AQUAGRID: A Problem Solving Platform for Contaminated Groundwater (A case Study in a Mining Area in Sardinia)

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Abstract
The paper describes the benefits of Grid technology to facilitate the access to distributed data, their processing and visualization in geosciences, by means of the AQUAGRID application. AQUAGRID is the subsurface hydrology service of the Sardinian GRIDA3 infrastructure, designed to deploy complex environmental applications via a user-friendly Web portal. The chief objective of the GRIDA3 project in the fields of spatial planning and environmental protection is to develop a distributed data infrastructure along with a Grid based decision support system, integrating GIS technologies, monitoring services and mathematical models for environmental simulation, optimization, analysis, and risk evaluation. The AQUAGRID service is oriented towards the needs of water professionals providing them a flexible and powerful tool to solve water resources management problems and aid decision between different remediation options for contaminated soil and groundwater. The problem solving capability of the platform is demonstrated with application to the pilot site of the Fluminese-Iglesiente mining district (South-Western Sardinia, Italy).

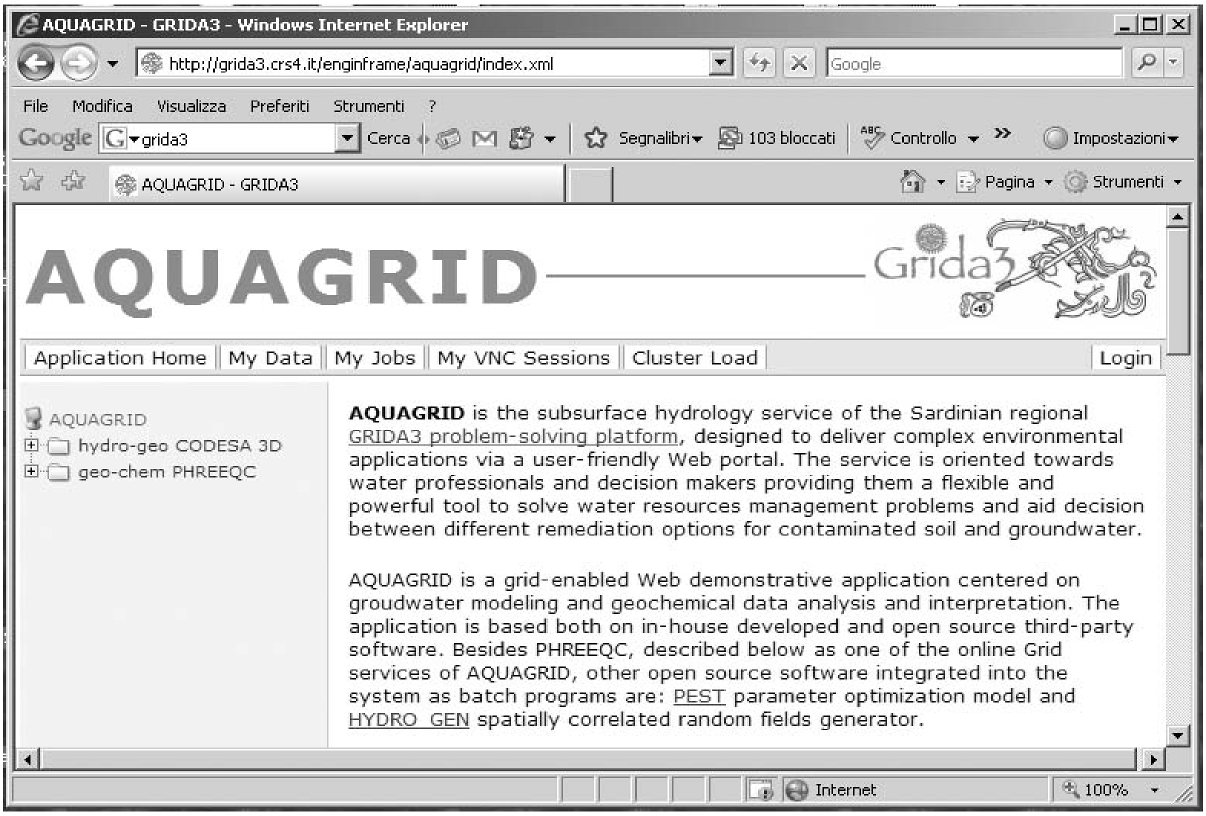
Key words: Grid infrastructure, mine contamination, geochemical modeling services, Web applications.

Introduction
The extent and the complexity of environmental problems and their consequences on the ecosystem, human health and economic development make necessary an integrated, multi-disciplinary approach to support the management of natural resources, and increase the technical knowledge and public awareness. For these reasons, earth and environmental sciences are uniquely positioned today to uptake advanced technological platforms, based on the collaborative potential of the Web and Grid paradigms. The Grid is a form of distributed computing developed by scientific communities since the early nineties, to solve very large problems requiring huge computation and storage resources. It is based on the dynamic sharing of existing resources to create a virtual system, which can be accessed by anybody from anywhere. Middleware tools provide secure and seamless access to distributed computational resources, data catalogues, archives, software libraries and scientific instruments. A number of Grids exist in the world today and the number is growing steadily (DEGREE consortium 2007). The GRIDA3 portal (http://grida3.crs4.it), funded by a three-year project of the Italian Research Ministry, is designed to provide an advanced problem-solving platform for the integration of human know-how, simulation software, instrumentation and resources for data communication, storage, visualization, and computation. To cite only a few of the environmental challenges addressed by the project, consider the remediation of industrial polluted sites, the non-rational use of water resources, and the hydrogeological risk related to meteorological extreme events and climate variability.

The AQUAGRID application
AQUAGRID is the subsurface hydrology service of the GRIDA3 problem solving platform, centered on groudwater modeling and geochemical data analysis and interpretation (Figure 1). AQUAGRID is oriented towards water professionals and decision makers providing them a flexible and powerful tool to solve water resources management problems and aid decision between different remediation options for contaminated groundwater. To accomplish this goal, AQUAGRID is an open system based both on in-house developed (CODESA-3D, Lecca et al 2007) and open source (PEST http://www.sspa.com/pest/, HYDRO-GEN http://www.ing.unitn.it/~bellin/frames/hydrogen.php, PHREEQC http://wwwbrr.cr.usgs.gov/projects/GWC_coupled/phreeqc/) software already in place. Other open source modules (e.g.: PostgreSQL database, Web-GIS mapping and statistical analysis

tools) are being progressively implemented into the system as the applications require them. The AQUAGRID portal is designed mainly as a front-end user interface for large scale dynamic processing using hydrogeochemical datasets. The application Web interface (Figure 2) is tailored to end-users without any specific expertise of the underlying physical models and technological background. Users access and control their computing and engineering resources via an intuitive Web interface, as close as possible to a typical desktop application, virtually from any device (e.g. Personal Digital Assistant, mobile phone, etc.) using a standard Web browser. The interface currently provides authorized users with two different Web applications: coupled groundwater flow and solute transport simulation (CODESA3D) and geochemical data analysis and interpretation (PHREEQC).
The PHREEQC application (Figure 2, service *Application Management*) allows to run, on a high performance cluster of PCs, a number of geochemical simulations based on field campaigns conducted by the Department of Earth Science of Cagliari University. The user performs the selection, using a Web menu, of the case study to be analysed. The selection dynamically loads on a Google map's mashup (Figure 2) the georeferenced locations of the corresponding groundwater samples. Each sample, when highlighted by a mouse click, allows inspection of its basic sample metadata (name, date, etc) in the framed box located below the map. Finally, the submit button launches the simulation of speciation for the whole set of samples, with the selected output option allowing to collect in a single file the synthetic results relevant to the analysis. After the job is completed, the user retrieves and downloads input and output results as text files and graphs. Further development will also allow results to appear as Web GIS thematic maps overlaying general geographic layers. The same application (Figure 3, service *New Location*) allows assembly of an *ex-novo* simulation in a dedicated end-user space, supplying via a user-friendly Web form a given aqueous solution sample.

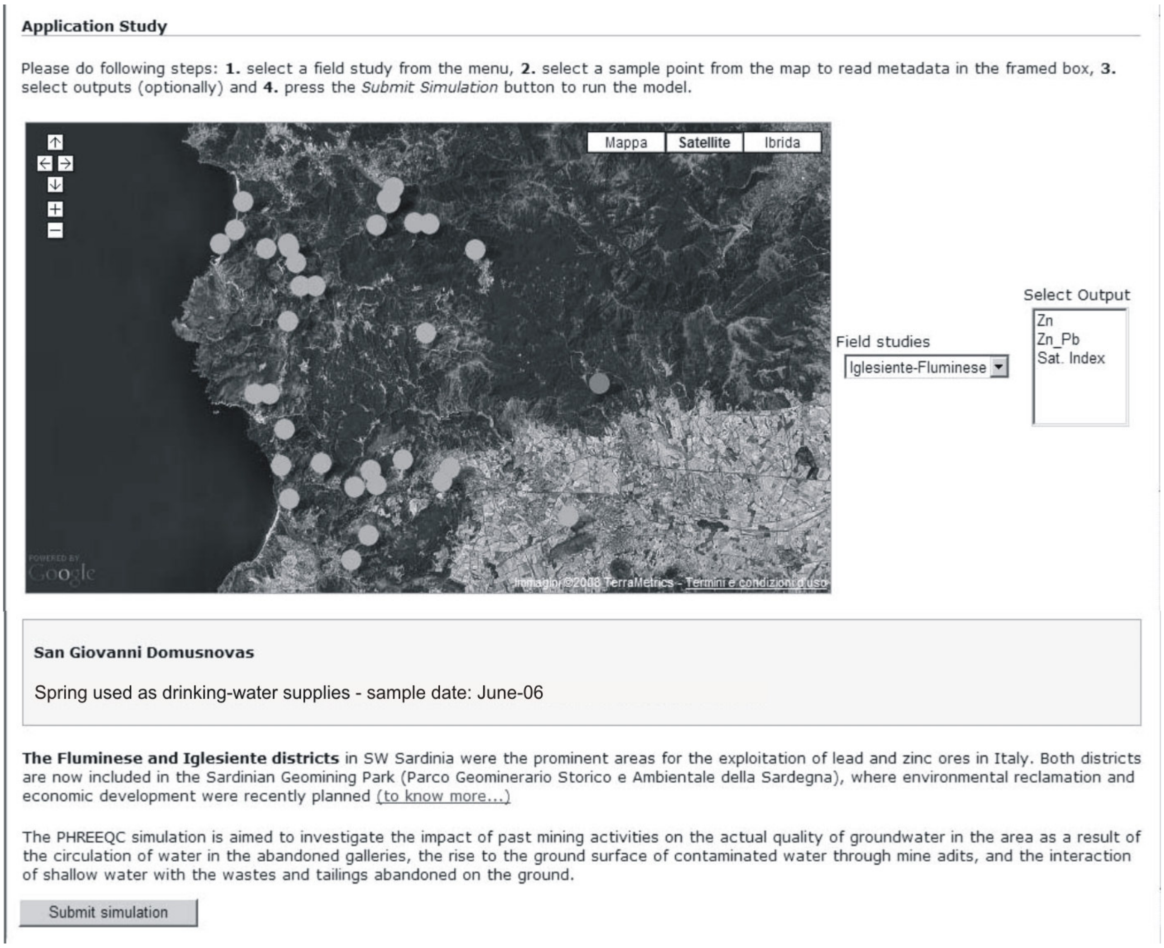
Figure 1 *Home page of the AQUAGRID service. Left bar shows the Web applications already deployed.*



First case study: Iglesiente-Fluminese mining district
The Iglesiente-Fluminese mining district, in SW Sardinia (Italy), was the prominent area for the exploitation of lead and zinc in Italy. The Pb-Zn deposits, located in the lower part of the Cambrian sequences, were intensely mined in the nineteenth century with a peak (more than 40 mines in

operation) in the 1950-decade (Boni 1994). The cessation of mining activity (1995) left large quantities of wastes from dumps and flotation tailings abandoned on the ground, estimated at about 48 million m^3 in the whole area. Based on the data reported in an extended paper that investigated the impact of past mining on the actual quality of groundwater (Cidu et al 2008), the district was chosen as a case study in GRIDA3. The impact of past mining activity on the quality of groundwater is described through a comparison of the chemistry of mine-influenced waters (adits and mine shafts, drainages from rock-wastes and tailings) with springs and wells in the same area at sites relatively far from any mine legacy. A feature, common to all waters, is the circumneutral pH, since the carbonate formations in the area are able to neutralise the acidity produced by the oxidation of Fe-bearing sulphide minerals in the mine impacted water. However, groundwater interacting with mine works is degraded in quality and shows high dissolved SO4, Zn, Cd and Pb contents. At the moment, the major risks derive from the flow of contaminated water from mine adits, tailings and waste dumps. In this respect treatment at the source is recommended to reduce the impact on the streams, especially in the dry season when they are fed by mine groundwater only. In the web page users find a file for each groundwater sample and a description of the geology and mineralogy of the area. As previously described, it is also possible to extract the simulated speciation for the whole existing dataset and any new sample previously inserted.

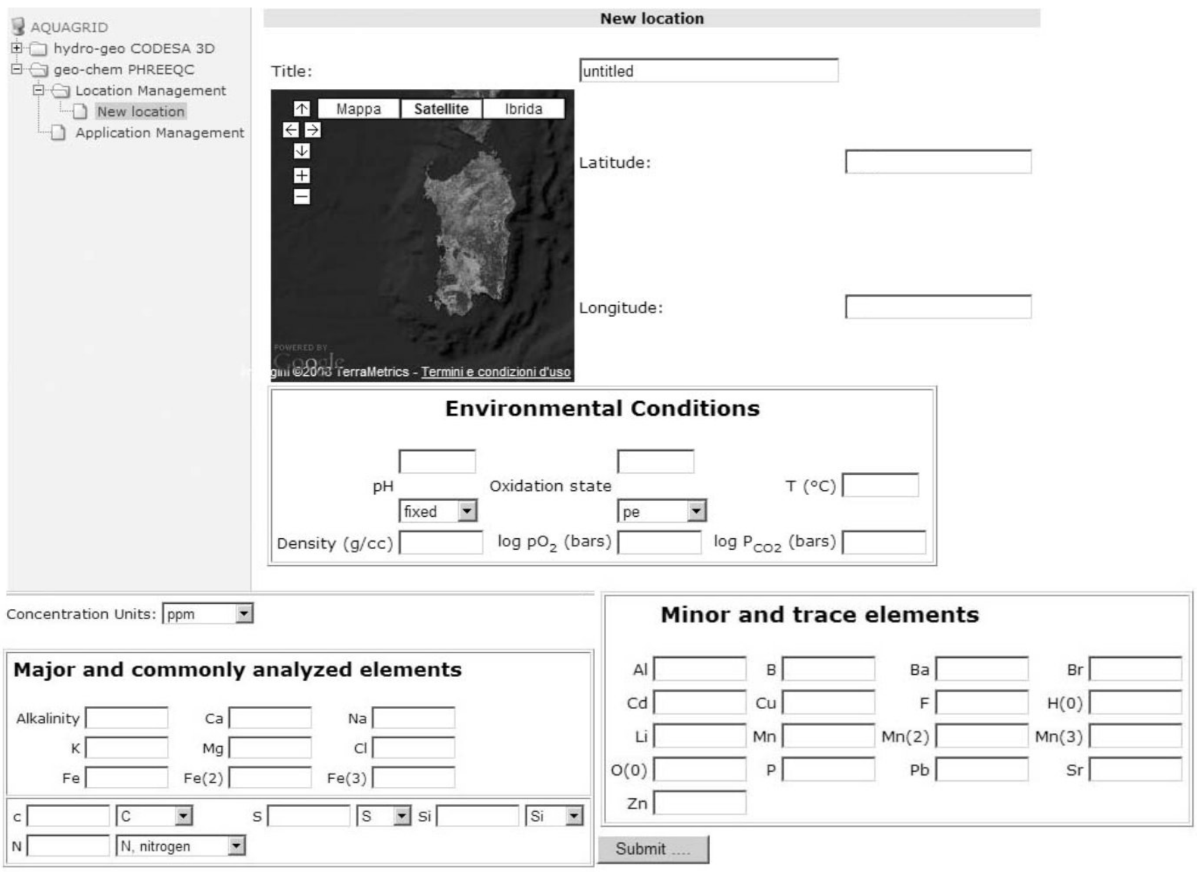
Figure 2 *Web user interface to the PHREEQC geochemical modelling service. Users select the field campaign (Iglesiente-Fluminese choice is displayed) among the available ones via the "Field Studies" menu.*



Challenges and final remarks

The most convincing argument for building a Grid problem solving platform for mine water, and generally for groundwater resources management, is the need for a dedicated framework to share data, computational models, simulation results and other project resources with different teams across Europe and the rest of the world. The open platform, providing access and control to virtualised resources, will enable the comparison and full validation of different approaches to solve water contamination problems and allow the integration into the system of different interrelated aspects of the solution (methods and techniques for site characterization, data analysis, monitoring, modelling, and identification of the most efficient and cost-effective remediation technologies) and the building of cross-organizational teamwork and partnership.

Figure 3 *Web user interface to the "New Location" service. The service allows to add to the geodatabase a sample with chemical data supplied by the user and to submit the simulation via the PHREEQC online service.*



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