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ABSTRACT

Geoportals are a consolidated web-based solution to provide open spatial data sharing and online geo-information management. Their roles and possible advancements according to the Digital Earth vision and implementation require investigations. This paper presents a review of the literature concerning geoportals and serves the following primary purposes. First, various geoportal approaches for discovering and accessing Earth observation data and geo-information, mainly with scientific purposes, are summarized according to their characteristics and functionalities. Second, current major challenges in geoportals are identified in terms of functionalities, technologies, and especially big data support, from geoportal cases of China. Finally, based on lessons learned from the international and Chinese geoportals, solutions and recommendations for the challenges in geoportals are proposed in terms of their architectures, services, and technologies. The results show that geoportals usually provide access to distributed data systems, offering maps, data discovery, and data downloads. Some of them are also capable of offering online analysis and processing service, enhanced semantic search engines, and dynamic visualization tools. The strength of geoportals could lead to a full-fledged online Digital Earth system that could provide better data sharing and dissemination solutions to the challenges posed by big data.

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1. Introduction

The amount of spatial data and geo-information have increased at an exceptionally fast rate due to rapid advances in space and other Earth observation technologies, as well as photogrammetric and surveying methods. The tendency of merging natural science and social science, and geo-referenced social media data and other data with coordinated attributes delivered from crowd-sourced observing systems also accelerate the increase (Goodchild 2012; Goodchild et al. 2012; Craglia et al. 2012; Guo, Wang, and Liang 2016; Scott and Rajabifard 2017; Goodchild 2018). Therefore, the era of big Earth data arrives (Guo et al. 2016), the challenges have been encountered to manage a huge amount of spatial data and geo-information in a systematic and logical way and also to effectively and efficiently interact with end users.

Over the past few decades, the concept of geoportals has emerged as one of the key solutions for spatial data and geo-information accessing and sharing. Recently, geoportals have played a dominant part in facilitating users to access and manage a huge volume of spatial data and geo-

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information through the Internet. Increasing interests for geoportals shows the usefulness of geoportals in the big Earth data era. Specifically, with an analysis of Google hits, a search count for the keyword 'geoportal' was 182,000 in 2007 (Goodchild, Fu, and Rich 2007), but is more than 4,000,000 hits in 2017. Using date constraints in the search also shows 47,344 hits until 2007 and 576,244 until May 2017. In addition, according to Google Trends, the search trend for geoportal shows a clear increase in the period 2008–2015, and then a small decrease followed by a stable interest at 75% of the peak. This may reflect that geoportals have reached their maturity.

The definition of geoportals and the mechanisms by which technology employed still differ depending on objectives of the geoportals (e.g. Gong et al. 2012; Vockner, Richter, and Mittlböck 2013; Innerebner et al. 2016). But, generally, a dictionary definition of 'portal' is an access or entry point. A geoportal is, therefore, a point of access to spatial data and geo-information. It is able to provide a geospatial data inventory linking to an inclusive collection of spatial data, geographic information, online services, and data processing tools. In this article, the use of the term 'geoportal' refers to the human-to-machine interface performing as a single point-of-access to spatial data and geo-information systems, offering sharing capabilities and connecting between geospatial data providers and end users. It is typically employed as a web-based graphical user interface (GUI) equipped with functionalities for accessing Earth observation data and geographical information. Besides that, this paper also broadens the discussion to infrastructure aspects from a system engineering perspective. This is because the functionalities that geoportals can provide are very much related to the capabilities of the underlying infrastructure.

Therefore, this article presents a review of geoportals particularly on issues related to adopted technologies and functionalities to serve the following primary purposes. First, various geoportal approaches for discovering and accessing Earth observation data and geo-information, mainly with scientific purposes, are summarized according to their characteristics and functionalities. Second, current major challenges in geoportals are identified in terms of functionalities, technologies, and especially big data support, from geoportal cases of China. Finally, based on lessons learned from the international and Chinese geoportals, solutions and recommendations for the challenges in geoportals are proposed in terms of their architectures, services, and technologies. To achieve the purposes, this article uses the following steps. First, the major international and national initiatives that have developed geoportals in the recent past are summarized into an inventory. Second, characteristics of the selected international geoportal cases for scientific use are analyzed. Third, potential challenges for Chinese geoportals are recognized and discussed. Finally, the emerging trends and innovative suggestions in terms of geoportal functionalities are proposed, and their potential usages are outlined for future geoportal projects.

2. A literature review of the major geoportal in international and national level

2.1 The origins of geoportals

The 'geoportal' term was first used in the scientific literature in 2005 (Maguire and Longley 2005), it refers to a web environment that acts as a gateway to connect with a Spatial Data Infrastructure (SDI) (Tumba and Ahmad 2014). Additionally, researchers considered that, from a technological perspective, one of the key elements of a regional or global SDI is the capability of searching for viewing, transferring, ordering, advertising, and disseminating spatial data from numerous sources from the Internet. This emphasizes the importance of the geoportal solution because geoportals are able to act as an entry point to these geospatial data-oriented systems. Besides the term 'geoportal', the term 'spatial web portals' is also widely used for defining a web-based gateway to access and manipulate geospatial data in the world via the Internet (e.g. Yang et al. 2007; Xia et al. 2015). The following literature review includes the portals that are developed under the name of both 'spatial web portals' and 'geoportals'.

2.2 Geoportals development driving forces

At their early development stage, geoportals were designed to be a sort of 'yellow page' service, providing links and addresses pointing to data. For example, the catalogue geoportals focused primarily on organizing and managing discovery of and access to all geospatial data and spatial information resources in the form of links and queries (Maguire and Longley 2005; Gong et al. 2012). These types of geoportals are usually deployed with simple website structures, making less use of advanced geospatial technologies (Wenjue, Yumin, and Jianya 2004). The advances of geoportals are coming from the following four drivers: (i) scientific geospatial projects and applications, (ii) international organizations, (iii) governmental agencies, and (iv) commercial purposes (refer Table 1).

2.2.1 Scientific geospatial projects and applications

One main driving force of geoportal development is the demand for geospatial data delivery from the scientific data owners, who are taking roles in scientific projects and applications. These data delivery geoportals are typically setup by these data owners (Mehdi et al. 2014) and give access to Earth observation data and geospatial products. The PNOA Portal is an example of a data delivery portal aiming to disseminate orthophoto products (Hernandez-Lopez et al. 2013). Also, these geoportals can grant users access to the data possibly with some added value services (e.g. format mapping, coordinate reference system transformation). These geoportals are meant to be set up for providing online, dynamic geographic web services on specific research domains (Maguire and Longley 2005; Gong et al. 2012). The main application domains are agriculture (Deng et al. 2013; Chen, Xiang, and Chao 2015), disaster and early warning (Martinelli and Meletti 2008; Pessina and Meroni 2009; Heim and Brewer 2012; Altartouri et al. 2013; Brennan and Corbett 2013; Currenti et al. 2014; Fago et al. 2014; Lathrop et al. 2014; Le Cozannet et al. 2014; Oliveira et al. 2014; Simeoni, Zatelli, and Floretta 2014; Albano, Sole, and Adamowski 2015; Bourova et al. 2016; Chen et al. 2016; Mazzetti et al. 2017), land (Mathiyalagan et al. 2005; Shi et al. 2010; Karantzalos, Bliziotis, and Karmas 2015; Xing, Chen, and Zhou 2015), water (Lu et al. 2014; Dahlhaus et al. 2016), urban planning (Lindenbeck, Ulmer, and Schulz 2007; Mansourian, Taleai, and Fasihi 2011), air quality (Carr, Rich, and Bartley 2008; Poorazizi and Alesheikh 2011; Schultz et al. 2015; Wiemann et al. 2016), and energy (Vosgerau et al. 2016).

2.2.2 International organizations

Geoportals can be promoted and constructed by international organizations, whose aim is to share Earth observation data from heterogeneous data sources. Examples are the Global Earth Observations System of Systems (GEOSS) Portal[1] developed in the context of the Group on Earth Observations (GEO) and the Committee on Earth Observation Satellite (CEOS) portal (Anderson et al. 2017). Countries who are members of these international organizations have also developed their own systems often including dedicated geoportals. For example, China GEOSS,[2] AmeriGEOSS,[3] and the planned EuroGEOSS[4] are conceived as GEOSS regional hubs. Meanwhile, GEO is promoting thematic geoportals for addressing specific users' needs, e.g. GEO supersites for the study of natural hazards in geologically active regions[5] and the GEOSS Community Portals. Since they need to connect many Earth observation systems, no matter international, national or local, these geoportals are part of a System of Systems (SoS) architecture, e.g. the GEOSS Platform (formerly GEOSS Common Infrastructure). The WDS Data Portal is another example driven by an international organization, in this case the International Council for science (ICSU), providing access to currently available metadata catalogues using international and community standards.[6]

2.2.3 Government

Other geoportals are constructed by governmental interests, either because of the concept of open government, which requires central government seeking to make the majority of governmental data publicly available, or because of the duties from the geospatial agencies.

Table 1. An inventory of geoportals.

Name	Driving force (*scientific projects (SP), international organizations (IO), governmental agencies (GA), companies and others (CO)*)	Main stakeholder or coordinator	Scope (*international, national)*	Website
European geoportal – INSPIRE	GA	Joint Research Centre (JRC) of the European Commission	International	http://inspire-geoportal.ec.europa.eu/discovery/
US Geospatial One-Stop and US Geo portal	GA	US government	National	http://(Geo.)Data.gov
GEOSS portal	IO	GEO	International	http://www.geoportal.org/
USGS GEO data portal	GA	USGS	National	https://cida.usgs.gov/gdp/
US National Carbon Sequestration Database and Geographic Information System	GA	US Department of Energy	National	http://www.natcarbviewer.com/
Finland geoportal	GA		National	http://www.paikkatietoikkuna.fi/web/en
India Geoportal	GA	India government	National	https://data.gov.in/
Czech Republic geoportal	GA		National	http://www.cuzk.cz/en
China geoportal	GA	China GEO	National	http://www.chinageoss.org/dsp/home/index.jsp
France geoportal	GA		National	https://www.geoportail.gouv.fr/
Poland geoportal	GA	Surveyor department of Poland	National	http://geoportal.gov.pl/
National library of Australia portal	SP	National library of Australia	National	http://trove.nla.gov.au/
CEOS WGISS Integrated Catalog (CWIC) portal	IO	Committee on Earth Observation Satellite	International	http://cwic.wgiss.ceos.org/
CEOS Spain portal	IO	CEOS Spain	National	http://ceosspain.lpi.uv.es/
Petlab	SP	GNS Science, New Zealand	National	http://pet.gns.cri.nz
Near-Earth Space Data Infrastructure Data portal	SP	EU-FP7	International	http://www.espas-fp7.eu
EuroGEOSS Discovery portal	IO	EU	International	http://www.eurogeoss-broker.eu/
ManUniCast	SP	University of Manchester	National	http://manunicast.seaes.manchester.ac.uk/
GPlates Portal	SP			http://portal.gplates.org
DRIHM portal	SP	EU	International	http://www.drihm.eu/
PREVIEW portal	SP	University of Geneva	International	http://preview.grid.unep.ch
U.S. drought portal	GA	NIDIS and the NOAA National Climatic Data Center	National	https://www.drought.gov/drought/
PNOA Portal	SP	The Regional Development Institute at the University of Castilla-La Mancha	National	http://ide.jccm.es/pnoa
OPS Portal	SP	University of Kansas	International	

(*Continued*)

Table 1. Continued.

Name	Driving force *(scientific projects (SP), international organizations (IO), governmental agencies (GA), companies and others (CO)*	Main stakeholder or coordinator	Scope *(international, national)*	Website
				http://ops.cresis.ku.edu/
Canada Open data	GA	Canada government	National	http://open.canada.ca/en
CIPRES Science Gateway	SP	Supported by NSF US	National	http://www.phylo.org/
DRIHM portal	SP		International	http://www.drihm.eu/
Lithuania geoportal	GA	National Centre of Remote Sensing and Geoinformatics	National	http://www.geoportal.lt/geoportal/en/web/en
Copernicus Open Access Hub	SP	EASA	International	https://scihub.copernicus.eu/
ICSU-WDS Data Portal	IO	WDS	International	http://www.icsu-wds.org/services/data-portal
Copernicus Open Access Hub	GA & SP	EASA	International	https://scihub.copernicus.eu/
EOSDIS	GA & SP	NASA	International	http://search.earthdata.nasa.gov/

These portals, which were built by answering the open government call (or named the e-government), act as the gateways, anchors, or major starting sites for governmental data, no matter whether the data is spatial or non-spatial in nature. Therefore, these geoportals are constructed with the objective of building electronic infrastructure for e-governments and for openly publishing government data (Beaumont, Longley, and Maguire 2005). Openness and transparency are fundamental to ensuring citizens' trust in their governments. Thus the objective of a government geoportal is to foster greater transparency and accountability, providing information available to the public from digital technologies. The government geoportal of the United States (U.S.) is one example of such an open government policy. Starting from the Geospatial One-Stop (GOS) initiative (Goodchild, Fu, and Rich 2007), the U.S. federal government gradually set up a web-based geospatial platform,[7] which aims to provide shared web services for significant national datasets including geospatial datasets. With reference to and partnership with the U.S., the India geoportal[8] followed the same pattern. An Open Government Partnership (OGP) formally launched in 2011 accelerated open government policy and government geoportal plans to be carried out for countries like Canada, Brazil, Indonesia, Mexico, Norway, the Philippines, South Africa, the United Kingdom, and the U.S.[9]

Another type of portal service driven by governments is from the geospatial agencies that have obtained large amounts of geospatial data and information, e.g. satellite mission agencies, and surveying and mapping agencies. These agencies built the geoportal for distributing their data and information, adopting the policies of open data, especially for data in the geospatial domain. The geoportals designed for satellite mission are the entry point to provide satellite imagery datasets. In most cases, these geoportals are developed in the context of Earth observation data, and the available data and products are coverage type datasets. For instance, the European Space Agency (ESA) Copernicus Open Access Hub provides complete access to the Sentinel satellite data,[10] and the NASA Earthdata portal allows interactive data discovery and downloads for the NASA satellite missions.[11] On the other hand, another type of the geoportals was born as the answer to the SDI to share specific spatial data layers, which has a more strict and mandatory approach for the data format and data type. One example is the Infrastructure for Spatial Information in Europe (INSPIRE) geoportal developed by the European Union (EU), in the context of the INSPIRE Directive. The INSPIRE geoportal gives access to geospatial datasets related to 34 themes from the 28 member states of the EU (European Environment Agency 2014). Besides facilitating the construction of the international INSPIRE geoportal, the member states applied the INSPIRE Directive also developing their own national portals to be adaptive to international objectives (Pashova and Bandrova 2017). Many examples of geoportals are implemented in line with the EU INSPIRE Directive in France,[12] Finland,[13] Czech Republic,[14] and Poland (Zwirowicz-Rutkowska 2016), and on-going activities in that direction in Western Balkan countries (Cetl, Tóth, and Smits 2014).

2.2.4 Commercial purposes and others

Industrial and commercial enterprises are also paying attention to geoportals. Thus another category of geoportals is coming from commercial interests, the 'commercial geoportal'. This is because Earth observation data commercial providers are willing to build geoportals for their satellite image data and geo-information products, e.g. the Digital Globe geoportal,[15] hexagon geoportal[16] (Dold and Groopman 2017), and the Chinese commercial TripleSat constellation.[17] Another type of geoportals is the digital library geoportals, which connect users to digital resources, including geospatial datasets, e.g. Big Ten Academic Alliance Geoportal,[18] an initiative of U.S. universities. However, these types of geoportals are not going to be discussed further in this review, because this review aims to concentrate on those geoportals developed and demonstrated for the scientific community.

2.3 Summary of the geoportal analysis

2.3.1 Data type

Data is the content that geoportals provide to end users. A single geoportal may provide heterogeneous geospatial datasets coming from multiple data sources. The data format and data type may differ, but it is possible to classify them into two macro-categories: geographical datasets and Earth observation datasets. Geographical datasets include maps and feature-based datasets, such as cadastral maps, national and regional boundaries, and other GIS-type data and information. Earth observation datasets are derived from in-situ or remote sensors (e.g. satellite-based sensors). In some contexts, the use of the term 'Earth Observations' might be limited to remote sensing datasets. Geoportals can provide remote sensing observation and products, e.g. Landsat 8 multispectral imagery (Karantzalos, Bliziotis, and Karmas 2015), SPOT-5 satellite images (Lu et al. 2014), and Moderate Resolution Imaging Spectro-radiometer (MODIS) data (Craciunescu et al. 2016). In addition, Geoportals may provide survey data like time-series topographic maps or geological maps (Jayakumar and Malarvannan 2016; Vosgerau et al. 2016). Geoportals can also offer model data, such as digital terrain models (DTM) (Granell, Diaz, and Gould 2010). Furthermore, geoportals serve not only the model output but also the possibility to run online geo-processing models (Goodall et al. 2008). Data generated from geo-referenced in-situ measurements such as wireless and wired sensors is another source for geoportals (Chen, Xiang, and Chao 2015). Finally, new data types like public participation data (Mansourian, Taleai, and Fasihi 2011), volunteered geographical information (Bordogna et al. 2016), and near real-time data (Deng et al. 2013) also provided allowing to better understand the phenomena these data depict (Shu 2016).

2.3.2 Data harmonization

Some geoportals not only provide data as they come from the original source, but they are also able to provide spatial data and geo-information coming from different sources into a common (i.e. standard) format. This process is referred to as *data harmonization*. Data harmonization can help to receive, process, and exchange data, and to ensure interoperability, because the harmonized data and information are accessible to end users at their demands. The data harmonization process is usually enabled by the underlying distributed infrastructure connecting the heterogeneous data sources.

Two approaches can realize data harmonization: the federated approach and the brokered approach.

The federated approach requires participants to agree on common specifications in terms of metadata, data models, and service interfaces (Fa et al. 2016), typically based on international de-jure or de-facto standards. The federated approach is usually adopted in systems based on services, i.e. a Service Oriented Architecture (SOA). The federated approach is able to play meaningful performance in controlled environments, where a strong legal framework ensures that stakeholders implement the agreed and approved standards and protocols (e.g. the NSDI of U.S. and INSPIRE of E.U.) (Mazzetti and Nativi 2012).

The brokered approach leverages middleware between the client and the server tiers by addressing heterogeneity through mediation (i.e. of metadata and data models) and adaptation (i.e. of interfaces). In the brokered approach, the brokers as key component are dedicated to mediation and harmonization. The brokered approach has been particularly appealing for those wanting to build Systems-of-Systems, e.g. distributed infrastructures connecting systems, which keep their autonomy at a certain degree. This approach has been successfully adopted by GEO in the GEOSS architecture (Nativi et al. 2015). It has also been demonstrated useful for data harmonization in the integration of high-performance computing (HPC) services and e-infrastructures for spatial data (Mazzetti et al. 2016).

For the Federated approach, it normally deploys a clearinghouse for the data register. All the resources are ingested into one clearinghouse, and then are transformed into a mandatory pre-defined format template for the coming data exchange and processing. For the brokered approach, it is able to mediate across the different systems, mapping metadata and data to an internal common model, thus enabling communication across the infrastructure for discovery and access (Craglia et al. 2017). Generally, the brokered approach is more effective in addressing variety and heterogeneity when central authority cannot be easily achieved.

2.3.3 Standards

A standard is an agreement among relevant stakeholders about a specific aspect. Standards can be de-jure – i.e. defined by a formal standardization organization [e.g. the International Organization for Standardization (ISO)] – or de-facto – i.e. created by an institution, organization, company without any specific mandate and later become widespread (e.g. OpenSearch).

In the geospatial domain, the most relevant standardization organizations are the Open Geospatial Consortium (OGC) and ISO (Bermudez 2017). OGC provides open standard specifications, which facilitates interoperability, playing a key role in geospatial information sharing on a global scale. Geoportals are usually compliant with several OGC standards, with some of the most popular ones being the Web Coverage Service (WCS), the Web Processing Service (WPS), the Web Coverage Processing Service (WCPS), the Web Map Service (WMS), the Web Feature Service (WFS), and the Catalog Service for Web (CSW). CKAN[19] and GeoServer[20] are typical implementations of OGC specification.

ISO is a worldwide federation of national standards bodies, organized in Technical Committees. In particular, the Technical Committee ISO/TC 211 is responsible for the International Standards for Geographic information/Geomatics. Four standards have significant relevance to geoportals, namely, ISO 19115 (Geographic Information – Metadata), ISO 19139 (Geographic Information – Metadata – XML schema implementation), ISO 19119 (Geographic information – Services), and ISO 19157 (Geographic information – data quality) (Table 2). Notable examples of ISO implementations are GeoNetwork[21] and Esri Geoportal Server.[22]

2.3.4 Basic functionality of geoportals

Geoportal common functionalities include a metadata registry, data discovery through a catalogue service, data visualization, and data access. A geospatial metadata catalogue provides data descriptions in terms of metadata (e.g. contributor, data type, language, contact point, keywords, and dataset

Table 2. ISO Standards for geoportals.

ISO Standards for geoportals	
ISO 19115	To provide the schema for describing geographic information and services To define metadata sections, entities, and elements, and provide information about the identification, extent, quality, spatial reference, and spatio-temporal aspects
ISO 19139	To facilitate encoding and implementation for carrying out ISO 19115 To provide Extensible Markup Language (XML) schemas for describing, validating, and exchanging metadata To enhance interoperability
ISO 19119	To provide specifications of services that can enable users to access, process, and manage geographic data
ISO 19157	To define data quality measures for evaluating and reporting data quality

identifiers for data localization and indexing). In addition, the metadata catalogue is often used for implementing harmonized data discovery. Since users are typically interested in finding datasets matching specific constraints, the data discovery functionality is one of the basic functions that geoportals offer. Specifically, geoportals providing data discovery generally allow searching datasets along the who, when, where and what axes, that is, by geo-location (where), data provider (who), time range (when), thematic layer, and keywords (what). The user interface provides graphical tools, like a bounding box on a map, to set spatial and temporal constraints. Moreover, users can be directed to a gazetteer, a thesaurus, or other knowledge bases for better scoping their query. Various approaches have been developed to enhance geoportal search capabilities, e.g. the use of thesauri, ontologies, and semantic text matching algorithms (Wang, Gong, and Wu 2007; Santoro et al. 2012).

Data visualization is another important functionality for communicating geospatial information to users (von Reumont, Arsanjani, and Riedl 2013). A popular method for visualizing data is to use an online map for allowing users to visually evaluate a dataset. Online maps can be interactive allowing panning and zooming and possibly changing the visual appearance of the base map (e.g. satellite image, vector map). Geoportals can also provide data download functionality providing either the data directly or through sharing of dataset links.

For implementing these common functionalities, additional functionalities are often required. For example, a geoportal should implement a subset of functionalities concerning privacy and security aspects, e.g. authentication, data access control, logging. Moreover, the geoportal administrators need dedicated management functionalities. Geoportals can also offer online processing functionalities, ranging from basic transformations (e.g. coordinate reference system re-projection, sub-setting, format mapping) to complex algorithms for classification, and statistical analysis. (Masó, Pons, and Zabala 2012). That may require an underlying infrastructure providing a work flow engine to orchestrate the multiple actions required to implement the required processing (Santoro, Nativi, and Mazzetti 2016).

2.4 Comparative study of the selected geoportals

A study aiming at comparing the selected geoportal solutions is discussed in this section. Specifically, our intention is mainly towards at finding how geoportal technologies addressing the big data challenges encountered in enabling Earth science. For this purpose, three geoportals are selected: the INSPIRE geoportal, the NASA EODIS geoportal, and the GEOSS Portal.

2.4.1 INSPIRE geoportal

In 2001, the European Commission initiated the INSPIRE Directive,[23] whose objective is to set the legal framework for supporting the availability of spatial data, information and services within the EU. Majority of member states has put INSPIRE into national legislation systems (Pashova and Bandrova 2017). In the process of shaping INSPIRE, the consensus was reached that an INSPIRE geoportal as an entrance point is obliged to be designed. The INSPIRE geoportal is able to offer online access to geospatial data and information services supplied by multiple national members, public and private organizations (Bernard et al. 2005).

2.4.2 NASA Earthdata

The Earth Observing System Data and Information System (EOSDIS), designed as a distributed system for NASA's Earth Science Data Systems Program, provides key capabilities for managing NASA's Earth science data from various sources (e.g. satellites, aircraft, field measurements, and various other programs), and for interdisciplinary studies (NASA 2017). It leverages the web application Earth Search[24] to provide relevant information available. Twelve EOSDIS Distributed Active Archive Centres (DAACs), located throughout the U.S., are key contributors to Earth data, offering the latest information on the atmosphere, solar radiance, cryosphere, human dimensions, land, and oceans. Earthdata Worldview uses the EOSDIS's Global Imagery Browse Services (GIBS) to rapidly retrieve and display near real-time global satellite imagery, imagery for an interactive browsing experience.

2.4.3 GEOSS Portal

The GEO is an international organization for exploiting the potential of Earth observations to support decision making in areas of sustainable development and environmental management (Anderson et al. 2017). The main objective of GEO is to implement the GEOSS. The GEOSS Portal[25] is the single web access entry point for the heterogeneous data available through GEOSS. The GEOSS Portal is developed by the ESA and it leverages the GEO DAB a brokering framework enabling discovery and access to diverse data from independent Earth observation, information and processing systems (Nativi et al. 2015).

2.4.4 Summary

We analyzed these three target geoportals from the following five aspects: architecture, standard, data, functionality, and user interaction (Table 3).

From the architecture point of view, these three geoportals hold the capacity of accessing to distributed servers at large scale. They adopt a top-down policy driven method to define processes of data entry, transfer, maintenance, and delivery. However, their system technological architectures differ and eventually lead to two ways of system architectures, the clearinghouse pattern of the federated architecture and the broker pattern of the SoS architecture. Specifically, the INSPIRE geoportal and the EOSDIS geoportal deploys the federated architecture. In order to work under this architecture, the metadata implementations rules for INSPIRE and the Common Metadata Repository (CMR) for EOSDIS are maintained. On the other hand, the GEOSS Portal provides access to the GEOSS SoS, enabled by a brokering middleware.

Policy and standards define the overall data management principles, metadata standards, and implementations rules for constructing these geoportals. The data policy and standards have many connections with the system architecture and interoperability geoportals can host. Interoperability issues could be solved by implementing the standards and rules given by OGC web services and ISO specifications.

The three geoportals can serve large volume and intensive categories of spatial data and geo-information generated from multiple data providers in Earth science. Data, datasets, and databases are identified by technologies like unique resource identifier and Digital Object Identifier (DOI). The identifier technology facilitates identifying and addressing the data.

The three geoportals are equipped with the functionality of accessing to metadata catalogue, visual and text searching function, and downloading through supporting output format. An atlas-like interface provides user a visualized world scale map, which can preview data and visualize data selection. User identification is also one of the functionalities in these geoportals, which manages users into groups (e.g. professional and non-professional user) and provides them various services. Moreover, it can also help to guarantee the legal use of data.

Table 3. Comparative table of the three selected geoportals.

Name	INSPIRE geoportal	GEOSS geoportal	EOSDIS geoportal (Earthdata)
URL	inspire-geoportal.ec.europa.eu	www.geoportal.org	earthdata.nasa.gov; search.earthdata.nasa.gov
Year	Since 2001	2016 (current version)	Since 1994
Region	EU	International	USA
Responsible party	JRC	GEO	NASA
Coordination	Top down (Policy and technical method)	Top down (Policy)/Bottom up (Technical Implementation)	Top down (Policy)/Bottom up (technical method)
Standards			
Main Standard	Normative specifications (metadata, network services, interoperability of spatial data sets and services, data and service sharing, monitoring and reporting) with Implementing Rules and Technical Guidelines	GEOSS Data Sharing Principles, GEOSS Data Management Principles	Data & Information Policy of Earth Science Data Systems (ESDS) Program
Catalog Service Standard	CSW	CSW, OpenSearch, others	Common Metadata Repository
Metadata standards	FGDC, ISO 19139/19115/19119, Dublin Core	Multiple metadata specification supported (mapped on an internal ISO19115 model)	ISO 19139/19115/19119, Unified Metadata Model
Underlying infrastructure			
System architecture	Federated Service-Oriented Architecture (SOA)	System of systems based on a brokered architecture	Federal DAACs Federated SoS architecture composed of independent components that can be integrated into the system as needed
Distributed server	YES	YES	YES
Solution adopted for Interoperability	SDI Policy oriented	Broker oriented	Linked data Policy oriented
Data			
Number of data providers	From EU members	150+ data catalogs and information systems	12 DAACs as main providers
Volume of data	PB level	PB level	PB level
Number of Data Theme	30+ in 3 annexes. ANNEX 1 (Addresses, Administrative units, Cadastral parcels, Coordinate reference systems, Geographical grid systems, Geographical names, Hydrography, Protected sites Transport networks). ANNEX 2 (Elevation, Geology, Land cover, Ortho imagery). ANNEX 3 (Agricultural and aquaculture facilities, Area management/ restriction/regulation zones &reporting units, Atmospheric conditions, Bio-geographical regions, Buildings, Energy Resources, Environmental monitoring Facilities, Habitats and biotopes, Human health and safety, Land use, Meteorological geographical features, Mineral Resources, Natural risk zones, Oceanographic geographical features, Population distribution and demography, Production and industrial facilities, Sea regions, Soil, Species distribution, Statistical units, Utility and governmental services)	8 Social Benefit Areas (Disaster Resilience, Public Health Surveillance, Energy and mineral resource management, Water resources management, Infrastructure and transport, Food security and sustainable agriculture, Biodiversity and ecosystem sustainability, Sustainable Urban Development)	6 (Atmosphere, Solar Radiance, Cryosphere, Human Dimensions, Land, and Ocean Science)

Data identifier	YES, Unique resource identifier	YES, partial (URL)	Yes, Digital Object Identifier (DOI)
Key functionality			
Access to metadata catalog	YES	YES	YES
Create and post metadata records	YES	NO	NO
Imagery Preview	NO	YES	YES
Visual spatial selection search	YES	YES	YES
Text field for free text searching	YES	YES	YES
Time filter for search	NO	YES	YES
Download	KML/KMZ	Multiple formats through dataset transformation	FTP
User interaction			
User Identification	NO	YES	YES
User Interface	Content management system like	Atlas-like	Atlas-like
Online private workplace	NO	YES	YES
Online translator	YES	NO	NO
Online solution to receive feedbacks from users	NO	YES	YES

Table 4. A list of geoportals in China.

Name	Main Stakeholder	Web
National Earth System Science data sharing Infrastructure	Data Sharing Union of Earth System Science	www.geodata.cn
China GEOSS	Ministry of Science and technology	chinageoss.org
Globalland 30	Ministry of Natural Resource	globallandcover.com
China Meteorological Data Service Center	CMA	data.cma.cn/en
National Natural Resources and Geospatial Basic Information Database	National Development and Reform Commission	www.geodata.gov.cn
Tiandi Tu	Ministry of Natural Resource	www.tianditu.com
Geospatial Data Cloud	Chinese Academy of Sciences	www.gscloud.cn
Geological Scientific Data Sharing Net	Chinese Academy of Geological Sciences	www.geoscience.cn

3. Status and challenges of geoportals

This section explores status and challenges of geoportals, especially on the cases of geoportals in China. These Chinese geoportals equip specific characteristics, but challenges these suffers have similarities with geoportals of other countries. Furthermore, dealing with issued brought by big data is a general challenge to all geoportals in the world. Thus investigating the challenges of the geoportals in China could provide some insights of future direction for geoportal development.

3.1 Current status of geoportals in China

The development of geoportals in China is mainly driven by the government. The government administrative management activities generate a large amount of data resources related to the geospatial data. Under the impetus of the national policies, the government's data sharing network and portal platforms are built to increase the degree of openness of government data. Examples are the National Bureau of Surveying and Mapping Geographical Information, the China National Geographical Survey Bureau, the China Meteorological Administration, and the State Oceanic Administration. Moreover, data generated from national scientific projects should be open to public. For example, the Ministry of Environmental Protection's National Eco-Environmental Survey (2000–2010) Remote Sensing Assessment Project mandates to establish an Eco-environmental Data Sharing Service System with a geoportal as the entry point to the system (Xue et al. 2015). Table 4 shows a list of geoportals in China.

3.2 Characteristics of geoportals in China

Most of the Chinese geoportals are adopting a 'top-down' methodology for the system architecture. As most of the projects are requested to construct a specialized data center, and the service of data and information are undertaken through a portal. For example, the Ministry of Science and Technology is implementing the National Science and Technology Foundation Platform Project. This project supports to build several national data portal systems including Earth data. Therefore, the national Earth system scientific data sharing platform adopts a system structure of 'one overall center, several certification centers and sub-centers ' (Ning and Zhao 2017).The structure makes it possible to distribute data and information in a centralized manner, principally based on the metadata management (Yunqiang et al. 2012).

The data categories in Chinese geoportals are classed based on the type or series of satellite. For one example, the data, in the National Earth System Science data sharing Infrastructure, are classified as terrestrial satellites, meteorological satellites, and marine satellites. For another example, in the National Satellite Meteorological Center Data Service network, the data are classified as the FY1/FY2/FY3/FY4 satellites. Data categories could be divided thematically in other cases, for example, data of Global land 30 has categories such as grass, forest, wetland, and other types of land covers.

The 'Tiandi Tu' has many themes such as agriculture, industry, transportation, and energy. Data could also be classed as the key words, such as the name, area, location, time, date, and the information similar as the metadata.

The users of the Chinese geoportals are mainly those in professional roles, e.g. researchers in most cases or people who need the data for research. While it is noteworthy that some geoportal cases perform multiple user needs, so the system has multiple interfaces. For instance, the 'Tiandi Tu' has a public version for ordinary users, and a government version for government agency users.

3.3 Challenges of geoportals

The term 'Big Data' is currently a significant trend in data and information research, including Earth data. Big data technologies have the potential to advance in-depth scientific discoveries for Earth science and research (Guo, Wang, and Liang 2016). However, big data are posing challenges that are usually referred as V challenges: large Volume, high Velocity, and wide Variety (Nativi et al. 2015). On the geoportal user interface side, they have an impact on discovering, visualizing, processing, and storing big Earth data. Specific challenges come from the continuity of data updating, methods of data harmonization, and multiple functionalities for professional users.

Geoportals, especially in China, aim to solve data sharing concerns and acts as an interface to data systems using a top-down approach. This approach (i.e. an administrative approach) can ensure that the geoportals and data sharing projects run effectively. Departments such as ministries, government agencies play key responsibilities in constructing these geoportals and data systems. By doing that, the geoportals are able to incorporate large amounts of spatial datasets and geo-information products, multi layered and multi types of data for earth sciences. The geoportals can facilitate researchers, government officers, and ordinary users in helping them to find the data they needed, with basic searching services equipped in the geoportals.

However, the 'top-down' approach raises the doubts about the data update mechanism. Although updating data on a time regular base is never an easy task for any geoportal owners, it becomes more complex if the top authority pays less attentions or budgets of the project coming to an end. Because the geoportal has no internal driving force to develop, and this approach make the users having to contribute but sometimes not willing to do so. Therefore, the continuity of data updating is a considerable challenge. Another challenge is the lack of connections between different data owners. Multi stakeholders have their own geoportals, where their data could be discovered, but as the data volume is increasing, the geoportals become isolated from each other simply because there are often no communications between their data owners. That could lead to many new data islands, which is the opposite effect of developing data sharing mission.

The third challenge comes from the functionality. Basic services like data search engine, data online browser can support finding and viewing for ordinary use demand, but not the requirements from the professional users. Some geoportals only act as a content management system or shopping system, instead of a professional web GIS system. Thus the searching ability is provided in default by the template of the system and is sometime not suitable for raster and vector geospatial data. Many Chinese geoportals provide the preview function, but, in some cases, they only provide previews, but not the data itself. Professional users may need to know the coverage and the topology information before downloading, and thus at that time an overlay or add layer function should be developed. In this case, Open Geographic Modeling System (OpenGMS) provides specific data process services (including data mapping services, refactoring services, and visualization services) beyond traditional data services to help modeler to prepare suitable data for geographic simulation the open web environment (e.g. Wang et al. 2018; Yue et al. 2019).

4. Future directions for geoportals

Our previous analysis of the three selected geoportals (INSPIRE, GEOSS, and EOSDIS) has indicated that general-purpose geoportals are still the main entry point to existing big geospatial data sharing systems. All three geoportals provide solutions to big Earth data challenges, providing good examples for the development and update of geoportals. This is supported by their experience with large volumes (petabyte level) of heterogeneous (many themes and types of data) Earth observation data and geo-information products, including coverage data and vector data with different data model and formats. However, the international experiences of geoportals still have the gaps remained and unsolved for big data challenges. The main challenges are, first, a geoportal is normally a general-purpose tool to discover spatial data and geo-information, but often there are community-specific needs that require customized geoportals with dedicated tools for scientists, policy-makers, and the general public. Second, big data brings a new procedure for research. Traditional research adopts a scenario of finding and downloading data, processing, and outlining patterns. This typical geoportal scenario (i.e. search-evaluate-download) does not fit well to in the era of big data. In the big data era, the typical scenario does not start from data but from application. The research procedure is shifting to a new scenario – 'search, evaluate, and process' –, that is, identifying the applications, discovering all data related, and running a processing model for knowledge generating.

The following section provides a discussion from the lessons learned from the international experiences in terms of their advantages and gaps, and aims to solve the challenges identified from Chinese geoportals. It also explains the recommendations the architectures, services, techniques proposed not only for Chinese geoportals, but also for future geoportal projects internationally.

4.1 A hybrid system architecture

The data systems, where the geoportals connect, are leveraging different methods for coordination, in terms of federated coordination (top-down) and broker coordination (bottom-up). Both coordination solutions are able to connect distributed data servers and information systems, and to facilitate complex systems for solving big data storage, management, and assessment problems. The federated approach generally shows better performance, but it requires that participants agree on participating in the overall system by-law or their own interests. If this is not available, a brokered approach is the only one that can be adopted. In addition, the brokered approach is better, if the requirements cannot be fully defined allowing one to select the best federal agreement. Therefore, a hybrid data system architecture for a complex data system is recommended for meeting the challenges posed by big data. Geoportals should be based on different technologies ranging from adaption of web portal technologies (e.g. portlet-based) to extensions of geospatial data systems (e.g. geonetwork, CKAN). To better support scientific collaboration, geoportals should also keep pace with the next generation of service infrastructures (e.g. scientific geospatial infrastructure; Bernard et al. 2013). Geoportals should also play a role as the interface of so-called social spatial data infrastructure (Schweers et al. 2016). New system architectures (e.g. Linked data and Semantic Web) to establish a shared information space relying on URLs and Resource Description Framework (RDF) can also provide another solution for accessing geoportal data.

The geospatial data system host should follow a certain type of classification methods. Generally, the hierarchy of classification should not be too complex because of compatibility concerns for the coming big data deluge. A reduced number of categories on the spheres of the Earth science (e.g. atmosphere, hydrosphere, biosphere, geosphere, and dedicated data themes) is recommended for geoportals. The processing of data ingest is suggested to adopt a 'six in one' mode. The six areas should be covered on the geoportal interface are including metadata, data thumbnail, data description document, data sample, data entity (i.e. download link), and connections and group. The goal of mode is to provide a more detailed description of the data on the geoportal and enable users enough information for faster data positioning and discovering.

4.2 Fundamental services

From the previous analysis, we have identified the three fundamental services: catalogue, preview, and access services. However, we also recommend adding an online analysis and processing service for geoportals.

Online analysis and processing service does not seem to be served to multiple communities sufficiently in general-purpose geoportals. Therefore, it is suggested to provide tools (e.g. API, widgets, configuration) to create community portals, and applications tailored to specific users. They would allow developing, discovering, and running of applications to support different online- and cloud-based scenarios in particular for big earth data processing. For example, system (e.g. Google Earth engine) provides a cloud-based platform for planetary-scale online geospatial analysis, in addition to data delivery (Gorelick et al. 2017). Geoportals could involve online spatial analysis functionality for addressing geospatial analysis tasks, e.g. online computing environments and geospatial processing web (Hofer 2013), online analysis (Zhao et al. 2012), and cloud computing (Evangelidis et al. 2014). For instance, the GEOSS Portal and the EOSDIS geoportal also have a private work place for professional users to process the data. However, data transformation (e.g. sub-setting, re-projection, interpolation, encoding) on-the-fly, and online data model processing are supported only by a few dedicated geoportals.

Besides data access functionality, e-Science geoportals aim to work across disciplines, and increase collaboration among researchers. Geospatial cyber-infrastructure has its roots in computing technology for data storage and computation (Hofer 2013), and thus, one of the driving forces for building an e-Science geoportal is the advancement of computing capability. The realization of an e-Science environment supporting data analysis and collaborative research requires e-Science geoportal computing for large data resources. E-science geoportals can provide collaborative web services for Earth observation data and its products. The geoportal is a dedicated access component for satellite projects, normally supported by space agencies. E-Science geoportals cover data from broad disciplines. For example, the CIPRES Science Gateway is a public resource for inference of large phylogenetic trees,[26] and the Distributed Research Infrastructure for Hydro-Meteorology (DRIHM) portal[27] assists Hydro-Meteorology experiments and collaboration (D'Agostino et al. 2016). In addition, the United States Geological Survey (USGS)[28] data portal has the capability of dealing with geoscience data (Blodgett et al. 2012), and Near-Earth Space Data Infrastructure for e-Science (ESPAS) data portal[29] is a implementation of an e-infrastructure providing a digital library like system for accessing data sources and model output data (Belehaki et al. 2016). The Petlab[30] also provides New Zealand's online national rock, mineral data, and geo-analytical database (Strong et al. 2016).

4.3 Technical components

4.3.1 Enhanced search engine

Data discovery is the main functionality provided by geoportals. Therefore, the search engine is the key component of geoportals. Search through the who and what axes should be generally supported. Because served datasets vary in spatial coverage and time in Earth observations, the when and where axes should be supported. Search engines should offer multiple search methods, e.g. text, theme, keyword, and map searches. The refinement of the search scope or provision of some direct search links could enhance search capability. Therefore, these geoportal functionalities should be enhanced. For example, the searching ability should offer more keyword options accordance to the strings of the metadata, which also means the content of the metadata should be improved. Many geoportals are using the open-source product (e.g. OpenSearch) as a solution or provide advanced functionalities through gazetteers to facilitate spatial selection. Furthermore, although current geoportals encountered many challenges to access and manage big data, semantic searching and analysis (e.g. Li et al. 2011; Vockner, Richter, and Mittlböck 2013) and machine learning (e.g. Jiang et al. 2018) offers some new solutions. These challenges can be changed to chances to discover knowledge through big data.

Geoportal search engines could also be enhanced by grid-enabled search techniques for geospatial data (Bashir et al. 2016). Web crawler tools could also be leveraged to enrich Geoportal search functionality (Bone et al. 2014), not only searching for data but also for OGC services (Li, Wang, and Bhatia 2016). To retrieve information about named geospatial objects and/or elements from a geoportal, some researchers have advocated to use the Atlas Information Systems (AIS), because it is convenient to form integrated digital models on the basis of atlas information or directly within AISs (Tikunov, Ormeling, and Milan 2008).

4.3.2 Dynamic visualization tools

The appearance of geoportals results from a user-friendly GUI for geoportal usability. A well-designed GUI is beneficial for interacting with the user and providing an easy-to-use experience and powerful visualized interactivities. Geoportals tend to prefer adopting an atlas-like user interface (using OpenLayers and Leaflet). This may result in the requirement of visualizing geographic distributions of the data and of the functionality for visualized data selection. An atlas-like user interface, as the metaphor, is recommended for geoportal design.

In order to address some Volume, Variety, and Velocity challenges on the user-interface side, the next generation geoportals should specify the time-series investigation (Li et al. 2013), graphs and charts for visual analytics, and 3D and 4D visualization widgets through dynamic visualization tools. The integration of 3D web technology (e.g. WebGL, Cesium, OSGEarth) and cloud services into geoportals could deliver spatial data and geo-information in a more interactive and enhanced visualization environment. An example is the GPlates Portal, a cloud-based Cesium.js globe built upon the Software as a Service (SaaS) model. It provides global geophysical and geological datasets in a virtual globe (Muller et al. 2016).

4.3.3 Others

This study also shows that the following components should be considered when one geoportal is planning to build from the perspective of functionality (Table 5).

Other technical components suggested for geoportals are the ability of collecting feedback online from users (e.g. through 'like' or full annotation) or providers (e.g. statistics of access for data providers), and the ability of responding to their feedbacks. Geoportals could also provide APIs to enable developers to create alternative user interfaces to data systems, including community portals and mobile/desktop apps. In addition, data storage and management is one of the critical technical components for addressing the volume challenges of big data. Currently, relational databases (e.g. Postgre SQL), NoSQLs (e.g. MongoDB and HBase), and distributed file systems (e.g. Hadoop) are widely used for big data storage and management. These technologies are also important for geoportals,

Table 5. Technical components proposed for geoportal design.

Component name	Functionality
Spatial Database and data server	Spatial databases store and maintain the data that will be delivered. The Database could be on the local sever or distributed servers
Geospatial Web Server	Geospatial web services provide geographic data to the user through forms of map data services under the guidance of OGC and ISO standards. Open-source options for web services are capable of hosting these web services, e.g. GeoServer and MapServer
Geospatial Metadata Catalogue Server	The geospatial metadata catalogue provides metadata in accordance with OGC and ISO standards and is retrieved by the geoportal
Other catalogue Server	Other catalogues could be supplemented by metadata catalogues for a data registry. A well-known catalogue is the Gazetteer Service which can host a location-based feature dataset
Download tool	A download tool incorporates the capability of obtaining data and metadata. Metadata could be downloaded by XML structured files, and data could be downloaded as raster or vector based data outputs through various ways, such as FTP

although the technical component for big data storage and management still requires more theoretical and practical developments (Yao and Guoqing 2018).

5. Conclusion

The growth in the volume of data for Earth science presents challenges to online spatial data and geo-information management. Geoportal is considered as the entry point and the human-to-machine interface of the data and information management system. The term 'geoportal' was invented aligned with advancement of SDI, and afterwards its developments have been driven by scientific geospatial projects and applications, international organizations, governmental agencies, and commercial purposes. The main application domains for scientific usages of geoportals have been identified as agriculture, disaster and early warning, land, water, urban planning, air quality, and energy.

From reviews of international and Chinese geoportals carried out in this paper, it shows that existing geoportals can partially deal with the challenges that big data brings. For data harmonization and interoperability, the policy-driven standards and specifications by OGC and ISO/TC211 advance the consistency for web services and metadata schema. However, gaps remain and new requirements for geoportals have recently emerged, in particular for the continuity of data updating, the method of data harmonization and multiple functionality for professional users in order to tackle the challenges posed by multi-disciplinarily demands and big data.

This article also presents the recommendations, in terms of the architectures, services, techniques proposed for future geoportal projects. Basic functionalities of geoportals are identified and should be kept, such as metadata catalogue, data discovery, data visualization, data sharing, and data downloads. Besides that, future geoportals should be capable of connecting multiple distributed systems under a hybrid system architecture. And the service for future geoportals is suggested to include the online analyzing and processing, enhanced search engine, dynamic visualization tools, and among others. Even more, it is suggested to provide tools (e.g. API, widgets, configuration) to create community portals, and applications tailored to specific users. It is noteworthy that other geoportal functionalities, such as user's feedback, statistics feedback to providers, APIs enabled mobile/desktop apps and user free authentication, are under experimentation (Nativi et al. 2017). Potential exists for adoption of WebGL, grid, and cloud technology to enhance the capability of geoportals. Furthermore, geoportals should deploy scientific database method for storing and managing a huge volume of big data.

This review will hopefully facilitate research attempts to address online data sharing issues through geoportals. In the long run, the strength of geoportals could lead to a full-fledged online Digital Earth system that could provide better solutions for spatial data sharing, geo-information management, and Earth science knowledge generation.

Notes

1. https://www.earthobservations.org/geoss.php.
2. http://www.chinageoss.org/dsp/home/index.jsp.
3. https://www.amerigeoss.org/.
4. https://ec.europa.eu/info/eurogeoss_en.
5. http://supersites.earthobservations.org/.
6. http://www.icsu-wds.org/services/data-portal.
7. https://Geo.Data.gov.
8. https://data.gov.in/.
9. https://www.opengovpartnership.org/.
10. https://scihub.copernicus.eu/.
11. http://search.earthdata.nasa.gov/.
12. https://www.geoportail.gouv.fr/.
13. http://www.paikkatietoikkuna.fi/web/en.
14. http://www.cuzk.cz/en.

15. https://discover.digitalglobe.com/.
16. http://www.hexagongeospatial.com/support/demo-portal.
17. https://www.21at.net/ATPortal/.
18. https://geo.btaa.org.
19. https://ckan.org/.
20. http://geoserver.org/.
21. https://geonetwork-opensource.org/.
22. https://www.esri.com/en-us/arcgis/products/geoportal-server/overview.
23. http://inspire.jrc.it.
24. http://search.earthdata.nasa.gov/.
25. http://www.earthobservations.org/geoss.php.
26. http://www.phylo.org/.
27. http://www.drihm.eu/.
28. https://cida.usgs.gov/gdp/.
29. http://www.espas-fp7.eu.
30. http://pet.gns.cri.nz.

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