

EGO: TOWARDS A GLOBAL GLIDER INFRASTRUCTURE FOR THE BENEFIT OF MARINE RESEARCH AND OPERATIONAL OCEANOGRAPHY

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Background

The concept of underwater gliders emerged from the work of Douglas Webb in 1986. His scientist colleague Henry Stommel anticipated their development and their use. He wrote an impressive “science fiction” article which was published in *Oceanography* (Stommel, 1989). In looking back on Stommel’s article anticipating autonomous gliders, we can now marvel at how much of what followed he had predicted. In the 1990 s, while gliders were being developed and successfully passing first tests, their potential use for ocean research started to be discussed in international conferences because they could help us improve the cost-effectiveness, sampling, and distribution of the ocean observations (see OceanObs’99 Conference Statement – UNESCO). After the prototype phase, three different operational gliders (Figure 1) were presented by their designers in Davis et al. (2002) and applications to ocean research were highlighted in Rudnick et al. (2004). Later on, one could only witness the growing glider activity throughout the world.

In 2004, the first European glider experiments were carried out in the framework of the European project MFSTEP of the Fifth Framework Programme (FP5). Later, the European FP6 project MERSEA in 2006-2009 and several national past and on-going projects have supported many glider operations in European and foreign waters. The first glider experiments in Europe brought together several teams that were interested in the technology and a consortium formed naturally from these informal collaborations. This relatively small group then expanded as increasing numbers of institutions began investing in this technology. In 2006, yearly European Gliding Observatories (EGO) Workshops and Glider Schools were first organized, which attracted teams from outside Europe (Australia, Canada, Mexico, South Africa, USA), whilst also becoming the international forum for glider activities (<http://www.ego-network.org>). Because of the international interest, as well as the relevance to a number of stakeholders, EGO has now come to mean “Everyone’s Gliding Observatories.”



Figure 1: The three operational gliders (from left to right: Seaglider, Slocum, Spray) transferring, while at surface, the data they just collected underwater and receiving new commands thanks to the bidirectional link Iridium link.

The group discussions within EGO turned into a Community White Paper presenting the glider activity of the last 10 years and some prospects for the next 10 years for the observation of the global ocean, which was presented at the OceanObs'09 Conference in Venice (Testor et al. 2010). Impressive results have already resulted from the glider activity. Using various on-board sensors, gliders resolve a wide range of spatial and temporal scales and reveal an amazing number of oceanic features. Glider data help us to better understand and characterize the oceanic physical and biogeochemical variability at basin scale, mesoscale, and even submesoscale (from 10^3 km horizontally and 1 month to 1 km and 1 hour). There is now a general agreement that the further development of ocean observations with gliders is necessary to better understand the ocean because they are capable to provide sustained synoptic observations of wide area ocean regions. Moreover, the assimilation of glider data in global and/or regional/coastal numerical models can significantly reduce the uncertainties of our ocean state estimates (physical and biogeochemical) leading to more accurate “ocean products” that provide new research opportunities and economic applications (e.g. fish farming, oils spill detection and spreading) but also satisfy safety aspects (e.g. search and rescue, naval applications) and decision making.



Figure 2: EGO - COST Action ES0904 partner countries in the European area on 2012/02/21 (BE, CY, DE, FI, ES, FR, GR, IL, IR, IS, IT, NO, PL, PT, SE, UK), South Africa has already joined the Action, Australia, Canada, Egypt, Mexico, Tunisia and Turkey have expressed their intention to join.

Some key challenges have emerged from the expansion of the glider system and require now setting up a sustainable European as well as a global system to operate glider and to ensure a smooth and sustained link to the Global Ocean Observing System (GOOS). Glider technology faces many scientific, technological and logistical issues. In particular, it approaches the challenge of controlling many steerable probes in a variable environment for better sampling. It also needs the development of new formats and procedures in order to build glider observatories at a global level. Several geographically distributed teams of oceanographers now operate gliders, and there is a risk of fragmentation.

Our consortium intends to solve most of these issues through scientific and technological coordination and networking. This approach is supported by the ESF through Cooperation in the field of Scientific and Technical Research (COST). The **COST Action ES0904 “EGO”** started in July 2010 aiming to build international cooperation and capacities at the scientific, technological, and organizational levels, for sustained observations of the oceans with gliders. Yearly calls provide the opportunity to grant student exchanges, travel, meetings, training, and publications that are related to our glider activity (see <http://www.ego-cost.eu>). One major impact of the COST Action was the inception of several European countries to get involved in aspects related to underwater glider operations (Figure 2). Another major impact of this Action was the elaboration of the EU Collaborative Project **GROOM, Gliders for Research, Ocean Observation and Management** for the FP7 call “Capacities – Research Infrastructures”, which addresses the topic “design studies for research infrastructures in all S&T fields” and its recent acceptance (see <http://www.groom-fp.eu>).

The GROOM project: A Design Study on a European Research Infrastructure for gliders

The GROOM project started in November 2011 and addresses more specifically the progress that can be achieved with gliders to improve the objectives, coverage, resolution and organization of existing marine observation systems. The overarching goal of GROOM is to assess the requirements and to provide a roadmap for the installation of a sustained and distributed glider component as part of a European Network of Marine Observatories and as such as a contribution to the GOOS. The European glider infrastructure should safely operate individual as well as fleets of gliders in order to create a continuum of observations. Operations shall be coordinated to fill the gaps left by present marine observation systems on global, regional and coastal scale, with benefits for both fundamental marine research and operational oceanography.

The GROOM objectives, as well as the assessment of its potential impacts, are mainly formulated in the context of the concepts, reference terms and calls raised by the instruments and roadmaps set up recently by the vision statement “Towards a European Network of Marine Observatories” of the Marine Board (MB) of the European Science Foundation and by the program Global Monitoring for Environment and Security (GMES). The MB highlighted that there is a crucial need for “a long term, stable and integrated network of strategic marine observatories, installed and operated through multinational cooperation and support, providing consistent in-situ data from the seas and oceans in support of the EU Integrated Maritime Policy and as a driver for smart, sustainable and inclusive growth in Europe (Europe 2020)”. The GMES started to be reality, with the Marine Core Service (MCS), which was rapidly established in line with discussions within the Group for Earth Observation (GEO). The MyOcean programme started in 2009 and is now implementing the adequate and sustained framework for the integration of data needed for the 4D mapping of the state of the ocean to deliver marine services. As an important consequence, the need for reliable sustained observing system providing adequate *in situ* data for assimilation and validation started to increase. The GMES In-Situ Coordination (GISC) was established in 2010 by EEA as an FP7 programme. It is now the reference frame for the assessment of marine observation systems aiming at providing real-time (RT) data for the MCS and is drafting an ocean in situ observing system convenient to the MCS, based on terms of feasibility, costs and benefits.

The objectives for this design study for a European glider Research Infrastructure (RI) are to demonstrate that

- 1) A distributed architecture of “gliderports” around the European seas and overseas (see figure 2), working in close coordination, is the required and cost effective way to operate fleets of gliders in combination with the other existing observing systems,
- 2) This glider infrastructure is suitable to deploy, maintain and operate individual as well as fleets of gliders continuously for operational monitoring and research.
- 3) Such infrastructure can provide a world-class service to the research and environment monitoring communities.

The geographical distribution (Figure 3) is desirable in the sense that it multiplies the possibilities for servicing gliders and is in phase with the ROOS concept. However, it is potentially a weakness as the European glider engineering teams may not individually reach the critical size to be able to pilot gliders. The GROOM goal here is to foster the different initiatives from these different teams avoiding duplicate efforts. GROOM will help us to reach a stage where gliders can be used in numbers by the scientific and marine monitoring communities to contribute to the GOOS/ROOS. Through GROOM we will deploy gliders for dedicated process studies and creative applications and seek to avoid duplication of the efforts required by such a glider activity.

Significant progress could be achieved with such an RI for gliders appearing as a single entity based on land facilities in a number of distributed “gliderports”. This would improve:

- Scientific coordination of the European resources (how/where to deploy gliders? which sensors?),
- Technological coordination (to develop new platforms/sensors),
- Harmonisation of the procedures for glider deployments, piloting and recoveries,
- Definition of ownership and governance definition of rules for transnational access,
- Data access and dissemination with single-point portal and a data/metadata format which is compliant with international standards.



Figure 3: GOOS/ROOS considered in the MyOcean project (1) Global ocean, (2) Arctic Ocean (Arctic ROOS), (3) Baltic Sea (BOOS), (4) Atlantic European North West Shelf Ocean (NOOS), (5) Atlantic Iberian Biscay Irish Ocean (IBI-ROOS), (6) Mediterranean Sea (MOON and Med-GOOS), (7) Black Sea (Black Sea-GOOS) ; European possible “gliderports” are indicated by yellow stars.

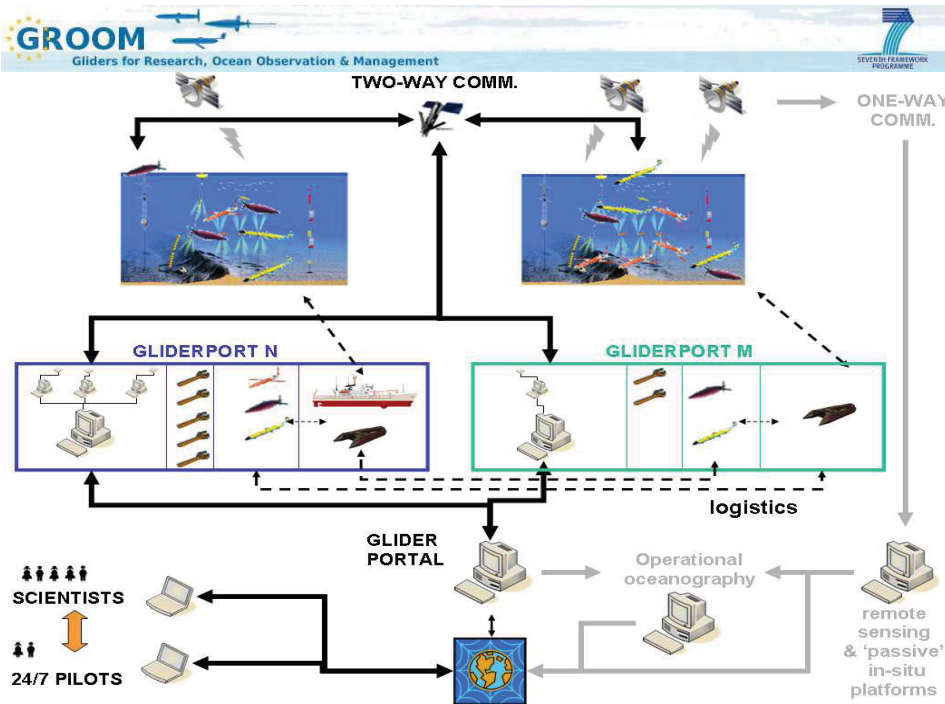


Figure 4: GROOM vision of integrating the two-way communication capabilities in the existing observing and modelling system. Scientists would interact with 24/7 pilots in order to steer the glider fleet in an optimised way, getting all relevant information on the marine environment (numerical products, remote sensing images, GIS, in-situ data from other platforms, etc.). This would be based on an infrastructure of several “gliderports” (from left to right: communication and computer resources, workshops for maintenance and development, pools of gliders, sea-access) distributed according to the GOOS/ROOS strategy.

A future European infrastructure for gliders will be defined in GROOM based on what exists and the existing, but fragmented, glider infrastructure. A network of gliderports could compose a distributed ground segment (Figure 4), which would have to be based on tight networking for computers and software, on efficient man-machine interfaces and tools from artificial intelligence, as well as on at-sea experience. A focus will be given to 1) the currently existing, distributed ground-segment, 2) the glider scientific payload technology, 3) the tools to plan/dimension the glider effort to be made in order to fulfil the scientific objectives defined by preparatory actions and 4) the costs of the individual Member State glider activity.

Such a structure to be designed by the GROOM project will have to stimulate and not stifle all the creative applications of the glider technology. Therefore, the innovative part in operating gliders for science will be explored. The use of new sensors and sensor combinations (synergy) on gliders to observe, in near real time, all the components of the marine environment, including ecosystems (and in particular in complex oceanic regions: fronts, sub-mesoscale features, under-ice observations) will be examined.

Another one of the main issues that GROOM has to address is to find the optimal topology for the gliders' sampling in relation with the gaps of the pre-existing networks (in-situ and satellites) and operational circulation models. Obviously, this depends on the objectives of the networks in terms of spatial and temporal resolution, the nature and variability of the parameters and processes to be monitored as well as on the estimate of the ocean state used for the decision. The design and execution of new missions will have to be carried out to guarantee that a successful implementation of the various infrastructure parts designed in GROOM is possible. At the same time, the GROOM project will trial new techniques and approaches that will be key features for the future ocean observing system.

Finally, the GROOM project aims also at assessing the possible governance of such a European glider observing system. The goal is certainly not an entity centralizing all European gliders, such as UNOLS for ships in the US or IMOS in Australia. A distributed version is preferred and in the long term, one can imagine that the different glider teams supported by the EU and national authorities might contribute with their resources to a European pool of gliders. Whether coordinated calls for proposals may be useful, also has to be discussed. This design study will first describe in detail why a governance structure would be required and investigate how it could be implemented.

Conclusions and perspectives

Sustained observations of the ocean are mandatory on a variety of space and time scales and gliders can certainly contribute to this, if deployed in combination with other existing ocean observing systems (research vessels, Ocean-Sites moorings, Argo profiling floats, XBTs, satellites, volunteer ships, surface drifters, radars, acoustic arrays, ...) according to science-driven objectives. The optimal configuration of the Research Infrastructure proposed by GROOM will have to be beneficial for both marine research and operational oceanography, being able to carry out both intense process studies and continuous monitoring. The gliders offer really new capabilities in terms of sampling and have a tremendous potential for the scientific payload, so we expect this project will lead to frontier-science studies that cut across platforms and types of ocean observations, and will develop synergies with projects contributing to the GOOS (like Euro-Argo, JERICO, FIXO3, ACOBAR ...) and the project MyOcean2 in the next coming years.

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