GEOSS Interoperability Assessment

A White Paper Prepared by the Standards and Interoperability Forum

A Draft In Development

Table 1: Paper Revision History

Revision Number	Description	Creation Date
0.1.0	Initial creation of document with content from ISRSE paper.	2011-FEB-07
0.8.0	Most content added.	2011-APR-26
0.9.0	All initial content added	2011-SEP-30
0.9.1	Minor edits made for initial SIF internal review.	2011-OCT-07
0.9.2	Minor edits made by SIF internal review.	2011-OCT-10

Those who contributed to the research and writing of this document are listed in the following table, in alphabetical order:

Table 2: Author List

Author	Affiliation	E-mail
Arctur, David	OGC	darctur@opengeospatial.org
Browdy, Steven F.	OMS Tech, Inc., IEEE	steven.browdy@ieee.org
Delory, Eric		
Eglitis, Paul	met.no, IEEE	paul.eglitis@ieee.org
Khalsa, Siri Jodha S.	Univ. Colorado, IEEE	sjsk@nsidc.org
Maso, Joan	CREAF	joan.maso@uab.cat
Nativi, Stefano	National Research Council of Italy, IEEE	stefano.nativi@cnr.it
Sonntag, William	U.S. EPA	

Table of Contents

1. Executive Summary

This GEOSS Interoperability Assessment White Paper is a result of research performed by the Standards and Interoperability Forum (SIF). The activities leading to this paper came from discussions entered into during the 2010 2nd annual Global Earth Observation System of Systems (GEOSS) Interoperability Workshop. Some of the inputs to these discussions came from other surveys conducted by the intergovernmental Group on Earth Observations (GEO) committees and tasks.

Over the course of many months, the SIF looked into the technical aspects of the GEOSS Common Infrastructure (GCI) and conducted a community survey for interoperability. The main conclusions are that certain GCI components need to be modified to better support interoperability. In particular, the Components and Services Registry (CSR) and the Standards and Interoperability Registry (SIR), and how they interact with each other. The GEO Web Portal (GWP) is still undergoing changes, but more of a focus on semantics would greatly enhance the GEOSS user's ability to discover and access desired data, especially from the point of view of merging or layering data from multiple sources.

Many recommendations have been made, and are detailed in Chapter 6, but they fall into a few key categories.

Recommendation Category 1: Enhance the GCI, including legal interoperability, so it is better understood and more usable.

Recommendation Category 2: Achieve standards convergence and integration of semantics.

Recommendation Category 3: Incorporate metrics into the GCI to monitor interopeability.

Recommendation Category 4: Engage communities more to understand their evolution and to cultivate relationships for GEOSS interoperability.

2. Introduction

The Global Earth Observation System of Systems (GEOSS) exists to allow Earth observations, from various and disparate communities, to be shared and exploited as seamlessly as possible for societal benefit (GEO 2005). This goal is supported by the GEOSS Common Infrastructure (GCI), which is a set of contributed software components that operate using international consensus standards. In most cases, these standards have been developed and promulgated by the Earth observation and geospatial communities. As a collection of components contributed by different GEO members the GCI itself

demonstrates interoperability between these components: registeries, clearing houses, and web portals. The GCI fulfills a central role in the discovery and utilization of GEO resources within GEOSS.

This paper will address the status of interoperability within GEOSS through an investigation of the components registered in the GCI holdings to assess the uptake of interoperability arrangements and an analysis of GEO communities that may or may not be utilising the GCI to achieve interoperability. Interaction with Earth observation communities and the GCI, through support from the GEOSS Standards and Interoperability Forum (SIF), can improve upon the delivery of interoperability to the GEOSS community at large. Recommendations will be made on how to address existing issues that are hindering interoperability, and how to focus better on the education and assistance of communities. A critical question underpinning this work is how to measure interoperability in order to make an assessment of the maturity of GEOSS and then to repeat this measurement in the future based on a definition of metrics for interoperability assessment to help monitor and guide development.

The SIF's core membership has collectively been the primary investor of time and effort to produce this paper. The hope is that the information and ideas presented here will be an impetus to improve the interoperability of the GEOSS. It is also hoped that, as the GCI and GEOSS evolve, this paper will also evolve to keep pace with the changes that take effect and study how the changes impact the state of interoperabiliy.

2.1 Background

The second GEOSS Interoperability Workshop took place in Ankara, Turkey in early September, 2010. This workshop was focused on community outreach and interoperability gaps, due mainly to the Monitoring and Evaluation Team findings, which suggested that users and providers of GEOSS did not fully understand the GCI and how to use it. The community outreach discussions were a result of informal exchanges of information that had taken place between SIF members and certain communities. There was much discussion about how to address community needs with regards to GEOSS. There was also much discussion around the meaning of GEOSS interoperability, the goals of GEOSS interoperability, and what the current state of GEOSS interoperability was.

The European GEOSS INSPIRE and GMES Action in Support (GIGAS) project engaged in an interoperability assessment comparing INSPIRE, GMES, and GEOSS (GIGAS 2009) . This study looked at many areas, such as catalog interoperability, architectural support, application schemas, use of ontologies, data quality, etc. This study is being used by the SIF as it moves forward with its interoperability assessment.

2.2 Scope, Purpose, and Methodology

A primary goal of the GEOSS is to improve the interoperability between the observational, modeling, data assimilation, and prediction systems contributed by member countries and organizations participating in GEOSS. The GCI comprises the elements designed to enable discovery and access to these diverse data and information sources. The purpose of the interoperability assessment being undertaken by the SIF is to assess the progress towards achieving the goal of interoperability as envisioned by the GEOSS, to

make recommendations regarding the evolution of the GEOSS architecture and overall data strategy to ensure fulfillment of the GEOSS vision, and to suggest metrics that can be reused to monitor interoperability going forward.

In performing this assessment, the SIF was looking for answers to the following main questions:

- To what degree can the mechanisms for discovering, accessing, understanding and using data, and the data themselves, be considered interoperable?
- Will the separate efforts by various Communities of Practice (CoPs 2011) within GEO, to build their own portals, lead to fragmentation or synergy?
- What communication, leadership, and outreach is needed with these and other communities to improve interoperability both within them and between them?

To proceed with the assessment, the SIF concentrated on GCI analysis, metrics, and community outreach. The GCI analysis looked at problems with, and recommended resolutions for, the ways in which the GCI functions. The work encompassing metrics sought consistent and meaningful ways to monitor and measure ongoing interoperability activity. Community outreach concentrated on gathering information from Earth observation communities regarding their own evolution with respect to interoperability, and how they were working, or intended to work, with the GEOSS.

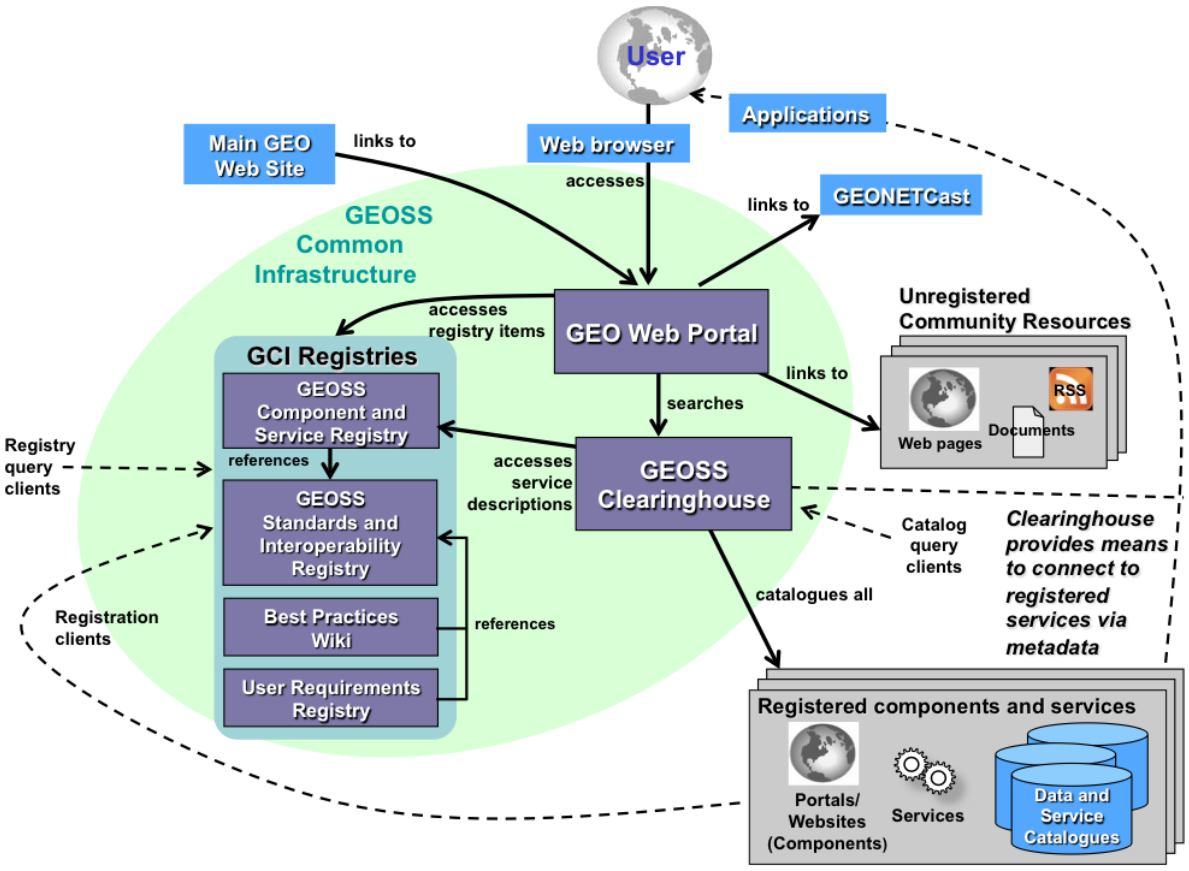


Figure 1. GEOSS Architecture Overview

3. Interoperability Metrics

The GEOSS Ten-Year Implementation Plan Reference Document foresees the development of outcome indicators for the "percentage interoperability achieved between collaborating systems." This requires an understanding of how interoperability is defined and how it can be observed in order to build indicators or interoperability metrics. The GCI Registeries are a working component of the GEOSS and statistical analysis of the population and use of the registeries is one factor in performing the assessment. Different GEO communities have reached different levels of interoperability and inter-comparison of their relative successes is another approach to determine objective measures of interoperability. The work so far carried out is detailed in the following sections.

3.1 Background

There are many facets to interoperability. Systems are said to be interoperable when they can exchange information in a way that is useful and meaningful with minimal or no intervention. From the perspective of an end user seeking to derive information from heterogeneous data sources, the data itself is said to be interoperable if those data can be accessed, combined and interpreted without special effort. Interoperability exists in a user's working environment if that user can discover and use information from distributed sources without needing to be concerned with the location, formats, protocols and conventions used by the systems providing those data.

In the broadest sense interoperability is the ability to communicate and share resources between systems, which can be information systems, organizations or individuals (Carney, et al., 2005). In this context interoperability can involve not just hardware and software, but policies, practices and responsibilities. Manso and Wachowicz (2009) extract 15 different kinds of interoperability from the literature and then describe the aspects of technical interoperability, syntactic interoperability, semantic interoperability, organizational interoperability, pragmatic interoperability, legal interoperability, dynamic interoperability and conceptual interoperability in the context of geographic information systems. Although some authors create a hierarchy of interoperability levels Manso and Wachowicz (2009) point out that there are dependencies and relationships between the various levels of interoperability making them non-hierarchical in nature.

3.2 Metrics for GEOSS Interoperability

Because it is such an important goal of GEOSS it is important that there be agreement on the definitions and measures of interoperability. In describing the implementation of Pan-European interoperability for eGovernment services the European Commission (EC, 2006) defined the following:

1. **Technical Interoperabilty**, which is concerned with the technical issues of linking up computer systems, the definition of open interfaces, data formats and protocols. Syntactic interoperability could be considered part of technical interoperability.

2. **Semantic Interoperabilty**, the objective of which is ensuring the precise meaning of exchanged information is understandable by the people, applications and institutions involved;
3. **Organizational Interoperabilty**, which deals with modelling organizational processes, aligning information architectures with organizational goals, and helping these processes to co-operate; it includes data policy and entry barrier level topics.

All three facets of interoperability are important for GEOSS. Initially, however, it is the technical aspect of interoperability that we must be concerned with. Semantic interoperability is more difficult to achieve, although efforts are being made to reference, and eventually link, the vocabularies, taxonomies and ontologies used by the SBAs and CoPs in GEOSS. By its very nature GEOSS is unlikely to achieve a state of full organizational interoperability since those who control the contributed resources do not share the same operational objectives, business models or information architectures. Legal interoperability is, however, an important issue in GEOSS which must be addressed if full and open data sharing is to be fully realized. For example, access constraints, licensing and intellectual property rights issues fall under legal interoperability. GEOSS can facilitate legal interoperability from a technical standpoint by supporting single sign-on, encouraging attribution and displaying licensing information.

GEOSS has to accommodate a greater degree of heterogeneity than national SDIs (???) or systems serving a single discipline or community. Thus, the measures of interoperability must align with practical, achievable goals for GEOSS. Interoperability is relative to the intended application of the data and information that is being supplied by component systems. This suggests the need for "interoperability models" that are specific to SBAs, or specific endeavors within SBAs. As our interoperability assessment process progresses and we learn more about how the SBAs and CoPs achieve interoperability within their domains, we will determine appropriate interoperability models. For this initial assessment our focus is on the overall technical/syntactic, semantic, and legal interoperability within GEOSS.

4. GEOSS Common Infrastructure

The GCI consists of a number of core components, each of which is registered as a GEOSS resource. The registries include the Standards and Interoperability Registry (SIR), the Components and Services Registry (CSR), The User Requirements Registry (URR), and the Best ractices Wiki (BPW). The Clearinghouse (CL) provides the main catalog of resources for the GCI, and the GEO Web Portal (GWP) is the public face of the GCI.

The GWP is the gateway to the GEOSS for a typical user. It provides search and browse capabilities to discover data, as well as information to assist in accessing that data. In addition to just being focused on the data itself, the GWP will also make users aware of any access conditions or restrictions on the data. These can include attribution requirements, user registration, monetary charges, and other licensing information. The GWP interacts with the CL to gain the metadata needed to process a user's query for data. The CL can either harvest information or perform distributed searches to aggregate a data query response.

The CSR contains all the registered components and services that are either datasets or mechanisms for serving data. The terms "components" and "services" are often confusing. In the context of the GCI, components are registered resources that either stand alone for providing information about data and how it is accessible, or serve as a container for "services." Services are the programmatic objects, deployed and registered by data providers, that are responsible for providing and realizing the interoperability mechanisms necessary for sharing data. To a large degree, the services are web-based, in keeping with the Service Oriented Architecture that the GEOSS is built upon.

The SIR contains all the registered standards and special arrangements that the services in the CSR implement in order to achieve interoperability. The standards are recognized as national or international, and typically published and maintained by standards organizations. Special arrangements are not standards, but interoperability mechanisms that are typically widely used within a community or multiple communities. The SIR has a special relationship with the CSR, since interoperability is better managed and realized when registered services are associated with registered standards or special arrangements. This relationship has been captured in a programmatic coupling between the registries.

The URR is under development[1], but promises to provide a means for GEOSS users to identify with a user type, which will translate into knowledge to assist in finding the kinds of data desired. Semantics will also be introduced to assist the user and associated user type in identifying the data parameters of interest. The BPW provides the means of registering and maintaining documents that describe the "best" or "common" practices that communities enagage in for acquiring data, making data available, and processing data.

4.1 Component and Services and the Standards and Interoperability Registries

The analysis of the GCI was initially focused on collecting statistics from the SIR and CSR to look for any issues that could be identified as obstacles to interoperability. Statistics reveled small issues about the CSR current interfaces but also intrinsic problems in GEOSS interoperability.

Since interoperability within the GEOSS is based on the publish-find-bind use case, it is necessary for all registered components in the CSR to have at least one associated registered service in the CSR so that service binding can take place to access data. Figure 2 indicates how many services are associated with a component. The red bar in the figure shows that 185 registered components in the CSR have no associated registered services. Many of these are catalogs that contain large amounts of metadata records for available community data. This seems very high, but could also indicate that much more focus should be on communities rather than individual data providers.

In the process of binding with a service to access data, it is vitally important to discover what standards are being used to access the data and process it. If these associations cannot be found, then interoperability severely suffers. Additionally, the study revealed that some standards taxonomic categories could be associated directly to components because they are some how service independent but

[1] http://www.scgcorp.com/urr

the current CSR does not support such functionality. Figure 3 tallies the number of standards associated with registered services. An obvious observation is that the current standards used deal with syntactic interoperability and rarely with semantic interoperability. Multiple associations can happen by associating a single primary standard with the service, and multiple secondary standards with the service. As can be seen, most services are only associated with a single standard (in a particular version or profile). Although there is nothing inherently wrong with this, the limit of one associated primary standard prevents references to multiple versions and profiles of that standard being supported by the service, and, therefore, impedes interoperability for the data users. Additionally, documenting one standard makes data usage interoperability more problematic, because there are always at least 2 standards involved in getting and using data: a data access standards and a data format standard. Some standards organizations have initiated a more modular approach to standards definition so, in the near future, the need for combining multiple standards to interoperate with a system will increase. More effort most be done in capturing all standards involved in components and services.

Convergence on a set of standards is a goal of the SIF, since it can improve interoperability. Convergence of standards makes it less complicated for data users to access and use data from multiple data providers. The more standards that are available for data providers to associate their services with, the more effort that can be imposed on data users to support those standards in order to achieve interoperability. Figure 4 shows how many standards are registered in the SIR for the current standards taxonomy categories, and, as shown in red, how many standards in those categories are being referenced by services registered in the CSR.

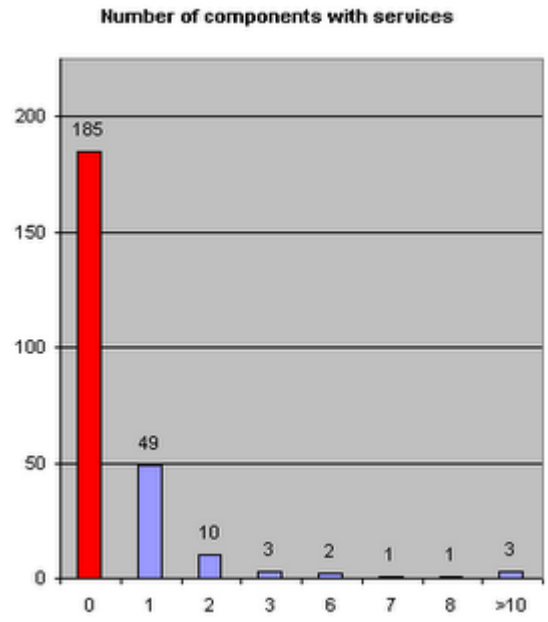


Figure 2. Number of components with associated services

The ICEO Standards Working Group in parallel conducts study on standards convergence in support of the SIF. At the November 2009 GEOSS Interoperability Workshop in Washington, D.C. it was decided to move forward with defining a user rating system for standards with separate criteria to cover technical- and user-driven

requirements as well as a score based on measured usage and the availability or not of other standards to meet the same needs. Since convergence on a core set of GEOSS standards would facilitate interoperability this is an area where more work is recommended.

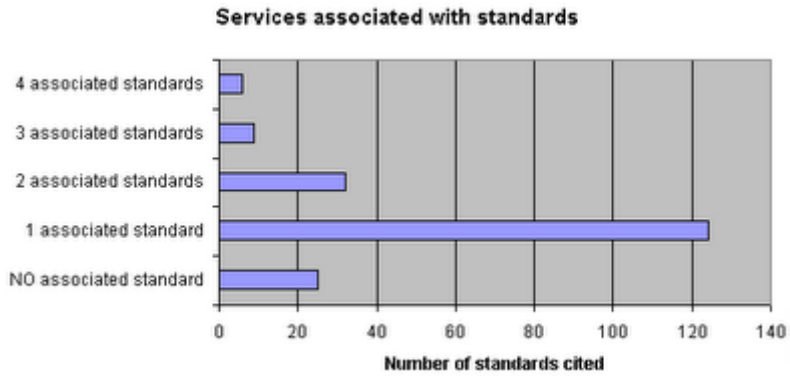


Figure 3. Number of standards associated with each service

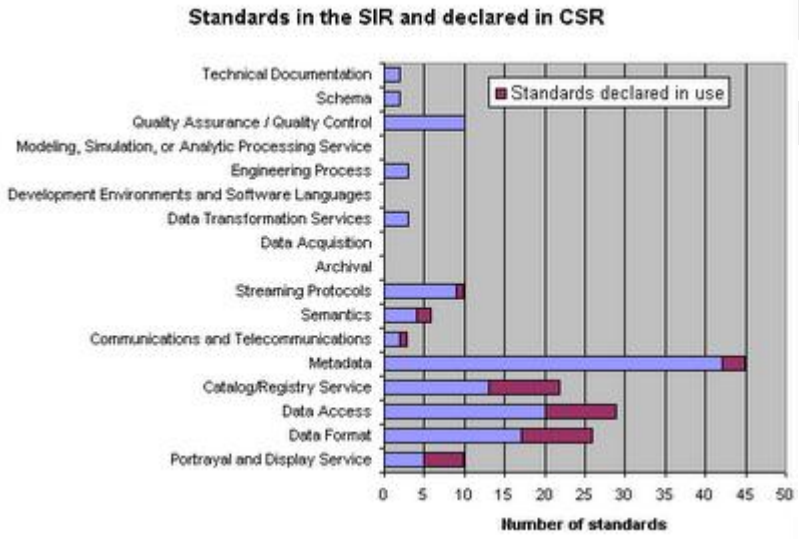


Figure 4. Standards registered in SIR, and referenced from CSR

Figure 5 shows how many references are being made to certain SIR entries by registered services in the CSR. Both Figures 4 and 5 show possible reasons why convergence of standards is desirable. Figure 4 shows that convergence is possible because current registered services are already prioritising a reduced subset of all the standards registered in the SIF. Particularly, Figure 5 shows that services use mainly 10 standards and the rest are referenced only lest that 5 times. Convergence will not result in the deletion of registered standards in the SIR, but will highlight the standards that are already most used and most useful to the data sharing community at large.

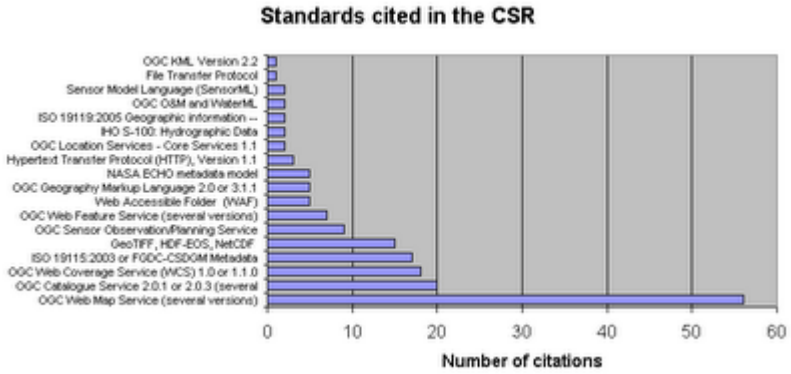


Figure 5. References to specific standards

GEOSS Common Infrastructure Analysis shows us the current state of the GCI and SIR registries. This analysis can not give us direct indications of the interoperability in GEOSS but it is a starting point to give us some clues and allow us to detect obvious problems. Nevertheless reproducing the same study in the near future future will give us clear indication if the interoperability is improving in GEOSS.

4.2 CSR and Clearinghouse catalogues

GEOSS has two data and services catalogues: the CSR catalogue and the GEOSS clearinghoure. The GEOSS CSR catalogue can be accessed by a web interface using the CSR URN of the resource (e.g. https://geossregistries.info/geosspub/component_details_ns.jsp?compId=urn:uuid:6a0fff42-8319-4723-8dfd-d1e62e6b8b2b) but also using CSW queries following the ebRIM profile using the same CSR URN (e.g. http://geossregistries.info:1090/GEOSSCSW202/discovery?SERVICE=CSW&Request=GetRecordById&Id=urn:uuid:6a0fff42-8319-4723-8dfd-d1e62e6b8b2b) and its content has been analyzed in the previous section.

The GEOSS clearinghouse is a big catalogue, based on the open source Geonetwork software, that includes the CSR records but expands on it and reinterprets them. When a record in a CSR points to a metadata catalogue, GEOSS clearinghouse harvests it and also includes all its records in the GEOSS clearinghouse. The clearinghouse can harvest Z39.50 "GeoProfile", CSW 2.0.2 baseline, AP ISO, ebRIM (with no extensions), FGDC CSDGM Version 2, WebDAV, sitemaps, and Web Accessible Folders (WAF), local file access for batch ingest of packaged, static metadata, THREDDS Catalog, OAI-PMH, ISO 23950 "SRU" and GeoNetwork "native". We can see that the clearinghouse has a very good interoperability with other catalogues and data services but it is not able harvest all the catalogue standards registered in the SIR. The GEOSS clearinghouse converts each metadata record to a ISO 19139 XML document using a set of XSL transformations. When a record in the CSR points to an OGC GetCapabilities (WMS, WFS, WCS) endpoint it is also harvest its ServiceMetadata document (GetCapabilities) and converted to ISO 19139. This results in a duplication of information in two records, one for the CSR record (e.g. http://clearinghouse.cisc.gmu.edu/geonetwork/srv/en/iso19139.xml?id=215153) and another for the

ServiceMetadata document (e.g. http://clearinghouse.cisc.gmu.edu/geonetwork/srv/en/iso19139.xml?id=41008).

The GEOSS clearinghouse exposed the data in at least four different catalogue formats: CSW in ISO profile (e.g.: http://clearinghouse.cisc.gmu.edu/geonetwork/srv/en/csw?SERVICE=CSW&Request=GetRecordById&Id=urn:geoss:csr:component:urn:uuid:6a0fff42-8319-4723-8dfd-d1e62e6b8b2b&ElementSetName=full&outputSchema=http://www.isotc211.org/2005/gmd), in Dublin core (e.g.: http://clearinghouse.cisc.gmu.edu/geonetwork/srv/en/csw?SERVICE=CSW&Request=GetRecordById&Id=urn:geoss:csr:component:urn:uuid:6a0fff42-8319-4723-8dfd-d1e62e6b8b2b&ElementSetName=full) in RSS simple queries (e.g.: http://clearinghouse.cisc.gmu.edu/geonetwork/srv/en/rss.search?uuid=212987ef-7268-4f27-bd85-bfcf0bc49939) and in ISO 23950 "SRU" that guaranties good interoperability with other catalogues and clients.

For each record the GEOSS clearinghouse uses an internal numeric id and a URI in the form of a UUID. Since an OGC service is harvested from the CSR and from the service itself, sometimes this results in 4 different identifiers for the same resource. This is not an interoperability problem but we recommend exposing only a single URI for each record and try to eliminate duplications that comes form different sources. By doing so, catalogue clients can provide better and unambiguous results.

GEOSS clearinghouse supports several catalogue protocols for harvesting (input) and for querying (output) demonstrating good interoperability. Unfortunately, there are not many catalogue clients that explode the GEOSS clearinghouse apart from the ESA FAO Geo Web Portal. There is a need to generate tutorials and other materials to stimulate the use of the GEOSS Clearinghouse by other catalogue clients and disseminate the GEOSS content.

4.3 Geo Web Portal

The Geo Web Portal (Albani, 2008) is a user oriented interface providing convenient access to the full range of GEOSS data and information. A set of portal requirements were originally defined by the Geo Secretariat and a number of other candidate web portals were proposed, most notably those by COMPUSULT [http://www.geowebportal.org] and ESRI [http://geoss.esri.com]. While this present paper analyses the experience of the designated Geo Web Portal with respect to interoperability it is very positive to note that the other portals are also operational and fulfil many of the original requirements and this is further complemented by the community portals accessible through the Geo Web Portal as well as directly from their registration in the GCI.

The Geo Web Portal provides many on-line functionalities (a full listing is provided at http://geoportal.org/web/guest/geo_about) of which the key features that exploit interoperability are (1) access to the GEO Clearinghouse, (2) visualization of geographical information, maps and imagery from various sources and (3) access information from GEONetcast. All of these three requirements are testable and are met by the Geo Web Portal. Searches at the interface allow one to navigate to a variety of data providers identified as GEOSS resources and the use

of the clearing houses is then implicit (and importantly for a portal user this is carried out transparently). The Map Viewer provides a number of defined external WMS that work well and adding a valid URL either selected from the CSR, or elsewhere, also provides the expected map layer. However, some URLs from the CSR fail, either becaus there is an error in the original CSR entry or the referred URL had been updated; that is an indication of the importance of maintaining accurate registry contents.

In summary, the Geo Web Portal has met the required interoperability targets but is reliant on accurate information being held in the harvested resources. Albani (2011) further points out that there are semantic problems to overcome; for example the SBA subcategories so far defined include terms that are either rarely used, too restrictive or too wide and, similarly to as found by this analysis, there are some incoherencies between local information on GEO Web Portal and information coming from Clearinghouse for GEOSS registered resources. The Geo Web Portal is also a work in progress and further improvements in interoperability are planned (Albani 2011):

- Improve interaction between search results and visualization
    - e.g. directly open standard services in GWP viewer (e.g. WMS)
- Improve viewer and display of WMS, WFS, WCS on the portal
- Enhance the globe and its capabilities
    - e.g. Google Earth portlet, RSS visualization
- Display of data sharing information
    - e.g. Data access conditions

that further strengthen the functionality of the portal.

A portal is only effective if it is exploited by end-users. Using a third party web traffic ranking engine (alexa.com) the portal was ranked at over 2 million (in comparison Google has a rank 1, IEEE ~3K, and esa.int ~18K … at the time of writing). One cannot assert too much significance to these figures since their exact origin is unknown and they are mere snapshots, but the overall impression is that the Geo Web Portal effectively provides an excellent interface to intreroperable services, but, as for the rest of the GCI, users need to be encouraged to make use of the resources that have been tied together. An effort is also required to bring key stakeholders to the web portal (e.g. decision makers) and walk them through the functionality and discern what level of information would be important for them.

5. Community Outreach

The SIF has an ongoing mission of education and outreach. Until recently, this has been primarily focused on data providers contributing individual services to the GEOSS. Assisting data providers and users with standards and interoperability has been accomplished via e-mail and the Architecture Implementation Pilot (AIP) program. More currently, the SIF has come to understand that a focus on communities is essential going forward, and decided to include an outreach activity in the interoperability assessment.

5.1 Community Survey on Interoperability

The SIF performed community outreach for this interoperability assessment to gauge the level of interoperability that communities have collectively achieved, to identify the interoperability impediments that communities face, and to determine what the relationships are between the communities and the GEOSS. The SIF engaged select communities to accomplish this outreach, beginning with a pilot study to assist in formulating the final questions for the general survey (OPP 1992). Through structured questions the survey design is intended to ascertain:

a. How easy is it for the community to discover, access, understand, share and integrate data from various systems within the community and systems outside the community?
b. The level of technical interoperability achieved, the standards in use and the impediments experienced.
c. Whether common lexicons, taxonomies, or ontologies employed and/or mainatained by the community?
d. What progress is achieved in Sematic Interoperaberability? Are any IT standards being used to achieve semantic interoperability, such as RDF, OWL, SPARQL, GML, and other W3C Semantic Web standards?
e. The commitment of the community to GEOSS

Once the pilot phase was completed, the survey was made available on a limited basis, although a more broadly disseminated surey is envisioned. The strategy for the limited survey was to have leaders in the communities hand pick the respondents to ensure that completed surveys reflect the knowledge of those who have expertise in the various categories being surveyed. Legal interoperability was not surveyed, since very few example implementations of this currently exist, but issues concerning security risk and the removal of responsibility to provide data that may arise in an open data architecture were expressed by particpants of the first Pilot Telecon. The Pilot Telecon also revealed serious concerns in the area of organizational interoperability because this often relies on management commitment and large agencies already supplying data need to make an extra investment to develop semantic interoperability in order to go beyond and expand their acknowledged customer base.

The limited release survey consisted of 9 respondents. These respondents represented 9 different organizations. The key results found from the limited release of the survey are summarized here:

- Funding for interoperability lags behind the realization of its need.
- True understanding of interoperability is not widespread.
- Communities generally do not have a legal obligation to interoperate (especially outside the community).
- Legal interoperability is viewed as an imperative.
- 50% of the respondents have not used the GEOSS for interoperability successes yet.
- None of the respondents has fully embraced the GEOSS, but all are either in the process of doing so or have future plans to.
- Harmonization of data and quality of data are impediments to interoperability.
- 67% of the respondents are using community standards or non-standards, not international standards.

- Standards are hard to implement, a major factor being a lack of resources to invest.
- Better outreach and assistance needed.

Although these points come from a limited release survey, they seem to coincide with responses gathered from informal conversations with scientists and managers at conferences and workshops.

5.2 Community Architecture Considerations

Some of the key findings from the community survey point to issues that are not easily addressed by the GCI. In particular, these include harmonization of data, quality of data, and lack of resources to implement standards. To a large degree, these are issues handled best by the communities, since they have a built-in desire and need to do it. However, when these issues are handled by communities separately the vision of sharing data globally, across disciplines and communities, is not typically served well. The idea of community brokers or mediators, software components that are built for the specific purpose of assisting the interoperability between diverse data access and use standards, can be used to address the issues raised by the survey.

Following is a set of evolutionary stages that communities can find themselves in with respect to interoperating with the GEOSS. Stage 4 is where many communities are heading, and where the GCI, arguably, should anticipate being in order to achieve the most interoperability globally. The presented stages build upon the current GCI architecture and do not replace it. The goal is to accommodate community efforts without penalizing community providers, and without losing their connection with the GEOSS and the GCI.

The different stages of community evolution with respect to the GEOSS are defined as follows:

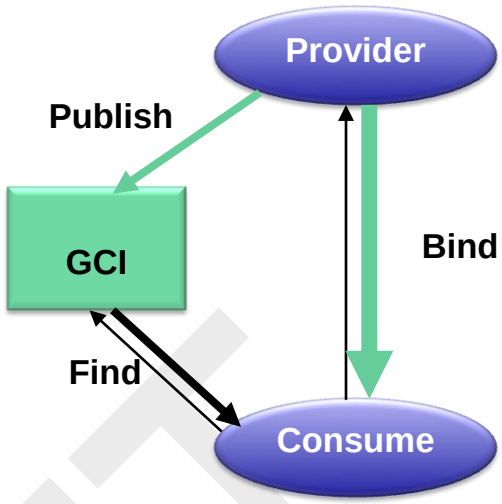
- **Stage 0** is when there is no discernible community, just individual providers.
- **Stage 1** is when there is a designated community, but the members of the community still behave as individual providers.
- **Stage 2** is when the designated community supports its own registries for standards and/or services.
- **Stage 3** is when the designated community supports its own registries and its own broker/mediator for interoperability.

Stage 0

The **Stage 0** evolution does not recognize a community, just a set of single providers using the GCI.

- It currently exists.
- It requires registration of resources in GCI.
- It is GCI-focused.

1. Single provider registers service interface or data pointer in the GCI, using interoperability arrangements provided in the GCI.
2. Consumer accesses data from provider using registered information (access URL, interoperability arrangement).

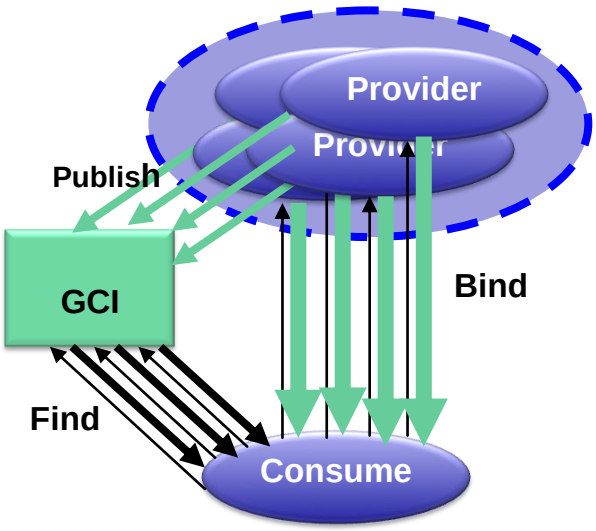


Stage 1

The **Stage 1** evolution recognizes an operational community, but operating as a set of single providers using the GCI.

- It currently exists.
- It requires registration of resources in GCI.
- It is GCI-focused.

1. Community providers register service interfaces or data pointers in the GCI, using interoperability arrangements provided in the GCI.
2. Consumer accesses data from community providers using registered information (access URL, interoperability arrangement).

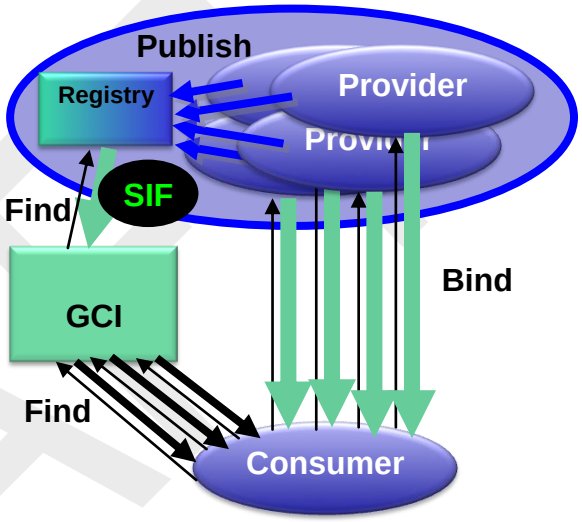


Stage 2

The **Stage 2** evolution recognizes a community using its own registries, but still operating as a set of single providers using the GCI. This stage of community still uses the GCI to achieve interoperability.

- It requires registration of community registries.
- It is more community-focused.

1. Community providers register service interfaces or data pointers in their community registry, using interoperability arrangements provided in the GCI.
2. The community registers its registry in the GCI, using interoperability arrangements provided in the GCI, and GCI harvests or searches that community registry.
3. Consumer accesses data from community providers using registered information (access URL, interoperability arrangement).

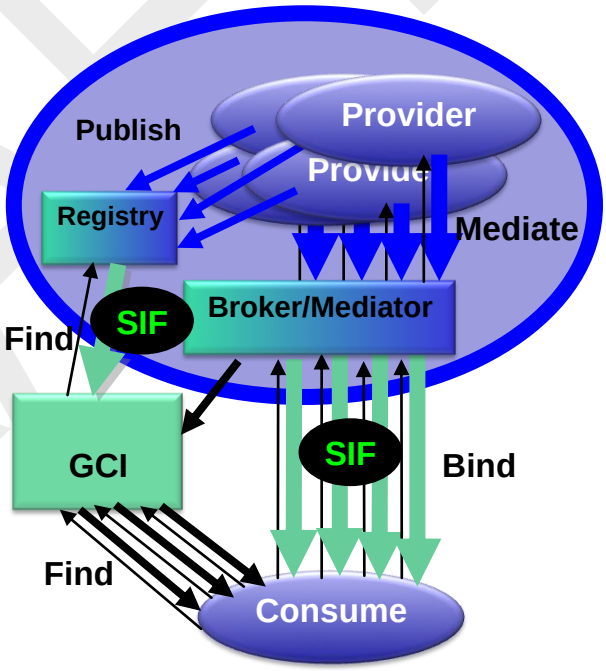


Stage 3

The **Stage 3** evolution recognizes a community using its own registries, and its own interoperability arrangements. This stage of community operates independent of the GCI, but can still use the GCI to support GEOSS interoperability via the mediator. The mediator can also deal with issues such as licensing, adjustments to metadata, etc. so that providers don't have to.

- It requires registration of community registries.
- It requires registration of community interoperability broker / mediators
- It is fully community-focused.

1. Community providers register service interfaces or data pointers in their community registry, using interoperability arrangements provided by the community.
2. The community registers its registry and broker / mediator in the GCI, using interoperability arrangements provided in the GCI, and GCI harvests or searches that community registry.
3. Consumer accesses data from community providers using registered information (access URL, interoperability arrangement) about the broker.



6. Conclusions and Recommendations

Preliminary recommendations arising from the interoperability assessment as well as from related work carried out in the Standards and Interoperability Forum:

R0 Interopability is achieved and demonstrated in the GCI, including the registeries, clearing house and geo web portal. There are also alternative ways to access the same data (e.g. see the clearing house analysis). However, interoperability is not fully exploited due to a lack of users leveraging the GCI and its various interfaces. Methods to engage users include reaching out to communities (see more details in R3) and provide more guidance to users through tutorials and cook book documentation.

R1 Lessons learned with the operations of the GCI until now must be taken into account to further develop the registeries to support interoperability. For example, the registeries only allow one associated primary standard and prevents references to multiple versions and profiles of that standard being supported by the service, and, therefore, impedes interoperability for the data users.

R2 Convergence on standards is an important goal and next step to further interoperability as indicated by analysis of the current registry holdings.

R3 More engagement with GEO communities is required to take benefit from interoperability already achieved within the respective domains, including:

- identification of interoperability achieved within existing communities and development of their relationship to GEOSS and the GCI
- through consultation with communities define mechanisms to enhance interoperability within GEOSS

R4 Facilitate semantic interoperability within GEOSS for users to access and fully understand GEOSS resources, supporting this with the development of GEOSS taxonomies and ontologies

R5 Establish metrics to measure the level of interoperability achieved and monitor the evolving performance of GEOSS and through monitoring interoperability metrics maintain effective performance of the GCI

R6 Assess requirements for interoperability related to data restrictions, rights, attribution, provenance, etc (legal interoperability) and align these with the GEOSS Interoperability Principles and GEOSS mission objectives and ensure the proper attribution of contributions.

R7 Establishs relationships with communities that promote their own self-evolutionary paths, yet maintain the interoeprability possibilities with the GEOSS through community registries and community brokers/mediators.

R8 Work with communities to establish a reference architecture and design for community components such as registries and brokers/mediators.

7. References

Albani M., The ESA-FAO GEOportal - Operational Gateway to GEOSS, March 2008, Earthzine [www.earthzine.org], March 2008. http://www.earthzine.org/2008/03/11/the-esa-fao-geoportal-%E2%80%93-operational-gateway-to-geoss/

Albani M.,GCI short term evolution - GEO Web Portal, GEO Architecture & Data Committee meeting Campos do Jordão, Brazil, 2011

Carney D., Fisher D., Morris E., Place P., Some current approaches to interoperability,Technical Note CMU/SEI-2005-TN-033, Copyright 2005 Carnegie Mellon University, August 2005.

CoPs 2011. "GEO Communities of Practice" Website accessed 3 February 2011. http://www.earthobservations.org/cop.shtml

EUROPEAN COMMISION 2006, Interoperability for Pan-European eGovernment Services , Brussels, 13.2.2006 COM(2006) 45 final

EVAL 2010. "Mid-term Evaluation of GEOSS Implementation", http://www.earthobservations.org/docs_od_ple.shtml

GIGAS 2010. A. Biancalana, S. Nativi, et al. "GIGAS Comparative Analysis Technical Note", GIGAS project deliverable D2.3b, Dec 2009
//// Is this GIGAS 2009 ???? ////

GEO 2005 "Global Earth Observation Systems of Systems – GEOSS – 10-Year Implementation Plan", GEO 1000 / ESA BR- 240, February 2005, Published by ESA, The Netherlands

Manso and Wachowicz (2009), M.-Á. Manso and M.Wachowicz, GIS Design: A Review of Current Issues in Interoperability , Geography Compass 3/3 (2009): 1105–1124, 10.1111/j.1749-8198.2009.00241.x

Onsrud 2010. Harlan J. Onsrud, “Legal Interoperability in Support of Spatially Enabling Society”, http://www.gsdi.org/gsdiconf/ gsdi12/papers/907.pdf

OPP 1992. A. N. Oppenheim, “Questionnaire Design, Interviewing, and Attitude Measurement”, ISBN 1855670437 (HBK) 0826451764, 1992