International Association for the Physical Sciences of the Ocean (IAPSO)

Activities in Italy (2011-2014)

Short summary

IAPSO related scientific activities in Italy are developed by several public research organizations and universities, the last coordinated in an inter-university consortium for marine science (CoNISMa). The main research activities are carried out by combining observational and modeling approaches, involving both analytical and numerical tools. The studies concern physical, biogeochemical and climatic phenomena and their interactions, at very different temporal and spatial scales, and focus on the Mediterranean Sea and its coastal areas, the subtropical gyres of the major world's oceans, the Southern Ocean and its marginal basins, and the Artic. Substantial efforts are also devoted to operational oceanography, in the framework of national and European observing systems. As a complimentary activity the community is involved in the development of marine data archives addressed to research, public authorities and public.

The present document summarizes the principal achievements, the participation to international programs and the most relevant projects in which the Italian scientific community is involved in the research fields of interest for IAPSO. For ease of presentation these have been organized into the following main thematic groups:

- Open ocean processes
- Coastal processes and interactions
- Thermohaline Circulation and Deep Currents
- Oceans and climate change
- Polar Research
- Sea level variability in the 19^{th}-21^{th} centuries
- Ocean sensing, modeling and forecasting
- Information Systems and Knowledge Management

Organization

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Profiles of involved Institutions

CMCC: Euro-Mediterranean Center on Climate Change. CMCC is a non-profit research institution managing and promoting scientific and applied activities in the field of international climate change research focusing on development and application of models of climate dynamics, impacts of climate change and adaptation and mitigation policies. www.cmcc.it

CNR: National Research Council of Italy. CNR is the largest Italian research organization, aiming to promote, transfer and improve the knowledge in the main sectors of the scientific, technological, economic and social research activities. The Department of Earth System Science and Environmental Technologies (DTA) hosts all CNR marine science activities covering most of the marine disciplines, including large scale and coastal physical and chemical oceanography, conducted in polar, oceanic and Mediterranean regions, conducted with a multidisciplinary approach. Since 2011, CNR is leading the Italian flagship project RITMARE. http://www.dta.cnr.it/

ENEA: Agenzia Nazionale per le Nuove Tecnologie, l'Energia e lo Sviluppo Economico Sostenibile. ENEA research activities are focused on the following sectors: Support to Public Administration, Information and Training; Advanced Technologies for Energy and Industry; Environmental Characterization, Prevention and Recovery; Environmental Technologies; Energy and Environmental Modeling; Marine environment and Sustainable Development; Antarctic Expeditions and Research in Polar Areas; Seismic Protection; Radiation Biology and Human Health; Radiation Protection; Metrology of Ionizing Radiation; Materials Technologies; Radiation Applications; Sustainable Development and Innovation of the Agro-Industrial System; ICT. Within ENEA, the Unit for Environment and Energy Modeling is active in modeling and observing regional climate systems, designing energy strategies and providing new technologies for the adaptation of infrastructures and human activities to environmental changes with special emphasis on low-carbon society. http://www.enea.it

ICTP: International Centre for Theoretical Physics, Earth System Physics (ESP). The Earth System Physics (ESP) section studies a wide spectrum of the Earth system, from its fluid components (oceans and the atmosphere) to the planet's interior. The ESP section maintains a range of models and datasets and coordinates the Regional Climate research NETwork (RegCNET), encompassing over 600 participants worldwide.

INGV: Italian National Institute of Geophysics and Vulcanology is an independent organization working under the supervision of the Italian Ministry of Education, University and Research (www.ingv.it). The Bologna group is responsible for the Mediterranean nowcasting/forecasting activities, both at the national and Copernicus Marine Service level. The Bologna group develops the numerical modeling at the basin and coastal scales, the data assimilation algorithms and the service for users such as coast guards, the national environmental protection agency, the Italian meteorological office and the Italian navy. INGV is the responsible of the Mediterranean Monitoring and Forecasting Centre in MyOcean, MyOcean2 and MyOcean FollowOn and is part of the NEMO Consortia for the development of European large scale ocean numerical modeling capacities. INGV has representatives in JCOMM-WMO-IOC. www.ingv.it

Istituto Superiore per la Protezione e Ricerca Ambientale (ISPRA, High Institute for Environmental Protection and Research) – It is the Italian governmental institution in charge of operating the national sea-level monitoring system, that includes the National Tide-Gauge Network (33 stations all along the Italian coastline) and the Venetian and Northern Adriatic Tide Gauge Network (54 stations in the north Adriatic lagoons of Venice and Marano-Grado). ISPRA is mostly committed to sea-level monitoring and distribution of sea-level data and derived products. Moreover it is the Italian representative in GLOSS and it contributes to the PSMSL databank with monthly data and the IOC Sea Level Station Monitoring Facility with real-time data. www.isprambiente.gov.it/

Istituto Idrografico della Marina (IIM, Hydrographic Institute of the Italian Navy). IIM is an institute of the Italian Navy, under the Italian Ministry of Defence. IIM is involved in many activities related to navigation safety and management among which, relevant for the present report, it operates the fundamental Italian tide gauge in Genoa Old Harbour. The tide gauge Zero represents the national altimetric basis for height measurements. IIM issues tidal predictions for Italian and foreign Mediterranean sea level stations. http://www.marina.difesa.it/

OGS: Istituto Nazionale di Oceanografia e Geofisica Sperimentale. OGS is a national research institution active in the major research fields of physical and biological oceanography and experimental geophysics. The Department of Oceanography of the Institute is deeply involved in many of the major European projects concerning the Mediterranean Sea, for studies related to both large scale and coastal oceanography. http://www.ogs.trieste.it/

University of Bologna, Alma Mater Studiorum. The University of Bologna, Alma Mater Studiorum, places special emphasis on the quality of education and research. It has gained a considerable experience in international and European research projects, also in coordination roles. The Department of Physics and Astronomy contains the Oceanography modelling research groups that develop relevant activities in the field involving numerical modeling of the ocean general circulation and biogeochemical cycles. http://www.unibo.it

University Cà Foscari of Venice – The Department of Environmental Sciences deals with a wide spectrum of disciplines, comprising: environmental chemistry, physical oceanography, climate science, ecological modelling, earth sciences. http://www.unive.it/

*University of Naples Parthenope***.** This University has a longstanding tradition in the research and teaching in the fields of Physical Oceanography and Meteorology that dates back to 1920, and is the only one in Italy that offers an undergraduate and postgraduate training in Physical Oceanography, with a strong physical and mathematical background. The faculty is composed of active researchers in experimental, theoretical and modeling aspects of both large scale and coastal oceanography, with particular reference to the Southern Ocean, the North Pacific and Atlantic oceans, and the Mediterranean Sea. Aspects of theoretical climate dynamics are also investigated. http://www.uniparthenope.it/

Univ. of Salento, DisTeBA. The University of Salento, which is located in Lecce, has grown remarkably in the last decades playing a leading role in the local cultural system. DiSTeBA (Department of Biological and Environmental Science and Technologies) covers 5 scientific-

cultural fields: cellular and molecular Biology, Human Biology and Health, Environmental Biology, Chemistry and Climatology. Main interest of the climate group in on climate analysis and change at regional (Mediterranean) scale. https://www.disteba.unisalento.it/home_page.

University of Trieste. – The Department of Mathematics and Geosciences research topics are related to coastal and lagoon contexts, their environmental issues, vulnerability assessments and erosional risks, assessment of sedimentological budgets, morphological changes, impacts of pollutants. http://www.units.it/

Open ocean processes

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A) Institutions involved in research activity

Most of the research activities concerning this topic were conducted by CNR, OGS, CMCC, ENEA, INGV, University Cà Foscari of Venice, and University of Naples Parthenope.

B) Scientific Report

Main Scientific Themes

The main open ocean processes research themes concern (i) the large scale ocean dynamics, with particular reference to western boundary current systems, and (ii) open ocean processes in the Mediterranean Sea and in some of its sub-basins.

(i) Large scale ocean dynamics, with particular reference to western boundary current systems.
As regards the western boundary current systems, model studies were implemented following a process-oriented approach, aimed at identifying mechanisms of oceanic intrinsic low-frequency variability, as for example the decadal bimodality of the Kuroshio Extension and the effects of stochastic forcing and the predictability of such a phenomenon (Kramer et al., 2012; Pierini, 2012). The Gulf Stream variability has been analyzed from the same viewpoint (Quattrocchi et al., 2012), and with lagrangian methods in which particle transport at submesoscale was properly parameterized (Haza et al., 2012). Analytical and laboratory studies have investigated the role of nonlinear effects on western boundary currents, with particular reference to the Gulf Stream separation due to inertial overshooting (Pierini et al., 2011). Analytical studies include a new integration of the classical Munk model of the wind-driven ocean circulation (Badin et al., 2012), the analysis of the low-frequency variability and coherence resonance in a low-order model of the wind-driven ocean circulation (Pierini, 2011), the two-layer skirted island problem (Pedlosky et al., 2011), and the propagation of Rossby waves on a quiescent abyss (Crisciani and Purini, 2011).

On-going efforts are also dedicated to the study of the North Atlantic inter-annual to decadal variability, the North and Equatorial Pacific Ocean circulation and the assessment of Antarctic Circumpolar Current and Southern Ocean Meridional Overturning Circulation (Danabasoglu et al., 2014; Pohlmann et al., 2013). A novel approach based on the concept of biogeochemical provinces was proposed as a diagnostic tool for the analysis and validation of global marine biogeochemistry models, to overcome the limitations imposed by data scarcity and the general undersampling of relevant ocean biogeochemical properties (Vichi et al. 2011).

(ii) Open ocean processes in the Mediterranean Sea and in some of its sub-basins.
The studies included in this theme principally investigate the dynamics and the physical and biogeochemical properties of the water masses in the Mediterranean Sea as a whole and its subbasins.

Surface circulation was mainly studied using drifter observations, completing findings obtained by means of hydrographic and eulerian measurements and concerning spatial structures and temporal variability also in relation to the atmospheric forcing. Studied area were the Marmara Sea (Gerin et al., 2013), the Liguro-Provençal basin and Gulf of Lion (Poulain et al., 2012), the Northern Aegean Sea (Gerin et al. 2014) and the Black Sea (Menna and Poulain, 2014). Drifter observation were also used to estimate transit and residence times in the Adriatic Sea as a contribution to the study of surface exchange between Adriatic and Ionian Sea through the Otranto Channel (Poulain et al., 2013), and to study relative dispersion in the Liguro-Provençal basin highlighting that sub-mesoscale transport is controlled by larger, mesoscale features in this region (Schroeder et al., 2011).

Thermohaline staircases have been investigated in the Western Mediterranean and their role in downward salt and heat fluxes and mixing in the deep waters has been highlighted (Bryden et al. 2014 a and b; Borghini et al. 2014).

Several studies examined processes in the Adriatic Sea. The Adriatic Water outflow through the Strait of Otranto was studied from long-term measurements evidencing the seasonal variability and dynamics (Ursella et al. 2011, 2012). Direct estimate of water, heat, and salt transport were also evaluated (Yari et al. 2012). Adriatic-Ionian interactions due to the Bimodal Oscillating System (BiOS) as an internally controlled mechanism has been studied and it was shown that climate variability can appreciably influence typical time scales (Gačić et al., 2011, 2014). Particular attention was paid to an extreme air-sea interaction event occurred in winter 2012 (Raicich et. al, 2013), causing dense water formation in the north and middle Adriatic shelf and coastal area (Mihanovic et al., 2013). The newly formed dense water spread southward (Benetazzo et al, 2014) and its signal was found in the Southern Adriatic Pit as a series of individual pulses, followed by a stronger and prolonged signal that significantly modified the local deep water stratification (Bensi et al., 2013).

Biogeochemical studies addressed the oceanic carbon cycle in a basin wide perspective. These include studies related to organic carbon dynamics and how it is influenced by stratification (Santinelli et al., 2012, 2013), and the CO2 system space-time variability by combining available historic and recent data (Álvarez et al., 2014) and using empirical relationships derived from ship-based observations including monthly climatological fields of hydrographic parameters (Lovato and Vichi, 2014). Moreover, physical-biological coupled models were used to study the spatial and temporal variability in terms of primary production and chlorophyll concentrations in the whole basin (Lazzari et al., 2012) and to estimate the effect of the physical processes at the Strait of Gibraltar over the biogeochemical features of the Atlantic Inflow towards the Mediterranean Sea (Ramirez-Romero et al., 2014).

Response of phytoplankton to physical processes was investigated in the surface layer of the Mediterranean Sea and in the Algero-Provençal Basin using satellite observations (Volpe et al., 2012; Olita et al. 2011b, 2014), also discussing the variability from seasonal to interannual scales of the primary production (Olita et al. 2011a). In the Southern Adriatic, phytoplankton abundance, prokaryotic dynamics and heterotrophic metabolism were studied in the full water column and related to deep water ventilation (Azzaro et al., 2011; Batistic et al., 2012).

Main Research Projects/Programmes

CORE-II : *Coordinated Ocean-ice Reference Experiments - Phase II,* http://www.clivar.org/clivar-panels/omdp/core-2, proposed by the CLIVAR Ocean Model Development Panel (OMDP) as a venue for comparing global ocean-sea ice models run under a common prescribed atmospheric state, with boundary fluxes computed via the same bulk formulae. CORE simulations complement the coupled climate and earth system models run for the Coupled Model Intercomparison Project (CMIP). Efforts across a broad community of modelling groups have produced CORE Phase 2 hindcast simulations (CORE-II) using 60 years (1948-2007) of inter-annual forcing. The CORE-II simulations provide a framework to evaluate ocean model performance, to study mechanisms of ocean phenomena and their variability from seasonal to decadal timescales, to identify forced variability changes, and to develop mechanistic descriptions of observed climate variability and change.

COCES2 (2011-2013, USA): *Coastal Ocean Circulation Experiment off Senegal*, www.inogs.it/en/projects/oceanography. Funded by the Office Naval Research (ONR). The dynamics of the ocean circulation off northwest Africa will be studies using in-situ and satellite observations in concert with numerical simulations with particular attention on the upwelling regime forced by the north and northeasterly Trade winds and prevailing in winter/spring off the coast of Senegal.

IMOCS (2010-2012, IT): this project has dealt with the assessment of the improvement of oceanic modeling by means of COSMO-SkyMed SAR surface wind data. Funded by A.S.I. (Agenzia Spaziale Italiana, the Italian Space Agency) in the framework of the COSMO-SkyMed© program.

MATH-ACC (2011-2013, IT): this project deals with the mathematical modeling and theoretical analysis of the dynamics of the Antarctic Circumpolar Current, with validation through *in situ* and altimeter data. Funded by the P.N.R.A. (Programma Nazionale di Ricerche in Antartide), the national program of the Italian Ministry of Education aimed at promoting basic research in all branches of science concerning the Antarctic continent.

MEDOR (2012-2014, IT). Funded by the Italian Ministry of Foreign Affairs (MAE). Study of the circulation in the Eastern Mediterranean from long-term data analysis and modeling approach.

RITMARE (2012-2016, IT): *La Ricerca Italiana per il Mare (The Italian Research for the Sea*), www.ritmare.it/en/. Funded by the Italian Ministry of University and Research (MIUR). Flagship project dealing with a wide range of marine and maritime issues. In particular, the Sub-project 4 (Planning of the Deep Marine Environment and Open Sea) includes specific study of the physical, biogeochemical and biological variability of deep water column, the circulation and abyssal mixing and their links with the superficial and intermediate circulation, the processes of the surface mixed layer in response to extreme weather events.

Organization of Conferences and Workshop of international relevance

In the years 2011-2014 scientists of the Italian IAPSO community participated in the organization of the following scientific events relevant to the *open ocean processes*:

- European Geosciences Union General Assembly 2012 (Vienna, 22-27 April 2012): P. Lionello (Convener of CL4.3); G.M.R. Manzella (Convener of ESSI1.2/OS4.7); S. Pierini (Co-convener of NP1.1, Science Officer of NP2); V. Lucarini (Convener of NP3.1).
- European Geosciences Union General Assembly 2011 (Vienna, 3-8 April 2011): N. Pinardi (Convener of OS2.2/EG10); G.M.R. Manzella (convener of ESSI2); S. Pierini (Co-convener of NP1.1 and NP3.1, Science Officer of NP2); P. Lionello (Convener of CL2.3).
- VII International Symposium on Stratified Flows (Rome, 22-26 August 2011): A. Cenedese (Conference Chair); S. Pierini and A. Sutera (members of the Scientific Committee).

C) Goals, priorities and plans for future activities

Future activities will be oriented towards further studies of the open ocean physical processes already analyzed, such as western boundary current system dynamics and variability, and the related mesoscale dynamics and eddy-mean flow interactions.

Directions for future research in the Mediterranean Sea have been suggested by Malanotte-Rizzoli et al. (2014). Unresolved issues to work out to address the physical forcing and physical/biochemical variability are included in three major topics:

1. Assessment of basin-wide physical/biochemical properties, of their variability and interactions.

2. Relative importance of external forcing functions (wind stress, heat/moisture fluxes, forcing through straits) vs. internal variability.

3. Shelf/deep sea interactions and exchanges of physical/biogeochemical properties and how they affect the sub-basin circulation and property distribution.

These include the Mediterranean Sea wind-driven and thermohaline circulation and associated variability over the various temporal scales; the decadal variability of the basin-wide Ionian circulation and its impact on the Adriatic and on the biogeochemistry of the two sub-basins; the impacts of physical processes on chemical processes and on the biogeochemical and biological compartments. Also the circulation and abyssal mixing, and their links with the surface and intermediate circulation will be investigated, as well as processes of the surface mixed layer in response to extreme weather events, and the impact on the ecosystem-modelling and experimental studies to future scenarios.

D) Scientific Publications

2011-2012

Azzaro, M., R. La Ferla, G. Maimone, L.S. Monticelli, R. Zaccone and G. Civitarese. Prokaryotic dynamics and heterotrophic metabolism in a deep convection site of Eastern Mediterranean Sea (the Southern Adriatic Pit). Cont. Shelf Res., doi:10.1016/j.csr.2011.07.011 (2011).

Badin, G., A.M. Barry, F. Cavallini and F. Crisciani. A new integration of Munk's linear model of wind-driven ocean circulation. Eur. Phys. J. Plus, 127, 4, Art. No. 45 (2012).

Balzarini, A., G. Pirovano, G.M. Riva, A. Toppetti, R. Bozzano, S. Pensieri and E. Canepa. WRF Evaluation exercise using open sea in situ measurements. Int. J. Environ. Pollut., 50, 1/2/3/4, 152-163 (2012).

Batistic, M., N. Jasprica, M. Cari, M. Ali, V. Kovačevic, R. Gari, et al. Biological evidence of a winter convection event in the South Adriatic: A phytoplankton maximum in the aphotic zone. Cont Shelf Res., 44, 57-71 (2012).

Crisciani, F. and R. Purini. On the linearization of the quasi-geostrophic potential vorticity equation at the ocean basin-scale. Eur. Phys. J. Plus, 127, 1, Art. No. 6 (2012).

Crisciani, F. and R. Purini. A note on long Rossby waves on a quiescent abyss. Eur. Phys. J. Plus, 126, 4, Art. No. 36 (2011).

Gačić, M., G. Civitarese, G. L. Eusebi Borzelli, V. Kovačević, P.-M. Poulain, A. Theocharis, M. Menna, A. Catucci, and N. Zarokanellos. On the relationship between the decadal oscillations of the northern Ionian Sea and the salinity distributions in the eastern Mediterranean, J. Geophys. Res., 116, C12002, doi:10.1029/2011JC007280 (2011).

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Lazzari, P., C. Solidoro, V. Ibello, S. Salon, A. Teruzzi, K. Beranger, S. Colella and A. Crise. Seasonal and inter-annual variability of plankton chlorophyll and primary production in the Mediterranean Sea: a modelling approach. Biogeosciences, 9, 1, 217-233, doi: 10.5194/bg-9-217-2012 (2012).

Lionello, P., L. Cavaleri, K.M. Nissen, C. Pino, F. Raicich and U. Ulbrich. Severe marine storms in the Northern Adriatic: Characteristics and trends. Phys. Chem. Earth, 40-41, 93-105 (2012).

Olita, A., R. Sorgente, A. Ribotti, L. Fazioli and A. Perilli. Pelagic primary production in the Algero-Provençal Basin by means of multisensory satellite data: focus on interannual variability and its drivers. Ocean Dynam., 61, 7, 1005-1016 (2011a).

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Coastal processes and interactions

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A) Institutions involved in research activity

Most of the research activities concerning this topic were conducted by CNR and OGS.

B) Scientific Report

Main Scientific Themes

The main coastal processes and interactions research themes concern (i) the hydrodynamics and the associated biogeochemical processes of coastal areas and lagoons, including acidification and hypoxia, (ii) pollution, (iii) the impact of rivers on dynamics and biogeochemistry, (iv) coastal ecosystems, (vi) sedimentological and geochemical processes.

The main part of those studies has been carried out on the coastal systems of the Adriatic Sea (Gulf of Trieste, lagoon of Venice, Boka Katotska in Montenegro, Gulf of Manfredonia), but also on other Mediterranean (Gulf of Lion, Gulf of Naples, Bonifacio Strait, Panarea island, Oristano Gulf, Capo Peloro, Mediterranean lagoons, Strait of Messina, Greek Ionian coast, Western Sardinian Sea, Sicily Channel, Turkish straits system and Marmara Sea) and non-Mediterranean (Mississippi river mouth, West Africa coast) regions.

The studies include modeling efforts and in-situ data based investigations. Data are collected from a variety of platforms, from fixed buoys and gliders to samples collected from ships and trajectories of drifters, as well as from remote sensing (satellite and coastal).

Hydrodynamics is investigated on the mesoscale and submesoscale, which is especially important in determining the coastal transport processes (along coast, and shelf/open ocean exchanges).

The influence of freshwater inputs on physical and biogeochemical properties in the Adriatic coastal areas is thoroughly investigated. Biogeochemical properties under observation are macronutrients (N, P, Si) but also the carbonate system parameters, to study the acidification processes at the coastal scale. Diagenetic and ecosystemic studies complete the picture.

Main Research Projects/Programmes

CoCoNET (2012-2016, EU): *Towards COast to Coast NETworks of marine protected areas (from the shore to the high and deep sea), coupled with sea-based wind energy potential*, http://www.coconet-fp7.eu/. Funded by the European Commission (FP7-KBBE). The project focuses to monitor Marine Protected Areas (MPAs) for an integrated approach of environmental management aiming at both environmental protection of MPAs and clean energy production (Offshore Wind Farms). The project will achieve scientific knowledge on oceanographical and biological connectivity between MPAs, enhance policies of effective environmental management, and assess the present network of MPAs.

HAZADR (2012-2014, IT): *Strengthening common reaction capacity to fight sea pollution of oil, toxic and hazardous substances in Adriatic Sea,* www.inogs.it/en/projects/oceanography. Funded by IPA Adriatic CBC Programme.

MHYWAQ-LSG (2012-2015, IT): *Modelling Hydrodynamics and Water Quality in Marine and Coastal Areas*. Funded by the Italian Ministry of University and Research (MIUR) and the Liguria District of Marine Technology (DLTM-MIUR). Development of coastal numerical models and application to the Gulf of La Spezia (Ligurian Sea).

PERSEUS (2012-2015). Funded by the European Commission (http://www.perseus-net.eu/). The overall scientific objectives of PERSEUS are to identify the interacting patterns of natural and human-derived pressures on the Mediterranean and Black Seas, assess their impact on marine ecosystems. In particular the Subtask 1.3.3 – ADREX: Adriatic and Ionian Seas Experiment - is involved in the development of integrated tools for environmental status assessment as well as in the study of the impact of anthropogenic CO2 increase on the biological carbon pump and the continental shelf pump.

OCEAN CERTAIN (2013-2017). Funded by the European Commission (http://www. http://oceancertain.eu/.eu), the project investigates the impact of climatic and non-climatic stressors on the food web and the connected biological pump, and the important feedback mechanisms. OCEAN-CERTAIN will identify and quantify multi-stressor impacts and feedbacks and how these alter the functionality and structure of the food web and efficiency of the biological pump in different bio-geographical regions. The stressors, key feedback mechanisms and indicators, form the basis for the design of an integrated Decision Support System (DSS).

RITMARE (2012-2016, IT): *La Ricerca Italiana per il Mare (The Italian Research for the Sea)*, www.ritmare.it/en/. Funded by the Italian Ministry of University and Research (MIUR). Flagship project dealing with a wide range of marine and maritime issues. In particular, the Sub-project 3 (Planning of the Maritime Space in Coastal Waters) includes specific actions for coastal oceanographic modelling: transformation, stratification and mixing of water masses, sediment mobilization and transport; interactions between ocean currents, wind waves, sediments and turbulent processes in the coastal area; hydrodynamics and transport processes of the Italian lagoon systems. In the frame of SP2, attempt to merge marine biogeochemical data and marine food webs has recently been developed in response to the need to understand how coastal processes impacts marine ecosystems and resources

SEA-PORT (PON R&C2007-2013): Sviluppo di tecnologie innovative per la Sostenibilità Energetica ed Ambientale di cantieri navali ed aree PORTuali, http://www.navtecsicilia.it/progetti-ricerca-dettaglio.php?ID=7&PAGINA=1. The project "SEAPORT" is divided into several development objectives (OR), each of which focuses on different aspects which have, however, one common denominator: the redevelopment of energy and environmental sites and port areas.

SOS-Bonifacio (2009-2011, IT): http://www.seaforecast.cnr.it/sosbonifacio/index.php/project-overview.html. Funded by the Italian Ministry for the Environment, Land and Sea (MATTM). Realization of an innovative numerical system to manage environmental emergencies for oil-spills in the Strait of Bonifacio.

STI-TAM (PON R&C2007-2013): Sviluppo di Tecnologie Innovative per il trattamento dei rifiuti liquidi della navigazione finalizzate alla Tutela dell'Ambiente Marino, http://www.navtecsicilia.it/progetti-ricerca-dettaglio.php?ID=15&PAGINA=1. The main objective of the research project is to propose a system of integrated treatment stages including physical, chemical and biological properties for the removal of contaminants from liquid waste from shipping activities, including bilge water and washing water in special tanks of oil tankers, products from shipping activities and maritime transport.

TOSCA (2010-2013, EU): *Tracking Oil Spills and Coastal Awareness Network,* www.tosca-med.eu. Funded by the European Regional Development Fund in the framework of the MED Programme. The core objective is to implement an integrated and scientific sustainable monitoring/forecasting design based on state of the art technology at the territorial scale and for local needs. Among the methodologies adopted by TOSCA, it is relevant the setting-up of an observational network based on HF radar and drifters providing direct information on ocean currents, coupled with other type of measurements and models.

ADRIPLAN (2013-2015, DG MARE) ADRiatic Ionian maritime spatial PLANning, www.adriplan.eu. Funded by the European Commission – DG Maritime Affairs and Fisheries (DG MARE) under the theme "Maritime Spatial Planning (MSP) in the Mediterranean sea and/or the Black sea". The ADRIPLAN project will improve the ongoing process to develop MSP in the Adriatic - Ionian Macroregion, to overcome barriers of full participation of all neighboring countries in the process and promote sound technically/scientifically based political decisions in order to promote a coherent transnational approach to the spatial planning of the marine seas.

BALMAS (Ballast Water Management System for Adriatic Sea Protection, 2013-2016) Funded by Adriatic IPA Cross Border Cooperation. The general objective of BALMAS is a common cross-border system linking all Adriatic research ,experts and national responsible authorities to avoid the unwanted risk to the environment and human from the transfer of Harmful Aquatic Organisms and Pathogens (HAOP), through the control and management of ships ballast water and sediments and the survey of the ports that are hotspots of Non Indigenous Species (NIS).

VECTORS (2011-2015, FP7) Vectors of Change in Oceans and Seas Marine Life, impact on Economic Sectors. VECTORS is a multidisciplinary large-scale integrated European Project supported within the Ocean of Tomorrow call of the European Commission Seventh Framework Programme, which aims to improve our understanding of how environmental and man-made factors are impacting marine ecosystems now and how they will do so in the future. http://www.marine-vectors.eu/

TRECORALA (2012-2014) "Trezze" and coralligenous formations in the North Adriatic: enhancement of the natural heritage and sustainable management in the Gulf of Trieste. Funded by Cross-Border Cooperation Italy-Slovenia (2012-2014). The purpose is to expand the biological knowledge on the "Trezze" (rocky outcrops present in the northern Adriatic coast) and coralligenous formations in the Gulf of Trieste and to identify guidelines for the management, protection and enhancement of the natural heritage by strengthening the attractiveness and competitiveness of the area and contributing to the protection of biodiversity.

ECO2 - Sub-seabed CO2 Storage: Impact on Marine Ecosystems (2011-2015). This EU FP7 project sets out to assess the risks associated with storage of CO2 below the seabed.

MEDSEA Mediterranean Sea Acidification in a Changing Climate (2011-2014). This EU FP7 project intends to estimate the impact of ocean acidification in the Mediterranean Sea, at organism and ecosystem level, and the consequences at socio-economic scale. The role of OGS concerns the participation to studies on the responses of planktonic organisms to possible alterations and to the modelling of the carbonatic system and of the main biogeochemical cycles in the pelagic environment under different scenarios of climate change

Organization of Conferences and Workshop of international relevance

In the years 2011-2014 scientists of the Italian community participated in the organization of the following scientific events relevant to the *coastal processes and interactions*:

- European Geosciences Union General Assembly 2011 (Vienna, 3-8 April 2011): N. Pinardi (Convener of OS2.2); B. Buongiorno Nardelli (Co-convener of OS3.2).
- European Geosciences Union General Assembly 2012 (Vienna, 22-27 April 2012): J. Chiggiato (Co-convener of OS4.1); S. Carniel (Co-convener of OS2.3); G. M. R. Manzella (Convener of OS4.7).
- XXI Congress of the Italian Association of Limnology and Oceanography (AIOL), Lignano (Ud), September 2013.
- ADRIPLAN Stakeholder Workshop organized in Trieste by OGS, in cooperation with the Friuli Venezia Giulia Region (7/7/2014)

C) Goals, priorities and plans for future activities

Future activities will be focused on several spatial and time scale with regards to areas of interests as straits, bays, lagoons, region of freshwater influence and shelf, including shelf/open ocean exchanges, mostly in the Mediterranean Sea. Particular effort will be devoted to understand the link between physics, geochemistry and biology, focusing in particular on (1) environmental stressors, e.g., carbon dioxide, pH, sea level, temperature, their variability and impact on the coastal areas, (2) climate change impacts on the coastal areas, through idealized scenarios and downscaling, (3) extreme events (floods, heat waves, severe cyclogenesis) and coastal risk, (4) cascading of energy from the mesoscale to the submesoscale with associated ecological implications (5) shelf – open ocean biogeochemical fluxes, in particular those linked to cascades and overflows of dense water.

D) Scientific Publications

2011-2012

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Thermohaline circulation and deep currents

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A) Institutions involved in research activity

Italian oceanographic institutions like ISMAR - CNR, OGS, University of Napoli "Parthenope" carry out studies of impact and interaction between the Mediterranean Overturning Circulation and circulation in Italian seas paying special attention to some key processes such as dense water formation, strait exchange and shelf-open sea interaction.

B) Scientific Report

Thermohaline circulation (THC) as a part of the Meridional Overturning Circulation (MOC), the total northward/southward flow in the World Ocean. In driving the thermohaline component of MOC, salinity presumably has a limited impact with respect to the temperature. Mediterranean Sea (MS) has been considered as a laboratory basin for a number of processes and circulation features taking place in the World Ocean. Thus, for a better understanding of oceanic processes and more specifically of the THC, one can identify similarities and differences between the MS and the oceanic circulation.

Contrary to the THC, the Mediterranean basin-wide circulation is driven and maintained to a large extent by the salinity contrast between the inflowing Atlantic Water (AW) and the Levantine surface and intermedieate waters. The high salinity of waters originating in the Levantine and, in general, in the Eastern Mediterranean (EM) is related to the excess of evaporation over precipitation. The Mediterranean Overturning Circulation (MedOC), due to the basin's zonal extension, is zonally oriented contrary to the THC which is essentially a meridional flow. Important difference between the MedOC and the THC is also that in the World Ocean, the entire or a larger part of the water column is impacted by the north/south flows. On the other hand, the MedOC is limited to the surface and intermediate layers due to two factors, the first one is that the Levantine Intermediate Water (LIW) in the EM is not dense enough to sink to larger depths and thus spreads in the intermediate layer (~ 300 m). Second factor limiting the MedOC to the surface and intermediate layers is the bathymetry in the Sicily and Gibraltar Straits (with depths < 500 m).

In contrast to the world ocean where vertical convection makes part of the MOC, in the MS the ventilation of the deep portion of the water column only partially interacts with the MedOC. The winter convection and deep water formation taking place in the northern parts of the MS i.e. more specifically in the Gulf of Lion in the WM and in the Adriatic/Aegean in the EM make part of the closed meridional circulation cells. The coupling with the MedOC is achieved via LIW whose presence in the dense water formation sites (Gulf of Lion and Adriatic/Aegean Sea) represents a key ingredient in facilitating the vertical convection and in determining thermohaline properties of the deep water formed. Therefore, in the MS two types of circulation cells co-exist: the zonal MedOC, driven mainly by the east-west salinity gradient interacting with two secondary cells controlled by the north-south temperature gradient where the driving mechanism is the winter vertical convection.

With respect to the world ocean, decadal variabilities of the MedOC are very well assessed. The idea of the Mediterranean circulation being in the steady state was definitely abandoned when in the early 1990's the Eastern Mediterranean Transient (EMT) was discovered. The phenomenon manifested essentially in the Aegean substituting the southern Adriatic as the dense water formation site. This sudden change was attributed in a number of numerical studies to a meteorological forcing and to the Levantine circulation changes bringing highly saline waters into the Cretan Sea. Salinity increase in the Levantine was also attributed in some experimental studies to a blocking of the Levantine water outflow through the Cretan Passage. Subsequently, winter convection in the Cretan Sea took place following severe winter climatic conditions. Recently, occasional salinity increase in the Levantine and the EMT preconditioning has been explained in terms of the feedback mechanism – Adriatic-Ionian Bimodal Oscillating System (BiOS), i.e. decadal reversals of the Ionian upper-layer basin-wide circulation. The Ionian cyclonic or anticyclonic circulation reinforces or weakens Mid-Ionian Jet, respectively which brings AW in the Levantine basin. This then results in a varying intensity of the AW advection towards the Levantine and consequently in a varying dilution of the Levantine surface waters. Considering that the LIW is formed in the Levantine, in the area of Rhodes Gyre, obviously the LIW salinity will change as a function of the intensity of the Levantine surface water dilution by the AW. During the Ionian anticyclonic mode the AW flow is mainly deflected northeastward impacting the northern Ionian and southern Adriatic. In that situation the flow of the AW towards the Levantine is reduced, the Levantine surface waters become saltier and the same applies to the LIW. The anticyclonic Ionian circulation mode is thus the preconditioning factor for the EMT-like phenomena. Possible occurrence of the EMT would then take place only if the air-sea heat losses in the Aegean are strong enough to produce deep convection.

"EMT-induced changes have been transferred through the Sicily Channel to the WMed, with the role of the Tyrrhenian becoming important for some years. Indeed, a significant warming and salinification of the whole water column has been observed also in the Western Mediterranean, comparable to the EMT, both in terms of intensity and observed effects. This event of high production of anomalously warm and salty new deep water during winters 2004/2005 and 2005/2006 is now known as the Western Mediterranean Transition (WMT). Therefore, we can conclude that the subsurface distributions of temperature and salinity, as well as of most other properties in the entire Mediterranean are far from a steady state.

Main Research Projects/Programmes and Funding Agencies

MEDGES (2013) Funded by the Italian Ministry of University and Research (MIUR). The project deals with the Adriatic-Ionian deep circulation and interaction Wight the surrounding shelf areas.

PERSEUS (2012-2015). Funded by the European Commission (http://www.perseus-net.eu/). The overall scientific objectives of PERSEUS are to identify the interacting patterns of natural and human-derived pressures on the Mediterranean and Black Seas, assess their impact on marine ecosystems.

RITMARE (2012-2016, IT): *La Ricerca Italiana per il Mare (The Italian Research for the Sea)*, www.ritmare.it/en/. Funded by the Italian Ministry of University and Research (MIUR). Flagship project dealing with a wide range of marine and maritime issues, including observing systems and

coastal and deep seas research. In particular, the Sub-project 3 (Planning of the Maritime Space in Open-Sea Waters) includes specific actions for studying deep circulation and its relation with the upper-thermocline processes.

C) Goals, priorities and plans for future activities

Future activities will be oriented towards studies of interaction between circulation features and functioning of biogeochemical systems of Italian seas. Specific attention will be devoted to ecological status of different sub-basins. Also long-term variability (interannual and decadal) will be addressed as a function of climatic forcing.

D) Scientific Publications

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Oceans and climate change

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A) Institutions involved in research activity

The institutions mostly involved in research activities on Ocean and Climate Change in the period, as coordinators or partners of main projects, are: CMCC, ENEA, ICTP (Earth System Physics Section), INGV, University of Bologna, University of Salento.

B) Scientific Report

Main Scientific Themes

In the last years innovative regional climate simulations in the Mediterranean Area have been performed with a multi-model system including a high-resolution Mediterranean Sea components (Dubois et al.2011, Gualdi et al. 2013). This framework allows a more accurate computation of the air-sea feedbacks in the climate of the region accounting for the mesoscale circulation features and the complicated land-sea distribution, which characterize the Mediterranean Sea. The initial set of projections was performed within the CIRCE project adopted the A1B emission scenario. Presently, a new set of simulations are being produced within the MedCORDEX project and adopt CMIP5 scenarios (mainly RCP8.5 and 4.5). They tend to agree with previous results from PRUDENCE, ENSEMBLES and CMIP3 and show a substantial warming and a significant decrease of precipitation progressively increasing during the 21st century. In the climate projections, the surface net heat loss of the Mediterranean sea decreases (weaker cooling by the atmosphere) and the net water mass deficit increases.

A growing set of Regional Climate simulation have provided material for studies that quantify and characterize the climate change signal in the Mediterranean basin (Conte e Lionello, 2013). Specific features such as the occurrence of Medicanes (Cavicchia et al. 2014) and cyclones (Sanna et al.2013) have been considered. The future evolution of Sea level in the Mediterranean and its large uncertainties remains an important issues to be addressed in dedicated studies (Scarascia e Lionello, 2013). New estimates of mean steric sea-level rise (confirming its future increase) and of the total sea level have been attempted (Carillo et al.2012, Griffies et al., 2014). The analysis of the hazard caused by marine storms (Lionello, 2012, Lionello et al.2012b) and its change in future climate scenarios has been extended to the whole Mediterranean coast. The analysis has implications for the vulnerability of the coastline and is mainly based on the modeling of climate change impacts on surges and wind waves. Results suggest attenuation of marine storminess in the future.

Italian scientists have contributed to the World Climate Research Programme (WCRP)'s Coupled Model Intercomparison Project (CMIP5) with future climate simulations and decadal predictions Using these simulations, a number of studies have been performed to explore the possible impacts of climate change on climate variability and, in particular, on extreme events, such as Tropical Cyclones and extreme precipitation in North America and in the Euro-Mediterranean region. On

the global scale, new results have been obtained on atmosphere ocean coupling, and on the role of oceans in the evolution and variability of the Earth climate. Emphasis has been on the role of climate mode of variability such as ENSO, tropical oceans and overturning circulation (Farneti and Vallis, 2011; Kucharski et al., 2011; Meredith et al., 2012; Farneti and Vallis, 2013; Farneti et al., 2014a; Farneti et al., 2014b).

Italian research activities are not limited to climate change scenarios, but have considered present climate variability as well. The analysis of the Mediterranean annual SST (Sea Surface Temperature) has revealed the presence of a significant oscillation with a period of about 70 yr and significant correlation between the Mediterranean and North Atlantic SST for periods longer than about 40 yr (Marullo et al., 2011). Detection of climate change impacts shows that present-day cold-water corals calcification in the Mediterranean Sea has already drastically declined (by 50%) as a consequence of anthropogenic-induced ocean acidification. New results have been obtained on the link between warm episodes and mass mortalities of benthic invertebrates (Rivetti et al., 2014). Other research has investigated the dynamics of the southern Ocean and its response to climate change (Meredith et al. 2012, Kwon et al., 2013), the dynamics of the tropical Pacific and its role on the evolution of the global temperature (Kucharski et al., 2011, Farneti et al. 2014a e 2014b), the low frequency variability of the Atlantic circulation and the related heat transport (Farenti e al. , 2013), Atlantic variability and sea level (Danabasoglu et al., 2014; Griffies et al., 2014). Finally, trends of marine storminess in the Mediterranean Sea have been analyzed (Lionello et al.2012a).

Main Research Projects/Programmes

CIRCE (2007-2011, EU): *Climate Change and Impact Research: the Mediterranean Environment,* http://www.circeproject.eu/. Funded by the European Commission, FP7-Infrastructures. The project aims at developing an assessment of the climate change impacts in the Mediterranean area. The objectives of the project are: to predict and to quantify physical impacts of climate change in the Mediterranean area; to evaluate the consequences of climate change for the society and the economy of the populations located in the Mediterranean area; to develop an integrated approach to understand combined effects of climate change; to identify adaptation and mitigation strategies in collaboration with regional stakeholders.

CLIM-RUN (2011-2014, EU): *Climate Local Information in the Mediterranean Region Responding to User Needs,* http://www.climrun.eu/. Funded by the European Commission, FP7-ENV. The project aims at developing a protocol for applying new methodologies and improved modeling and downscaling tools for the provision of adequate climate information at regional to local scale that is relevant to and usable by different sectors of society (policymakers, industry, cities, etc.).

CO2MONITOR Development of innovative techniques for monitoring of storage sites of carbon dioxide (CO2). This Italian project arises from a scientific topic which has a significant impact on the industrial sector. It consists in a multidisciplinary study focused on the monitoring of potential leakages of CO2 from a storage site. Specific scientific features will be treated, but, after the project experimental phase, the use of specific technologies developed in the framework of the project will be also considered for other scientific sectors.

GEMINA (2010-2015, IT): Funded by the Italian Ministry of University and Research (MIUR) and the Italian Ministry for the Environment, Land and Sea (MATTM). The project aims to create a coherent structure that, based on the results obtained and taking advantage of the network of research and expertise built over the years by CMCC, strengthens and consolidates the activities and infrastructures of the Centre.

HyMeX (2011-2021) *HYdrological cycle in the Mediterranean Experiment* http://www.hymex.org/ Hymex is a major International cooperation programme aiming at a better quantification and understanding of the hydrological cycle and related processes in the Mediterranean. It consists of 5 working groups with WG1 "water budget of the Mediterranean Sea" and WG4 "intense sea-atmosphere interactions" including the analysis of the role of the Mediterranean Sea on climate change. The programme organization involves a Hymex-Italia national component for the coordination of the Italian contribution.

IMPACT2C (2011-2015, EU): *Quantifying projected impacts under 2° C warming,* http://www.hzg.de/mw/impact2c/. Funded by the European Commission, FP7-ENV. EU research project on impacts of 2 degrees global warming on various regions. IMPACT2C utilizes a range of models within a multi-disciplinary international expert team and assesses effects on water, energy, infrastructure, coasts, tourism, forestry, agriculture, ecosystems services, and health and air quality-climate interactions.

Med-CORDEX , https://www.medcordex.eu/, a coordinated contribution to CORDEX, supported by HyMeX and MedCLIVAR international programs. Med-CORDEX initiative has been proposed by the Mediterranean climate research community as a follow-up of previous and existing initiatives. Med-CORDEX initiative has been proposed by the Mediterranean climate research community as a follow-up of previous and existing initiatives. Med-CORDEX includes new very high-resolution Regional Climate Models (RCM, up to 10 km) and of new fully coupled Regional Climate System Models (RCSMs), coupling the various components of the regional climate.

MedCLIVAR Mediterranean Climate Variability http://www.medclivar.eu. MedCLIVAR is an international network endorsed by CLIVAR and supported by ESF (European Science Foundation) during its initial five years activity. The Network adopts a multidisciplinary vision of the evolution of the Mediterranean climate through studies that integrate atmospheric, marine, and terrestrial climate components at time scales ranging from paleo-reconstructions to future climate scenarios.

MEDSEA (2011-2014): *MEDiterranean SEA acidification in a changing climate,* http://medsea-project.eu/. Funded by the European Commission, FP7 SP1-COOPERATION. MedSeA assesses uncertainties, risks and thresholds related to Mediterranean acidification at organismal, ecosystem and economical scales. It also emphasizes conveying the acquired scientific knowledge to a wider audience of reference users, while suggesting policy measures for adaptation and mitigation that will vary from one region to another.

MEECE (2008-2012)**:** *Marine Ecosystem Evolution in a Changing Environment.* http://www.meece.eu/. Funded by the European Commission, FP7-ENV. The project aims to gain a better understanding of the direct and interactive effects of climatic change and human activity

on marine ecosystems by investigating the key drivers of change set by the European Union's marine strategy (changes in temperature, ocean circulation, stratification and acidification, consequences of pollution, overfishing, invasive species and eutrophication).

PERSEUS (2012-2015). Funded by the European Commission (http://www.perseus-net.eu/). The overall scientific objectives of PERSEUS are to identify the interacting patterns of natural and human-derived pressures on the Mediterranean and Black Seas, assess their impact on marine ecosystems. In particular, the Subtask 1.3.3 – ADREX: Adriatic and Ionian Seas Experiment studies the microbial biogeochemistry and the impact of circulatory routes on microbial dispersal or entrapment within the main Mediterranean water masses.

RISES (2013-2016) R*esponses to coastal climate change: Innovative Strategies for high End Scenarios – Adaptation and Mitigation,* http://risesam.eu/, addresses the economy-wide impacts of coastal systems to various types of high-end climatic scenarios (including marine and riverine variables). The emphasis is on the advantages of flexible management with novel types of coastal interventions (e.g. "green" options) within an adaptive pathway whose tipping points will be identified/quantified in the project. The extended/improved suite of models will be applied across scales and focusing on the most vulnerable coastal archetypes such as deltas, estuaries, port cities and small islands. The project shall evaluate the direct and indirect costs of high-end scenarios (e.g. the increasing demand for safety under increasingly adverse conditions) for coasts with/without climate change and contribute to determining which policy responses are needed at the European and global levels in the context of international climate discussions

RISCS Research into Impacts and Safety in CO2 storage EU FP7 project. Within studies on CO2 emissions from storage sites, the objective of the Project RISCS is to determine the impact of exposure to CO2 streams in different environments. Evaluations will be based on laboratory experiments, measurements of emission sites of natural and numerical simulations, both marine and terrestrial ecosystems. This work will help to obtain new constraints on the impact of the emission of carbon dioxide on human health, marine and terrestrial ecosystems.

SESAME (2006-2011): *Southern European Seas: Assessing and Modelling Ecosystem changes,* http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_RCN=9465639. Funding agency: European Commission, FP6-SUSTDEV. This project was concluded in 2011. It aimed to assess and predict changes in the Southern European Seas (Mediterranean and Black Sea) ecosystems and their ability to provide key goods and services with high societal importance, such as tourism, fisheries, ecosystem biodiversity and mitigation of climate change through carbon sequestration in water and sediments.

Organization of Conferences and Workshop of international relevance

Italian scientists have plaid a key role in the sequence of MedCLIVAR Conference "Mediterranean Climate: From past to the future", held in Lecce on June 6-9th 2011, The climate of the Mediterranean region: understanding its evolution and effects on environment and societies", held in Madrid 6-29 September 2012, "Understanding Climate Evolution and Effects on Environment and Societies in the Old World region" held in Ankara, 23-25 June 2014. A large

group of scientists contributed to the scientific and steering committees of the conference, chaired by P.Lionello.

Sessions at the annual European Geosciences Union General Assembly have been convened by Italia scientists on topics relevant for the links between Mediterranean Sea and Climate change. The contributions have concentrated in the CL part of the program ("Mediterranean Climate: from past to future " , CL2.3 in 2011 and CL4.3 in 2012, "The climate of the Mediterranean region: from basic science to impacts" CL4.6 in 2013 and CL5.9 in 2014, with P.Lionello and A.Toreti as Italian Conveners).

Several meetings and activities have been organized at ICTP: Targeted Training Activity: El Nino Southern Oscillation Monsoon in the Current and Future Climate (30 July - 10 August 2012, Italian organizers R.Farneti); Workshop on Variability in the Western Tropical Pacific: Mechanisms, Teleconnections and Impacts on Sub-Seasonal, Inter-Annual and Inter-Decadal Time Scales (12 November - 16 November 2012). Other have been organized with the contribution of ICTP (R.Farneti acting as ICTP organizer): Workshop on South Atlantic circulation variability and change: integrating models and observations (Buenos Aires – Argentina, 1-5 December 2014, ICTP organizer: R.Farneti); Fundamentals of Ocean Climate Modelling at Global and Regional Scales (Hyderabad - India, 5 -14 August 2013, ICTP organizer: R.Farneti); Joint ICTP-TWAS Workshop on Climate Change in Mediterranean and Caribbean Seas: Research Experiences and New Scientific Challenges (Guayaquil - Ecuador, 7 May - 12 May 2012, ICTP organizer: R.Farneti).

C) Goals, priorities and plans for future activities *(next two years)*

Global scale climate variability remains a topic with many unresolved issues. Teleconnections and low-frequency processes involving the atmosphere, ocean, cryosphere and land need to be further investigated in order to improve predictability at timescales from intra-seasonal to decadal and increase confidence on projections. On a global scale, much effort will be devoted to the study of the identification and characterization of mechanisms of decadal climate variability that are rooted in the ocean. A sound physical understanding of processes leading to low-frequency natural variability and its representation by state-of-the-art models will help disentangle the internal signal from the impacts of external radiative forcing on decadal climate variability. Natural and externally-forced variability in the Atlantic can significantly shape Mediterranean climate. Studies involving global climate models of different complexity and available observational data will be used to identify the impacts of Atlantic variability and change on the Mediterranean system.

At regional Mediterranean scale, recently developed regional climate models have a higher resolution and include more realistic features than previously. Particularly some of them include an interactive high resolution model of the circulation of the Mediterranean Sea. The exploitation of the information provided by these new model systems for impact studies is expected to provide new interesting results at regional scale. In fact, this new generation of models allows a more accurate simulation of future evolution of the Mediterranean Sea and the assessment the effect of climate change on its thermohaline circulation, energy and mass budget. An improved reproduction of water masses, their formation and distribution can be used for a new evaluation of the steric contribution to future sea level evolution. New numerical tools will be able to improve

our understanding of the interaction between the Mediterranean Sea and the Atlantic Ocean by a more accurate representation of the dynamics of the Gibraltar Strait. In general a large ensemble of new climate simulations should allow a better characterization of uncertainties of projections and possibly to reduce them. In spite of several new results, a major goal remains to provide climate projections of mean sea level, sea level extremes and waves to match the needs of coastal management and achieve a strong integration of climate model simulations and impact on ecosystems.

The assessment of observed impacts of climate evolution and variability in the Mediterranean Sea is receiving an increasing level of attention. Studies documenting impacts and extending it to projections are a priority and are expected to become more frequent. The difficulty of establishing links between physical parameters and impacts on the environment strongly suggest the need of a systematic strategy for monitoring at basin scale and, if possible, recovery of information on past events.

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Polar research

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A) Institutions involved in research activity

The most significant activities of physical oceanography performed by Italy in the polar area are mainly carried out in the Pacific and the Southern Ocean in the Ross Sea within the National Program for Antarctic Research (PNRA). In this program all the universities, research centers and agencies are involved to carry on two years long (mainly) research projects.

In addition to the polar research in the southern hemisphere, the Italian National Research Council (CNR) is also part of the International User Group for the Ny-Ålesund Marine Laboratory, a new Kings Bay facility - opened on June 2005 – which provides a unique support to marine ecology, physiology, and biochemistry studies as well as physical sciences.

B) Scientific Report

Since the signature of the Antarctic Treaty in 1981, Italy started a national program to support research in Antarctica, the so called National Program for Antarctic Research (PNRA). The Program is funded by the Italian Ministry of University and Research (MIUR), and put into practice by three actors: the National Scientific Commission for Antarctica (CSNA), whose role is to propose the strategic objectives, ENEA, whose role is to manage the operative scheduling and the logistics, and CNR which supervises the research planning and the scientific coordination.

During the last years the oceanographic activities have been carried out mainly in the Ross Sea and in the Pacific Sector of the Southern Ocean on board of the M/V Italica which serve also as supply vessel for the Italian shore base "Mario Zucchelli Station" located at Terra Nova Bay (western Ross Sea). Usually the ship operates during the summer months (December - February) and hosts a variety of scientific projects.

More specifically, during the period 2011-2014 the following projects have been carried out in the frame of the Italian PNRA:

PdR 2009/B.09 SOChIC (Southern Ocean ChokePoints, Italian Contribution, p.i. G. Spezie – Univ. of Napoli "Parthenope"). This project was focused on the variability of the thermal fronts characterizing the Antarctic Circumpolar Current (ACC), mainly in correspondence of its chokepoints, and to study the role of mesoscale eddies in the global heat budget generated by the ACC.

PDR 2009/A2.04 T-REx (Terra Nova Bay Experiment, p.i. G. Budillon – Univ. of Napoli "Parthenope"). Was a 24 months coordinated experiment in the polynya of Terra Nova Bay. The main objectives concerned the study of the formation and distribution of water masses in the polynya area and their role in the capture of some atmospheric greenhouse gases and - consequently - in the ventilation of the deep ocean.

PdR 2010/A4.01 (p.i. P. Picco – ENEA). The research was aimed to the development and testing of technologies based on the underwater acoustic methodologies finalized to the realization of a remote monitoring system to be used for the study of oceanographic processes in polar areas.

PdR 2010/A2.11 (p.i. S. Pierini – Univ. of Napoli "Parthenope"). The aim of the project was to investigate the potential generation of variability intrinsic in Antarctic Circumpolar Current, as well as its influence in the general circulation, by means of long numerical simulations (order of hundreds of years) using an eddy permitting model.

PdR 2013/AN2.04 (p.i. G.Spezie, Univ. of Napoli "Parthenope"). This is a coordinated, interdisciplinary study using remote sensing and in situ data to analyze how the mesoscale dynamics, that strongly characterize the surface layer of the Ross Sea, can regulate the primary production, especially in the redistribution of iron which acts as a limiting factor and, more generally, the efficiency of the biological pump.

PdR 2013/B2.13 (p.i. E. Zambianchi - Univ. of Napoli "Parthenope"). The project started in 2013 is aimed to study the dynamics of the ACC, the impact of mesoscale processes on the surface oceanic transport and water mixing masses in the Southern Ocean, on the effects of changes in physical forcing at local and large-scale, the identification and analysis of the intrinsic ACC variability and their interaction with the atmospheric fluctuations.

PdR 2009/C1.05 (p.i,. G. Fusco– Univ. of Napoli "Parthenope"). The goal of the project is based on the estimation of the regional dynamics and on the study of inter ocean exchanges in the Southern Atlantic Ocean uing oceanographic data acquired both with CTD and Argo floats.

PdR 2013/B2.03 (p.i. F. Colleoni - Centro Euro-Mediterraneo sui Cambiamenti Climatici). This is a modeling study aiming at identifying the changes in teleconnections between Antarctica and low latitudes occurring across the Plio-Pleistocene transition (~3 Ma).

PdR 2013/C3.02 (p.i. D. Iovino - Centro Euro-Mediterraneo sui Cambiamenti Climatici). This is a modeling study on the climatically-driven changes of Antarctic sea ice and their role in the climate system.

Moreover, the Italian PNRA has deployed since 1994 a number of oceanographic moorings in the Ross Sea to monitor the oceanographic condition of the shelf waters, which are precursor of the Antarctic Bottom Waters, and to study the biogeochemical cycling in the water column of the largest continental shelf sea and most biologically productive region of Antarctica. This mooring network was modified over the years with changes in scientific focus of the funded projects, and today comprises 4 moorings located in the western part of the Ross Sea. The management is at University of Napoli "Parthenope" (p.i. G. Spezie, G. Budillon, http://morsea.uniparthenope.it/). As an ancillary activity, a number of floats and drifters were deployed during the last two years between New Zealand and Antarctica in the framework of a collaboration with the ARGO ITALY project (http://nettuno.ogs.trieste.it/jungo/argoitaly/floats.html).

Organization of Conferences and Workshop of international relevance

ASOF - Arctic SubArctic Ocean Fluxes) meeting, October 8-10, 2012, Lerici, Italy (http://www.asof.awi.de/fileadmin/user_upload/News/LericiASOFagenda.pdf).

ESF - Exploratory Workshop: Oceanic Heat Transport To Floating Glaciers In Antarctica, WOHTAN, May 13-15, 2014, La Spezia, Italy (http://www.esf.org/coordinating-research/exploratory-workshops/workshops-list/workshops-detail.html?ew=13106).

C) Goals, priorities and plans for future activities

The Italian National Scientific Commission for Antarctica (CSNA) updated in 2014 the strategic guidelines for the Italian Antarctic research in the triennium 2014-16 (http://www.csna.it/Documenti/PNRA_Programma_triennale_2014_2016.pdf, in italian).

In order to optimize funding and to maximize the available resources, the program is now structured according to new criteria, including:

- strengthen international collaboration to develop different strategies and support participation in research activities promoted, supported and conducted by platforms and / or laboratories of other countries;
- support the development of new observation technologies and the creation and the use of large scientific infrastructures;
- modular research on two-year cycles, in order to optimize the activities and human presence at field;
- give greater relevance for projects focused on the analysis of data and materials, on remote sensing, modeling and meta-analysis of data and the use of autonomous and remote controlled equipment.

In February 2015 a new call for monitoring activities and 4 years long research projects, with also a bi-polar perspectives, was launched by MIUR with, among others, the following themes of IAPSO interest:

- Atmosphere dynamics and climate processes;
- Polar ocean dynamics.

It is likely that a new call for two years long scientific projects will be launched by the MIUR in 2015.

It is expected the M/V Italica will operates in the Ross Sea only during the Austral Summer 2015-16 and 2016-17, while small scientific vessels will operate close to the Italian “Mario Zucchelli Station” for coastal research in January and February during each expedition.

D) Scientific Publications

2011-2012

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Sea level variability in the 19th – 21th centuries

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A) Institutions involved in research activity

CMCC studied sea-level changes through climate models under different scenarios, focusing on multidecadal to secular variability in the Mediterranean region.

CNR research related to sea level is performed in the Institute for Marine Sciences (ISMAR). The activity is mainly concentrated in the north Adriatic and includes sea-level monitoring, modelling and prediction of storm-surges and analysis of long-term mean sea level and extreme events frequency, with specific emphasis to the management of the Venice Lagoon, in cooperation with local administrations. ISMAR also contributes to GLOSS (Global Sea Level Observing System) with hourly data from the "Trieste Molo Sartorio" station (GLOSS Core Network No. 340) and to the PSMSL (Permanent Service for Mean Sea Level) databank with monthly data.

IIM operates the fundamental Italian tide gauge in Genoa Old Harbour. The tide gauge Zero represents the national altimetric basis for height measurements. IIM issues tidal predictions for Italian and foreign Mediterranean sea level stations.

ISPRA operates the national sea-level monitoring system, that includes the National Tide-Gauge Network (33 stations all along the Italian coastline) and the Venetian and Northern Adriatic Tide Gauge Network (54 stations in the north Adriatic lagoons of Venice and Marano-Grado). ISPRA is mostly committed to sea-level monitoring and distribution of sea-level data and derived products. Moreover it is the Italian representative in GLOSS and it contributes to the PSMSL databank with monthly data and the IOC Sea Level Station Monitoring Facility with real-time data.

B) Scientific Report

Main Scientific Themes

This report concerns the research on sea-level changes during the period covered by instrumental observations, corresponding to approximately 1870 onwards. Moreover, only the activities related to physical oceanography are taken into account, thus excluding those prevailingly involving the solid Earth (e.g. subsidence, post-glacial rebound).

Sea level is a key "interdisciplinary" environmental observable, whose changes result from land, ocean and atmospheric processes and causes significant impacts on human life and activities. The Italian coastline hosts historic cities and important harbours and a large part of it is vulnerable to sea-level changes in terms of erosion and flooding, with potentially severe impact on human activities and the environment. Studying the past sea-level evolution and predicting the future is, therefore, a crucial research activity.

Two main approaches are followed, namely the analysis of past observations, mainly from tide gauges and, for the last two decades, satellite altimetry, and the implementation of models capable to reconstruct past sea level evolution and provide insight on the future evolution under different climate scenarios.

Tide gauge data is a major resource for estimating secular global and regional sea level rise and decadal time scale sea level fluctuations. Four of the few Mediterranean sea level time series longer than a century belong to active Italian stations, namely Venice (since 1871), Trieste (1875) and Porto Corsini (1896) in the north Adriatic Sea, and Genoa (1883) in the Northwest Mediterranean. The maintenance and development of a sea-level station network is an essential task for research.

Most of the research concerns the Mediterranean Sea, however, particular attention is devoted to the north Adriatic, because of the high impact of sea level variability on the Venice Lagoon system. Both the storm surges intensity and frequency and the long-term sea-level rise are objects of data analysis, modelling and prediction.

A work of past data rescue and analysis is under way, but, at the moment, without a national coordination.

Past data rescue, validation and analysis is under way, although without a national coordination.

Main Research Projects/Programmes

EMODnet-MedSea Checkpoint – It is a tender funded by the European Commission. Its aim is to quality assess, extract the synergies between, and identify the gaps of the present monitoring data sets for the entire Mediterranean Sea in view of several applications ('challenges'). One of these applications, namely 'Climate and coastal protection', involves sea level observations both from tide gauges and satellite altimetry. The Istituto di Scienze Marine of CNR and CMCC are the Italian research institutions involved in this activity.

eSurge-Venice *(ESA Storm Surge for Venice)* – It is funded by the European Space Agency, part of its Data User Element (DUE) programme. It aims to increase the usage of Earth Observation (EO) satellite data, from both ESA and other spacecraft, within the storm surge community. It runs in tight connection with the ESA DUE Storm Surge project eSurge, which is developing an open-access database (Surge Event Analysis and Repository Service, SEARS) to give users easy access to EO and other data relevant for studying storm surges. SEARS includes the data selected by the eSurge-Venice project. The consortium participating to the project is composed by three Institutes belonging to the National Research Council of Italy, namely the Istituto di Scienze dell'Atmosfera e del Clima, the Istituto di Scienze Marine and the Istituto di Biofisica, and by the Istituzione Centro Previsioni e Segnalazioni Maree of the Venice Municipality.

GLOSS *(The Global Sea Level Observing System)* – It is an international programme conducted under the auspices of the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) of the World Meteorological Organisation (WMO) and the Intergovernmental Oceanographic Commission (IOC). GLOSS aims at the establishment of high quality global and regional sea level networks for application to climate, oceanographic and coastal sea level

research. The programme became known as GLOSS as it provides data for deriving the "Global Level of the Sea Surface". The main component of GLOSS is the "Global Core Network" (GCN) of 290 sea level stations around the world for long term climate change and oceanographic sea level monitoring.

MedCLIVAR *(Mediterranean Climate Variability)* – It is a research network which aims to coordinate and promote the study of the Mediterranean climate. It is supported by the European Science Foundation and endorsed by CLIVAR. The main goals of MedCLIVAR include reconstruction of Mediterranean past climate variability and extremes and natural hazards, the description of patterns and mechanisms characterising its space-time variability, the identification of the forcing parameters responsible for the observed changes, and its response to future emission scenarios. The project focuses on long instrumental data as well as documentary and natural proxy evidence resolving different time and spatial scales. All these data sources are important for the construction of high quality data sets, in order to extend the record of past Mediterranean climate variability over decadal and centennial timescale.

C) Goals, priorities and plans for future activities

Mean sea level projections for the 21st century will be performed in the context of climate-related activities.

It is expected to improve the collaboration between the various national organizations for the rescue, digitization and assessment of sea level data.

The work on the reconstruction of the sea level evolution in the Mediterranean and, particularly, along the Italian coastline for the last century, has been started and will be continued.

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Ocean sensing, modeling and forecasting

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A) Institutions involved in research activity

Nearly all the public research organizations and universities working in the field of physical and chemical oceanography are contributing to the development of tools for sensing, modelling and forecasting ocean state variables.

Four institutes of the *CNR* - IAMC, ISAC, ISMAR and ISSIA - are working on developing a holistic marine observational system that will integrate different operational elements:cruise activities carried out by the organization's research fleet, several multi-parametric fixed observing systems, drifting buoys, HF costal radar networks, and a Satellite Observing System producing ocean colour and sea surface temperature products for the Mediterranean Sea. The CNR is also putting a lot of effort into Ocean Forecast Modeling, focusing particularly on water current and wave field forecasting, and on innovative applications involving the management of the marine system and its resources.

ENEA has been active in Operational Oceanography since 1994, when it began to set up and implement the Ships Of Opportunity Programme in the Mediterranean (WMO and UNESCO-IOC). It is presenly maintaining XBT lines in the western Italian Seas.

The Department of Oceanography of the *OGS* has extensive experience and expertise in designing, managing and operating marine observing infrastructure. It is presently running, an extensive, distributed real-time marine monitoring system in the northern Adriatic Sea and coordinating EUROARGO-ITALY, the Italian component of ARGO, the broad-scale global array of temperature/salinity profiling floats.

Finally, a team made up of by scientists from the *University of Bologna, Alma Mater Studiorum*, *INGV* and *CMCC* is actively collaborating on a number of joint activities involving ocean technology for operational oceanographic systems and real time forecasting, and the development of data assimilation algorithms for ocean hydrodynamics and marine biogeochemistry.

B) Scientific Report

Main Scientific Themes

For the purposes of this Report, the pertinent scientific activities have been broadly classified under the following three topical research areas: (i) improvement and exploitation of ocean observations, (ii) development and validation of models of the ocean circulation and the marine ecosystem, and (iii) forecasting of ocean state variables for core marine applications, including maritime safety, marine and coastal environment and climate, seasonal and weather forecasting.

(i) Improvement and exploitation of ocean observations

The studies relating to this theme have focussed on developing new methods and techniques for overcoming inaccuracies in *in situ* and remotely sensed measurements to obtain derived parameters that better characterize ocean properties and processes.

In the case of *in situ* observing techniques *I*, research is ongoing to develop new methods for obtaining realistic measurements of ocean temperature from expendable bathythermographs (XBTs), widely used in the Ships Of Opportunity and Volunteer Observing Systems, to map the vertical distribution of this parameter for the ocean interior, monitor its changes and estimate ocean heating (and the associated global warming). Attention is also paid to novel measurement devices such as gliders, for which a method for testing temperature and conductivity sensors in the laboratory was developed to estimate the qualitative changes in pre- and post-deployment sensor performances in order to mitigate measurable drift effects on collected data.

In the field of remote sensing, efforts have been directed towards advancing the methodologies employed for the realtime and offline quality control of data from HF radar systems to improve the measurement of surface currents and to reproduce current patterns and the temporal evolution of different related physical processes. Moving to satellite observation, studies have focused on assessing sea surface temperature (SST) products obtained from different satellite instruments by comparison with *in situ* measurements and the development of a novel technique for the high-resolution interpolation of *in situ* sea surface salinity (SSS) from SST.

Several studies have combined data coming from different platforms to derive properties which help in depicting ocean circulation patterns and property distributions. Drifter data were used together with other *in situ* and/or satellite data (altimetry, SST, chlorophyll concentration, etc.) to study the surface circulation of the Mediterranean Sea and its sub-basins, and to describe the circulation features and the distributions of temperature, salinity and chlorophyll pigments, with a particular focus on fronts and jets. One study combined remotely sensed chlorophyll-a, SST and Absolute Dynamic Topography data to investigate the relationships between physical and biological processes in the Mediterranean.

(ii) Development and validation of models of the ocean circulation and the marine ecosystem

The activities relevant to this theme were mainly devoted to advancing the skill of data assimilation methods in hydrodynamic and biogeochemical modeling, and to calibrating and validating numerical models against field measurements.

The initiatives involving global ocean modeling and data assimilation were based on the NEMO (Nucleus for European Modelling of the Ocean) platform. A substantial portion of the efforts have gone into developing and maintaining the NEMO-OPA Ocean General Circulation Model, via active roles in the NEMO Consortium. In 2014, an eddying ocean configuration with a horizontal resolution of 1/16° at the equator was developed to realistically reproduce the effect of mesoscale features on the large-scale ocean circulation, which is the highest resolution implemented in aglobal NEMO domain to date. The NEMO ocean model is also a component of a variational data assimilation system which is being continuously maintained and developed. Data assimilation is the process that combines ocean observations with numerical models in order to provide the best

estimate of the ocean state. This has a twofold application: production of global ocean reanalyses (C-GLORS) and high-resolution global ocean operational forecasts. The former activity is being conducted in the context of several international projects and initiatives aimed at providing an estimate of the ocean climate over the last decades for use in climate studies, in the initialization of seasonal and decadal predictions, and as constraints or inputs for regional or downstream applications, respectively. Note that the mentioned downstream applications include the production of forecasts of the ocean weather in real-time, in which have a wide variety of societal applications (e.g. search and rescue, oil spill response, tourism, ship routing, etc.).

Many efforts have been devoted to the production and assessment of ocean reanalyses, too. This field has reached some degree of maturity at the present time, justifying the idea of promoting coordinated multi-reanalysis intercomparisons such as the CLIVAR Ocean Reanalyses Inter comparison Project (ORA-IP) and the MyOcean project. Italy is deeply involved in both these projects. The underlying assumption is that the averaging operation over many ensemble members will be able to reduce the systematic biases of the individual products, and that the ensemble mean of the reanalyses can be evaluated as one single system from the standpoint of the reliability of reproduced climate signals whose variability and uncertainties are assessed through the spread and the signal-to-noise ratio.Ocean reanalyses have also begun to be applied to many key climate indexes used for assessing the interannual variability and trends of a series of parameters generally considered as Essential Ocean Variables within the scientific community: SST, SSS, temperature and salinity (averaged over meaningful layers of the water column), sea level, transport (across predefined sections), and sea ice criteria. An ensemble prediction system has been developed and successfully applied to the prediction of storm surges in the North Adriatic.

Special attention was given to modeling the dynamics of the marine ecosystem in the Northern Adriatic Sea to investigate the coupling of the hydrodynamic and transport components. The sensitivity of model results to the coupling methods used were studied , and the performance of different filters used to assimilate biogeochemical data were evaluated with a view to improving the quality of simulations. Italian scientists have also contributed to the implementation of an advanced assimilation system for the Pagasitikos Gulf (Aegean Sea) ecosystem combining satellite ocean color (chlorophyll-a) data with the predictions of a three-dimensional coupled physical–biochemical model of the area.

Another important research topic was the simulation of ocean transport and dispersion processes using Lagrangian stochastic models coupled with Eulerian circulation models. Studies were completed: (a) to quantify the sub-grid scale diffusion of the Lagrangian models in terms of horizontal eddy diffusivity using a large database of released drifter trajectories from different regions of the Mediterranean Sea, (b) to assimilate Lagrangian data in a primitive-equation ocean model by implementing a novel method for three-dimensional variational assimilation, and (c) to assess the impact of Argo float data assimilation on the forecast skill of operational models.

(iii) Forecasting of ocean state variables for core marine applications (including maritime safety, marine and coastal environment and climate, seasonal and weather forecasting)

A number of specific applications have been developed to manage environmental emergencies relating to oil spills at sea and to facilitate the rapid planning and coordination of remedial actions

by local authorities. On the regional scale, the Mediterranean Operational Oceanography Network (MOON, now MOONGOOS) is providing near-real-time information on oil-spill detection (ocean color and SAR) and predictions (ocean forecasts and oil spills). The products from this system were used to study the Lebanese oil-pollution crisis in summer 2006, and the predictions were validated by satellite and *in situ* observations. At the local level, an innovative forecasting system has been implemented in the Bonifacio Strait area, between Corsica and Sardinia (Western Mediterranean), which predicts the sea state and the dispersion of hydrocarbon spills, and provides scenarios and risk maps of oil pollution in relation to vessel traffic. The ability of the system in simulating the water circulation and the surface transport processes has been validated by experimental datasets.

Main Research Projects

COMMON SENSE (2013–2017, EU): *Cost-effective sensors, interoperable with international existing ocean observing systems, to meet EU policies requirements*. The COMMON SENSE project will contribute to support the implementation of the Marine Strategy Framework Directive (MSFD) and other EU policies (e.g. Common Fisheries Policy) by providing easily usable, cost-effective, multi-functional innovative sensors across several platforms for reliable in-situ measurements of key parameters by means of methodological standardization. This proposal is focusing on eutrophication, contaminants, marine litter and underwater noise descriptors of the MSFD. The project is an EU-FP7 Collaborative Project funded by (Grant agreement no: 614155)

EURO-ARGO related projects. Euro-Argo started in 2008 as a project aiming at developing a European Infrastructure for ARGO (http://www.euro-argo.eu/). It is aimed at enabling Europe to build and sustain its contribution to the global ARGO programme whilst providing enhanced coverage in sea areas of particular European interest. Several project have been built around Euro-Argo. The ones running at present are: E-AIMS (*Improvements and use of Euro-Argo infrastructure for the GMES Marine Service*, EC FP7-SPACE, 2013-2015) and SIDERI (*Strenghtening International Dimension of Euro-Argo Research Infrastructure*, EC FP7 - Infrastructures, 2011-2013).

EUROFLEETS (2009-2013, EU): *Towards an Alliance of European Research Fleets* (http://www.eurofleets.eu/); funded by the European Commission (FP6-Infrastructures). The project was aimed at creating an alliance of marine research centres across Europe to promote the cost effective use of research vessels and their facilities, and to improve the quality of marine research in Europe.

GROOM (2011-2015, EU)**:** *Gliders for Research, Ocean Observation and Management* (http://www.groom-fp7.eu/); funded by the European Commission (FP7-Infrastructures). The objective of the project was to design a new European Research Infrastructure of underwater gliders for collecting oceanographic data, beneficial for a large number of marine activities and societal applications related to climate change, marine ecosystems, resources, and security.

JERICO (2011-2015, EU)**:** *Towards a Joint European Research Infrastructure Network for Coastal Observatories* (http://www.jerico-fp7.eu); funded by the European Commission (FP7-Infrastructures). The project was planned as an Integrating Activities Action contributing to the international and global effort on climate change research (GEOSS), to provide coastal data inputs

for operational ocean observing and forecasting, and to answer to some specific scientific and societal needs.

MAREFRAME (2014-2016, EU): MareFrame, a EU-FP7 RTD project, is seeking to remove the barriers preventing more widespread use of the ecosystem-based approach to fisheries management (EAFM). This entails development of new tools and technologies, development and extension of ecosystem models and assessment methods, and the development of a decision support framework that can highlight alternatives and consequences, all in close collaboration with the stakeholders in a co-creative process. The vision of MareFrame is to significantly increase the use of the EAFM when providing advice relating to European fish stocks.

MEDESS4MS (2012–2015, EU): *Mediterranean Decision Support System for Marine Safety* (http://oceania.research.um.edu.mt/cms/MEDESS4MS/); funded by the European Regional Development Fund in the framework of the MED Programme. The project deals with the setup of an integrated real time operational oil spill forecasting service for the Mediterranean for national response agencies, REMPEC and EMSA, thereby contributing to maritime risk prevention and safety.

MFS-VOS (1999 - ongoing, IT): The action, comprehending the Ships Of Opportunity and Volunteer Observing Systems initiatives in the Mediterranean Sea, are regional components of the JCOMM - SOOP and EUMETNet. Since 2010, three tracks are being maintained in the framework of an international cooperation (XBTs are being provided by NSF, also) to monitor the thermal variability in the Mediterranean (http://moon.santateresa.enea.it).

MyOCEAN 1&2 (2009-2014, EU): *Development and pre-operational validation of upgraded GMES marine core services and capabilities* (1) and *Prototype Operational Continuity for the GMES Ocean Monitoring and Forecasting Service* (2) (http://www.myocean.eu.org/); funded by the European Commission (FP7-SPACE). The project embodied the deployment of the first concerted and integrated pan-European capacity aimed at delivering and operating an Ocean Monitoring and Forecasting system for the GMES Marine Service (OMF/GMS) to users for all marine applications: maritime safety, marine resources, marine and coastal environment and climate, including seasonal and weather forecasting.

OPEC (2012-2014, FP7): *Operational Ecology* (http://marine-opec.eu/default.html). . The aim of the OPEC project was to evaluate and develop ecosystem forecast tools to enhance marine GMES applications. These tools were to serve in the assessment and management of the risks posed by human activities on the marine environment, thus improving the ability to predict the “health” of European marine ecosystems. The project focussed on four European regional seas (the North-East Atlantic, and the Baltic, Mediterranean and Black Seas).

RITMARE (2012-2016, IT): *La Ricerca Italiana per il Mare (The Italian Research for the Sea*; www.ritmare.it/en/). This is a national flagship project dealing with a wide range of marine and maritime issues project that is being funded by the Italian Ministry of University and Research (MIUR). Sub-project 5 (Observation Systems for the Marine Mediterranean Environment) of the project, in particular, aims to move from distributed autonomous observational systems and devices to an 'integrated network' of 'observers', connected with marine forecasting systems to ensure advanced monitoring and forecasting capabilities.

Organization of Conferences and Workshop of international relevance

- ERVO (European Research Vessels Operators) meeting, May 10-11, 2011, Oristano, Italy (http://www.eurocean.org/np4/65).
- LAPCOD (Lagrangian Assimilation and Prediction Ocean Dynamics) meeting, June 11-15, 2012, Miami, Florida (http://www.rsmas.miami.edu/LAPCOD/).
- GNOO (Italian Operational Oceanography Group) meeting, title: Operational oceanography, innovative technologies and applications, June 3-5, 2013, Oristano, Italy (http://www.seaforecast.cnr.it/convegno_gnoo/)

C) Goals, priorities and plans for future activities

Ocean observation is a key enabling area of activity, which underpins all marine and maritime activities. The European Union recognizes it as a strategic component invaluable for its continued growth, and economic and social well-being. Many projects supported by the European Commission are therefore aimed at the coordinated development of marine observational activities at a transnational level in cooperation with Member States. These projects are contributing to the establishment of an interlinked, mutually supportive pan-European platform for developing and testing new technologies, ameliorating observational strategies, and confronting sensitive data quality issues.Italy is active in many of these projects. This participation is reinforcing cooperation between organizations and groups nationally, and is also serving to improve governance and interoperability of the country's infrastructures on the European scale.

In the future, efforts to expand national observational systems and connect them to integrated regional and global networks will continue. These efforts will include numerical ocean modelling to reinforce current marine forecasting systems and to ensure advanced monitoring and forecasting capabilities.

D) Scientific Publications

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Information systems and knowledge management

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A) Institutions involved in research activity

Activities concerning this topic were conducted by ENEA, CNR, OGS and University of Bologna.

B) Scientific Report

Main Scientific Themes

Knowledge society needs to have open and free access to data and to scientific productions. Knowledge society needs also to educate new generation on understanding scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. The activity is based on two pillars: provide and open and free access to data on marine environment and implementation of tools for the education of students. The activity is also including an assessment of the quality and of the services offered to data users.

The main purpose of the activity is to unlock fragmented and hidden marine data resources and to make these available to individuals and organisations (public and private), and to facilitate investment in sustainable coastal and offshore activities through improved access to quality-assured, standardised and harmonised marine data which are interoperable and free of restrictions on use.

Main Research Projects

EMODnet Chemistry (2009 - ongoing, EU): European Marine Observation and Data Network – Lot Chemistry. This EMODNet Chemical joint tender proposal has been prepared and submitted by the SeaDataNet consortium, represented by almost the complete partnership, in order to cover all sea basins in European waters with data input from almost all coastal states and also to bring in specific expertise, relevant for the EMODNet chemical lot. The same consortium had been awarded the previous call for preparatory actions for Lot 3 Chemical Data and has developed and is operating the present EMODNet Chemistry portal which provides overview and access to already an impressive volume of marine chemistry data sets and data products based upon inputs gathered and collated from national monitoring institutes in many European coastal states. (www.emodnet-chemistry.eu)

EMODnet Physics (2009 – ongoing, EU): The Physics preparatory action had the overall objectives to provide access to archived and near real-time data on physical conditions as monitored by fixed stations and Ferrybox lines in European sea basins and oceans and to determine how well the data meet the needs of users. The existing EMODnet-Physics portal makes layers of physical data and their metadata available for use and contributes towards the definition of an operational European Marine Observation and Data Network (EMODnet). It is based on a strong collaboration between EuroGOOS associates and its regional operational systems (ROOSs), MyOcean and SeaDataNet consortia. (www.emodnet-physics.eu)

EMODnet – Mediterranean CheckPoint (2014 – ongoing) The EMODNET Med Sea checkpoint is a Mediterranean Sea wide monitoring system assessment activity based upon targeted end-user applications. The innovative outcome of this evaluation will be the depiction of 'fitness for purpose' indices capable to show performance and gaps of the present monitoring system. The checkpoint service is aiming to: 1. Clarify the observation landscape at the scale of the Mediterranean Sea, pointing out to the existing programs, national and international, and their roles and synergies 2. Depict fitness for purpose monitoring indices that will show the performance, accessibility and usability of observational and modeling data sets in the overall Mediterranean Sea basin 3. Prioritize the needs in order to optimize the system (*in situ* and satellite data collection and assembling, data management and networking, modelling and forecasting, geo-infrastructure) and release recommendations for evolutions to better meet the application requirements. (www.emodnet-mediterranean.eu)

IONIO (2007-2013): *Ionian Integrated Marine Observatory,* http://www.ionioproject.eu/. Funded by European Territorial Cooperation Operational Programme "Greece-Italy". An InterRegional project initiating a transformation of ocean science toward an integrated marine observatory initiative. IONIO is designed to produce new, persistent, interactive products and services for ocean science. The core activities and the principal objectives of IONIO are collecting real time data, analyzing data, modeling. forecasting the South Adriatic and Ionian Sea end provide access to documentation on data.

ODIP (2012-2015, EU): *Establishing and operating an Ocean Data Interoperability Platform,* http://cordis.europa.eu/search/index.cfm?fuseaction=proj.document&PJ_RCN=13380280. Funded by European Commission, FP7 Infrastructures. A project for building up and operate an Ocean Data Interoperability Platform (ODIP) which will include all the major organizations engaged in ocean data management in EU, US and Australia aimed to remove impediments hindering the effective sharing of data across scientific domains and international boundaries. It is supported by IOC-IODE who also will participate in its implementation and operation. The ODIP platform will organise international workshops to foster the development of common standards and develop prototypes to evaluate and test selected potential standards and interoperability solutions. The ODIP partnership will provide a forum to harmonize the diverse regional systems, while advancing the European contribution to the global system.

PERSEUS (2012-2015, EU): *Policy-orientated marine Environmental Research for the Southern European Seas*, http://www.perseus-net.eu/. Funded by European Commission, FP7 Environment. EU project for the development of a shared approach to understand the natural and human-derived pressures on the Mediterranean and Black Seas, assess their impact on marine ecosystems, and to design an effective and innovative research governance framework for informed decision-making, with particular reference to the Marine Strategy Framework Directive and other relevant European policies and initiatives.

RITMARE (2012-2016, IT): *La Ricerca Italiana per il Mare (The Italian Research for the Sea*), www.ritmare.it/en/. Funded by the Italian Ministry of University and Research (MIUR). Flagship project aiming at the development of: maritime technologies, planning of the Maritime Space in

Coastal Waters; planning of the Deep Marine Environment and the Open Sea Observation System for the Marine Mediterranean Environment Research. The activity is also including the development of an interoperable Infrastructure for the Observation Network and Marine Data.

SeaDataNet 2 (2011-2015): *A Pan-European Infrastructure For Ocean And Marine Data Management*, http://www.seadatanet.org. Funded by European Commission, FP7 Infrastructures. An EU project that is developing an efficient distributed Marine Data Management Infrastructure for the management and access of large and diverse sets of data deriving from *in situ* and remote observation of the seas and oceans.

SSD PESCA (2011-2014, IT): *Decision support system for a sustainable management of fishery in the South of Italy***.** Funding agency: Italian Ministry of Economy and Finance, MEF. The project aims at supporting the development of productive activities in the South of Italy..

TESSA (2012–2015, IT): *TEchnology for the Situational Sea Awareness*. Funded by Italian Ministry of Research (MIUR), PON. The project aims to strengthen and consolidate products and services of operational oceanography in South Italy and integrate them with technology platforms of dissemination of information for the knowledge of the marine environment.

TRIDEC (2010-2013): *Collaborative, Complex, and Critical Decision-Support in Evolving Crises,* http://www.tridec-online.eu/. Funded by European Commission, FP7-ICT. An Integrated Project focusing on new approaches and technologies for intelligent geo-information management in complex and critical decision-making processes in Earth sciences.

Organization of Conferences and Workshop of international relevance

- European Geoscience Union, Earth and Space Science Information, Informatics in Oceanography and Ocean Science (EGU ESSI1.2 Session) - all years
- EMODnet Chemistry Plenary meeting (Trieste, June 2013)
- Organization EMODNet Expert workshop (Split, June 2014)

C) Goals, priorities and plans for future activities

Computed mediated decision support system

A decision Support System is composed by four main steps. The first one is the definition of the problem, the issue to be covered, decisions to be taken. Different causes can provoke different problems, for each of the causes or its effects it is necessary to define a list of information and/or data that are required in order to take the better decision. The second step is the determination of sources from where information/data needed for decision-making can be obtained and who has that information. Furthermore it must be possible to evaluate the quality of the sources to see which of them can provide the best information, and identify the mode and format in which the information is presented. The third step is relying on the processing of knowledge, i.e. if the information/data are fitting for purposes. It has to be decided which parts of the information/data need to be used, what additional data or information is necessary to access, how can information be best presented to be able to understand the situation and take decisions. Finally, the decision

making process is an interactive and inclusive process involving all concerned parties, whose different views must be taken into consideration. A knowledge based discussion forum is necessary to reach a consensus.

D) Scientific Publications

2011-2012

Manzella, G.M.R. and M. Gambetta. Implementation of Real-Time Quality Control Procedures by Means of a Probabilistic Estimate of Seawater Temperature and Its Temporal Evolution. J. Atmos. Oceanic Technol., 30, 609-625, doi: http://dx.doi.org/10.1175/JTECH-D-11-00218.1 (2013).

Rubino, A., What will a new generation of world climate research and computing facilities bring to climate long-term predictions? Theor. Appl. Clim., 106, 473-479, doi: 10.1007/s00704-011-0448-2 (2011).

Sorgente, B., R. Sorgente, A. Olita, L. Fazioli, A. Cucco, A. Perilli, M. Sinerchia and A. Ribotti. Effects of protection rules and measures in an important international strait area: the Bonifacio Strait. J. Oper. Oceanogr., 5, 1, 35-44 (2012).

Tonani, M., J.A.U. Nilsson, V. Lyubartsev, A. Grandi, A. Aydogdu, J. Azzopardi, G. Bolzon, A. Bruschi, A. Drago, T. Garau, J. Gatti, I. Gertman, R. Goldman, D. Hayes, G. Korres, P. Lorente, V. Malacic, A. Mantziafou, G. Nardone, A. Olita, E. Ozsoy, I. Pairaud, S. Pensieri, L. Perivoliotis, B. Petelin, M. Ravaioli, L. Renault, S. Sofianos, M. G. Sotillo, A. Teruzzi and G. Zodiatis**.** Operational evaluation of the Mediterranean Monitoring and Forecasting Centre products: implementation and results. Ocean Sci., 9, 1913-1851 (2012).

2013-2014

Bechini, A. and A. Vetrano. Management and Storage of In-situ Oceanographic Data: An ECM-based Approach. Inform. Sys., 38, 3, 351-368, doi:10.1016/j.is.2012.10.004 (2013).

Bergamasco, A., A. Benetazzo, S. Carniel, F.M. Falcieri, T. Minuzzo, R.P. Signell and M. Sclavo. Knowledge discovery in large model datasets in the marine environment: the THREDDS Data Server example. Advances in Oceanography and Limnology, 3(1), 41-50, http://dx.doi.org/10.1080/19475721.2012.669637 (2012).

Manzella G. Knowledge Building and Computer Tools. In Collaborative Knowledge in Scientific Research Networks, P. Diviacco, P. Fox, C. Pshenichny and Leadbetter (Eds), 177-190 (2014).

Partescano, E., A. Brosich and A. Giorgetti. A System for Managing Oceanographic Metadata Using XML and XQuery. J. Comput. Commun., 2, 6-12. doi: 10.4236/jcc.2014.21002, http://www.scirp.org/journal/CTA.aspx?paperID=41245 (2014).

Prizes and honours

2011 - Katrin Schroeder and Andrea Toreti, MedClivar Young Scientist Award (MEDCLIVAR)

2014 - Jacopo Chiggiato, Science Achievement Award CMRE (NATO)

2014 - Katrin Schroeder, Arne Richter Award for Outstanding Young Scientist (EGU)

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