Transactions in GIS

Short Technical Note

Transactions in GIS, 2016, 00(00): 00–00

Bringing GEOSS Services into Practice: A Capacity Building Resource on Spatial Data Infrastructures (SDI)

Gregory Giuliani,* Pierre Lacroix,* Yaniss Guigoz,* Roberto Roncella,† Lorenzo Bigagli,† Mattia Santoro,† Paolo Mazzetti,† Stefano Nativi,† Nicolas Ray* and Anthony Lehmann*

*University of Geneva, Institute for Environmental Sciences, EnviroSPACE and GRID-Geneva
†CNR, Institute of Atmospheric Pollution Research

Abstract

Data discoverability, accessibility, and integration are frequent barriers for scientists and a major obstacle for favorable results on environmental research. To tackle this issue, the Group on Earth Observations (GEO) is leading the development of the Global Earth Observation System of Systems (GEOSS), a voluntary effort that connects Earth Observation resources world-wide, acting as a gateway between producers and users of environmental data. GEO recognizes the importance of capacity building and education to reach large adoption, acceptance and commitment on data sharing principles to increase the capacity to access and use Earth Observations data. This article presents *"Bringing GEOSS services into practice" (BGSIP)*, an integrated set of teaching material and software to facilitate the publication and use of environmental data through standardized discovery, view, download, and processing services, further facilitating the registration of data into GEOSS. So far, 520 participants in 10 countries have been trained using this material, leading to numerous Spatial Data Infrastructure implementations and 1,000 tutorial downloads. This workshop lowers the entry barriers for both data providers and users, facilitates the development of technical skills, and empowers people.

1 Introduction

Research in environmental sciences is currently hindered by various barriers that impede efficient data discovery and access (Giuliani et al. 2011; Craglia et al. 2012). Earth Observation (EO) data are an essential prerequisite to analyze past, current, and future environmental trends (Beniston et al. 2012; Nativi et al. 2013a). EO can be considered as the collection of necessary data to measure and monitor Earth's physical, chemical and biological systems. They are usually acquired through remote sensing techniques (e.g. satellite, airborne systems) or field sensors (e.g. thermometer, wind gauge, ocean buoy, seismometer). The difficulties in efficiently accessing data are a major obstacle for success in research themes like climate change, biodiversity, or disasters management (Lehmann et al. 2014). To tackle this issue and facilitate environmental data discovery and access, it is essential to convince data holders to make their data

Address for correspondence: Gregory Giuliani, University of Geneva – Institute for Environmental Sciences, EnviroSPACE, 66 Boulevard Carl-Vogt, 1211 Geneva 4, Switzerland. E-mail: gregory.giuliani@unige.ch
Acknowledgments: The authors would like to acknowledge the European Commission "Seventh Framework Program" that funded the EOPOWER (Grant Agreement no. 603500), IASON (Grant Agreement no. 603534), enviroGRIDS (Grant Agreement no. 227640) and MEDINA (Grant Agreement no. 282977) projects. A special thank to all testers of the material: Mick Wilson (United Nations Environment Program), Julie Binder (Federal Geographic Data Committee), Mark Noort (HCP International), Omer Nadin and Pablo de Roulet (University of Geneva). We thank Martin Lacayo for reviewing an earlier draft. The views expressed in the article are those of the authors and do not necessarily reflect the views of the institutions they belong to.

 doi: 10.1111/tgis.12209

available to a larger audience and to understand the benefits of data sharing (Charvat et al. 2013; Myroshnychenko et al. 2013). Currently, one of the main challenges that authorities are facing worldwide is the coordination and effective use of the vast amount of environmental data that is generated (Giuliani et al. 2013). To address this challenge, the concept of the Spatial Data Infrastructure (SDI) has emerged (Masser 2005; Nebert 2005; Craglia et al. 2010). This framework aims at integrating data sources, systems, network linkages, standards and institutional issues to efficiently deliver environmental data from heterogeneous sources to the widest possible audience (Nebert 2005; Giuliani et al. 2011; Giuliani and Gorgan 2013; Lehmann et al. 2014). According to the Global SDI Association (GSDI), SDIs are *"an umbrella of policies, standards, and procedures under which organizations and technologies interact to foster more efficient use, management, and production of environmental data"* (Nebert 2005) and have the ultimate objective to support easy access to and utilization of environmental data (e.g. discovery, visualization, evaluation, access).

SDIs depend on interoperability to significantly enhance data discovery and accessibility. Interoperability can be defined as the ability to exchange and make use of data and information between two or more components. The Open Geospatial Consortium (OGC) is leading the international effort to develop open interoperability standards for geospatial data and information, to enable data discovery (e.g. Catalog Service for the Web – CSW), data visualization (e.g. Web Map Service –WMS), data download (e.g. Web Feature Service – WFS and Web Coverage Service – WCS), and data processing (e.g. Web Processing Service – WPS). Indeed, there are many other ways of sharing environmental data (e.g. download of static files, physical support like DVD or USB keys); the preferred option depends on various factors such as Internet connectivity or computer performance (Giuliani et al. 2014). However, the BGSIP approach focuses on data sharing through web services as this is an emerging technology supporting the major data sharing initiatives at national/regional/global scales, ensures access to up-to-date data sets, enables interoperability, and is well adapted in a environment with good Internet connectivity.

At the global scale, the leading effort to enhance coordination and provisioning of environmental data is represented by the Group on Earth Observations (GEO) that is developing the Global Earth Observation System of Systems (GEOSS) (GEO Secretariat 2005). The aim of GEOSS is to enhance the relevance of EO for addressing environmental problems, and to offer full and open access to comprehensive information on and analyses of the environment. GEO adopted Data Sharing Principles (https://www.earthobservations.org/dswg.php) to expend data reuse through GEOSS and promote open data access to answer broad societal challenges (GEO 2009). To achieve GEOSS vision and objectives, anyone who wishes to participate in GEO should endorse the Data Sharing Principles: *"(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; and (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"*. GEO recognizes the importance of Capacity Building and education to reach large acceptance, adoption, and commitment on Data Sharing Principles to increase the capacity to access and use EO data (Giuliani et al. 2013; Donert 2015). GEO's capacity building definition follows the United Nations Conference on Environment and Development (UNCED) definition of including "*human, scientific, technological, organizational, and institutional resources and capabilities*" to "*enhance the abilities of stakeholders to evaluate and address crucial questions related to policy choices and different options for* *development*" (GEO Secretariat 2006). Within its current work plan, GEO has a dedicated task on Capacity Building (ID-02 Developing Institutional and Individual Capacity) that aims at implementing the vision stated in its strategy (GEO Secretariat 2006; European Commission 2014).

In its strategy, GEO defines three levels of capacity building: (1) human (e.g. education and training of individuals); (2) institutional (e.g. enhancing the understanding within organization and governments of the value of geospatial data to support decision-making); and (3) infrastructure (e.g. installing/configuring/managing of the needed technology). GEO also recommends demonstrating the benefits of data sharing through appropriate examples, best practices, and guidelines in order to strengthen: (1) existing observation systems; (2) capacities of decision-makers to use it; and (3) capacities of the general public to understand important environmental, social and economical issues at stake. Such initiatives can also give data providers the opportunity to become more visible and trustworthy nationally and internationally by participating in the effort of building GEOSS. The GEO capacity-building strategy also identifies several issues that represent at the same time as many opportunities to improve the situation such as (Noort 2010, 2012, 2013): (1) limited access to capacity building resources; (2) lack of e-science infrastructure for EO education and training; (3) need for criteria and standards for EO capacity building; (4) gaps between EO research and operational application; (5) inefficient connectivity between providers and users of EO systems; (6) need for cooperation within and between developed and developing countries and regions; (7) lack of awareness about the value of EO among decision makers; and (8) duplication of EO capacity building efforts.

Currently, there are many tutorials, for example OpenLayers (http://openlayers.org/en/v3.9.0/doc/tutorials/), GeoServer (http://docs.geoserver.org/2.7.1/user/tutorials/index.html), PostGIS (http://postgis.net/documentation/), QGIS (http://www.qgistutorials.com/en/) and workshop materials (Boundlessgeo Workshops; http://workshops.boundlessgeo.com) that are available on the Internet explaining how to use OGC and ISO standards to publish, document, visualize, and process data. However, one of the major issues is that they focus on one or two topics or tools, but to our knowledge none of them gives a clear vision of both the data provider and the consumer perspectives. It becomes therefore more difficult for stakeholders to understand the benefits of concepts like data sharing and interoperability. This can potentially lead to a lack of interest and commitment, and finally act as a barrier to participation to initiatives such as GEOSS. The GEOSS tutorials are probably the best attempt to integrate these resources and are available from http://wiki.ieee-earth.org/Documents/GEOSS_Tutorials. However, these tutorials tend to be outdated (i.e. not maintained and using old versions of software) and they do not cover all the aspects of providing and consuming data. Furthermore, learners are required to identify and go through several tutorials before being able to share and use interoperable services.

Recognizing these issues and opportunities, the "*Bringing GEOSS services into practice*" (BGSIP) workshop (Giuliani et al. 2014) has been initiated in the framework of the European research project enviroGRIDS (Lehmann et al. 2015) as an integrated set of teaching material and software to give the necessary knowledge to efficiently share and use environmental data through web-based services. This material is simple to use and easy to deploy, and facilitates the publication and use of data and metadata through discovery, view, download, and processing services, as well as the registration of data into GEO/GEOSS. This article discusses the strategy put in place to achieve a coherent set of teaching material and its effective delivery specifically addressing the needs of GEO/GEOSS.

2 Objectives

The main objective of the *BGSIP* workshop is to promote the GEO Data Sharing Principles by teaching how to configure, deploy, and use a set of open source software to set up a spatial data infrastructure. This general goal is supported by three specific objectives to assist trainees to learn: (1) how to publish and share data and metadata using OGC and ISO standards; (2) how to register services into GEOSS; and (3) how to use services discovered through GEOSS in desktop and web-based GIS clients. The main requirements in designing the course are the following:

1. Alternate theory and hands-on exercises;
2. Simple start and intuitive user interface;
3. Platform independent (e.g. Windows, Mac, Linux);
4. Geospatial standards explained, taught, and used;
5. Scalable infrastructure for both learning and production environments;
6. Open to modification of all teaching material;
7. Multilingual instructions; and
8. Ease of deployment in case participants want to rapidly set up a SDI in a production environment.

This workshop concentrates mostly on the human and infrastructure levels of the GEO Capacity Building Strategy. The ultimate strategy behind this workshop is to train the trainer by enabling the participants to train other colleagues within their own institutions and to spread the word about data sharing. The institutional level is therefore also tackled by raising awareness internally on the benefits of data sharing.

This workshop cannot cover all topics related to data sharing. The primary objective is to give data providers and users the necessary knowledge to share and consume data through widely used interoperable standards. Once the necessary knowledge is acquired, it becomes possible for them to tackle other issues like data quality or to handle other types of data sources (e.g. sensors or crowd-sourced data). In the long-term, this will enable their participation not only in GEO/GEOSS but also in other data sharing initiatives like the Infrastructure for Spatial Information in the European Community (INSPIRE) (European Commission 2007).

3 Workshop Material

Based on the requirements presented in the previous section, the following teaching material has been produced and developed: (1) a tutorial documentation available as a PDF document and eBook (available on iTunes and Google Play); (2) introductory PowerPoint presentations on essential SDI concepts; and (3) a virtual machine (VM) with all software, documentation and data already installed. The following open source software (Table 1) and standards (Table 2) are used in the workshop.

The choice has been made to use open source software and open standards because they are valuable resources to develop freely available education and teaching material. This will help to freely disseminate this material to the widest audience possible, allowing trainees to become trainers. Finally, they are efficient solutions to share data and to ensure a sustainable technology transfer by making accessible cost-effective and user-friendly solutions.

The approach taken is that each chapter starts with a question that is addressed and answered by interweaving theory and step-by-step practical exercises (Table 3).

Table 1 Software used in "Bringing GEOSS services into practice"

Name	Version	Website
Provider/Server-side		
PostgreSQL	9.3.1	http://www.postgresql.org
PostGIS	2.1	http://postgis.refractions.net
GeoServer	2.6.1	http://geoserver.org
GeoNetwork	2.10.4	http://geonetwork-opensource.org
PyWPS	3.2.2	http://pywps.wald.intevation.org
GI-cat	10.0.2	http://essi-lab.eu/do/view/GIcat
GI-axe	2.0.3	http://essi-lab.eu/do/view/GIaxe/
Consumer/Client-side		
OpenLayers	3.3.0	http://openlayers.org
QGIS	2.8	http://www.qgis.org

Table 2 Standards used in "Bringing GEOSS services into practice"

Name	Abbreviation	Reference
OGC Web Map Service	WMS	(de la Beaujardiere 2006)
OGC Web Feature Service	WFS	(Vretanos 2005)
OGC Web Coverage Service	WCS	(Whiteside and Evans 2006)
OGC Keyhole Markup Language	KML	(Wilson 2008)
OGC Styled Layer Descriptor	SLD	(Lupp 2007)
OGC Catalog Service for the Web	CSW	(Nebert et al. 2007)
OGC Web Processing Service	WPS	(Schut 2007)
ISO 19115		(ISO 2003)
ISO 19139 - Geographic information – Metadata – XML schema implementation		http://www.iso.org/iso/catalogue_detail.htm?csnumber=32557
ISO 19119 – Geographic information – Services		http://www.iso.org/iso/catalogue_detail.htm?csnumber=39890

The material follows a structured order reflecting a general path from service providers to consumers (Figure 1). After an introduction on concepts of SDI, Chapters 2 to 5 concentrate on the provider side explaining how to create a PostgreSQL/PostGIS geospatial database and load vector data; how to publish vector and raster data as OGC services with GeoServer; how to document data with ISO-compliant metadata and store it in a metadata catalog; and finally how to create a geoprocessing script to analyze geospatial data. Chapters 6 to 8 focus on the consumer side, illustrating how to visualize data with WMS in various clients (e.g. OpenLayers, QGIS, Google Earth); how to download data with WFS and edit a

Table 3 Structure of the workshop, with related tools and standards

Chapter	Title	Software	Standards
1	Concepts on SDI	N/A	N/A
2	How to store geospatial data?	PostgreSQL/PostGIS	N/A
3	How to publish geospatial data?	GeoServer	WMS, WFS, WCS, KML, SLD
4	How to document and search geospatial data?	GeoNetwork	CSW, ISO
5	How to process geospatial data?	PyWPS	WPS
6	How to view geospatial data?	OpenLayers, QGIS	WMS, KML
7	How to download geospatial data?	QGIS	WFS, WCS
8	How to analyze geospatial data?	QGIS	WPS
9	How to share geospatial data?	GI-cat, GI-axe	WMS, WFS, WCS, CSW, WPS

vector layer; and how to consume a WPS service in a GIS client for geospatial analysis. The final chapter discusses how to share these services and participate in GEOSS by registering resources in the GEO Discovery and Access Broker (Nativi and Bigagli 2009; Nativi et al. 2013a, b; Nativi et al. 2015).

In the same spirit, the data used in this workshop are based on international environmental data platforms, such as the Global Risk Data Platform (Giuliani and Peduzzi 2011), the Transboundary Water Assessment Program, regional environmental data platforms (e.g. ECOWREX, project on renewable energy in West Africa) and project-related environmental data platforms (e.g. enviroGRIDS; Giuliani and Gorgan 2013; Lehmann et al. 2014), IASON and EOPOWER on the use of EO for environmental applications). These datasets cover the following themes: risk to natural hazards, water, renewable energy, hydrology, and climate. All these datasets are openly and freely available (i.e. no copyright issues) and are used in several chapters to create continuity within the workshop. The data used are neither voluminous nor spatially complex so can be easily handled by beginners. The same reasons for using open source software apply to use the open data sets and in particular their rights to redistribute. Commercial datasets were not an option in our case because we wanted to freely redistribute datasets together with the software to handle them. This is in line with the free and open sharing spirit promoted by GEO/GEOSS and supported by the workshop.

All the material (i.e. software, data, and tutorials) is integrated and provided in a dedicated and tailored Linux VM based on Oracle VirtualBox. This VM can be executed on Windows, MacOS, or Linux and requires a minimum of 4 GB of memory and at least 20 GB of disk space. Once the VM is installed, users can start the tutorial directly. Furthermore, having a VM that is already preconfigured allows users to first train with SDI concepts and technologies; once they are familiarized they can deploy it as a production server. By using the VM users are able to save time on setup, focus on open standards, and later deploy it as a production environment and make adjustments if necessary. This is an important incentive for the users. This material comes with a 200-slide PowerPoint presentation of the theoretical content of the workshop. This teaching material of the workshop is already available in seven languages: Arabic, Croatian, English, French, Russian, Serbian, Spanish and soon in Czech.

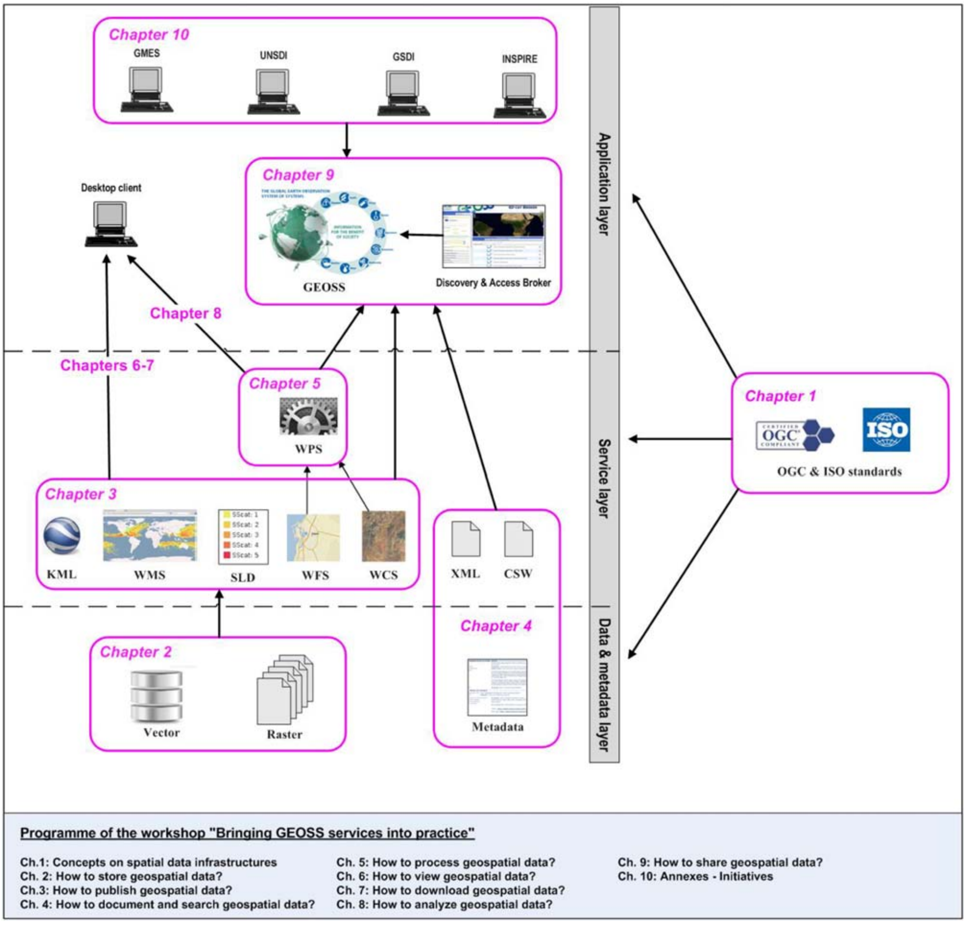

Figure 1 The general structure of the workshop

4 Dissemination

The material of the workshop can be downloaded on a dedicated website: http://www.geossintopractice.org and the tutorial is available as an interactive ebook on both iTunes/iBooks Store (https://itunes.apple.com/us/book/bringing-geoss-services-into/id806182409) and Google Play Books (https://play.google.com/store/books/details/Gregory_Giuliani_Bringing_GEOSS_services_into_prac?id=Nv6nAgAAQBAJ). The material is completely free-of-charge and is licensed under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License. This type of license allows any user to freely share (e.g. copy and redistribute in any medium or format) and adapt (e.g. remix, transform and build upon) the material. However, users are obliged to give appropriate credit (e.g. Attribution), are not allowed to use this material for commercial purposes (e.g. NonCommercial) and if users remix, transform or build upon the material, they must distribute their contributions under the same license (i.e. ShareAlike).

The workshop itself can take various formats by teaching one, some, or all chapters, with an estimated maximum of 12 hours. This is complemented by videos presenting each chapter of the tutorial on a dedicated "*Bringing GEOSS services into practice*" YouTube channel (https://www.youtube.com/channel/UCfBVYFBQw1aEU7M1j9zbW7A). In terms of dissemination, the workshop has been taught 15 times between 2010 and 2015 to about 520 participants in Bulgaria, Georgia, Morocco, the Netherlands, Romania, Serbia, Switzerland, Tunisia and Turkey (the up-to-date agenda is available at: http://goo.gl/lWBz8M). At the University of Geneva, the workshop has been included as a course that lasted two days and students were then asked to put their knowledge into practice by developing and publishing a web application. In two other cases the last half-day of the workshop was dedicated to the integration of geospatial data into the SDI of the hosting institution. The workshop was also presented at international events, e.g. as a side event during the GEO-X Plenary (http://www.earthobservations.org/me_sevent.php?id=147) and followed by discussions on how to assess its impact. The workshops have addressed diverse audiences ranging from students to teachers, scientists to policymakers, NGOs and public employees to private companies. However, the workshop remains quite technical and is ideally suited to environmental scientists with technical background. In order to reach a broader audience, other formats of the workshop are planned, less technical and/or more thematic (e.g. in the field of water resources, climate change or mineral exploitation). In addition, more than 1,000 downloads of the workshop material have been recorded since March 2014. The tutorial is registered in GEOSS and in GEOCAB (http://www.geocab.org), and is promoted by the GEO Secretariat.

A questionnaire was also sent to 450 past attendees to help measure the impact of the workshop (Figure S1). While the number of respondents is low (e.g. only 50 people have replied so far), 32 of them stated they have taught others what they learned at the workshop. Even if this does not mean they have reproduced the exact workshop, it shows that the workshop's principles can be reproduced. Seventy-five percent of the respondents say they are in a position to teach this workshop in their organization; 65% say they have / are planning to share data through GEOSS; and finally, one-third of the respondents set up an SDI in their organization.

These results show that the objectives of being simple, interoperable, flexible, scalable, and multilingual have been successfully achieved. In particular this can be also helpful for users of a specific scientific community to participate in an initiative like GEOSS and use what is in GEOSS to develop a tailored application targeting the needs of a specific community, e.g. Community portals (Cau et al. 2013; Gorgan et al. 2013).

5 Lessons Learned and Recommendations

Since 2010, the experience gained and the lessons learned in developing, implementing, and assessing the workshop to develop capacities of different user groups allow us to draw some recommendations for creating a capacity building resource on SDI, but also to highlight some limitations.

5.1 Benefits and Impacts

The workshop had an impact on research project partners, countries and institutions where the Bringing GEOSS services into practice workshop was taught (Giuliani et al. 2013). At the human level, several partners of EU/FP7 projects decided to implement their own SDI. They have all stated that having participated in the workshop convinced them about the necessity to share data and the benefits of using web-based interoperable services. The many positive comments in the impact survey echo this sentiment, e.g. "*I want to use GEOSS services in my PhD works*"; "*We hope to be able to collaborate with you in other research and education / training projects related to web-based data sharing*". At the institutional level, institutions like the

Commission on the Protection of the Black Sea Against Pollution (whose International Secretariat has been accepted as an Observer in GEO in November 2015) and the International Commission for the Protection of the Danube River (ICPDR) found that sharing data using OGC and ISO standards could bring several benefits for their assessment and reporting processes and prompted the effort to implement and/or upgrade their infrastructures. At the country level, these workshops helped to raise awareness about GEO/GEOSS: three countries (Armenia, Bulgaria, Georgia) where workshops were given became GEO members. Finally, the wide adoption of OGC standards among project partners facilitated the development and implementation of different software solutions and enabled communication between different computing infrastructures (Charvat et al. 2013; Giuliani and Gorgan 2013; Giuliani et al. 2013). This allowed large amounts of environmental data to be processed on distributed computing infrastructures to analyze high-resolution satellite images or execute large hydrological models (Gorgan et al. 2011; Gorgan et al. 2012a, b; Bacu et al. 2013; Balcik et al. 2013; Mihon et al. 2013a, b).

Besides these general impacts, several other benefits measurable both directly (e.g. questionnaire sent to participants) and indirectly (e.g. following the work of some participants/ institutions) can be mentioned. At the technological level, participants have registered several services into GEO/GEOSS. This demonstrated the increase of awareness and use of open standards and will ultimately facilitate discovery and access to hundreds of datasets. The use of Free and Open Source Software (FOSS) was really instrumental in building capacities and implementing data sharing solutions. In particular, these solutions are attractive for students, professionals, enterprises, and institutions that do not have the means to afford expensive commercial solutions. More importantly the open source software solutions used in the workshop have proven to be very reliable and efficient (Giuliani et al. 2014). The fact that all the teaching material can be freely disseminated helps trainees to become trainers. This helps to lower entry barriers for both data providers and users, strengthens the development of technical skills, and empowers people. This can potentially have a scientific and societal impact by increasing the number of data sets available; facilitating discovery and access to data; enabling decision-makers and the general public to access relevant, up-to-date, and scientifically sound environmental information; giving a sense of belonging to an active community; and possibly taking better political decisions. Finally, this workshop may have an impact on GIS educators and curricula because sharing and documenting data is part of the elementary scientific approach enhancing accountability, credibility, and reproducibility. It gives them access to a complete teaching resource presenting cutting-edge web-based technology and helping them to educate students on the benefits of data sharing.

5.2 Limitations

During this workshop several challenges have been identified. In addition to technological aspects (e.g. computer languages, computer performances) the main issues are related to institutional (e.g. political/cultural context, policies, organization, resources) and human (e.g. skills, knowledge) aspects.

Based on our own experience in giving the workshop together with collected feedback from participants, other limitations have been identified. Our experience shows that a one-day session with no more than 10 participants per instructor is ideal for both teaching and learning. Alternating between talks, hands-on and videos proved to be a good way to capture and keep the attention of the audience. However, the heterogeneity of participant's skills, the balance between the number of participants and instructors, and the fact that the workshops depends greatly on a fast (>2 Mbps) Internet connectivity, are important factors to take into consideration to ensure a good user experience. This is illustrated by a comment in the user survey feedback stating, *"Less demanding data would be easier, loading and processing the current data is quite slow"*. Based on user feedback, it seems that the chapter on storing data is too technical, and this is a notable barrier for some participants since it includes the first hands-on exercise. Furthermore, in terms of assessment of the workshop, the number of respondents was limited. Increasing the number of answers can help to improve feedback and draw more robust conclusions based on participants' comments. Finally the question of sustainability of the workshop is critical. We could evaluate that upgrading the full material (virtual machine with latest software versions, tutorial, presentations in one language) requires between two and three weeks of work. The recent integration of the workshop in courses at the University of Geneva (2014) is positive but a successful dissemination beyond the academic sphere will require identifying key mechanisms (e.g. GEO processes), projects, and people. A possible solution is to integrate capacity building workshops into future projects, as was done in IASON, EOPOWER and ClimVar (http://www.globalclimateforum.org/index.php?id=127).

5.3 Recommendations

Based on the experience acquired and the identified benefits, impacts, and limitations, there are several recommendations for developing a capacity building resource on SDI such as the BGSIP workshop:

1. Promote the use of FOSS software and the development of freely available education and teaching material. This will facilitate reaching and disseminating teaching resources to the widest audience possible. This will also ensure a sustainable technology transfer by making available cost effective and user-friendly solutions.
2. Massive learning solutions like MOOC are promising teaching solutions to better promote data sharing needs and solutions to a large audience. However, MOOC might not be appropriate for some technical hand-on exercises that would require heavy live interaction with the teacher.
3. Capacity-building activities should let users experience the benefits of data sharing through appropriate examples, by communicating best practices and developing guidelines and policies. Altogether this will facilitate reaching agreement and endorsement on the use of new standards and enhance an "open and sharing spirit".
4. Specific measurable goals must be defined during the planning phase of a workshop development. Such a strategy should consider various indicators (e.g. web material download statistics, user surveys, agreement with some users for a long-term impact follow-up, etc.). This will help to assess impact, get feedback, and better understand how the workshop has influenced their work.
5. The targeted audience of such a Capacity Building resource must be well defined from the beginning, and tailored material ready depending on the audience (e.g. be prepared for technical issues such as connectivity, hardware or language issues that might require translators). The audience is usually heterogeneous and therefore the materials should not be too technical or too conceptual, as participants may not be able to follow.
6. In order to maximize the impact, it is essential to target and include key high-level institutional individuals when delivering such a capacity-building workshop. We found that having a pre-workshop high-level presentation on the benefits of data sharing would often facilitate the adoption of the technical choices later on.

7. A long-term maintenance and upgrade mechanism must be also planned from the beginning in order to ensure the quality and cutting-edge sustainability of the Capacity Building resource.
8. A final recommendation is to clearly highlight the anticipated benefits of the workshop, such as: increased awareness of data sharing issues and solutions; complete technical understanding of the chain from data collection to data publication; improved technical skills; increased regional and national capacities with the potential increased development; enabling institutions and people to cooperate closely and share a common vision.

6 Conclusions and Future Perspectives

In order to encourage data providers to be more "open" and facilitate access to their data, a long-term commitment to education, capacity building, and research is essential. The *"Bringing GEOSS services into practice"* teaching material is probably the first attempt to build capacity simultaneously for both data providers and data users. It facilitates the configuration, use, and deployment of a set of open source software to implement an SDI. It also explains how to publish and share data and metadata using OGC and ISO standards and how to register published services into GEOSS. Finally, it explains how to use services that are discoverable in GEOSS to develop tailored applications for specific purposes and/or a community of users. This material has been developed in the train-the-trainer spirit enabling the reuse and exchange of knowledge and new capacities that have been acquired. The main features of the workshop are simplicity, data interoperability, interoperability of material, flexibility, multilingual, and scalability. As a result, 520 participants in 10 countries have been trained using this material, leading to dozens of on going SDI implementations (Astsatryan et al. 2012; Asmaryan et al. 2014), and more than 1,000 downloads. The introduction material (PowerPoint presentations) is translated into several languages (Arabic, Croatian, English, French, Russian, Serbian, Spanish, Czech). This workshop lowers entry barriers for both resource users and providers, facilitates the development of technical skills, and empowers people.

Experience has shown that this material is useful, but some chapters are probably too technical for beginner users. The authors are planning to develop a lighter and shorter version of this training material with less technology and simpler tools (e.g. GeoNode). Another option for further user targeting is to develop training material based on "*Bringing GEOSS services into practice*" but focusing on thematic issues such as the GEO/GEOSS Societal Benefits Areas (SBAs: Agriculture, Biodiversity, Climate, Disasters, Ecosystems, Energy, Health, Water, Weather). Finally, to complement the workshop other chapters can be added to take into account subjects that are not yet discussed in detail such as the use of sensors, the management of crowdsourced data, or the assessment and control of data quality. The latter is of particular importance and has been explored by several EU-funded projects that define data quality indicators (e.g. GeoViQua, QA4EO) (Diaz et al. 2012) or deal with managing uncertainty (e.g. UncertWeb) (Bastin et al. 2013). With such substantive additional material, the development of a dedicated Massive Open Online Course (MOOC) would be possible, and greatly increase the EO capacity building range in line with the GEO CB strategy.

Beyond overall capacity building of the technical aspects of SDI implementation, in some countries the workshop had a direct influence on national policies on Earth Observation and data sharing. For example, Georgia and Armenia recently became GEO members (in 2013 and 2014, respectively). Armenia was an early adopter of the technical and institutional recommendations of the workshop, notably with the creation of a Master-level course in SDI and computational technology. In 2014, the country also adopted its national resolution N136 aiming at building a national Spatial Data Infrastructure. The recent nomination (in November 2015) of Armenia as a member of the GEO Executive Committee is yet another success that can be, in part, attributed to the positive outcomes of the BGSIP workshop.

Although a few preliminary success stories have been discussed, such as with Armenia, the impacts and benefits of such a workshop typically continue to accrue over a longer period of time. These insights will be part of future articles in which the impacts of SDI capacity building activities will be studied in more detail, including sharing the lessons learned in each country, with the goal of ultimately empowering others to follow their lead.

The sustainability of the workshop material itself is also at stake. Indeed, the SDI community is dynamic and changes over time, so there is the risk that the workshop could become outdated. Therefore, it is important to maintain and regularly upgrade the workshop material with new software versions that would come out or with new standards that will emerge in the future. To this end, advantage will be taken of this workshop also being taught at the University of Geneva, as part of the Certificate of Geomatics (http://www.unige.ch/sig/enseignements/cgeom.html). This will provide the necessary resources for maintaining it.

Besides, it is planned to enrich the course with practical exercises based on thematic data, in fields such as climate change, water resource and mineral exploration.

Some characteristics of BGSIP facilitate its sustainability. First of all, the tutorial has a modular structure, making it easy to update specific sections or even to add entirely new ones where required. Moreover, the tools for the hands-on part of the course are provided in a virtual machine that can be easily updated during the preparatory phases. These characteristics allow quite a fast update and tailoring of courses. Upgrading the VM and the tutorial requires a few person-weeks, a limited time and effort that can be easily allocated on most initiatives and project budgets. Since its creation in 2010 the workshop has been upgraded each year, utilizing various project funding sources.

The *"Bringing GEOSS Services into practice"* course has been proposed by the EU-FP7 IASON project (http://iason-fp7.eu) as a best practice for actions aiming to reduce technical barriers to data sharing. The integration of the workshop as a guideline in the revised version of the EGIDA Methodology (Nativi et al. 2014; Bigagli and Lipiarski 2015), a general methodological approach for the re-engineering of Earth Observation infrastructures, itself integrated in the EOPOWER Methodological Framework for Impact Assessment of Earth Observation for Environmental Applications (http://www.eopower.eu/?q=node/118), will give an increased visibility of the workshop. This might provide new opportunities for further developing or updating the workshop, contributing to its sustainability.

References

Asmaryan S, Saghatelyan A, Astsatryan H, Bigagli L, Mazzetti P, Nativi S, Guigoz Y, Lacroix P, Giuliani G, and Ray N 2014 Leading the way toward an environmental National Spatial Data Infrastructure in Armenia. *South-Eastern European Journal of Earth Observation and Geomatics* 3: 52–62

Astsatryan H, Narsisian W, Ghazaryan V, Saribekyan A, Asmaryan S, Guigoz Y, Giuliani G, and Ray N 2012 Toward to the development of an Integrated Spatial Data Infrastructure in Armenia. In *Proceedings of the Fourth ICT Innovations Conference*, Ohrid, Macedonia

Bacu V, Mihon D, Stefanut T, Rodila D, and Gorgan D 2013 Calibration of SWAT hydrological models in a distributed environment using the gSWAT application. *International Journal of Advanced Computer Science and Applications* 3(3): 66–74

Balcik F B, Mihon D, Colceriu V, Allenbach K, Goskel C, Dogru O, Giuliani G, and Gorgan D 2013 Remotely sensed data processing on grids by using GreenLand web-based platform. *International Journal of Advanced Computer Science and Applications* 3: 58–65

Bastin L, Cornford D, Jones R, Heuvelink G B M, Pebesma E, Stasch C, Nativi S, Mazzetti P, and Williams M 2013 Managing uncertainty in integrated environmental modelling: The UncertWeb framework. *Environmental Modelling and Software* 39: 116–34

Beniston M, Stoffel M, Harding R, Kernan M, Ludwig R, Moors E, Samuels P, and Tockner K 2012 Obstacles to data access for research related to climate and water: Implications for science and EU policy-making. *Environmental Science and Policy* 17: 41–8

Bigagli L, and Lipiarski D 2015 EOPOWER WorkPackage 4 – Science Valorisation. WWW document, http://www.eopower.eu/sites/default/files/D4.01.pdf.

Cau P, Manca S, Soru C, Muroni D, Gorgan D, Bacu V, Lehmann A, Ray N, and Giuliani G 2013 An interoperable, GIS-oriented, information and support system for water resources management. *International Journal of Advanced Computer Science and Applications* 3: 75–82

Charvat K, Vohnout P, Sredl M, Kafka S, Mildorf T, De Bono A, and Giuliani G 2013 Enabling efficient discovery of and access to spatial data services. *International Journal of Advanced Computer Science and Applications* 3: 28–31

Craglia M, de Bie K, Jackson D, Pesaresi M, Remetey-Fulop G, Wang C, Annoni A, Bian L, Campbell F, Ehlers M, van Genderen J, Goodchild M, Guo H, Lewis A, Simpson R, Skidmore A, and Woodgate P 2012 Digital Earth 2020: Towards the vision for the next decade. *International Journal of Digital Earth* 5: 4–21

Craglia M, Pavanello L, and Smith R S 2010 *The Use of Spatial Data for the Preparation of Environmental Reports in Europe*. Ispra, Italy, Institute for Environment and Sustainability Joint Research Centre, European Commission

de la Beaujardiere J (ed) 2006 *OpenGIS Web Map Server Implementation Specification* (Version 1.3.0). Wayland, MA, Open Geospatial Consortium Document No. 06-042

Diaz P, Maso J, Sevillano E, Ninyerola M, Zabala A, Serral I, and Pons X 2012 Analysis of quality metadata in the GEOSS Clearinghouse. *International Journal of Spatial Data Infrastructures Research* 7: 352–77

Donert K 2015 Digital Earth – Digital World: Strategies for geospatial technologies in 21st century education. In Muñiz Solari O, Demirci A, and van der Schee J (eds) *Geospatial Technologies and Geography Education in a Changing World: Geospatial Practices and Lessons Learned*. Berlin, Springer: 195–204

European Commission 2007 *Directive 2007/2/EC of the European Parliament and the Council of 14 March 2007 Establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)*. Brussels, Belgium, European Commission

European Commission 2014 *Capacity Building for GEOSS: European Contributions to Capacity Building Activities in GEO*. Brussels, Belgium, European Commission

GEO 2009 Implementation Guidelines for the GEOSS Data Sharing Principles (Document 7; Rev2). WWW document, https://www.earthobservations.org/documents/geo_vi/07_Implementation%20Guidelines%20for%20the%20GEOSS%20Data%20Sharing%20Principles%20Rev2.pdf

GEO Secretariat 2005 *Global Earth Observation System of Systems 10-Year Implementation Plan*. Brussels, Belgium, GEO Secretariat Reference Document No. 209

Giuliani G, Dubois A, and Lacroix P 2014 Testing OGC web feature and coverage service performance: Towards efficient delivery of geospatial data. *Journal of Spatial Information Science* 7: 1–23

Giuliani G and Gorgan D 2013 Editorial: EnviroGRIDS special issue on "Building a Regional Observation System in the Black Sea catchment". *International Journal of Advanced Computer Science and Applications* 3: 4–8

Giuliani G, Lacroix P, Guigoz Y, Bigagli L, Ray N, and Lehmann A 2014 *Bringing GEOSS Services into Practice*. Geneva, United Nations Environment Programme

Giuliani G and Peduzzi P 2011 The PREVIEW Global Risk Data Platform: A geoportal to serve and share global data on risk to natural hazards. *Natural Hazards and Earth Systems Science* 11: 53–66

Giuliani G, Rahman K, Ray N, and Lehmann A 2013 OWS4SWAT: Publishing and sharing SWAT outputs with OGC standards. *International Journal of Advanced Computer Science and Applications* 3: 90–8

Giuliani G, Ray N, and Lehmann A 2013 Building regional capacities for GEOSS and INSPIRE: A journey in the Black Sea catchment. *International Journal of Advanced Computer Science and Applications* 3: 19–27

Giuliani G, Ray N, Schwarzer S, De Bono A, Peduzzi P, Dao H, van Woerden J, Witt R, Beniston M, and Lehmann A 2011 Sharing environmental data through GEOSS. *International Journal of Applied Geospatial Research* 2: 1–17

Gorgan D, Abbaspour K, Cau P, Bacu V, Mihon D, Giuliani G, Ray N, and Lehmann A 2011 Grid based data processing tools and applications for Black Sea catchment basin. In *Proceedings of the Sixth IEEE International Conference on. Intelligent Data Acquisition and Advanced Computing Systems*, Prague, Czech Republic

Gorgan D, Bacu V, Mihon D, Rodila D, Abbaspour K, and Rouholahnejad E 2012a Grid-based calibration of SWAT hydrological models. *Natural Hazards and Earth System Science* 12: 2411–23

Gorgan D, Bacu V, Mihon D, Rodila D, Stefanut T, Abbaspour K, Cau P, Giuliani G, Ray N, and Lehmann A 2012b Spatial data processing tools and applications for Black Sea catchment region. *International Journal of Computing* 11: 327–35

Gorgan D, Giuliani G, Ray N, Lehmann A, Cau P, Abbaspour K, Charvat K, and Jonoski A 2013 Black Sea catchment observation system as a portal for GEOSS community. *International Journal of Advanced Computer Science and Applications* 3: 9–18
ISO 2003 *ISO19115: Geographic Information – Metadata*. Geneva, Switzerland, International Standards Organization
Lehmann A, Giuliani G, Mancuso E, Abbaspour K, Sözen S, Gorgan D, Beel A, and Ray N 2015 Filling the gap between Earth observation and policy making in the Black Sea catchment with enviroGRIDS. *Environmental Science and Policy* 46: 1–12
Lehmann A, Giuliani G, Ray N, Rahman K, Abbaspour K C, Nativi S, Craglia M, Cripe D, Quevauviller P, and Beniston M 2014 Reviewing innovative Earth observation solutions for filling science-policy gaps in hydrology. *Journal of Hydrology* 518B: 267–77
Lupp M (ed) 2007 *Styled Layer Descriptor Profile of the Web Map Service Implementation Specification* (Version 1.1.0; Revision 4). Wayland, MA, Open Geospatial Consortium Document No. 05-078r4
Masser I 2005 *GIS Worlds: Creating Spatial Data Infrastructures*. Redlands, CA, Esri Press
Mihon D, Colceriu V, Bacu V, and Gorgan D 2013a Grid-based processing of satellite images in GreenLand platform. *International Journal of Advanced Computer Science and Applications* 3: 41–9
Mihon D, Colceriu V, Bacu V, Rodila D, Gorgan D, Allenbach K, and Giuliani G 2013b OGC compliant services for remote sensing processing over the grid infrastructure. *International Journal of Advanced Computer Science and Applications* 3: 32–40
Myroshnychenko V, Ray N, Lehmann A, Giuliani G, Kideys A, Weller P, and Teodor D 2013 Environmental data gaps in Black Sea catchment countries: INSPIRE and GEOSS state of play. *Environmental Science and Policy* 46: 13–25
Nativi S and Bigagli L 2009 Discovery, mediation, and access services for earth observation data. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 2: 233–40
Nativi S, Craglia M, and Pearlman J 2013a Earth science infrastructures interoperability: The brokering approach. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 6: 1118–29
Nativi S, Mazzetti P, Craglia M, and Pirrone N 2013b The GEOSS solution for enabling data interoperability and integrative research. *Environmental Science and Pollution Research* 21: 4177–92
Nativi S, Mazzetti P, Santoro M, Papeschi F, Craglia M, and Ochiai O 2015 Big Data challenges in building the Global Earth Observation System of Systems. *Environmental Modelling and Software 6:* 1–26
Nebert D (ed) 2005 *Developing Spatial Data Infrastructures: The SDI Cookbook*. Orono, ME, Global Spatial Data Infrastructure Association
Nebert D, Whiteside A, and Vretanos P (eds) 2007 *OpenGIS Catalogue Services Implementation Specification* (Version 2.0.2, Corrigendum 2 Release). Wayland, MA, Open Geospatial Consortium Document No. 07-006r1
Noort M 2010 *GeoNetCab: Capacity Building Strategy*. Enschede, the Netherlands, Faculty of Geo-Information Science and Earth Observation, University of Twente
Noort M 2012 The GEONetCab approach to capacity building. In *Proceedings of the GEO European Projects Workshop*, Rome, Italy
Noort M 2013 *GeoNetCab: Marketing Earth Observation Products and Services, Part #2*. Enschede, the Netherlands, Faculty of Geo-Information Science and Earth Observation, University of Twente
Schut P (ed) 2007 *OpenGIS Web Processing Service* (Version 1.0.0). Wayland, MA, Open Geospatial Consortium Document No. 05-007r7
Vretanos P A (ed) 2005 *Web Feature Service Implementation Specification* (Version 1.1.0). Wayland, MA, Open Geospatial Consortium Document No. 04-094
Whiteside A and Evans J D (eds) 2006 *Web Coverage Service (WCS) Implementation Specification* (Version 1.1.0). Wayland, MA, Open Geospatial Consortium Document No. 06-083r8
Wilson T (ed) 2008 *OGC KML* (Version 2.2.0). Wayland, MA, Open Geospatial Consortium Document No. 07-147r2

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Figure S1: Online questionnaire used to assess the *Bringing GEOSS Services into Practice* workshop since 2010.

