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

Activities in Italy (2011-2012)

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:

Organization

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OPEN OCEAN PROCESSES

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A) Institutions involved in research activity

Most of the research activities interesting the open ocean processes topic in the biennium 2011-2012, were conducted by

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.

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.

Unibo: University of Bologna. UNIBO Oceanographers operate mostly at the Department of Physics and Astronomy. 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.

*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.

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 subbasins.

(i) This theme includes model, analytical and laboratory studies. The model studies (implemented following a process-oriented approach) are aimed at identifying mechanisms of oceanic intrinsic low-frequency variability. The decadal bimodality of the Kuroshio Extension has in fact been interpreted as resulting from mechanisms of that kind. The effects of stochastic forcing and the predictability of such a phenomenon have also been investigated. The Gulf Stream variability has been analyzed from the same viewpoint, and also through lagrangian methods in which particle transport at submesoscale was properly parameterized. Analytical and laboratory studies have been performed as well. Analytical studies include a new integration of the classical Munk model of the wind-driven ocean circulation, the analysis of the low-frequency variability and coherence resonance in a low-order model of the wind-driven ocean circulation, the two-layer skirted island problem, and the propagation of Rossby waves on a quiescent abyss. A laboratory study performed with a 5-m diameter rotating tank has investigated the role of nonlinear effects on western boundary currents, with particular reference to the Gulf Stream separation due to inertial overshooting.

(ii) The studies included in this theme are based on *in situ* and satellite data, and investigate the dynamics and the physical and biogeochemical properties of the water masses in Mediterranean subbasins, such as the Algero-Provençal and Ligurian basins and the Adriatic Sea, and in the Mediterranean Sea as a whole. The open ocean processes analyzed in the Algero-Provençal basin are the surface circulation (as observed by satellite tracked drifters), the pelagic primary production, the SLA-chlorophyll-a variability and covariability. In the Southern Adriatic Sea the variability of water mass properties in the last two decades, footprints of mesoscale eddy, and the biological evidence of winter convection events have been analyzed; severe marine storms have been studied in the Northern Adriatic. As far as the Mediterranean Sea is concerned, seasonal and interannual variability of plankton chlorophyll and primary production, C, N and P stoichiometry have been analyzed; operational forecasts of the biogeochemical state of the Mediterranean Sea have also been carried out.

Main Research Projects/Programmes

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 2011-2012 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, the related mesoscale dynamics and eddy-mean flow interactions, and the Mediterranean Sea wind-driven and thermohaline circulation and associated variability over the various temporal scales. The impacts of these physical processes on chemical processes and on the biogeochemical and biological compartments will be addressed as well. 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

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).

Batisti, 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).

Cardin, V., M. Bensi and M. Pacciaroni. Variability of water mass properties in the last two decades in the South Adriatic sea with emphasis on the period 2006-2009, Cont. Shelf Res.31, 9, 951-65 (2011).

Chang, Y., D. Hammond, A. Haza, P. Hogan, H.S. Huntley, A.D. Kirwan, Jr, B.L. Lipphardt, Jr., V. Taillandier, A. Griffa and T.M. Ozgokmen. Enhanced Estimation of Sonobuoy Trajectories by Velocity Reconstruction With Near-Surface Drifters. Oc. Modelling, 36, 179-19 (2011).

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Kovačević, V., B.B. Manca, L. Ursella, K. Schroeder, S. Cozzi, M. Burca, E. Mauri, R. Gerin, G. Notarstefano and D. Deponte. Water mass properties and dynamical conditions of the Eastern Mediterranean in June 2007, Progr. Oceanog., 104, 59-79, doi:10.1016/j.pocean.2012.05.006 (2012).

Kramer W., H. A. Dijkstra, S. Pierini, and P. J. Van Leeuwen. Measuring the impact of observations on the predictability of the Kuroshio Extension in a shallow-water model. J. Phys. Oceanogr., 42, 3-17 (2012).

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).

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Pedlosky, J., R. Iacono, E. Napolitano and M.A. Spall. The two-layer skirted island. J. Mar. Res., 69, 347-382 (2011).

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Santinelli, C, V. Ibello, R. Lavezza, G. Civitarese and A. Seritti. New insights into C, N and P stoichiometry in the Mediterranean sea: The Adriatic sea case. Cont. Shelf Res., 44,83-93 (2012).

Schroeder, K., A. C. Haza, A. Griffa, T. M. Özgökmen, P.M. Poulain, R. Gerin, G. Peggion and M. Rixen. Relative dispersion in the Liguro-Provencal basin: from submesoscale to mesoscale, Deep-Sea Res. I, 58, 209-228, doi:10.1016/j.dsr.2010.11.004 (2011).

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Ursella, L, V. Kovačević and M. Gačić. Footprints of mesoscale eddy passages in the strait of Otranto (Adriatic Sea). J. Geophys. Res. C: Oceans, 116, 4, (2011).

Volpe, G., B. Buongiorno Nardelli, P. Cipollini, R. Santoleri and I.S. Robinson. Seasonal to interannual phytoplankton response to physical processes in the Mediterranean Sea from satellite observations. Remote Sens. Environ., 117, 223–235 (2012).

COASTAL PROCESSES AND INTERACTIONS

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A) Institutions involved in research activity

Most of the research activities concerning the topic of coastal processes and interactions in the biennium 2011-2012, were conducted by

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.

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.

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.

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.

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, including acidification, (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 (e.g. Gulf of Trieste, lagoon of Venice), but also on other Mediterranean (e.g. Gulf of Lion, Gulf of Naples) and non-Mediterranean (e.g. Mississippi river mouth) regions.
The studies include modeling efforts and in-situ data based investigations. Data are collected from a variety of platforms, from fixed buoys, to samples collected from ships and trajectories of drifters, as well as from remote sensing (satellite and costal).

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).

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.

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 Bocche di Bonifacio.

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.

Organization of Conferences and Workshop of international relevance

In the years 2011-2012 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 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).
- 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).

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

Acquavita, A, S. Covelli, A. Emili, D. Berto, J. Faganeli, M. Giani, et al. Mercury in the sediments of the marano and grado lagoon (northern Adriatic sea): Sources, distribution and speciation. Estuar Coast Shelf Sci. (2012).

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Cossarini, G, C. Solidoro and S. Fonda Umani. Dynamics of biogeochemical properties in temperate coastal areas of freshwater influence: Lessons from the northern Adriatic sea (Gulf of Trieste). Estuar. Coast Shelf Sci. (2012).

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Falcini, F., D.J. Jerolmack and B. Buongiorno Nardelli. Mississippi River and Sea Surface Height Effects on Oil Slick Migration, PloS one, 7, 4, doi:10.1371/journal.pone.0036037 (2012).

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Falcini F., S. Fagherazzi and D.J. Jerolmack. Wave-supported sediment gravity flows currents: Effects of fluid-induced pressure gradients and flow width spreading. Cont. Shelf. Res., 33, 37-50, doi:10.1016/j.csr.2011.11.004 (2012).

Giani, M., T. Djakovac, D. Degobbis, S. Cozzi, C. Solidoro and S. Fonda Umani. Recent changes in the marine ecosystems of the northern Adriatic Sea, Estuar. Coast. Shelf Sci., 115, 1-13 (2012).

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Schroeder, K., J. Chiggiato, A. C. Haza, A. Griffa, T. M. Ozgökmen, P. Zanasca, A. Molcard, M. Borghini, P. M. Poulain, R. Gerin, E. Zambianchi, P. Falco and C. Trees. Targeted Lagrangian sampling of submesoscale dispersion at a coastal frontal zone, Geophys. Res. Lett., 39, L11608, doi:10.1029/2012GL051879 (2012).

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THERMOHALINE CIRCULATION AND DEEP CURRENTS

Report by Miroslav Gacic, OGS, Italy
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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

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.

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

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.

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.

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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 biennium, as coordinators or partners of the main projects, are:

CMCC: Euro-Mediterranean Center on Climate Change. 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.

ENEA - Unit for Environment and Energy Modeling. A unit of the Italian government agency responsible for the areas of new technology, energy and the environment. Its activities include 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.

INGV - Dynamic Climatology division. A division of the Istituto Nazionale di Geofisica e Vulcanologia (INGV), taking part to several European and international projects with different dimension and partnerships, both as Partner and Coordinator. It collaborates with all the main climate research centres in Europe and in the rest of the world.

University of Bologna, Alma Mater Studiorum. 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.

University of Salento, Lecce: It has expertise in wave and storm surge modelling, air-sea interaction, regional coupled atmosphere ocean models, modelling of turbulence and dispersion in the urban environment, analysis of synoptic variability and cyclone tracking algorithms.

B) Scientific Report

Main Scientific Themes

In the last years regional climate simulation in the Mediterranean Area have been performed with an innovative multi-model system including a high-resolution Mediterranean Sea components. 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 projections (performed within the CIRCE project) , which adopted the A1B emission scenario confirm previous results from PRUDENCE, ENSEMBLES and CMIP3 and show a substantial warming (about 1.5°-2°C) and a significant

decrease of precipitation (about 5%) for the mid of this 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. These simulations lead to a new estimate of mean steric sea-level rise in the range 7-12cm in about 50 years.

The vulnerability of the North Adriatic coastline to marine storms is the motivation for a sequence of studies analyzing the impact of climate change on surges and wind waves in this basin. Results confirm previous analysis, in that a weak sensitivity is found and results suggest the possibility modest attenuation of marine storminess in the future.

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. 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.. On the global and centennial perspective past climate multidecadal SST fluctuations in the North Atlantic, North Pacific, and tropical Indian Ocean Sea Surface Temperatures are suggested to be reproducible as ensemble-mean responses in climate simulations only for periods dominated by major external forcings.

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.).

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.

MedCLIVAR (2006-2013) 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).

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

The MedCLIVAR Conference "Mediterranean Climate: From past to the future", held in Lecce on June 6-9th 2011, brought together nearly 130 international participants working on climate change in the Mediterranean region.

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

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. These new generation of models should allow a more

accurate simulation of future evolution of the Mediterranean Sea and assess the effect of climate change on its thermohaline circulation 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. In general a large ensemble of new climate simulations should allow a better characterization of uncertainties of projections and possibly to reduce them. A major goal is 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.

D) Scientific Publications

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POLAR RESEARCH

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A) Institutions involved in research activity

The main institution involved in Polar Research of Physical Oceanography in the biennium 2011-2012 was the University of Napoli "Parthenope" who carried the research programs described in the following with the collaboration of other Italian Universities and some Institutes of the Consiglio Nazionale delle Ricerche (CNR – the National Research Council of Italy), and by ENEA who contributed remarkably to the scientific production.

In addition to the polar research in the southern hemisphere, the 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 Programme for Antarctic Research (PNRA). The Programme 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. Usually the ship operates during the summer months (December - February) and hosts a variety of scientific projects.

More specifically, during the period 2009-2012 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.

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.

Moreover the Italian PNRA manage a marine observatory network that during the biennium 2011-12 was constituted by 4 moorings located in the western sector of the Ross Sea. The management is at University of Napoli "Parthenope" (p.i. G. Spezie).

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).

C) Goals, priorities and plans for future activities

The Italian National Scientific Commission for Antarctica (CSNA) indicated in 2012 the strategic guidelines for the Italian Antarctic research in the triennium 2012-14 (http://www.csna.it/Documenti/PNRA_Programma_triennale_2012_2014_2012_06_27.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 March 2013 a new call for research projects in Antarctica of 24 months years long, 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 expected that during the next biennium, the M /V Italica will operates in the Ross Sea only during the Austral Summer 2013-14, while two small scientific vessels will operate close to the Italian "Mario Zucchelli" Station for coastal research in the summer months during each expedition.

D) Scientific Publications

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SEA LEVEL VARIABILITY IN THE 19th – 21th CENTURIES

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A) Institutions involved in research activity

Consiglio Nazionale delle Ricerche (CNR, National Research Council) – It is the largest Italian research organization, involved in disciplines covering all fields of knowledge. Research related to sea level is performed in the Institute for Marine Sciences (ISMAR), belonging to the Department for the Earth-system sciences and environmental technologies. 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.

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 to the IOC Sea Level Station Monitoring Facility with real-time data.

Centro Euro-Mediterraneo sui Cambiamenti Climatici (CMCC, Euro-Mediterranean Center on Climate Change) – It is a non-profit research institution supported by the Italian Ministry of Education, University and Research. CMCC manages and promotes scientific and applied activities in the field of climate change research. Among other issues, sea-level changes are studied through climate models under different scenarios, focusing on multidecadal to secular variability in the Mediterranean region.

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.

Main Research Projects/Programmes

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.

Depending on funding availability, it is planned to reconstruct the sea level evolution in the Mediterranean and, particularly, along the Italian coastline for the last century, on seasonal to secular time scales.

D) Scientific Publications

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OCEAN SENSING, MODELING AND FORECASTING

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A) Institutions involved in research activity

Almost 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. In particular,

CNR: National Research Council of Italy. Four institutes of the CNR, IAMC, ISAC, ISMAR and ISSIA, are working on developing a holistic marine observational system that will integrate cruises on board the CNR research fleet, several multi-parametric fixed observing systems, drifting buoys, HF costal radars, and a Satellite Observing System producing ocean colour and sea surface temperature products of the Mediterranean Sea. Ocean Forecast Modeling activities are also being carried out, particularly focusing on providing an innovative assist in the management of the marine system and its resources, and to water current and wave field forecasting.

ENEA: Italian National Agency for New Technologies, Energy and Sustainable Economic Development. ENEA is active in Operational Oceanography since 1994, when it began to set up and implement the Ship Of Opportunity Programme in the Mediterranean (WMO e UNESCO IOC). ENEA is now maintaining XBT lines in the western Italian Seas.

OGS: Istituto Nazionale di Oceanografia e di Geofisica Sperimentale. 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.

A team made up of by scientists from the *University of Bologna, Alma Mater Studiorum*, *INGV* and *CMCC* is jointly engaged in relevant 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

Research under this subject comprises (i) improvement and exploitation of ocean observations, (ii) development and validation of models of the ocean circulation and marine ecosystem, and (iii) forecasting of ocean state variables for several marine applications, including maritime safety, marine and coastal environment and climate, seasonal and weather forecasting.

(i) The studies around this theme concentrate on developing new methods and techniques for overcoming inaccuracies in *in situ* and remotely sensed measurements, and to obtaining derived parameters thata better characterize ocean properties and processes.

In the case of the techniques for *in situ* observation, research is ongoing to develop new methods for obtaining realistic measurements of ocean temperature from expendable bathythermograps (XBTs), widely used in the Ships Of Opportunity and Volunteer Observing Systems, to map the vertical distribution of this parameter for the ocean interior, to monitor its changes and to estimate ocean heating and the associated global warming. Attention is also given to novel measurement devices, such as the 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 performance, in order to mitigate measurable drift effects on the collected data.

In the field of remote sensing, efforts are directed towards advancing the methodologies employed for the real-time 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 focused on assessing the performance of sea surface temperature (SST) products obtained from different satellite instruments by comparison with *in situ* measurement and to the development of a novel technique for the high-resolution interpolation of *in situ* sea surface salinity (SSS) from SST.

Several studies combine data 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 (altimeter, sea surface temperature, chlorophyll concentration) 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 Mediterranean Absolute Dynamic Topography data to investigate the relationships between physical and biological Mediterranean processes.

(ii) The activity around this theme was 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.

Special attention was given to implementing marine ecosystem dynamics modeling in the Northern Adriatic Sea to investigate the coupling of the hydrodynamic and transport components, by studying the sensitivity to the coupling methods used in the models, and to improve the quality of simulations by evaluating the performance of different filters used to assimilate biogeochemical data. Moreover, Italian scientists 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 line is the simulation of ocean transport and dispersion processes using Lagrangian stochastic models coupled with Eulerian circulation models. Studies were completed to quantify the sub-grid scale diffusion of the Lagrangian models in terms of horizontal

eddy diffusivity using a large database of drifter released trajectories from different regions of the Mediterranean Sea, to assimilate Lagrangian data in a primitive-equation ocean model by implementing a novel method for three-dimensional variational assimilation, and to assess the impact of Argo float data assimilation on the forecast skill of operational models.

(iii) This theme groups activities aiming at providing forecasting services to end-users for several marine applications, including maritime safety, marine and coastal environment and climate and weather forecasting.

Specific applications have been developed to manage environmental emergencies related to the 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) provides 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 against 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 against experimental datasets.

Main Research Projects

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/. This new infrastructure is beneficial to all partners and enables Europe to build and sustain its contribution to the global array whilst providing enhanced coverage in sea areas of particular European interest. Several project are 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. A project aiming 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 is 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. It is 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 also to answer the needs of the environmental research and societal communities.

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, contributing to maritime risks prevention and maritime safety.

MFS-VOS (1999 - ongoing, IT): Ships Of Opportunity and Volunteer Observing Systems in the Mediterranean are regional components of the JCOMM - SOOP and EUMETNet. From 2010 three tracks are maintained in the framework of an international cooperation (NSF is also providing XBTs). The aim is the monitoring of the thermal variability/changes 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 embodies the deployment of the first concerted and integrated pan-European capacity aiming to deliver and operate an Ocean Monitoring and Forecasting system of the GMES Marine Service (OMF/GMS) to users for all marine applications: maritime safety, marine resources, marine and coastal environment and climate, seasonal and weather forecasting.

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 5 (Observation Systems for the Marine Mediterranean Environment) 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 activities.

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/).

C) Goals, priorities and plans for future activities

Ocean observation is a key enabling area of activity, which underpins all marine and maritime activities. A number of projects launched by the European Commission aims at organizing a coordinated development of marine observation at European level in cooperation with Member

States. Italy is active in many of these projects that are reinforcing cooperation between organizations and serving to improve governance and interoperability on a European scale within categories of distributed infrastructures. 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.

Efforts will be devoted to connect such observational systems to an 'integrated network', including numerical ocean models, to reinforce present marine forecasting systems and to ensure advanced monitoring and forecasting capabilities.

D) Scientific Publications

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INFORMATION SYSTEMS AND KNOWLEDGE MANAGEMENT

Report by Giuseppe Manzella, ENEA, Italy
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A) Institutions involved in research activity

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

CNR: National Research Council of Italy. Information and Communication Technologies (ICT) for Geosciences is treated as a multidisciplinary subject. CNR utilizes informatics and telecommunications technologies to facilitate the exploitation and the fruition of Earth Sciences results. It provides the Information Society with Earth Sciences resources, in a near-real-time and transparent way. The standardization process of Geospatial Information is extremely important for providing systems interoperablity and enable the development of effective Spatial Data Infrastructures.

OGS: Istituto Nazionale di Oceanografia e Geofisica Sperimentale. OGS applies its own expertise in Earth Sciences, and in Marine and Polar regions to contribute not only to the spreading and widening of the knowledge, but also to the practical solution of environmental, economical and social issues. The aim is to ease the transfer of the results of the research from the scientific world to that of production and thus contribute to the technological and socio-economic development of the Country.

Unibo: University of Bologna. Has wide experience in several aspects of tsunami research, with special focus on the modelling of the generation of tsunamis by earthquakes and landslides, of the propagation of tsunami waves and of their impact on the coasts, on the elaboration of tsunami scenarios, with main focus on the EuroMediterranean region, on the probabilistic assessment of tsunami hazard and the implementation of tsunami early warning systems. UNIBO has participated (and is participating) in several projects funded by the European Commission. UNIBO coordinated projects GITEC and GITEC-TWO in the 1990s, and the TRANSFER project in 2006-2009. UNIBO was partner in 3HAZ-Corinth, SCHEMA and DEWS projects. Moreover, UNIBO was involved in several national projects funded by the Italian Ministry for Education, University and Research, and by the Italian Civil Protection Department.

B) Scientific Report

Main Scientific Themes

"Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity" (http://www.literacynet.org/science/scientificliteracy.html). It is important to widen the bridge between science and society, in order to have scientifically literate persons capable to:

- understand experiment and reasoning as well as basic scientific facts and their meaning
- ask, find, or determine answers to questions derived from curiosity about everyday experiences
- describe, explain, and predict natural phenomena
- read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions
- identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed
- evaluate the quality of scientific information on the basis of its source and the methods used to generate it
- pose and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately

Scientific literature is a component of the social progress. From a social standpoint, the ability to connect discourses within and between communities opens new possibilities for barrier-crossing and mutual support. A virtuous cycle can be realized along a development trajectory that is containing *lifelong learning, flexibility, creativity, higher-order thinking skills, collaboration, distributed expertise, learning organizations, innovation, technological literacy, scientific literacy.*

Main Research Projects

EMODnet (2009-…, EU): *European Marine Observation and Data Network***,** https://webgate.ec.europa.eu/maritimeforum/category/162. Funded by European Commission, DG MARE. The overall objective is to improve stakeholders' access to marine environmental data for developing new products and services and fostering understanding of seas' behaviour. Fragmented and inaccessible marine data are being organized into interoperable, continuous and publicly available data streams for complete maritime basins. The results will help to define processes, best technology and approximate costs of a final operational European Marine Observation and Data Network.

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

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.

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ITALIAN RESEARCH ON TSUNAMIS

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A) Institutions involved in research activity

The main institutions involved in tsunami research in the biennium 2011-2012 are universities and research institutions of national relevance. More specifically they are the University of Bari, University of Bologna, University of Catania, University of L'Aquila, University of Roma Tre and the University of Lecce where groups of researchers of various Departments (mainly of Earth Sciences, Physics-Geophysics and Engineering) have conducted research on tsunamis in the framework of specific programs using funds from national and international projects.

In addition the Istituto Nazionale di Geofisica e Vulcanologia (INGV) and the Istituto di Scienze del Mare (ISMAR-CNR) have conducted researchers by continuing programs initiated in previous years. It is to be mentioned that INGV is a key element in the Italian system of Tsunami Early Warning that has recently started a pre-operational stage and is planned to become operational in the next years. The system is a candidate system of the European Tsunami Warning System (called North-East Atlantic and Mediterranean TWS with acronym NEAM-TWS) in the frame of which Italy will act as a regional Tsunami Watch Provider.

Further to notice is that ISMAR is handling through the Director Dr Fabio Trincardi the flagship project RITMARE (Ricerca Italiana per il Mare –Italian Research on the Sea). The project has a lifetime of 5 years, started in 2012, and will be partly devoted to tsunami hazard assessment and tsunami mitigation studies also through the development of early warning activities.

B) Scientific Report

The main areas of interest of the tsunami research where Italian scientists have contributed most can be categorized as: 1) geological investigation in marine environment to identify tectonic sources of tsunamis and tsunamigenic mass failures; 2) identification of signatures of tsunamis impact through geological tools; 3) simulation of tsunamis by means of numerical models and assessment of tsunami hazard, vulnerability and risk; 4) development of tsunami detection algorithms and of tools for TWS decision makers; 5) improvement of tsunami catalogue data

<u>Tsunami sources investigated through marine geology</u>

Most contributions in this field came from researchers from ISMAR who covered various geographical regions. Intense studies were devoted to recognize seismogenic structures along the southwest Iberian margin (Bartolome et al. 2012), in central Mediterranean, like Messina straits and the Calabrian arc (Polonia et al., 2011 and 2012) and along eastern Sicily (Argnani et al., 2012), in southern Adriatic (Fracassi et al., 2012), and in the Marmara sea (Gasperini et al., 2011). The relevance of submarine mass failures for tsunamigenesis has been stressed by several studies. Argnani et al. (2011) concentrated on a case study in southern Adriatic; Iglesias et al. (2012) studied the case of the so-called Big '95 submarine landslide, which occurred on the Ebro margin

in the western Mediterranean Sea in prehistoric times (11,500 yr BP); and Lo Iacono et al. (2012) investigated the tsunamigenic potential of a huge (80 km^3) deep-water landslide that occurred along the northern flank of the Gorringe Bank in the southwest Iberian margin.

Coastal tsunami signatures identified through geological means

Geological investigations can identify coastal morphological changes induced by tsunamis and tsunami erosional and depositional pattern. The role of earthquakes and tsunami in modeling the coast of northern Apulia and in modifying the course of the river Fortore was investigated by Mastronuzzi and Sansò (2012). How boulders deposits can be identified and quantified through advanced terrestrial laser scanner techniques and used to make assessment on tsunami impact has been exemplified by a joint study of researchers from the University of Catania and of Bari focused on boulders found on the coasts of the Maddalena peninsula, south of Siracusa, eastern Sicily (Schicchitano et al., 2012). A possible association between the calcarenitic boulders field identified at Punta Saguerra, a few kilometers south of Taranto, and an historical tsunami occurred in 1836 and documented at Rossano Calabro on the opposite side of the Gulf of Taranto, is proposed in a study by Mastronuzzi and Pignatelli (2012).

Tsunami simulations and hazard to risk assessments

Tsunami numerical modeling and utilization of tsunami simulations to assess tsunami hazard and risk are activities mainly undertaken by the teams of the University of Bologna and of INGV. Lorito et al. (2011) have used inversion techniques on a composite set of data including tsunami observations to estimate the slip distribution of the great 27 February 2010 Chile tsunamigenic earthquake and concluded that it was not totally filling the seismic gap following the 1835 earthquake, which means that a large zone of high preseismic locking remained unbroken with the possibility of the occurrence of a major tsunamigenic earthquake in the near future. The same joint inversion technique of tsunami and geodetic data was applied by the same INGV team to the great Tohoku earthquake of 11 March 2011. Romano et al., (2012) were able to prove that only by using near-source data a detailed image of the co-seismic slip distribution can be derived and the high-slip small-scale patch (up to 48 m) can be identified, which shows the importance to monitor offshore sources through off-shore stations.

The research team of the University of Bologna has used numerical models of tsunami generation and propagation to find constraints on the tectonic source of the 29 September 2009 tsunami that impacted Samoa islands in the Pacific ocean (Tonini et al., 2011), and to study the tsunami generated by the ischia Debris Avalanche (IDA), a speculated flank collapse of the Mt Epomeo with an estimated volume of 1.5-3 km^3 (Tinti et al., 2011a). Probabilistic Tsunami Hazard Analysis and analysis based on the worst case credible scenario technique have been respectively used by Grezio et al. (2012) to assess losses and damage induced by tsunamis in the town of Messina and by Tonini et al. (2011) to evaluate possible inundation areas for the town of Catania, that are two towns located in one of the most earthquake- and tsunami-prone areas of Italy and of the Central Mediterranean.

It is known that tsunami impact on the coast can be amplified by the excitation of the oscillation modes of coastal basins. How to determine the eigenfrequencies and the eigenmodes of these basins is not a trivial matter. Bellotti et al. (2012a and 2012b) from the Universities of Roma Tre

and of L'Aquila have set up a method based on finite-element long wave models for modal analysis and have tested it on idealized geometries as well as to real coastal basins (e.g. Poverty and Kuluk Bays respectively in New Zealand and in Adak island, Alaska; and the harbor of Marina di Carrara, Italy), finding good agreement between the theoretical and the experimental spectra.

Development of tsunami detection algorithms and of tools for TWS decision makers

Italian researchers have been the most active in developing, proposing and testing the performance of tsunami detection algorithms. Bressan and Tinti (2011 and 2012) have developed an algorithm called TEDA to use real-time in coastal tide-gauge station that works in the time domain and is based 1) on a module (called tsunami detection module) examining the detided instantaneous and background slope of the tide-gauge records and quite effective in quickly recognizing tsunamis with impulsive first arrivals and 2) on a module (called secure detection module) computing a modified integral of the instantaneous slope which was proven to be quite sensitive to detect soon high amplitude oscillations of whatever origin (tsunamis or local seiches).

Beltrami (2011) and Beltrami et al. (2011) focused on algorithms that can be applied real-time to offshore sensors, like DART buoys in deep ocean or wind-wave gauges capable of detecting long-period sea-level oscillations: they studied the performance of existing algorithms and proposed variants that could provide better efficiency.

One of the main tools used in the TWS operational today is the decision matrix that provides criteria to launch the first alert on the basis of the seismic data, like hypocenter coordinates and magnitude, that are first available (only a few minutes after the earthquake occurrence according to the today's technology). Tinti et al. (2012) have examined the performance of the decision matrix adopted by the Mediterranean TWS (NEAM TWS) on the dataset of the historical Italian earthquakes crossed with the tsunami catalog data and concluded that the efficiency of this tool is quite modest, since it leads in too many cases to the issuance of tsunami messages either overestimating or underestimating the effects of tsunamis.

Improvement of tsunami catalogue data and of the tsunami sources

Tsunami catalogue play a fundamental role to study tsunami hazards and tsunami risk and to set up adequate monitoring and alerting systems. Italy has a long tradition of assembling historical data on tsunami occurrences and of building and maintaining organized catalogues of historical and instrumental tsunamis. INGV contributed to the re-examination of historical tsunamis in the Adriatic sea by integrating Italian and Croatian sources (Pasaric et al. 2012). An analysis of the present knowledge of the tsunami sources in the Mediterranean (Tinti et al., 2011b) have shown that the most active areas are offshore Algeria, but mainly in Calabria and eastern Sicily, and along the Hellenic arc, and has also shown that there are still a lot of uncertainties as regards the characterization of the tectonic tsunami sources and especially of submarine mass-failure tsunami sources.

C) Goals, priorities and plans for future activities

Tsunami research in the next two years will continue on the main themes that have been object of research during the biennium 2011-2012 and will be undertaken by the same groups of research. It is expected that on national level the project RITMARE will foster and finance significant progress in tsunami research mostly focused on hazard and risk assessment for the Italian coasts and on the creation of a tsunami scenarios database to be used in the frame of a national tsunami warning system.

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