LIFE Integrated Projects 2016

Optimising the implementation of the 2nd RBMP in the Malta River Basin District

LIFE 16 IPE MT 008

Action A7:

Designing a marine observing and modelling system for the Maltese Islands

Designing an observing and forecasting system for the Maltese Islands

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Progress Report

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INTRODUCTION

The Physical Oceanography Research Group (PO.Res.Grp) established within the Dept. of Geosciences at the University of Malta has been entrusted to support the Environment Resources Authority (ERA) in Action A.7 of a preparatory action of the LIFE RBMP project, LIFE 16 IPE MT 008: *Optimising the implementation of the 2nd RBMP in the Malta River Basin District.* The expected outcomes contemplate the design of: (i) a marine data acquisition system of operational automated observing platforms for routine long term and real time monitoring for the Maltese Islands to complement the existing local station observations, comprising the setting up of a first phase of operational installations at sea, and (ii) a comprehensive marine modelling system to serve as a tool to provide a baseline oceanographic characterisation of Maltese waters down to coastal scales, contributing to the requirements of the EU Water Framework Directive (WFD) and Marine Strategy Framework Directive (MSFD), with particular focus to the development of a capacity to assess hydrographical changes.

This short report is a summary of actions made to implement the task according to the agreed terms of reference comprising the design of the operational observing and modelling system for the Maltese Islands and a comprehensive report identifying the structure and components for the marine modelling system and how it fits the observing system to address the monitoring strategies and obligations. The actions are ongoing and target to be completed by the end of 2018 when the design phase is expected to be elaborated. The full marine observing and modelling system will build upon existing assets, infrastructure and expertise, such as those held or in planning phase by the PO.Res.Grp, so as to avoid duplication and maximise efforts. The intention is also to propose systems that will also serve other users, such as national stakeholders as well as the private sector, where appropriate, and extending the use of the data for the provision of services of wide interest and application, thus creating a multiplier effect at the same cost for the country.

INTERNATIONAL WG

The networking with international experts in ocean observations and modelling, in particular experts that have already been engaged and have a track record in operational oceanography systems, is sought through a dedicated expert WG. The WG is composed of two interacting units, one concerning marine observations and operational data acquisition systems, and another unit dealing with the numerical modelling backbone needed to simulate the marine environment in all its ecosystem components down to the local coastal scales. Members on the this WG were chosen on the basis of their expertise and practical level in such systems as proved through their CV and publications, or through direct contacts in previous collaborative work with the PO.Res.Grp. The WG meets and delivers through remote conference sessions in addition to exchanges by electronic means. The WG is chaired by Prof. Aldo Drago who conducts the work of the WG and sustains one-to-one exchanges with members for further elaboration of important thematics relevant to this work.

NAME	AFFILIATION	ROLE	EXPERTISE
Mr. Julien MADER	AZTI-Tecnalia, Spain	Head of Marine Technologies Area	*Observations*
Dr. Enrique ALVAREZ FANJUL	Puertos del Estado, Spain	Head of Physical Oceanography Division	*Modelling*
Dr. Giovanni COPPINI	Centro Euro-Mediterraneao sui Cambiamenti Climatici, Italy	Director of Ocean Predictions and Applications Divison	*Observation and Modelling*
Prof. Marco MARCELLI	Laboratorio di Oceanografia Sperimentale di Ecologia Marina, Università della Tuscia, Italy	Head of the Laboratory; Dept. Ecological and Biological Science	*Observation*
Prof. Georgios SYLAIOS	Democritus University of Thrace (DUTH), Dept. Of Emvironm. Eng., Lab of Ecological Engineering and Technology	Director of Lab of Ecol. Eng.; Prof at DUTH	*Modelling*
Eng. Reimer de GRAAFF	Deltares, Netherland	Harbour Coastal and Offshore Engineering	*Observation and Modelling*
Dr. Ghada EL SERAFY	Deltares, Netherland	Data Scientists	*Data Assimilation*
Prof. Marco ZAVATARELLI	University of Bologna, Italy	Associate Professor	*Observation and Data Management*
Dr. Katerina SPANOUDAKI	Deltares, Netherland	Harbour Coastal and Offshore Engineering	*Observation and Modelling*
Dr. Silva ADELIO	Hidromod, Portugal	General Manager	*Modelling and Operational System*
Mr. Ivano BARLETTA	CMCC - Centro Euro Mediterraneo sui Cambiamenti Climatici	Research Fellow	*Modelling and Observation*
Dr. Alice MADONIA	Tuscia University, Viterbo, Italy	Research Fellow	*Observation*
Dr. Cosimo SOLIDORO	National Institute of Oceanography and Experimental Geophysics (OGS)	Head of the Marine Systems Modelling Group (ECHO)	*Modelling*
Mr. Paulo CHAMBEL			

Table 1. List of experts participating in the WG

The WG made a first meeting on 18th September 2018 in which Prof. Drago made a long and detailed presentation of the project. The presentation posed the ideas and basic design aspects with a number of questions and pointers for follow up; members engaged in suggestions and comments that were then followed up by direct contacts with key members.

MARINE MODELLING SYSTEM

The PO.Res.Grp is already running sub-regional shelf scale models to deliver forecasting services of key marine parameters. These comprise the Princeton Ocean Model eddy resolving ROSARIO forecasting system which runs at two resolutions, $1/64^0$ and $1/96^0$ resolution with 1hr and 3h averaged output fields respectively of temperature, salinity and velocity; and the WAM model at $1/8^0$ resolution covering the whole Central Mediterranean area with forecasts of significant wave height, peak period, mean period and spectral outputs over a regular grid. For sea waves the forecast fields are further downscaled to coastal areas and resolving the embayments of the Maltese Islands through the use of a SWAN model that goes down to a finer resolution using a regular grid of $1/500^0$. For coastal hydrodynamics a high resolution version of the ROSARIO forecasting system is being developed through the use of a finite element modelling approach using SHYFEM and implemented by an unstructured mesh over a domain comprising the Maltese Islands and the Malta Channel up to a substantial part of the Sicilian southern coast.

The models described above will provide the baseline model fields that will support the full national modelling system that is being designed as a hierarchy of nested models that links the coarser resolution sub-regional shelf scale and coastal models to a fully integrated suite of nearshore local scale super fine resolution models that are the ultimate target of this project. The coarser resolution models will generate the essential data and boundary conditions for the local scale models. These super resolution local models are intended to provide key marine information and forecasts in a number of selected areas; they will also serve as a platform to enable assessments at local scale such as for sediment transport studies, dispersion of pollutants, siltation processes, harbour impacts, water quality in restricted water bodies, impacts from coastal engineering works, and serving in general to provide the tools in support of WFD and for reporting of hydrographical changes in relation to MSFD commitments.

The local scale models are expected to be established at specific chosen areas like in proximity and inside the five principal harbours, and in other key areas that warrant special operational services. It is also envisaged that the same suite of local models will be deployed as a relocatable version that enables the same modelling platform to be applied in any other specific area of interest with the same setup and modelling infrastructure according to ad hoc specific needs and assessments including the hydraulic behaviour in harbours and in coastal sites.

The local scale modelling system will comprise two levels of interlinked models:

(i) the **primary models** which will provide the hydrographical and dynamical fields at very high resolution through the use of transport/flow numerical models, and the detailed description of sea states at a local scale by wave modelling that comprises the effect of shoaling, diffraction and refraction of waves within complex coastal configurations; and
(ii) the **process models** which are used to study or monitor nearshore environmental and engineering situations through quantified process identification and analysis, simulation of impacts, and prediction of alterations. Some examples of process application models comprise sediment, pollutant and heat transport models as well as more specific aspects like water quality modelling, siltation modelling, harbour flushing modelling, marine impact modelling and coastal erosion. The process models are interlinked to the primary models which provide the basic fields for their running.

The overall design and plan of the modelling system is being coordinated and detailed by the project responsible Prof. Aldo Drago. Inputs from an international WG will be integrated to prepare a state-of-the-art design and implementation plan of the modelling platform, building on the local existing numerical modelling expertise and making use of the best available numerical models that meet the demands of the project.

For what concerns numerical modelling the following points are being considered:

- a detailed review and assessment of existing local scale numerical models that are available from different sources. The task is intended to list the available models and their sources and documentation, detail their numerical characteristics and skill/reliability through existing applications, identify the strengths and weaknesses of each model in terms of performance, cost, computational efficiency resources required for their running, user friendliness, available documentation for their setup and implementation including their linkage to existing to the coarser coastal and shelf scale models. Separate reviews are expected for the primary models and for the process models respectively, and on how the process models can be linked to the primary models. Some of the model suites that are expected to be reviewed are the Delft suite of models by DELTARES, HR Wallingford, Danish Hydraulic Institute, MOHID, TELEMAC and other systems to be identified.

- Identification of the steps needed to link the various local scale numerical models modelling systems to the existing sub-regional shelf scale and coastal scale numerical modelling infrastructure currently run by the Physical Oceanography Research Group. This might include suggested alterations/enhancements that might be needed on the coarser scale models.

- review the adaptability of the various local scale models to be used in forecasting mode vs process or assessment mode

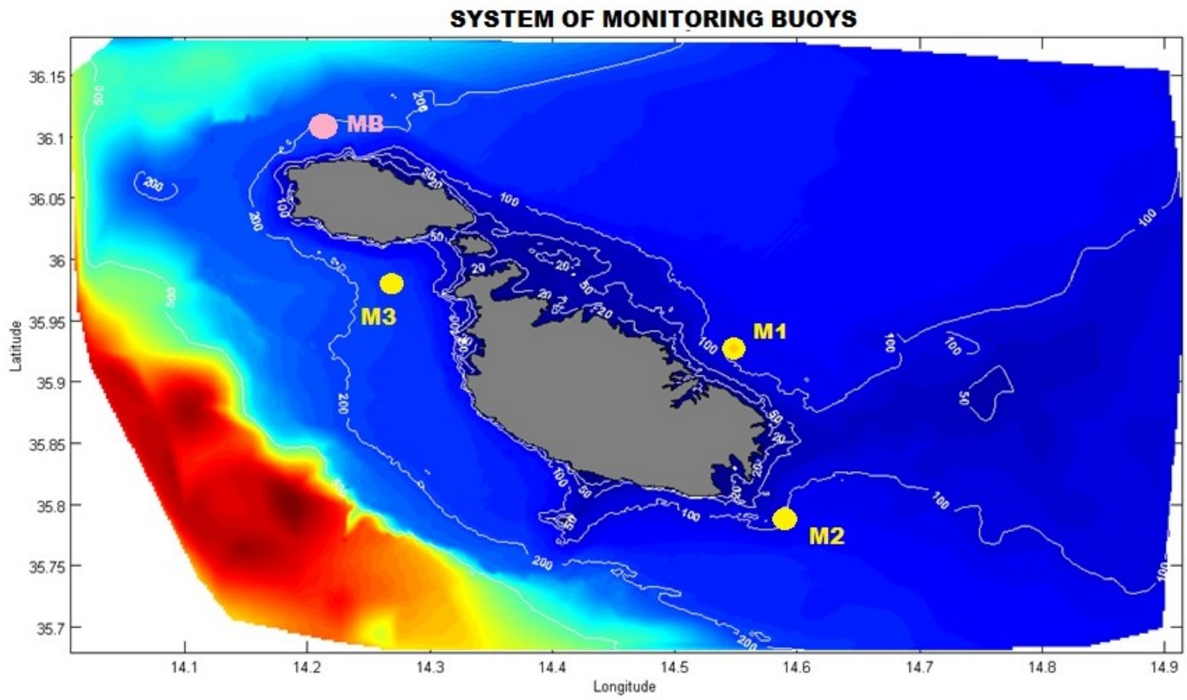
- review the adaptability of the various local scale models to be used in a relocatable model setup so as to be able to monitor ad hoc local scale marine domains within the coastal area of the Maltese Islands.

MARINE OBSERVING SYSTEM

Another aspect of the report consists in the design of a dedicated marine observing system for the Maltese Islands consisting of monitoring systems in coastal waters, extending over the shelf and open sea areas, providing multiple parameters to assess important physical, chemical and biological processes, and to provide snapshots as well as long term datasets on the state of the sea. Observations are generally made at a high frequency (several times per day, even several times per hour), often at multiple depth levels. Data is provided in (near) real-time, by using telemetry to transfer measurements back to land for onward publication on web interfaces and dissemination to users. Observing systems generally consist of a number of fixed platforms and/or buoys with a number of instruments and sensors to measure a range of physical (temperature, salinity, current profiles, waves and meteorological) and biochemical (dissolved oxygen, pH, fluorescence and turbidity) parameters. More recent technologies provide solutions for adaptive observing systems especially through automated vehicles (like sea gliders) which can sample the sea by remotely controlled systems and according to need and interest.

The marine observing system under consideration comprise the following main components:

MOORED OBSERVING SYSTEM consisting of a network of automated buoys deployed at selected locations around the islands. These stations will routinely measure key meteo-marine parameters in the sea surface and subsurface layers in order to assess and monitor the state of the sea. The measurements are transmitted and disseminated to users through a dedicated communications and internet based system. The system will provide long term data sets to enable the identification of trends, improve the assessment of variability against reliable background fields, and provide an efficient alert to



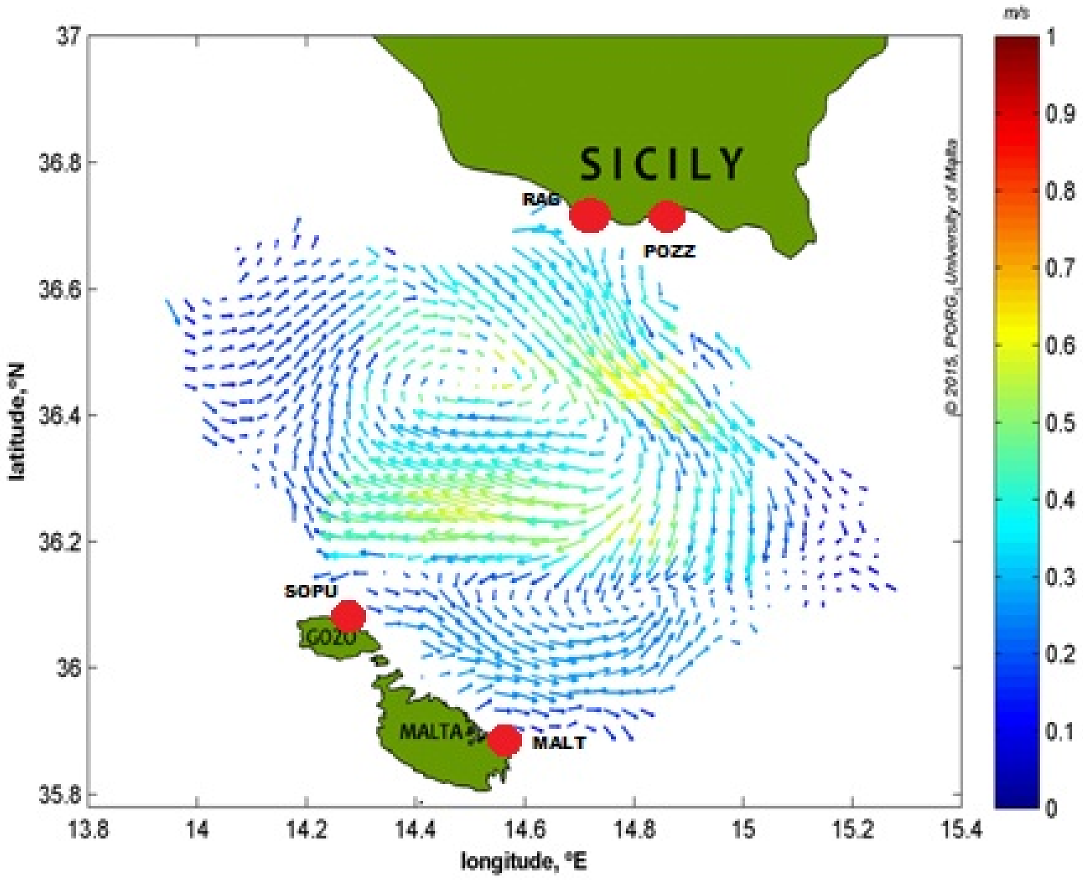
Configuration of marine offshore buoys for 'in situ' observations; in pink the main multi-parametric buoy and in yellow the secondary buoys.

key environmental indicators. It will moreover provide the basis for ocean predictions, improved atmospheric forecasts especially in the open sea areas, supporting environmental assessments to aid the decision making process, and enabling more efficient rescue operations. A primary multi-parametric buoy will be deployed to measure key parameters at the surface and in the water column and located at a strategic offshore location. Four other secondary buoys will be positioned at locations closer to the coast and target more basic parameters and with a focus on surface conditions. The main buoy will monitor waves, measure meteo, physico-chemical and biological parameters in the surface and water column providing general information on the weather and circulation, and serve to give an early warning against remote sources of pollution. It will provide 'background' data for comparison with nearshore levels. The buoy will be designed to support additional moored and seabed sensors as well as sediment traps for biogeochemical lower trophic parameters to be added in a second stage. The secondary buoys will be deployed closer to shore in strategic positions to also serve other usage such as in proximity to ports. Their main target is to furnish data to monitor coastal processes and to assess trends closer to the coast. Besides surface waves, temperature, salinity and other key parameters these moorings will also carry ADCP sensors to measure profiles of subsurface currents; temperature/conductivity sensor arrays for time series of sea temperature and salinity profiles would be a first choice addition. The full set of buoys are necessary since the Maltese Islands are positioned close to th e shelf break and the coastal circulation is very much dictated by forcing from the open sea areas.

SEA LEVEL OBSERVATION NETWORK

This system will at least comprise three sea level gauges installed at selected locations on the coastline of the Maltese Islands, measuring sea level variations at high temporal resolution as well as sea water temperature and a suite of meteorological properties, sampled and transmitted in real-time; This system is already being executed by the Physical Oceanography Research Group (University of Malta) with a permanent coastal station already established in PortoMaso, and another two planned in Marsaxlokk and Mgarr Harbour. The network can be combined to arrays of open sea pressure sensors on the seabed at strategic locations, and to supplementary geodetic measurements (including permanent GPS surveying) to provide early warnings against tsunami hazards. This kind of network will be fully compliant to international standards and integrated into the international GLOSS network and its Mediterranean MedGLOSS sub-system. The network will primarily support port operations and navigation, ocean prediction, storm surge predictions, climate change, and hazard from anomalous sea level phenomena like tsunami.

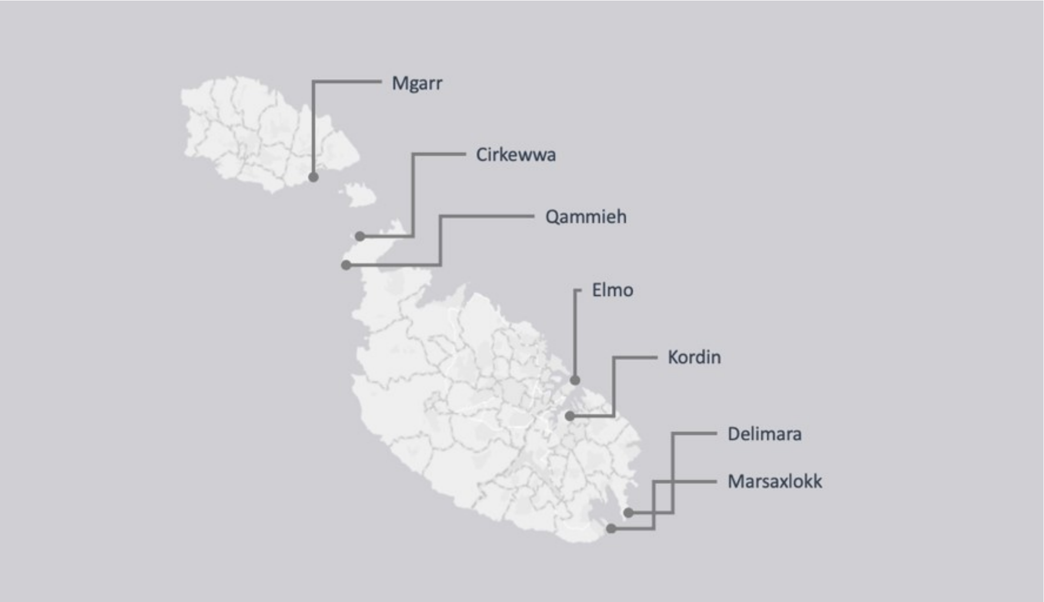
COASTAL RADAR NETWORK consisting of a number of HF radar stations for real time concurrent observations of sea surface currents and waves in the marine domain around the Maltese Islands. The network will furnish routine updates in the form of 2D maps in real time (nominally every hour). The network will rely on combining radial HF radar data from stations on the Sicilian coast. Through the CALYPSO series of projects led by the Physical Oceanography Research Group (University of Malta) a network is already in operation since 2012 (www.capemalta.net/calypso) comprising four CODAR SeaSonde HF radar stations, two on the side of Malta and another two on the side of Sicily. A new project, CALYPSO South led by Prof. Aldo Drago, has secured funds to extend the CALYPSO HF radar network by three additional radars, two which are intended to be installed on the southern shores of Malta and Gozo respectively so as to monitor the southern approaches to the Maltese Islands. In conjunction with numerical models, the network will serve as a tool to assist in oil spill contingency planning and response, to strengthen the response against marine hazards, and improve safety at sea. Such a radar network would also open the way to important applications including improved meteo-marine forecasts, monitoring of currents in critical areas such as ports, safety and rescue, marine transportation including short ship routing, etc.



Existing HF Radar stations measuring sea surface currents

COASTAL METEO OBSERVATION NETWORK

This system builds on existing elements currently maintained by the Physical Oceanography Research Group (University of Malta) (http://ioi.research.um.edu.mt/WeatherStations/index.php/welcome/index), and will establish an extensive national network of automatic weather stations on the coastal fringe sampling the coastal maritime environment. Such a system is already in plan for implementation in 2019 within the CALYPSO South project. The system will comprise a stations situated in harbours and specific locations where high resolution wind and meteo information on the local scale is required. Besides linking to similar stations that are being set up within the same project on the southern Sicilian coast, the network will be further integrated to measurements from the offshore stations. It will be necessary to converge all observations through a common robust and reliable networked system for validation and for the delivery of consistent, quality controlled marine meteorological data.



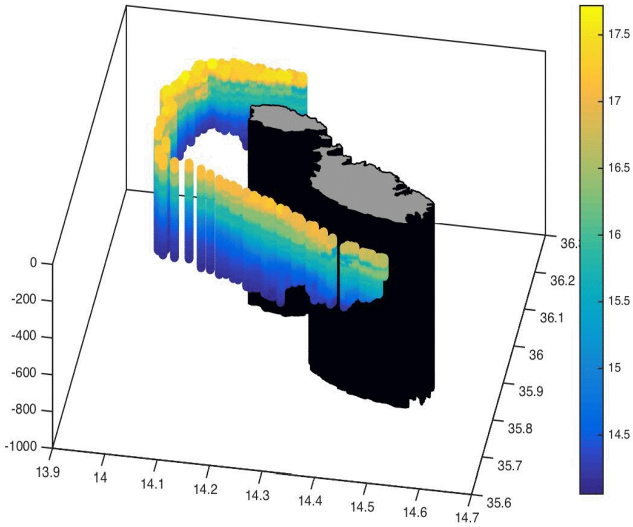
PORTO network of automatic weather stations

AUV FACILITY

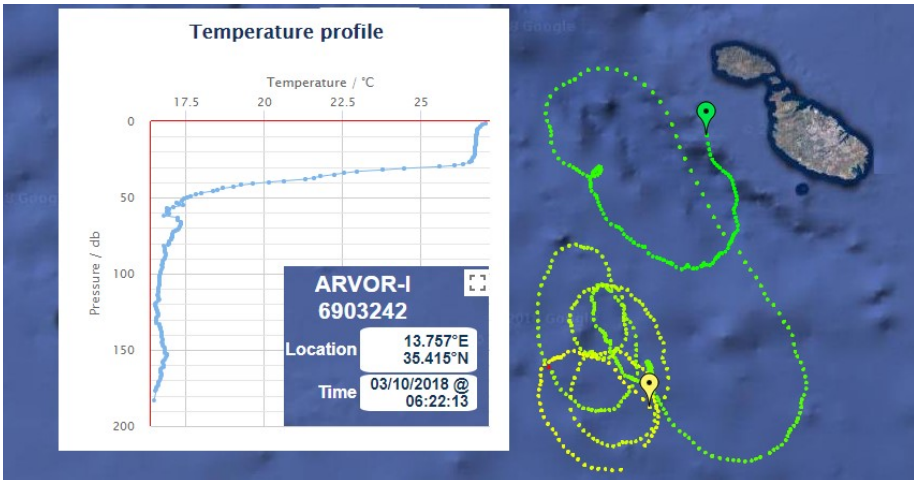
Autonomous underwater vehicles (like profilers, sea gliders and propelled UVs) are becoming essential - and relatively low cost components of marine observing systems, offering a new perspective on adaptive observations in the field of ocean dynamics and marine biogeochemistry, as well as for operational oceanography. In particular, the operational use of gliders for mesoscale studies at regional and coastal scale is becoming increasingly used especially with the integration of sensors like CTD, optical sensors (measuring Chlorophyll-a, Backscatter) and oxygen optodes. Sea gliders harvest their propulsion from the ocean itself by changing their buoyancy to descend and ascend the water column. A pair of fixed wings, vertical tail fin, rudder and movable internal battery packs steer them during their silent journeys soaring through the oceans. Being unmanned and fully-submersed, the ocean gliders can work around the clock in all weather conditions continuously sampling the water for temperature, salinity, dissolved oxygen, chlorophyll and turbidity. Their positions are fixed by the Global Positioning System (GPS) when they surface and communicate with a land base via Iridium satellite, relaying collected data and receiving any new commands for the next set of measurements. The gliders have the potential to obtain repeat profiles at much lower cost than traditional methods and have the potential to replace expensive and logistically difficult ocean moorings. They also offer the possibility of obtaining data under all weather conditions which is not always feasible using ship borne platforms.

For the Maltese Islands a minimum of 2 gliders deployed at any time and moving in synchronous paths around the Maltese Islands with a phase shift of half a turn would suffice to offer intensive round-the-clock monitoring of the coastal waters with 360^o vertical parameter field snapshots every ten days for key physical, chemical and biological properties. The gliders to be proposed in the report will offer high manoeuvrability and are suitable for use in shallow coastal waters (< 200m). A glider fleet of three units would be needed to execute this kind of sampling strategy.

Use of a sea glider fleet to map key water parameter vertical profiles around the Maltese Islands



The Physical Oceanography Research Group has already had experience with the use of sea gliders in the GLIDER South project led by Prof. Aldo Drago in 2017. In this project a SLOCUM sea glider from the French CNRS-INSU Glider National Facility was used to cover transects between Malta and Libya collecting over 2000 profiles in 66 days of mission.



ARGO float deployed SW of the Maltese Islands and display for real time transmission of data

The marine observing system is also expected to avail of drifters and ARGO floats which can be employed to autonomously collect data from sensors attached to a floating system that follows currents and can make vertical profiles at programmed time steps with transmission of data in real time. The Physical Oceanography

Research Group has been deploying such devices at sea for the last five years, the most recent deployment being in Summer this year with a float that is still active collecting data SW of the Maltese Islands.

REMOTE SENSING OBSERVATIONS

Data from satellite platforms with resolutions suitable for shelf scale and coastal areas are important components of an integrated observing system. Coastal applications of remote sensing require significantly finer temporal, spatial and spectral resolution compared to open-ocean studies. The answer comes from the use of satellite platforms with a hyper-spectral environmental suite for coastal waters and with complementary payloads of atmospheric sounding sensors.

In the report the availability of useful satellite data fields available from the COPERNICUS Marine Environment Monitoring Service (CMEMS) will be reviewed to highlight essential applications such as for the larger scale water quality assessments, the calculation of environmental indices, and for oil spill alerting. It is however also necessary to point to the need of establishing bilateral agreements for access to higher resolution datasets such as with Italy for COSMOSKYMED as well as to identify the need of direct acquisition by aerial surveying.

The most important satellite data refer to meteorology (already supported by the local Meteorological Office), ocean colour (primarily chlorophyll-a), sea surface temperature and sea surface winds.

COASTAL ENVIRONMENTAL QUALITY MONITORING SYSTEM

This will consist of a coastal ecosystem monitoring and surveillance system composed of hydromorphological, physico-chemical and biological observations made on a routine basis through the use of ‘in situ’ sensors, sea floor surveying as well as laboratory analysis on water samples collected from an array of station points covering the coastal waters of the Maltese Islands for at least up to 1 nautical mile. Such monitoring is already being co-ordinated by the Environment Resource Authority to support environmental compliance and reporting commitments to the various international provisions and EU Directives (such as the Water Framework Directive, 2000/60) and UNEP/MAP, to monitor the general state of health of the marine environment.

COMPUTING AND IT INFRASTRUCTURE

A design recommendation is also being prepared for the infrastructure needed to house the necessary processing power and workflows to sustain the expected volumes of data from observations and from the modelling platforms, including the data post processing, archival, management, service production and dissemination.

The overall Marine Data & Information Generation, Management and Dissemination System will comprise and integrate the following components:

- the computing platform comprising high performance computational machines to run numerical models
- the processing of data from models and observational platforms to perform quality control, file formatting, data archival and management
- the dissemination of data and derived products through dedicated web services and user interfaces.

It is anticipated that such a system could be set up as a standalone for the marine component of the LIFE IP, but would ideally be integrated into the overall data systems of the full project, providing a cost effective and state-of-the-art system that serves the full range of data generated within the project.

The design will deal with the:
Observations Data Nodes (Ingress) comprising the data reception, validation and quality control. An important element of these nodes will ensure that various stages of data levels and processing are kept in the database under different schemas for ease of reference. Such stages are necessary in cases where derived applications and services need to be run under different criteria to produce different processed output results.

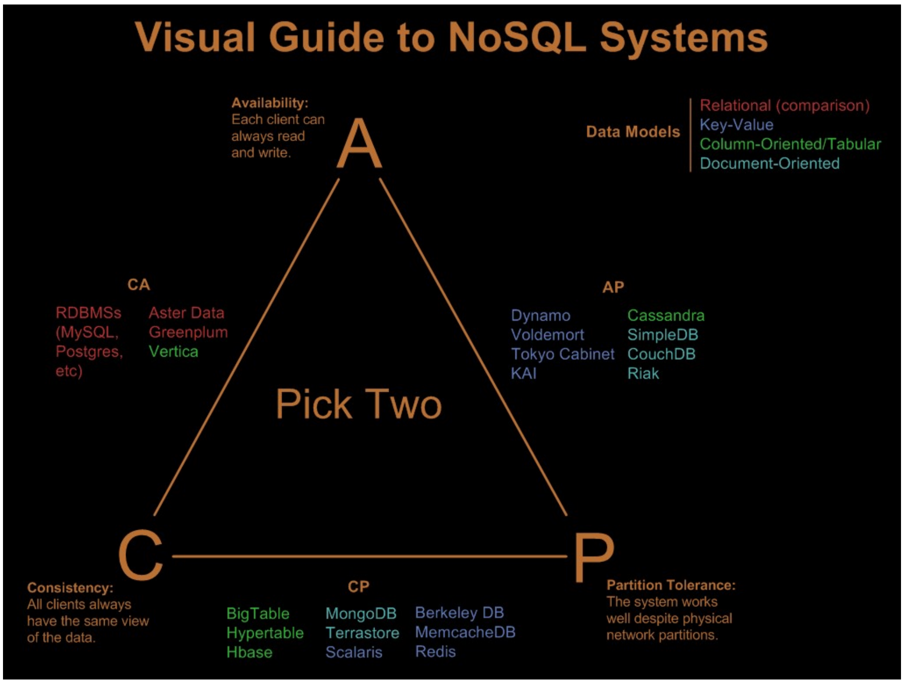
Numerical Model Data Nodes (Internal) to cater for the number crunching numerical simulations for the generation of forecast data fields by dedicated mathematical models. The platform will be robust enough to handle high resolution coastal scale models that require much higher computational power than we have today. This will also be coupled with an architecture to offer a reliable and redundant performance seeking to deliver model runs from alternative data resources in case of lack of boundary and forcing data. The platform will need to also switch over to alternative computing standby resources in case of system failures in orfer to secure an uninterrupted service provision.

Data Management Nodes (Internal) for the handling of metadata, connection and mapping of data layers as well as data archival in a structured system.

Delivery Nodes (Egress) to manage the external access to the data warehouse. The design of these nodes will funnel requests through one API gateway, ensuring consistency across different data consumers, ease of API fixes/upgrades given that this is the only channel of data egress and security through user tokens and access criteria.

This part of the work will furthermore deal with the:

Databases mainly to make the case in favour of NoSQL databases vs the traditional relational databases. The flexibility brought about by NoSQL databases is gaining traction, and therefore suited for use in this project. The figure below highlights the main pillars of a NoSQL system, and hence, the basis upon which to favour this database system.



CAP Triangle [Ref: https://blog.scottlogic.com/2014/08/04/mongodb-vs-couchdb.html]

Platform Architecture to define the logical and technical components for the data handling, and to propose the hardware configuration needed to house effectively the proposed system solution.

Hosting Solution dealing with the options and costs for on premise solutions vs externally supported (cloud) solutions; this will include budget estimates for CAPEX at start, CAPEX for growth and OPEX.

OPERATIONAL OCEANOGRAPHY CENTRE

The report will also define the scientific and technical setup needed to secure the running of the observations platform, the modelling platform and the operational system managing the data and delivering the services. The suggested plan is to build upon and make use of the existing human and infrastructural resources within the Physical Oceanography Research Group (PO.Res.Grp) of the University of Malta (ex Physical Oceanography Unit) which has a 25 year experience in operational oceanography and already delivers some of the data and product services targeted by the proposed system. The proposed arrangements should be able to handle the equipment, hardware and software properly to maintain high quality in the production chain ranging from the sensors in the sea to the delivery of services to the end users. The setup must be appropriate to match the required response time or product update frequency associated with each product. The current project will need to provide additional human resource potential to the PO.Res.Grp through hands-on training during the implementation phase of the project, targeting to build the local expertise on all the elements of the proposed system so as to secure a continued delivery and long term sustained goals after the end of the funding and development phases.

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