight and the hydrodynamic drag of the depressor. Beside to be a support, the cable is the sliding guide of the SAVE vehicle. The selected cable has the following characteristics: anti torsion zink-plated steel cable, 133 leads covered with RILSAN, external diameter 9mm.
The characteristics of the cable allow the electromagnetic induction transmission of the data between the underwater vehicle and the ship.
The power supply of the electronic components and of the electromechanical actuators comes from 12 rechargeable NiMH batteries (1.2 V, 7Ah).

4.2.5 Data acquisition/transmission system

Depressor and underwater vehicle transmit data to the on board unit during the navigation. The data transmission realizes both in descent and ascent in continuous way, thanks to a magnetic ring located between the pulleys. The cable passes through the ring, that realizes a coupling model, utilizing the electromagnetic induction to transfer the digital information.

5. Field tests: Results and discussions

Both systems have been developed and tested in the Laboratory of Experimental Oceanography and Marine Ecology in Civitavecchia.
32 T-FLAP prototypes were built and were launched by R/V Urania in several oceanographic surveys and from the university boat to perform specific tests.
One SAVE prototype was built and it has been tested to CNR IAMC of Messina from the R/V Luigi Sanzo.

5.1 T-FLAP field tests

In this paper we show the results of the T-FLAP field tests, carried out during two CNR oceanographic surveys both aboard the R/V Urania:

- MEDGOOS13, held from October 28 to November 8, 2006;
- ADR0208 Oceanographic Cruise, held from 17th of October 2008 to 28th of the same month.

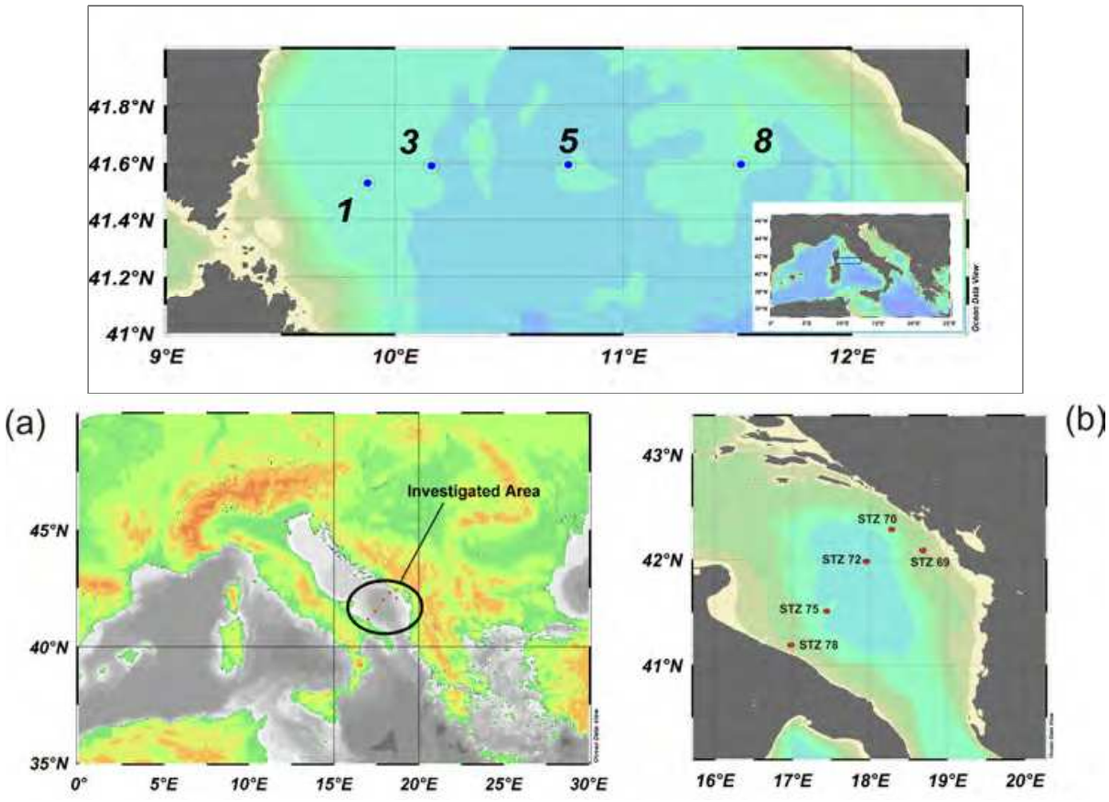


Fig. 12. On the left, the map of the Tyrrhenian sea stations (MEDGOOS13 cruise); on the right the map of the ADR0208 Oceanographic Cruise (a) and the location of the T-FLAP stations (b) (data analysed with ODV - Schlitzer, 2011)

In the Tyrrhenian Sea, the MEDGOOS13 cruise comprehended an oceanographic transect between Lazio and the Strait of Bonifacio, where several measurement stations were positioned in order to characterize the water column by multiparametric profiles and sampling water.

In each measuring station of this transect CTD casts were made by a Sea-Bird probe SBE 911 Plus equipped with an Aquatraka Chelsea MkIII chlorophyll a fluorometer.
In four station of the transect (Figure 12), T-FLAP prototypes were successfully launched, and profiles of chlorophyll a fluorescence, photosyntetic efficiency, PAR and temperature were measured by a high quality fluorometer probe: the PrimProd 1.08 (Antal et al 1999, 2001).
Data processing allowed the analysis of the upper oceanographic features along the transect as below described.
Because of this experiment looks to demonstrate the possibility to utilize T-FLAP from Ship Of Opportunity, it was decided to compare directly the results of data analysis obtained by means of T-FLAP profiles with the same analysis obtained by means of CTD and reference fluorometer casts.
This kind of approach derives from the impossibility for a Ship of opportunity to collect water sample for the post calibration.
Temperature and fluorescence profiles obtained from T-FLAP data were compared with the profiles obtained from Sea-Bird probe SBE 911 plus and from Aquatraka Chelsea MkIII chlorophyll a fluorometer.
As can be seen in fig. 13a, the T-FLAP has given good results both for temperature and fluorescence measures.
The sections infact represent the comparison between temperature and fluorescence distribution along the transect obtained by means of the T-FLAP and the reference sensors respectively.
CTD and T-FLAP stations have been represented in the same way in order to understand if T-FLAP is able to detect the water mass characteristics as the reference probe.
As can be seen in the left side of the figure, temperature sections of both T-FLAP and SBE CTD evidence the thermocline structure between 20 and 40 m depth with a mean value of about 14 °C.
Chlorophyll a sections obtained by means of both T-FLAP and Chelsea Aquatraka fluorometer, describe the trend of fluorescence of chl a indicating an higher biomass concentration in the central region of the transect decreasing in the western area. As it can be seen, the T-Flap can successfully describe the Chlorophyll distribution in the water column.
Results obtained by the analysis of depth-distance sections show that T-FLAP allows to well describe water mass main feature existing in the investigated area.
The T-FLAP probe has still some operative limits such as the launch method and the surface lightning. In some cruises, at the moment of the launch, outside the water, the high sensitive photodiode was saturated by the environmental light radiation, generating a measure error in the first water layer. This error was higher with a higher day lightning.
A similar approach was followed for the analysis of the results of the ADR0208 cruise. The CTD and T-FLAP data were represented in depth - distance sections, along the Dubrovnik-Bari transect. The objective was to test the possibility to detect mesoscale structures, in particular the Southern Adriatic gyre.
This gyre influences and modulates the DCM distribution, which has the main concentration, in the period of the ADR0208 cruise, near the Balkan coast. The temperature sections show a similar trend for both the probes, as shown in Fig. 13b.

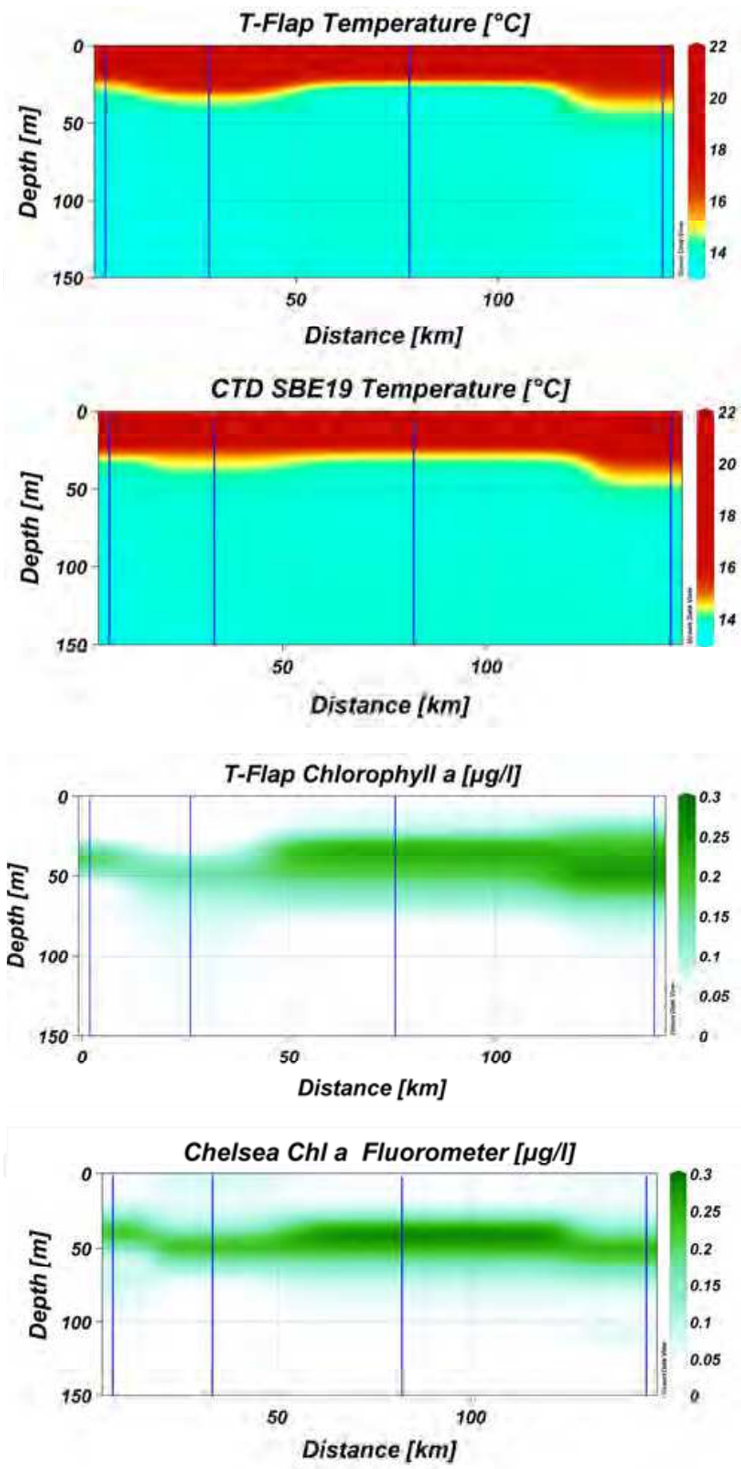


Fig. 13a. MEDGOOS13 cruise: depth-distance sections (W-E oriented) obtained by means of T-FLAP and SBE 911 plus CTD-Chelsea Aquatraka fluorometer: temperature upside, fluorescence downside. The mesoscale features are well idetified both from CTD and from T-FLAP (data analysed with ODV - Schlitzer, 2011)

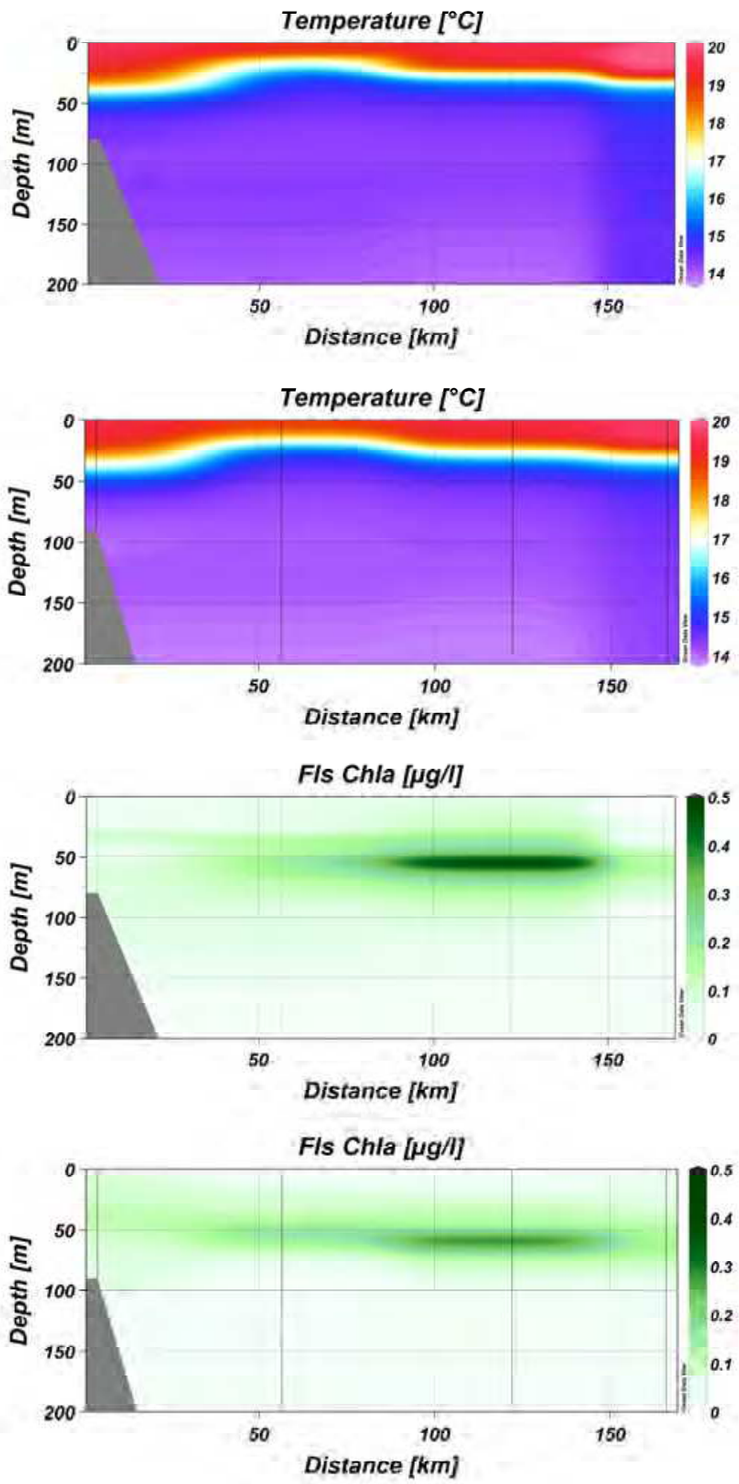


Fig. 13b. ADR0208 cruise: depth-distance sections (W-E oriented) obtained by means of T-FLAP and SBE 911 plus CTD-Chelsea Aquatraka fluorometer: temperature upside; fluorescence downside (data analysed with ODV - Schlitzer, 2011)

5.2 SAVE field tests

After the realization of the first prototypes, two different cruises were performed on board of the Luigi Sanzo, of the CNR IAMC Section of Messina, and a longer cruise on board of the Thetis, of the CNR IAMC.
The depressor was realized in PVC, with an internal steel structure to join together the ribs, that compose the wing.
To increase the rotation stability, compared with the longitudinal axis (rolling), a Λ configuration was chosen, with a consequent increasing of the wings half-opening, that allows a higher lift and resistance (Fig. 14).

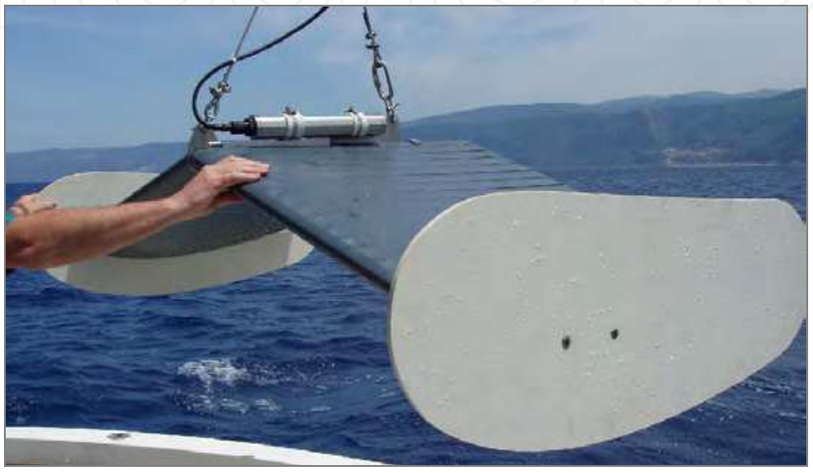


Fig. 14. SAVE wing

At the end of the wing, two plates reduce the fluid motions between the overpressure margin and the depressor margin.
The first depressor was realized to test his behaviour in the water, at different depths.
The first tests were inherent in the signal of the stability control sensors (Fig. 15 left); the chosen final sensor is very little (65mm, but it can be reduced to 50 mm) so that it will not take up a lot of the pressure hull both of the vehicle and the depressor. It is a SUNDSTRAND sensor, with range of linear measure of ± 45° and non-linear up to ± 90°. A test has been effected on the depth sensor too (Fig 15 rigth). It is a GE DRUCK miniature pressure transducer with thermal compensation, high signal outputs, good linearity, negligible hysteresis and good repeatability performance with long term stability. For this reason a cylindrical pressure vessel was installed on board the depressor. The vessel was equipped with a miniature pressure transducer, a biaxial inclinometer and a data acquisition board.
The characteristics of the instrumental payload are:

- depth range: 0-500 dBar
- depth resolution: 0.1 dBar
- roll angle: ± 100 degrees
- pitch angle: ± 100 degrees

The data acquisition performances are:

- rate: 1 sample/second
- storage: up 4000 samples
- serial com: 0.5 sample/second

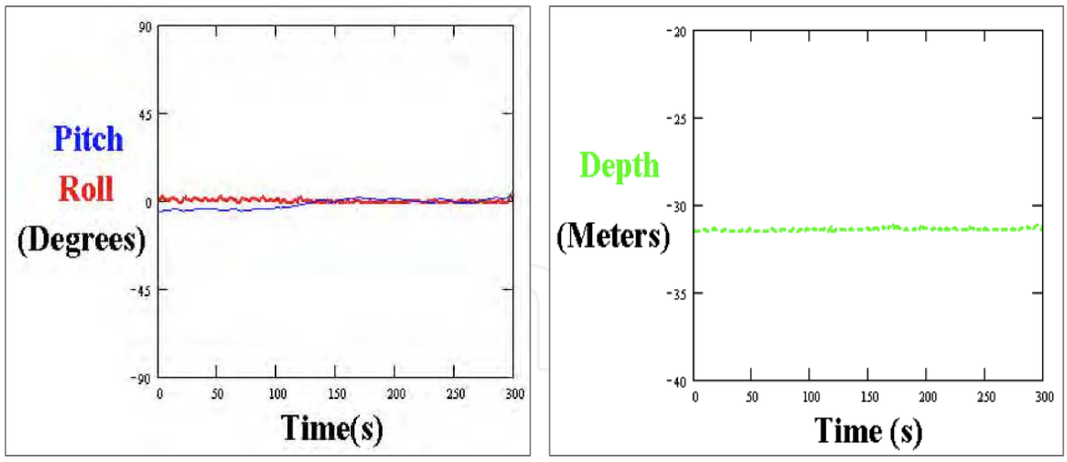


Fig. 15. On the left it is represented the stability of roll and the pitch movement; on the right the towing of the depressor at a fixed depth (of about 31m)

The transmission data method is a Frequency Modulation Encoded, with a spectrum: 500 Hz to 50 kHz.
The power supply was internal 7.2V Lithium battery, with a capacity of 30 days in continuous.
The basis payload has been completed with Falmouth OEM Conductivity and Temperature sensors. These analogic sensors do not need pumps, have high accuracy and stability and require low power.
A pressure cylinder equipped with these sensors was installed on the depressor. The cylinder was casted to test the response of the sensors in a towed application. In figure 16 it is represented a Temperature acquisition at a fixed depth.

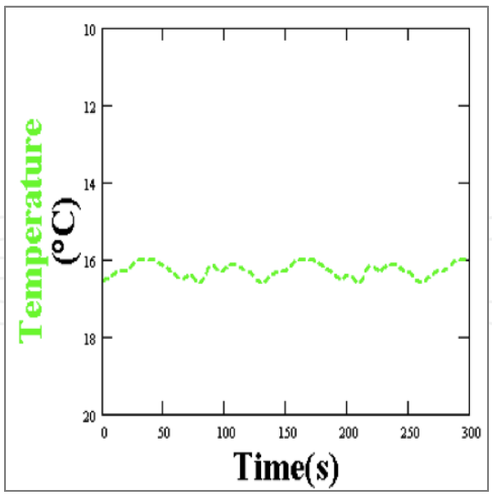


Fig. 16. Temperature distribution recorded at a fixed depth

The SAVE vehicle was a simulacre containing an Idronaut probe for CTD, fluorimetric and PAR measures. It was connected to the cable through a sliding system of Teflon, so that it was possible to acquire physical-chemical and biological parameters of the water column, from the surface till the depressor depth (Fig.15).

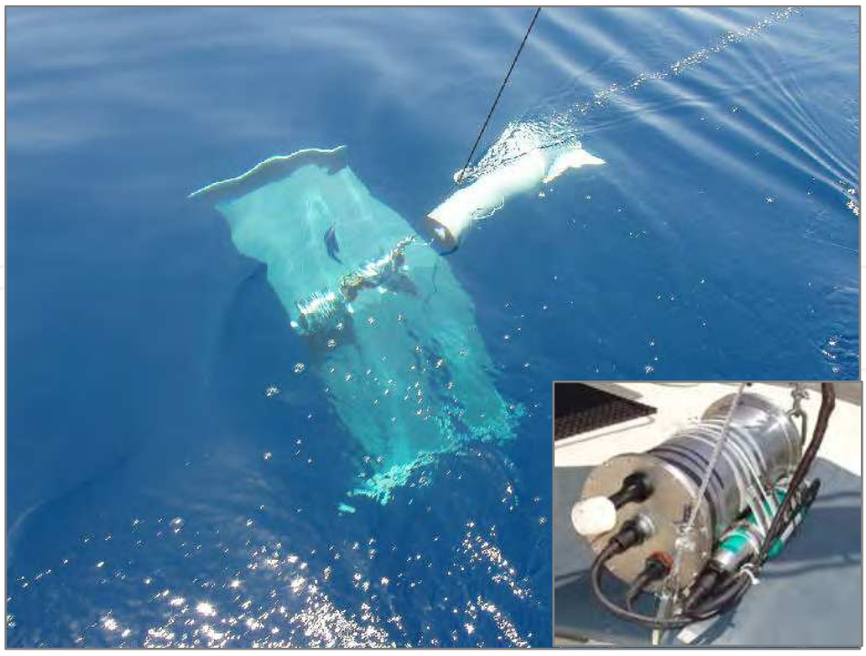


Fig. 17. CT sensor , data acquisition and data transmission unit on board the cylindrical vessel. SAVE was simulated by a IDRONAUT CTD probe.

6. Conclusions

Though many advances have been made in the technological innovation for the study of the seas and oceans, at present there is an increasingly need for technological development, both as regards the development of measurement platforms and so far with respect to the innovative sensors.

In fact, in most cases, either the measurement platforms are still too costly or they are limited in the use by the operational capabilities (eg, autonomy, depth, etc..).

To the development of new measurement platforms must also be joined efforts for the development of new sensors, especially for the physical measurement of biological variables.

Basically, on the one hand, the platforms to be developed must take into account the spatial and temporal scales of oceanographic phenomena, on the other hand, they must meet the need to be the sea truth of the satellites and mathematical models, that require large amounts of data for their calibration.

Even more it is to do to biological measures.

In fact, many solutions are still to be explored both for the measurement of nutrients and for the measurement of bio-optical variables, able to measure the optical absorption of light by phytoplankton.

The study of biological samples takes a lot of time and the use of highly specialized personnel, something that involves high costs.

Also commonly measured variables, such as oxygen and pH, require the development of new sensors: more stable, less fragile and less subject to attention from researchers (eg, calibration).

Other innovations are required to support marine technology: supporting innovations but fundamental.
For example, oceanographic research requires new materials (such as for the polar seas), new power systems, new computational capabilities.
For example:

- the AUVs are limited because of the weight, the lack of autonomy, the volume of electronics, and the inability to accommodate complex measuring systems (eg. for nutrient analysis);
- the gliders and floats profiling are limited by the ability to host complex and big sensors;
- the moorings are limited by the power support and from foulings on sensors;
- moreover satellites and models, for their calibration, require a very large number of measures that can be made available only by ad hoc developments of low-cost reliable and user friendly tools to be used extensively;
- the coastal shallow water represents a sea area where the develop of monitoring networks, with high spatial and temporal resolution, become increasingly crucial. This will only be possible as affordable technologies will became available.

Our choices of technological development were born in this scenario, with the aim to realize:

- a modular measurement technology, low cost and user-friendly, usable by different measurement platforms as more as possible: the T-FLAP;
- a measurement platform for the study of shallow water phenomena with high spatial and temporal resolution: the SAVE.

The T-FLAP was designed in 2003-2006 during UE MFS-TEP project, and after a long period of prototype development it was tested in different operative conditions.
The in situ tests analysed in this work, were performed in November 2006 along a transect in the central Tyrrhenian sea. The different profiles obtained show in this case the full satisfaction of the project requirements.
Comparing the T-FLAP measurements with the reference tool, the temperature profiles of the two instruments overlap almost perfectly.
The resolution of temperature measurement required by the project, at least 0.1 °C, was achieved and exceeded by an order of magnitude, infact T-FLAP temperature sensor has a resolutiony of 0.01 °C and a dynamic response of 0.5 ms.
With regard to the measurement of chlorophyll a, the comparison between the T-FLAP and the Aquatraka profile, shows that the fluorescence peak was well identified also by T-FLAP.
Since then, it is possible to identify correctly the depth of the DCM, satisfying also in this case the project requirement (i.e. the localization of the Deep Chlorophyll Maximum).
It is necessary to point out that the Tyrrhenian Sea is a really oligotrophic area of the western Mediterranean basin, especially during the summer season, where the mean values of Chlorophyll a is 0.06 mg/m3 , for the top layer of the water column (Bosc et at. 2004) , while the DCM reaches 0.6 mg/m3 in late summer (Marcelli et al. 2005). The identification of DCM in the Tyrrhenian Sea, during the month of November, grants a much better response of the instrument if the same is used in most eutrophic areas, such as the Adriatic Sea.

Because of the estimate of chlorophyll a concentration expresses a fundamental biological characteristic of the seas, the T-FLAP, once commercially produced, should be targeted not only for oceanographic research, but also for fishery, sea water quality, and coastal management.
The T-FLAP temperature measurements, will instead integrate the now ten-year XBT measurements, contributing, with high resolution temperature measurements, to SOOP programs and operational ocean forecasting.
Regarding to the SAVE it is a modular, flexible and versatile monitoring system to provide continuous profiles of physical and optical measure, along the water column, from a moving ship.
The system was designed for the most possible manageability and ship of opportunity use and was composed by a depressor, towed at fixed depth, and a vehicle, that slides autonomously along the cable, performing continuous profiles in the water column, for a fine physical and biological characterization.
The main objective of this research was to create a system that would provide quasi-synoptic measurements of ecological and physic-chemical variables in marine environment. Its main application are the basic scientific research, the environmental monitoring and the assessment of biological resources. Therefore it was created a module system capable to support different instruments and to expand its own working operating capabilities (Marcelli & Fresi, 1997).
This sliding platform allows to ride over the methods of traditional oceanography research and of marine environment monitoring, which are limited to the time scale of the observer and therefore they cannot carry out synoptic observations.

7. References

Aiken, J. (1985). The Undulating Oceanographic Recorder Mark 2 - Mapping Strategies in Chemical Oceanography. Advances in Chemistry, American Chemical Society, Vol. 209 ISBN 13:9780841208629, pp.315-332

Alpineà A.E. & Cloern, J.E. (1992). Trophic interactions and direct physical effects control phytoplankton biomass and production in an estuary. *Limnol. Oceanogr.*, 37(S), pp. 946-955

Antal, T. K., Venediktov, P. S., Konev, Yu. N., Matorin, D. N., Hapter, R., Rubin, A. B. (1999). Assessment of vertical profiles of photosynthesis of phytoplankton by fluorescentic method. Oceanologia (Russia), 39(2), pp: 314-320

Antal, T.K., Venediktov, P.S., Matorin, D.N., Ostrowska, M., Wozniak, B., Rubin, A.B. (2001). Measurement of phytoplankton photosynthesis rate using a pump-and probe fluorometer. Oceanologia (Poland), 43(3), pp: 291-313

Balch, W. & Byrne, C.F. (1994). Factors affecting the estimate of primary production from space. *Geophys. Res. J.*, 99, pp: 7555–7570

Bosc, E., Bricaud, A., Antoine, D.; (2004). Seasonal and interannual variability in algal biomass and primary production in the Mediterranean Sea as derived from 4 years of SeaWiFS observations, Global Biogeochemical Cycles, 18 GB1005, 10.1029/2003 GB 002034

Bruzzi, D. & Marcelli, M. (1990). Sviluppo di una metodologia strumentale automatica per il monitoraggio dei fondali marini, *Proceedings of VI Colloquio AIOM,* pp. 79-84

Dickey, T. D. & Bidigare, R.R. (2005). Interdisciplinary oceanographic observations: the wave of the future, *SCI. MAR.,* 69 (Suppl. 1), pp. 23-42

Favali, P. & Beranzoli, L. (2006). Seafloor Observatory Science: a review, Annals of Geophysics, vol. 49, N. 2/3, pp: 515-567

Hardman-Mountford, N. (2008). The chlorophyll global integrated network (chlorogin), *Changing Times: An International Ocean Biogeochemical Time-Series Workshop*, La Jolla, California 5-7 November 2008 IOC Workshop Report No 217, pp. 11-12

Lazzara, L., Bianchi, F., Falcucci, M., Modigh, M., & Ribera D'Alcala`, M. (1990). Pigmenti Clorofilliani, *Nova Thalassia*, 2, pp. 207–223

Mann, K. H. & Lazier, J. R. (1991). Dynamics of Marine Ecosystem, Blakwell Sci., 23–90, ISBN 0-86542-082-3, Michigan, United States of America

Manzella, G. M. R., Scoccimarro, E., Pinardi, N., & Tonani, M. (2003). Improved near real time data management procedures for the Mediterranean ocean Forecasting System – Voluntary Observing Ship Program, *Ann. Geophys.*, 21, pp. 49–62

Marcelli, M. & Fresi, E. (1997): "The SARAGO" project: new undulating towed vehicle for developing, testing new technologies for marine research and environmental monitoring. Sea Technology pp 62-67

Marcelli, M., Di Maio, A., Donis, D., Mainardi, U. & Manzella, G.M.R. (2007). Development of a new expendable probe for the study of pelagic ecosystems from voluntary observing ships, *Ocean Sci.*, 3 pp. 1-10

Nomoto, M., Tsuji, Y., Misumi, A. & Emura, T. (1986) An advanced underwater towed vehicle for oceanographic measurements. Advances in underwater technology, *Ocean science and offshore engineering*, vol. 6, pp. 70-88

Piermattei, V., Bortoluzzi, G., Cozzi, S., Di Maio, A., & Marcelli, M. (2006). Analysis of mesoscale productivity processes in the Adriatic Sea: Comparison between data acquired by Sarago, a towed undulating vehicle, and CTD casts. Chemistry and Ecology , Vol. 22, Supplement 1/ pp: 275-292

Pinardi, N., Allen, I., Demirov, E., De Mey, P., Korres, G., Lascaratos, A., La Traon, P-Y., Millard, C, Manzella, G. & Tziavros, C. (2003) The Mediterranean ocean Forecasting System, first phase of implementation (1998-2001), *Ann.Geophysicae*, 21, pp. 3-20

Reseghetti, F., Borghini, M., & Manzella, G. M. R. (2006) Improved quality check procedures of XBT profiles in MFS-VOS. Ocean Sci. Discuss., 3, 1441–1480.

Richardson, A.J., Walne, A.W., John, A.W.G. , Jonas, T.D., Lindley, J.A., Sims, D.W., Stevens, D., Witt, M. (2006) Using continuous plankton recorder data, Progress in Oceanography, 68, pp: 27–74

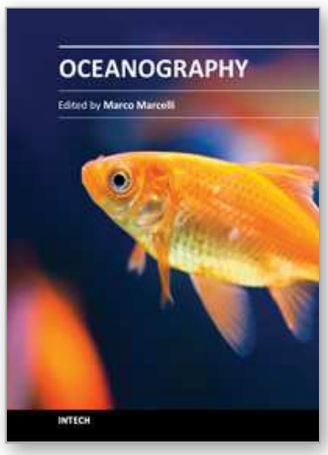
Schlitzer, R., Ocean Data View, http://odv.awi.de, 2011.

Thorpe, S. A. (2009). *Encyclopaedia of Ocean Science: Measurement Techniques, Sensors and Platforms*, Elsevier Academic Press, ISBN: 978-0-08-096487-4, Italy

Wiebe, Peter, H., Stanton, Timothy, K., Greene, Charles, H., Benfield, Mark, C., Sosik, Heidi, M., Austin, Thomas, C., Warren, Joseph D., and Hammar Terry (2002) BIOMAPER-II: An Integrated Instrument Platform for Coupled Biological and Physical Measurements in Coastal and Oceanic Regimes, ieee journal of oceanic engineering, 27, 3, pp: 700-716

IntechOpen

IntechOpen



Oceanography

Edited by Prof. Marco Marcelli

ISBN 978-953-51-0301-1
Hard cover, 348 pages
Publisher InTech
Published online 23, March, 2012
Published in print edition March, 2012

How inappropriate to call this planet Earth when it is quite clearly Ocean (Arthur C. Clarke). Life has been originated in the oceans, human health and activities depend from the oceans and the world life is modulated by marine and oceanic processes. From the micro-scale, like coastal processes, to macro-scale, the oceans, the seas and the marine life, play the main role to maintain the earth equilibrium, both from a physical and a chemical point of view. Since ancient times, the world's oceans discovery has brought to humanity development and wealth of knowledge, the metaphors of Ulysses and Jason, represent the cultural growth gained through the explorations and discoveries. The modern oceanographic research represents one of the last frontier of the knowledge of our planet, it depends on the oceans exploration and so it is strictly connected to the development of new technologies. Furthermore, other scientific and social disciplines can provide many fundamental inputs to complete the description of the entire ocean ecosystem. Such multidisciplinary approach will lead us to understand the better way to preserve our "Blue Planet": the Earth.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

Marco Marcelli, Andrea Pannocchi, Viviana Piermattei and Umberto Mainardi (2012). New Technological Developments for Oceanographic Observations, Oceanography, Prof. Marco Marcelli (Ed.), ISBN: 978-953-51-0301-1, InTech, Available from: http://www.intechopen.com/books/oceanography/new-technological-developments-for-oceanographic-observations

INTECH
open science | open minds

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

© 2012 The Author(s). Licensee IntechOpen. This is an open access article distributed under the terms of the Creative Commons Attribution 3.0 License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

IntechOpen

IntechOpen