

SUSTAINABLE WATER MANAGEMENT: AN OPERATIVE TEST FOR MONITORING LAKES THROUGH INTEGRATED EARTH SENSING

Oggioni A., Carrara P., Pepe M., Manca D., Giardino C. and Criscuolo L.

Abstract - Monitoring water resources is a crucial issue for the sustainable development of Earth. Also in regions where water is abundant, like around European Alps, lower precipitation levels, raise of temperature, glacier retreat, anthropic pressure are factors that affect future availability of 'good' water; to avoid or at least mitigate socio-economic impacts, methods to monitor ongoing processes are required. They are based on dynamic and updated geo-data, depicting the behaviour of the environment through time.

Unfortunately, Spatial Data Infrastructures (SDI), i.e. the current architecture framework to discover, access and distribute geo-data, serve mainly static spatial data, such as topography, land use, etc. On the other side, recent advances in digital data collection, processing and communication have led to the development of more systematic capabilities for data acquisition, for accessibility of sensor data/metadata and for the integration of remote sensing observations with in situ measurements. In this context the Sensor Web (SW) is a straightforward approach coupling distributed and heterogeneous measurements from different sensor types in a unique information system that collects, processes, fuses and distributes sensed information.

Pushing the idea that an integration of SW within SDI is crucial for water monitoring at local and regional level, in this work we investigate the opportunities offered by current technological solutions in the SW with its core services, in compliance with OGC (Open Geospatial Consortium) standards. They provide an interoperable web-based interface to make sensors and their dynamic observations accessible. The test here described has implemented distributed services to access observations and measurements sensed by either in situ stations located on the lakes of Northern Italy, or remotely sensed images of the same area.

The objective is to evaluate the improvements and limitations of SW approach and its technological advances, to assess the level of interoperability of distributed services, and to test integration with an operating SDI. In particular, we have tested interoperability between SDI and SW services and examined some candidate client applications, to evaluate their suitability for supporting many services such as Catalogue Service Web (CSW - <http://csw.ise.cnr.it/> and <http://150.145.35.14/>), Sensor Observation Service (SOS - <http://thinclient.ise.cnr.it/>), Web Map Service (WMS - <http://ows.ise.cnr.it/>), and Web Coverage Service (WCS - <http://owsdemo.irea.cnr.it/>).

Keywords - Sensor Web (SW), Sensor Observation Service (SOS), Web Coverage Service (WCS), freshwater monitoring, Web geoservices interoperability

Affiliations:

Alessandro Oggioni, Researcher
CNR - Institute of Ecosystem Study
L.go Tonolli 50-52
28922 Verbania-Pallanza
ITALY
Phone: +39 0323 518300
Fax: +39 0323 556513
e-mail: a.oggioni@ise.cnr.it

Paola Carrara, Researcher
CNR - Institute for Electromagnetic Sensing of the Environment
Via Bassini 15
20133 Milano
ITALY
Phone: +39 02 23699 295
Fax: +39 02 23699 300
e-mail: carrara.p@irea.cnr.it

Monica Pepe, Researcher
CNR - Institute for Electromagnetic Sensing of the Environment
Via Bassini 15
20133 Milano
ITALY
Phone: +39 02 23699 550
Fax: +39 02 23699 300
e-mail: pepe.m@irea.cnr.it

Dario Manca, Technician
CNR - Institute of Ecosystem Study
L.go Tonolli 50-52
28922 Verbania-Pallanza
ITALY
Phone: +39 0323 518300
Fax: +39 0323 556513
e-mail: d.manca@ise.cnr.it

Claudia Giardino, Researcher
CNR - Institute for Electromagnetic Sensing of the Environment
Via Bassini 15
20133 Milano
ITALY
Phone: +39 02 23699 292
Fax: +39 02 23699 300
e-mail: giardino.c@irea.cnr.it

Criscuolo Laura, Research fellow
CNR - Institute for Electromagnetic Sensing of the Environment
Via Bassini 15
20133 Milano
ITALY
Phone: +39 02 23699 550
Fax: +39 02 23699 300
e-mail: criscuolo.l@irea.cnr.it

1. INTRODUCTION

The definition of monitoring (<http://en.wikipedia.org/>) - i.e. to observe a situation for any changes which may occur over time, using a monitor or measuring device of some sort - makes clear that to monitor an environmental phenomenon we need to measure it over time. Moreover the spatial variability of environmental phenomena requires related measurements to be distributed over the Earth surface.

Recent developments in sensor technology for monitoring purposes, such as electronics miniaturization and wireless communication, were impressive and led to great capacities of collecting environmental data in space and time. On the other hand the technologies related to data management and distribution did not follow this pace so that the outputs of sensor networks still remain not so easily accessible and exploitable.

Even if the concept of Sensor Web (SW), defined as a system of intra-communicating spatially distributed sensor pods that can be deployed to monitor and explore the Earth surface, has been introduced by NASA already in 2001 (Delin and Jackson, 2001), and a couple of years before Murray (1999) could imagine that the technologies were mature because the Earth was wearing an "electronic skin" composed of millions of measuring devices that are connected by the Internet, the implementation of web technologies enabling such interoperable sensor architecture is still under development and testing.

From these ideas many international initiatives take a start to which the SW refers, among the most important: GEOSS (Global Earth Observation System of Systems, <http://earthobservations.org/>), GMES (Global Monitoring for Environment and Security, <http://www.gmes.info/>) and above all the initiative Sensor Web Enablement (SWE, <http://www.opengeospatial.org/projects/groups/sensorweb>) planned by OGC (<http://www.opengeospatial.org/>), which includes a suite of open standards for the use of web-connected sensors and sensor systems of all kinds.

Though environmental monitoring and research can be counted among the sectors involved in this type of technological development, in order to provide an improvement as respect to the routine monitoring it is necessary that the whole system architecture is fully operational, which means that heterogeneous and distributed sensors are interoperable (Liang *et al.*, 2005), that the data they collect are stored and integrated into centers of information, to be processed and distributed through web services.

At the best of our knowledge there are not many examples of the use of this approach and even fewer are published studies that describe operational SW-based approaches applied to a range of environmental domains (Sensing a Changing World, 2008; Paulsen H., 2008). One of the few works in this sense is (Kooistra *et al.*, 2009) that describes a SW based approach combining Earth observation and *in situ* sensor data offered by a dynamic Web Mapping Service (WMS) for evaluating the vegetation productivity.

The work we introduce here is a test bench for the integration of a SOS in a SDI, where discovery and access services are implemented, using the environmental monitoring of lakes, as an applicative test case and surface temperature as a parameter of study. Lake environments that are limited in space well suit this approach (Rigler and Peters, 1995). In particular, we have tested interoperability between services and examined some candidate client applications, to evaluate their suitability for supporting many services such as CSW (<http://csw.ise.cnr.it/> and <http://150.145.35.14/>), SOS (<http://thinclient.ise.cnr.it/>), WMS (<http://ows.ise.cnr.it/>), and WCS (<http://owsdemo.irea.cnr.it/>).

2. SERVICES ARCHITECTURE AND IMPLEMENTATION

2.1 Rationale

Lake monitoring is a complex task, with different target objectives being, by example, water quality, biodiversity, flood risk, availability of water resource, etc. All these activities include the collection of data (either *in situ* or remotely acquired), their storage, analysis, elaboration (sometimes by means of models), and the final delivery of monitoring results in different forms (reports, graphs, images, Web sites, cell phone messages, emergency sound signals, etc.) that are suitable to the end-users purposes and habits. When designing and implementing an overall Web system to the purpose of specific activities, such as those involved in operations of lake monitoring, a very important issue is to define the requirements of the application with respect to its users' needs as far as tasks to be performed, human-system interfaces and data/information to be managed from input to final results. In 'closed' application development environments, the requirements guide to customized implementations that should fit exactly the target users. The drawback of such a solution is the lack of interoperability (data formats, process modules, operating systems couldn't vary), scalability (any request for either new data sources or operation to be performed means the redesign and rebuilding of the whole application), and robustness (the lacking of any piece of information/operation means the failure of the whole system).

Above problems could be avoided by adopting a Service Oriented Architecture (SOA) that is interoperable, scalable and robust. From the user perspective, this approach has theoretically the same potential of an application built by a closed development environment; however it is relatively new and could still present technological gaps as regards the fulfilment of all the requirements for a specific application.

This section is devoted to briefly analyse the requirements of our application in terms of tasks and data, listing and briefly describing available services coping with them and the solutions we adopted to implement them in our experiment. The potential user is an operator involved in lake monitoring foreseeing some actions he/she could want to perform as regard water quality related assessment, which can be summarized as follows:

- A. Discover which measurements and geo-data are made available by the application and have knowledge about their characteristics according to the operator requirements, i.e. spatial extent covered, temporal coverage, frequency of sampling/mapping, data quality, related methodologies, accessibility, etc.
- B. Have access to geo-data from different sources in order to perform operations at different level of complexity, such as:
 - a. To perform a visual check of data locations, in order to evaluate their suitability by the geographical point of view. By example to verify if a set of point stations measuring dissolved organic matter is properly distributed as respect to the region of interest and to the knowledge of the phenomenon by the expert;
 - b. To get information about data values (and their spatial variability). By example to investigate if there are significant differences in the surface temperature as measured in different sub-basin of a lake;

- c. To download data to local facilities. By example to get a bathymetry layer to be integrated to river pollution data sets in a desktop GIS to model pollutants spread in a lake basin;
- d. To create graphs to represent the trends of data/measurements in time. By example to plot the temperature content as measured monthly at the same station within a lake in the last 5 years;
- e. To perform spatial analyses and geo-processing of data to improve knowledge and/or create new data sets (i.e. spatial interpolation, selection of interesting features or intervals, masking of raster data, intersection, etc.). By example by selecting regions with a temperature higher than the average, then selecting stations measuring high chlorophyll contents to recognize if there are correlation patterns.

The architecture of the experiment here described is aimed at coping with the above listed requirements. It is made up by two main components: SW and SDI services (Fig.1).

The SDI is designed and implemented according to the INSPIRE Directive (Infrastructure for Spatial Information in Europe) (INSPIRE, 2007) and OGC standards, while the OGC standards rule the SW services. The whole architecture is divided into three levels: data sources, service layer and presentation layer. The first level (Data sources) consists of the systems to store and manage the measurements collected from satellites and stations outside the architecture; the intermediate level (Service layer) hosts the web services for the experiment; the last level (Presentation layer) contains tools to let users' discover and access resources offered.

As regard SW framework, Sensor Model Language (SensorML) and SOS are implemented to provide discovery and access services to ground data; in the SDI framework, CSW and WCS are used to provide discovery and access services to satellite data. The services' implementation was aimed to offer the possibility to verify a true interoperability of services, the discovery of geo-data sources and the access to them.

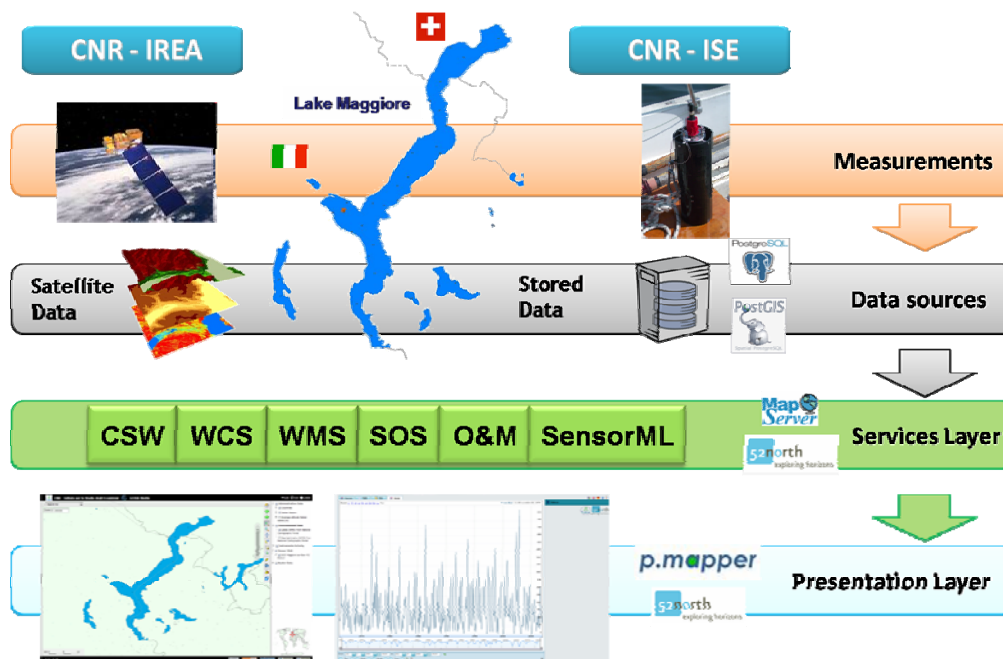


Figure 1. The architecture of the experiment.

2.2 Spatial data sources

The data used in this test are grouped into two categories: on one hand, temperature measurements of surface water collected *in situ* by a multiparametric probe at 27 stations located in different parts of a subalpine lake area; on the other one, temperature measurements sampled on the whole lake surface through ETM⁺ sensor (*Enhanced Thematic Mapper*) mounted on the satellite Landsat7, offering observations on the thermal band radiometric temperature and the kinetic temperature. By their nature and characteristics, each of these measurements can be offered by different services: in fact, ground data, that are extremely variable through time but referred to a well defined location, can be made discoverable and accessible by the suite of services of SW, while services of an SDI, in particular WMS and WCS, better suit the visualization and access to data acquired by satellites, which present less frequency through time but cover wider areas.

Surface water temperature of Lake Maggiore (Italy) was ground surveyed on 27 August 2008 in order to be synchronous to satellite data. The Landsat7-EMT⁺ image acquired on the same date was properly processed to obtain maps of exo-atmospheric radiometric (or blackbody) temperature (Fig. 2); the field observations, that are in the form of temperature values, did not undergo further processing and were stored as collected in a geodatabase (using PostgreSQL/PostGIS).

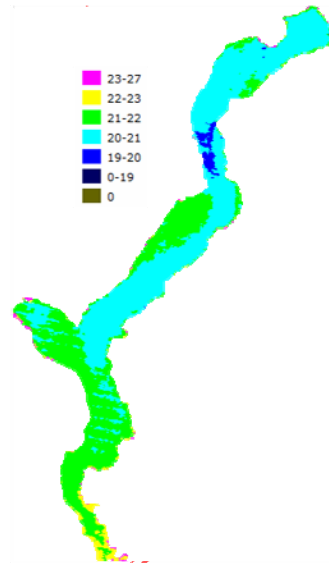


Figure 2. Map of surface water temperature, in Celsius degree, of Lake Maggiore (Italy) as surveyed on 27 August 2008.

2.3 Discovery services

Metadata of the temperature maps are edited according to ISO19115 standard and in compliance with the INSPIRE metadata profile; they are served in a CSW implemented using the GeoNetwork open source catalogue (<http://geonetwork-opensource.org>).

The metadata for discovering temperature field data were served using a standard SensorML statement that allows describing sensors and measurement processes. The functions supported by a service based on SensorML include: sensor discovery, sensor geolocation, processing of sensor observations, a sensor programming mechanism, subscription to sensor alerts (OGC, 2007a).

2.4 Access services

A WMS and a WCS have been implemented to provide access to the satellite temperature maps. The University of Minnesota MapServer open source solution (<http://mapserver.org/>) has been used. WMS “provides a simple HTTP (HyperText Transfer Protocol) interface for requesting geo-registered map images from one or more distributed geospatial databases. A WMS request defines the geographic layer(s) and area of interest to be processed. The response to the request is one or more geo-registered map images that can be displayed in a browser application” (see <http://www.opengeospatial.org/standards/wms>). WMS does not allow accessing the information content of gridded data. The choice of the WCS as an access service is strictly related to the characteristics of the satellite derived maps, in fact WCS is defined as a standard interface and operations that enables interoperable access to geospatial “coverages”. The term “grid coverages” typically refers to content such as satellite images, digital aerial photos, digital elevation data, and other phenomena represented by values at each measurement point (see <http://www.opengeospatial.org/standards/wcs>). Using these services, available data can be accessed, queried and downloaded by using the standard requests GetCapabilities (for requesting a self-description of the service), GetMap (that returns an image of a map according to the user’s needs), DescribeCoverage (for requesting the spatial extent, spatial resolution, grid size, data format, available coordinate reference systems, and expected pixel values of the map), and GetCoverage (that returns the actual raster data).

A different service, i.e. the SOS, lets access the temperature values collected in the field. The SOS was implemented using the facilities offered by the 52°North incubator to make sensors and sensor data archives accessible via an interoperable web based interface (<http://52north.org/>). Through this service data for ground temperature of the stations on Lake Maggiore were made available. SOS supports the mandatory operations on data as GetCapabilities (for requesting a self-description of the service), and GetObservation (for requesting the pure sensor data in time and space). Data, i.e. observations, are encoded by Observations & Measurements (O&M) language (OGC, 2007b).

2.5 Presentation layer: applications/geoportals

This layer of the web service architecture should contain tools to allow user interaction with the discovery and access services provided. In the experiment these tools are Web clients to the implemented services, i.e. CSW, SOS, WMS and WCS.

For testing access, we have tried geoportals built by p.mapper (<http://www.pmapper.net/>), as well as the SOS ThinClient implemented by 52°North.

For CSW, the client we used is included in the Geonetwork implementation of the discovery service and it lets users look for the services and data provided by the SDI, i.e. in our experiment WMS and WCS and related layers.

As far as discovery of SW services and their provided observations, at the best of our knowledge there is not an available client: one has to know the existence of a service (by example an SOS) and its Web address to access it. That knowledge can be acquired by accessing to a registry, as the GEOSS one.

3. DISCUSSION

In general, our experiment proved a full interoperability of data coming from the heterogeneous sources we used, i.e. both temperatures collected *in situ* and derived from satellite imagery.

In particular, this section discusses the experiment with respect to the use cases proposed in the above section 2.1, trying to assess if the experiment satisfies the listed requirements. We'll try to answer the queries, by evaluating if the services implemented and the available clients are adequate to the candidate user's purposes.

To cope with the first requirement, i.e.:

- A. *Discover which measurements and geo-data are made available by the application and have knowledge about their characteristics according to the operator requirements, i.e. spatial extent covered, temporal coverage, frequency of sampling/mapping, data quality, related methodologies, accessibility, etc.*

we need discovery services that proved to be adequate and technologically mature only in the case of CSW (to discover services and data provided by SDI). On the contrary, in the case of services of SW, a possibility to search for SOS is offered by the GEOSS Registry (<http://geossregistries.info/>), but it is a general purpose search engine for services, not dedicated to the services of SW only. Moreover it prevents searching for provided observations.

In summary, our user has not a mean to perform contemporary searches in the two temperature datasets offered by our architecture. In perspective a broker system such as GI-Cat (<http://zeus.pin.unifi.it/cgi-bin/twiki/view/GIcat>) could serve the purpose.

- B.a *To perform a visual check of data locations, in order to evaluate their suitability by the geographical point of view.*

The above requirement is fully satisfied by WMS and SOS requests. As far as presentation, many clients for both services are available and we verified with the client tools we tested that the user can visually check the locations of available data. By example the user can verify if the temperature map from satellite covers the same area where stations are located.

- B.b *To get information about data values (and their spatial variability).*

The above requirement is fully satisfied by WCS and SOS requests as far as getting the needed values. With reference to presentation, the tool we built by p.mapper serves both SOS observations and WCS maps, but the last ones are served as pure images, without letting access to the pixel information content. It is possible that other clients for accessing WCS and SOS, such those build by OpenLayer, could fit the purpose. The 52°North ThinClient has been conceived for SOS only and could not access WCS maps.

- B.c *To download data to local facilities.*

The above requirement is fully satisfied by WMS, WCS and SOS requests. With reference to presentation, our p.mapper tool lets download SOS observations, and WMS maps, but doesn't allow downloading information content from the maps served by WCS. The 52°North ThinClient can download SOS observations only. It is possible that other clients could download values from both SOS and WCS.

- B.d *To create graphs to represent the trends of data/measurements in time.*

The above requirement is fully satisfied by WCS and SOS requests as far as providing the values needed for plotting the graphs. The 52°North ThinClient is able to plot line and scatterplot charts of *in situ* observations trends through time of different styles and sampling units. Charts are interactive: the user can zoom on the time range provided; can pan the visualization window; can explore value detail by moving the mouse over the chart.

Also p.mapper includes a tool to create chart layers (maps with charts related to mapped entities), but they are neither interactive nor time-dependent.

At our knowledge there is not yet a client able to perform this operation on both WCS and SOS.

B.e To perform spatial analyses and geo-processing of data to improve knowledge and/or create new data sets (i.e. spatial interpolation, selection of interesting features or intervals, masking of raster data, intersection, etc.).

WCS and SOS requests allow performing value filtering. All other listed geoprocessing operations are prevented by the services we implemented, and require Web Processing Services (WPS) for each purpose. Neither our p.mapper tool nor 52°North ThinClient are able to perform advanced geo-processing out of filtering observations from a SOS, and anyway neither of the clients can perform this operation on both WCS and SOS.

4. CONCLUSION AND PERSPECTIVES

In this contribution we propose an experimental implementation of some standard SDI and SW services to verify their interoperability capacities in lake monitoring environmental domain in order to couple *in situ* data with satellite derived data, in particular water surface temperatures. The experiment took into account both discovery, visualization and access services, as ruled by a test case regarding the user requirements for assessing lake water quality.

Open source technologies (GeoNetwork, UNM MapServer, p.mapper, 52°North incubator and Thin Client for SOS) were used to implement the architecture components according to OGC and - where applicable - INSPIRE standards.

All services implemented are able to offer the required level of operability and interoperability required for the application case as regards the different kinds of data.


The main bottleneck at the moment seems to be related to the “presentation layer” part of the architecture, which lacks of tools able to completely cope with SDI and SW at the same time, especially regarding discovery and data access, while visualization is well addressed.


5. ACKNOWLEDGEMENTS


The authors wish to thank the staff of 52°North incubator for the given support and prompt assistance as related to technological issues encountered during the SW implementation.


6. REFERENCES

- Delin K.A., and Jackson S.P. 2001. The Sensor Web: a new instrument concept. In: *Proceedings of the SPIE International of Optical Engineering*, vol. 4284, pp. 1-9.
- Kooistra A., Bergsma A., Chuma B., and de Bruin S. 2009. Development of a Dynamic Web Mapping Service for Vegetation Productivity Using Earth Observation and in situ Sensors in a Sensor Web Based Approach. *Sensors*, 9: 2371-2388; doi:10.3390/s90402371
- Paulsen H. 2008. PermasensorGIS - real time permafrost data. *GEOconnection International Magazine*, 2: 36-38.
- Sensing a changing world 2008. *Proceedings of International Workshop “Sensing a Changing World 2008”* CGI report CGI-08-005, Wageningen, the Netherlands, 19 - 21 November, 2008. - Wageningen : Wageningen University and Research Centre, (Kooistra L., Ligtenberg A., eds.), 120 pp.
- Liang S.H.L., Croitoru A., and Tao V. 2005. A distributed geo-spatial infrastructure for sensor web. *Computers and Geosciences*, 31: 221-231.
- Murray, C. 1999. The Earth will don an electronic skin, interview di N. Gross for “21 ideas for the 21st Century Internet”. http://www.businessweek.com/1999/99_35/b3644024.htm.
- Open Geospatial Consortium. 2007a. OpenGIS Sensor Model Language (SensorML) Implementation Specification, OGC 07-000, ver. 1.0, 2007-07-17. Ed. M. Botts, online http://portal.opengeospatial.org/files/?artifact_id=21273.
- Open Geospatial Consortium. 2007b. Observations and Measurements - Part 1 - Observation schema, OGC 07-022r1, ver. 1.0, 2007-12-08. Ed. S. Cox, online http://portal.opengeospatial.org/files/?artifact_id=22466.
- Rigler F.H., and Peters R.H. 1995. Science and limnology. Excellence in Ecology. V. 6. Ecol. Inst., Oldendorf/Luhe. 239 p.
- Teillet P.M., Gauthier R.P., Chichagov A., and Fedosejevs G. 2002. Towards integrated earth sensing: advanced technologies for in situ sensing in the context of earth observation. *Canadian Journal of Remote Sensing*, 28-6, 713-718 p.
- Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 (INSPIRE), online: http://www.ec-gis.org/inspire/directive/1_10820070425en00010014.pdf, 2007

	<p>Alessandro Oggioni, Researcher CNR - Institute of Ecosystem Study L.go Tonolli 50-52 28922 Verbania-Pallanza ITALY Phone: +39 0323 518300 Fax: +39 0323 556513 e-mail: a.oggoni@ise.cnr.it</p>
<p>Graduated in Natural Sciences in 2000 and gained a PhD in Ecology of Phytoplankton at Parma University in 2005, I have always worked in lake ecology with particular reference to morpho-functional aspects of the algal stands and their temporal and spatial distribution. Since 2006, I also dealt with ecology of macrophytes as regards the management in lake environment, mapping through GIS systems, but also and especially their use as indicators of lake water quality in response to the needs of WFD (2000/60/EC). In last years I am also interested in the management of issues of environmental data, in particular data relating to biological diversity, and for this aspect I'm responsible GIIDA project (Integrated and Interoperable Invironmental Management of Data) for the implementation Biodiversity in INSPIRE Directive.</p>	

	<p>Paola Carrara, Senior Researcher CNR – Institute for Electromagnetic Sensing of the Environment, Milan chapter Via Bassini 15 20133 Milano ITALY Phone: +39 02 23699295 Fax: +39 02 23699300 e-mail: carrara.p@irea.cnr.it</p>
<p>Paola Carrara is graduated in Phisycs at the University of Milan, Italy. She has been a researcher of the National Research Council (CNR) of Italy since 1986. Her scientific activity regards designing and managing information systems. Her main interests are in (Fuzzy) Information Retrieval, spatio-temporal archives of images, architectures, technologies and standards for geographic information on the Internet, in particular Spatial Data Infrastructures and the INSPIRE Initiative. She was responsible of the Italian branch of the project IDE-Univers which created the first European Spatial Data Infrastructure in the research field.</p>	

	<p>Monica Pepe, Researcher CNR – Institute for Electromagnetic Sensing of the Environment, Milan chapter Via Bassini 15 20133 Milano ITALY Phone: +39 02 23699550 Fax: +39 02 23699300 e-mail: pepe.m@irea.cnr.it</p>
<p>Monica Pepe received the master degree in Geology in 1993 and the PhD in Physical Geography from the University of Pavia, Italy. She has been with the National Research Council (CNR) of Italy since 1994. Her research activity regards the use of remote sensing for environmental studies and for pattern recognition tasks. She has worked on automatic interpretation methods of multisource data for thematic and environmental mapping, on the basis of the combined use of remote sensing image analysis and domain knowledge representation. In the last few years she has been interested in Spatial Data Infrastructures (SDI) and OpenGIS Web Services (OWS) issues in order to make geographic information derived from her research activity retrievable, accessible and exploitable in an interoperable framework, with particular focus on the INSPIRE directive.</p>	

	<p>Dario Manca, Technician CNR - Institute of Ecosystem Study L.go Tonolli 50-52 28922 Verbania-Pallanza ITALY Phone: +39 0323 518300 Fax: +39 0323 556513 e-mail: d.manca@ise.cnr.it</p>
<p>Graduated in Electronic and specializing in "Designers of Microprocessor Systems and Telecommunication Network" beginning in 1993 to develop for a small Farm an intelligent Electronic equipment based on Motorola Cisc Processors</p>	

series 68000 and PowerPC, used for industrial automation processes , typically for plastic [bag] and marble/granite sector. Development is complete with planning of firmware for the electronic equipment and software engineering for end-user application. Since 2002 I work on ICT services at the Institute of Ecosystems Study, where I'm involved in several projects relating GIS Web Technologies, Sensor Development, DataBase Designer, and Web protocols.



Claudia Giardino, Researcher
CNR – Institute for Electromagnetic Sensing of the Environment, Milan chapter
Via Bassini 15
20133 Milano
ITALY
Phone: +39 02 23699298
Fax: +39 02 23699300
e-mail: giardino.c@irea.cnr.it

Claudia Giardino graduated in Environmental Engineering, in 1995 and received the PhD in Geodetic and Topographic Science in 2001 from the Polytechnic of Milan, Italy. She has been with the National Research Council (CNR) of Italy since 1996. She is specialised on quantitative aspects of remote sensing, including atmospheric corrections and retrieval of biophysical parameters from Earth Observation data, particularly focused on applications related to aquatic ecosystems. Her main interests include: retrieval of water quality parameters from remote sensing, Case-2 water systems, harmful algal blooms, submerged vegetation recognition, medium/low resolution satellite data and hyperspectral signal. She is responsible for the experimental station "Eugenio Zilioli" of CNR-IREA at Sirmione del Garda, Italy.



Laura Criscuolo, Research Fellow
CNR - Institute for Electromagnetic Sensing of the Environmental, Milan chapter
Via Bassini 15
20133 Milano
ITALY
Phone: +39 02 23699550
Fax: +39 02 23699300
e-mail: criscuolo.l@irea.cnr.it

Laura Criscuolo graduated in 2009 in Environmental Engineering at Politecnico di Torino, with a course of study focussed on territorial management, especially under its geotechnical, hydrological and infrastructural aspects. She gaining experiences in GIS utilities for environmental analysis. She has worked for the Joint Research Centre, Institute for the Protection and Security of the Citizens in developing and testing dynamic GIS instruments, aimed to perform routing analysis for international disaster response. At present she is involved, at National Research Council, Institute for Electromagnetic Sensing of the Environmental, Milan chapter, in the research projects related to a Spatial Data Infrastructure implementation and in the setting up of OpenGIS Web Services, aimed at spatial information management and sharing.