Editorial

EnviroGRIDS Special Issue on "Building a Regional Observation System in the Black Sea Catchment"

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***Abstract*—The Black Sea Catchment Observation System has been developed in the frame of the EU/FP7 enviroGRIDS project to inform about crucial regional environmental issues. This system is now making resources accessible to a large community of users for data management and publishing, for hydrological models calibration and execution, for satellite image processing, for report generation and visualization, and for decision support. In this special issue, we present the different components that were developed as well as the encountered challenges in order to bring innovative contributions into the Global Earth Observation System of Systems. One of the major issues was to enable data exchange across different heterogeneous components and infrastructures, more specifically Spatial Data and Grid infrastructures. The interoperability standards proposed by the Open Geospatial Consortium (OGC) support the scalability and the efficient combination of the complex specialized functionalities and the computation potential of these platforms. Another important issue was to build the human, institutional and infrastructure capacities to contribute and use this new observation system.**

Keywords—enviroGRIDS; Observation System; Spatial Data Infrastructure; Grid computing; Black Sea; Remote sensing; Hydrological modeling; GEOSS

I. INTRODUCTION

Earth Observation specialists recognize that the lack of systematic monitoring and access to reliable time-series on environmental, statistical, and socio-economical data are a major barrier to effective and efficient informed policy- and decision-making [1]. This problem has been recently reinforced by several EU funded projects related to water. They are all highlighting discrepancies between the objectives of guiding policy, and limited access and availability of data [2]. Policy-relevant researchers and end users are still facing the problem of timely access and exchange of needed data.

Supported by the latest technological advances in Earth Observation and Web technologies, Spatial Data Infrastructures (SDIs) have been developed and implemented at accelerated pace at regional and national levels, with the long-term vision of creating global and regional SDIs. The benefits of SDI have been analyzed and reported extensively, as they allow for trans-sectorial and trans-national sharing of- and access to geospatial data, and their assimilation (consumption) in novel and inventive software applications that can provide wide range of social, economic and environmental benefits.

For achieving these purposes, SDIs provide a suite of services for data publishing, discovery, gathering and integration, which enable interoperability of the different components involved [3]. Therefore, the concept of SDI was developed to facilitate and coordinate the exchange and sharing of geospatial data, encompassing data sources, systems, network linkages, standards and institutional issues involved in delivering geospatial and information from many different sources to the widest possible group of potential users. The vision of an SDI incorporates different databases, ranging from the local to the national, into an integrated information highway and constitutes a framework, needed by a community, in order to make effective use of geospatial data.

Climate change is a worldwide concern that is affecting many areas of human activities. The last report of the Intergovernmental Panel on Climate Change [4-6] predicts important changes in the coming decades that will not only modify climate patterns in terms of temperature and rainfall, but will also drastically change freshwater resources qualitatively and quantitatively, leading to more floods or droughts in different regions, lower drinking water quality, increased risk of water-borne diseases, or irrigation problems. These changes may trigger socio-economic crises across the globe that need to be addressed well in advance of the events in order to reduce the associated risks. Consequently water resources are particularly sensitive to climate change and human activities.

Water is a fundamental natural resource and critical for the well being of individuals in terms of health, agriculture, energy production, ecosystem services and economic development. However, water resources are increasingly under pressure causing a shift in balance between demand and supply, and having a negative influence on its quality [7]. Effective and efficient water management requires coordination of actions, one of them being access and provision of reliable data and information (e.g., state of the resources, changes, pressures) and the capacities to interpret correctly and meaningfully these information [8, 9].

Water management and hydrological modeling, due to their interdisciplinary nature and being complex and dynamic systems, intrinsically ask for better integration of data, information and models [10-12]. The aim is to bring to policy/decision-makers suitable and reliable information through efficient scientific tools and models. .

Beniston et al. [2] have reported that researchers in climate and water sciences are regularly facing the problem of searching, finding, and accessing data. These authors have highlighted several barriers that are impending a timely and efficient usage of water-related data. In particular, incomplete and non-standardized time series data are an important issue obliging scientists to spend a lot of their time in data gathering and harmonization [13]. Moreover, these data are often redundant because of the lack of coordination between providers. This situation leads to the fragmentation of repositories [14], making them difficult to find even if they are available. Furthermore, data are not or only poorly documented by their metadata and users cannot evaluate if they fit their purposes. Searching and downloading interfaces are often complex and difficult to understand for non-experts. Therefore, facilitating the exchange and access to water-related data is essential to easily integrate them with other distributed data sources [2]. This requires implementing commonly agreed standards, in particular, documenting data with standardized metadata, and making them searchable through catalogs.

Interoperability is needed to develop an open science framework allowing scientists and researchers to publish, discover, evaluate and access data. Current technologies are suitable to match these requirements only if open software interfaces and standards are developed allowing these technologies to interoperate on a global scale [15]. The Open Geospatial Consortium (OGC) aims at providing such standards enabling communication and exchange of information between systems operated with different software. Indeed, a non-interoperable system cannot share data and computing resources, inducing scientists to spend much more time than necessary on data discovery and transformations. One of the major benefits of interoperability is to enable locally managed and distributed heterogeneous systems (e.g., different operating systems, databases, data formats) to exchange data and provide services [16].

Moreover, with the emergence of technologies (e.g., Web Services, Web 2.0) and the greater affordability of digital devices, we are currently seeing a deluge of data in quantity and diversity (e.g., real-time data, archived data, crowd-sourced data, high-resolution data) [17]. This poses new challenges and offers new opportunities to turn this huge amount of data into understandable information. Consequently, efficient processing solutions are required, and distributed high performance computing infrastructures appear as promising solutions [18-20]. Indeed, there is an increasing need for large computational power to answer the demand for high-resolution modeling. The associated activities of uncertainty and sensitivity analyses bring forward the integration requirements of different sources of geospatial data, which are provided by SDIs via diverse web services, together with other data within Grid or Cloud computing environments. Consequently, an important effort is currently made to improve hydrological modeling [21] on a shared SDI and Distributed Computing platform [7, 22-25].

To tackle all the previously mentioned issues, the intergovernmental Group on Earth Observations (GEO) is coordinating a worldwide effort the development of the Global Earth Observation System of Systems (GEOSS) on the basis of a 10-Year Implementation Plan until 2015 [26]. GEOSS is aiming at connecting already existing SDIs and Earth Observations infrastructures and thus will not create and/or store its own data. The GEOSS portal is foreseen to act as a gateway between producers of environmental data and end-users. The aim is to enhance the relevance of Earth observations for global issues, and to offer a public access to comprehensive, near-real time data, information and analyses on the environment on following nine Societal Benefits Areas: Disasters, Health, Energy, Climate, Water, Weather, Ecosystems, Agriculture, Biodiversity. The mechanisms for data and information sharing and dissemination are described in the 10-Year Implementation Plan Reference Document [26]. Participating members must endorse data sharing principles [27]: (1) There will be full and open exchange of data, metadata, and products shared within GEOSS, recognizing relevant international instruments and national policies and legislation. (2) All shared data, metadata, and products will be made available with minimum time delay and at minimum cost. (3) All shared data, metadata, and products being free of charge or no more than cost of reproduction will be encouraged for research and education. GEOSS is also advocating for an increased sharing of methods for modeling to transform data into useful information.

The Black Sea Catchment (2.2 mio. km^2, 24 countries, 160 million inhabitants) is affected by severe environmental degradations. In 1995, the sea itself was rated with the highest concerns in five out of seven environmental categories, making it the worst of any of the European seas [28]. The Danube River, the major Black Sea tributary, was described as following an *"ecologically unsustainable development and inadequate water resources management"* [29]. The problems are caused by different factors, such as: inadequate management of wastewater/solid waste, ecological unsustainable industrial activities, inadequate land management and improper agricultural practices. These are generating several direct consequences: pollution of surface/groundwater, eutrophication, and accelerated runoff /erosion. These consequences have, on the other hand, the following main effects: decline in quality of life, human health risks, degradation of biodiversity, economic decline, and reduced availability of water. Therefore, the Black Sea hydrological catchment represents a very interesting case study to test the capacity of integrating large data sets to assess vulnerability and sustainability issues related to freshwater resources as various scales.

The EU FP7 enviroGRIDS research project [1] aims at providing approaches for achieving data integration by developing a SDI for the whole Black Sea catchment that can

1 http://indico.cern.ch/getFile.py/access?resId=0&materialId=0&confId=45555

be utilized by a SWAT (Soil Moisture Assessment Tool) hydrological model [30]. The goal of the integration is to enable the analysis of the impacts of future climate, development-induced land use and demographic changes on selected social benefit areas, such as water, agriculture, energy, health, disasters, ecosystems and biodiversity. The results are made available though the Black Sea Catchment Observation System[2] (BSCOS, fig.1). This system is a shared information system that operates on the boundary of scientific/technical partners, stakeholders and the public. It allows to discover, gather, store, distribute analyze, visualize and disseminate data on the environment with the aim of increasing the capacity of decision-makers and other interested stakeholders to use it for selecting the most relevant management options on a 50-year time horizon. In summary, enviroGRIDS aims[3] at building the capacity of scientist to assemble such a system in the Black Sea catchment, the capacity of decision-makers to use it, and the capacity of the general public to understand the important environmental, social and economic issues at stake.

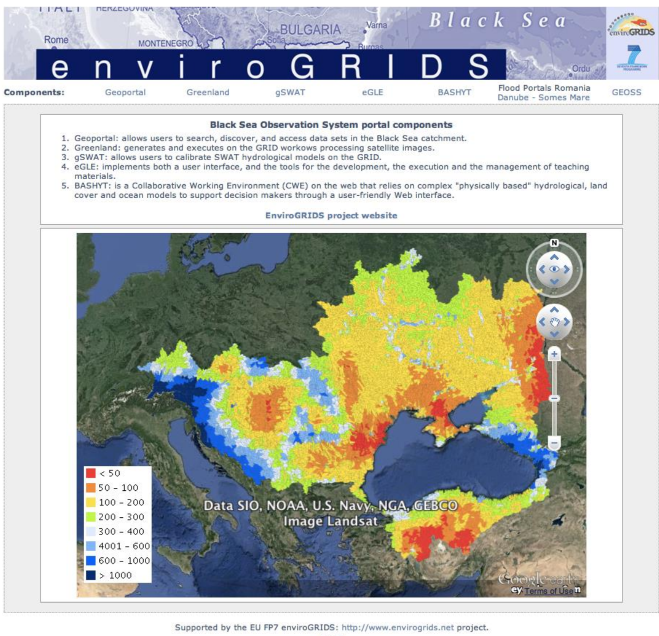

Fig. 1. The Black Sea Catchment Observation System

The objective of this Special Issue is to highlight the main contributions and to present the technical progresses made in building the Black Sea catchment regional observation system. The focus is on putting SDI into practice by improving data and metadata interoperability, by using new geoprocessing tools, by developing innovative geoportal solutions and by building capacity.

The first contribution [31] highlights issues and solutions used for the implementation of the BSCOS portal through heterogeneous technologies, typically SDI and distributed computing, the aim is to create and control the flow, processing, and visualization of spatial data for both the community of Earth Science specialists and Web users. The OGC standards support the scalability and the efficient combination of the complex specialized functionalities, as well as the computation potential of these platforms. These standards act as glue between the different components of the BSCOS portal that are presented in the different papers.

One of the main challenges currently faced is to convince and help regional data holders (like the World Data Center[4]) to make available their data and metadata in order to improve our capacity to assess the sustainability and vulnerability of the environment.. Giuliani et al. [32] present experiences and lessons learnt in the enviroGRIDS project for raising awareness and creating commitments on the benefits of data sharing using interoperable services.

The first component of the BSCOS, the Geoportal, allows to search, discover, view, and access data in the Black Sea catchment. However, setting up services is not sufficent, maintaining them, ensuring they are working correctly and they are offering good and reliable performances are also important. Charvat et al. [33] introduce an innovative approach through a quality check to ensure efficient discovery and access to data services based on OGC standards.

Remote sensing is an important source of Earth Observations data for understanding environmental issues. In a large area such as the Black Sea catchment, it is almost impossible to analyze high to medium resolution remotely sensed data on a single computer. Consequently, distributed computing appears as a promising solution to efficiently process an increasing volume of data. Moreover, a standardized access to these data is required in order to integrate raw and already-processed data in complex models and workflows. Three papers [34,35,36] are discussing these different issues by presenting solutions developed with the Greenland application. This web-based component allows to process large amount of remote sensing images over a Grid infrastructure and implementing OGC standards to access, process, and publish data. Additionally, a contributing paper from Balcik et al. [37] demonstrates the applicability and usefulness of the Greenland component in different case studies. In complement, an e-learning platform was developed to allow non-specialists to easily use computing resources, remote-sensing data in order to develop teaching and learning materials.

Assessing water sustainability and vulnerability of the Black Sea catchment in a global change framework requires to first develop spatially explicit scenarios of climatic, demographic and land cover changes that can serve as inputs for hydrological modeling. One of the software developed in enviroGRIDS is gSWAT for the calibration of SWAT hydrological models in a flexible environment that uses distributed computational infrastructures to speed-up the simulations [38]. SWAT models produce several useful outputs (e.g., evapotranspiration, soil moisture, aquifer recharge, river discharge) as text files. However, visualizing and publishing SWAT outputs as geospatial data is time consuming and repetitive. Moreover, data used and produced are often not interoperable and restricted to dedicated software impending an

[2] http://portal.envirogrids.net

[3] http://indico.cern.ch/getFile.py/access?resId=0&materialId=0&confId=45555

[4] http://wdc.org.ua

efficient use and integration of SWAT outputs with other sources and/or models. To tackle this issue, Giuliani et al. [39] are proposing the OSW4SWAT framework to facilitate SWAT outputs publishing and exchanging with other sources using OGC standards. In addition, Almoradie and Jonoski [40] present a first use-case in Romania using the recently adopted OGC standard WaterML2.0 to publish hydro-metrological time series to monitor and forecast floods.

Finally, to help decision-makers to take sound and informed decisions, the BASHYT component offers a set of web-based components to predict the effect of management decisions on water, sediment, nutrient and pesticide yields on large river basins. This allows users to quantify at different scales (e.g., time, space) the independencies between natural and anthropogenic pressures and states of water bodies [41].

We hope that the readers of this special issue will share the enthusiasm and interest that the enviroGRIDS consortium put into the development of this innovative regional Earth Observation system, on the border between spatial data and Grid infrastructure, and on the edge between computing and environmental sciences. While serving the needs of the Black Sea region, it is clear that all the developed piece of software and solutions can be implemented elsewhere in the World.

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