GEO 2016 Work Programme Progress Report

This Document is submitted to the GEO-XIII Plenary for information.

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1 INTRODUCTION

1.1 General

This document is intended to provide the Plenary with a summary overview of the introduction of the new Implementation Mechanisms, together with an overview of the progress made on the GEO 2016 Work Programme activities.

After the GEO-XII Plenary approval of the GEO 2016 Work Programme, the Secretariat provided its support and, where requested, the necessary coordination to advance implementation of the activities. It is important to recall that 2016 was defined as a transitional year with the understanding that changes from either the Programme Board or feedback and lessons learned from the Community may well be introduced. Finally, considering the four different mechanisms defined by the new Strategic Plan, the Foundational Tasks present the highest level of engagement from the Secretariat, and the greatest change for the community at large.

1.2 Implementing Provisions of the Strategic Plan

By and large, the four proposed mechanisms have been well-received by the Community, and have been put into practice.

For Community Activities and GEO Initiatives, which are implemented with almost 100% of the resources coming from in kind contributions of Members and Participating Organizations (POs), one major action item for each team was to re-assess their plans, and to develop a revised description of the current and planned activities in order to meet the "requirements" set forth in the Strategic Plan and its Reference Document. This was especially true for those activities being proposed as GEO Initiatives or GEO Flagships that were required to submit updated Implementation Plans and that are now included in the 2017-2019 Work Programme.

Relevant Secretariat Experts have established the necessary connections and collaborations, and are supporting and facilitating the interactions of the different Teams with the other GEO activities, covered by the Foundational Tasks, both from a technical and an organizational point of view.

The implementation of the Foundational Tasks made good progress, both in the management arrangements of each of them, and in the overall Secretariat organization. The transition, however, has been impacted by the reality of the requirement to adapt the content and plans of the Foundational Tasks (as described in the Plenary-approved 2016 Work Programme) to the actual Trust Fund resources for 2016 (currently estimated to be about 30% less than the 2016 budget approved by GEO-XII) and to the lack, for a few Tasks, of the expected in kind contributions.

Current progress in consolidating the Teams and the plans for all the Foundational Tasks can be summarized as follows:

- The formation of all Task Teams and identification of co-leads is almost complete;
- Periodic calls are organized, supported by the Secretariat;
- The Secretariat (through identified Experts) is supporting each of the Tasks, in accordance with the Work Programme provisions and compatible with the resource constraints.

1.3 Activities Progress

A summary of the progress achieved on the different activities are described below.

The GEO Initiatives and Community Activities consist of a compilation of the inputs received by the different Teams.

For Foundational Tasks, the Secretariat prepared the summary progress on specific inputs based on the day-to-day interaction of the teams with Secretariat.

2 GEO INITIATIVES

2.1 Introduction

GEO Initiatives allow Members and Participating Organizations to coordinate their actions and contributions towards a common objective within an agreed, yet flexible framework. They develop and implement prototype services according to GEO priorities and have identified committed resources to a certain extent. GEO Initiatives demonstrate technical feasibilities through pilot services, or serve a user need. Naming of the activities is according to the new Work Programme (2017-19) with a reference to the name of the Community Activity according to the Transitional Work Programme, 2016.

2.2 GEO BON

Reference to the activity GI-02.

- The GEO BON Open Science Conference and All Hands Meeting, attended by 261 participants from 40 countries, was held in July 2016, leading to the development of a new organizational structure and feeding in to a new Strategic Plan;
- A Letter of Agreement was signed by representatives of the GOOS BioEco Panel, IOC OBIS, and GEO BON MBON confirming their cooperation on jointly developing a Global Marine Biodiversity Monitoring Network;
- BON in a Box Version 1 beta was released. BON in a Box is a collection of tools to facilitate development of Biodiversity Observation Networks;
- The first version of the Essential Biodiversity Variable (EBV) Portal was released at the Open Science Conference, 2016. In time, the portal aims at being the main source of information on EBVs;
- The "GEO Handbook on Biodiversity Observation Networks" (publishing date: last quarter of 2016) was finalized;
- The European funded GLOBIS-B project, of which GEO BON is one of the partners, started in June 2016;
- The host institution of the GEO BON Secretariat, the German Center for Integrative Biodiversity Research Halle-Jena-Leipzig (iDiv), had its funding renewed for another four years by the German government.

2.3 GEOGLAM

Reference to the activity GI-01.

- Monthly delivery of the operational Crop Monitor for the Agricultural Market Information System (AMIS) since September 2013 – monthly coordination of evidence-based consensus building amongst newly and well-established global, regional, and national monitoring systems;
- Successful development and deployment of the operational Crop Monitor for Early Warning, with first monthly publication on 5 February, 2016. This report is the result of collaboration amongst multiple well-established groups monitoring countries at risk;
- Growth of a regional Asia-RiCE initiative geared toward strengthening methods and developing national capacity for rice crop monitoring, under Japanese leadership supported by France/ESA in cooperation with ASEAN framework;

- Initiation and development of a Rangeland and Pasture Productivity (RAPP) activity aiming to establish a system to monitor the condition of global grazing lands and their ability to sustain animal protein production (RAPP Map: map.geo-rapp.org), while building on a Community of Practice (~ 10 pilot countries) under Australian leadership;
- Prototyping of a crop information system in Tanzania (in partnership with the MAFC National Food Security Office - NFSO) and in Uganda, funded by the Bill and Melinda Gates Foundation;
- Start of national crop monitoring demonstrations based on Sentinel-2 and Landsat-8 in producer and food secure countries in Ukraine, Mali and South Africa, funded by ESA;
- Development of EO-based products aiming at individual farmers in developing countries by projects of the G4AW programme (Geodata for Agriculture and Water), led by the Netherlands space office;
- Monitoring of rice crops using satellite remote sensing (Sentinel 1, Sentinel 2 and SPOT Pleiades imagery) and GIS technologies in Northern and Eastern Afghanistan (FAO-DDNS). Rice crop area estimation/area frame and rice crop masks are being developed for selected provinces;
- Curricula and E-learning courses related to geospatial information and technology for agriculture monitoring and statistics, and environment impact assessment are being developed from FAO-DDNS, Bologna University and Twente University (under Pakistan Agriculture Monitoring and SIGMA Project);
- As a partner of the Sentinel-2 for Agriculture project, the Pakistan Space and Upper Atmosphere Research Commission (SUPARCO) is testing the use of Sentinel-2 satellite images to estimate wheat area and yield for the 2016 crop season;
- FAO-DDNS is testing Sentinel 1 and Sentinel 2 data with an aim to develop sustainable methods and tools for crop area and yield estimation in Iran.

2.4 GFOI

Reference to the activity GI-03.

A GFOI policy forum was held in London UK on 6 September, 2016. Subsequently, GFOI 10th Space Data Coordination Group (SDCG-10) was held from 7-9 September 2016, hosted by the UK Space Agency at the University of Reading. It was a great opportunity to inform various UK communities about GFOI and the space data component, encourage its uptake; and to establish an improved understanding and connection to relevant UK activities, expertise and current and future UK data sources

A Collaboration Forum was held in Washington DC on 28 June 2016. The Forum provided an opportunity for stakeholders to interact with GFOI partners and explore opportunities for new collaborations with GFOI.

At the Oslo REDD Exchange, 14–15 June 2016, GFOI partners the Governments of Norway and the United States of America issued a joint statement for deeper collaboration on forests and climate change. It was announced by the US Secretary of State, John Kerry and the Norwegian Minister of Climate and Environment, Vidar Hegelson, the statement listed GFOI as a priority activity. At the top of the list of specific activities, the statement said that the two countries would consider enhancing existing collaboration under GFOI to help REDD+ countries to develop greenhouse gas inventories and management tools.

GFOI together with its partner the European Space Agency (ESA) and others hosted a side event at the UN Climate Change Conference in Bonn Germany on 20 June, 2016. The event was well attended and allowed for constructive discussions between the GFOI team and stakeholders.

GFOI partners NASA and SilvaCarbon will host a series of webinars. NASA's Applied Remote Sensing Training (ARSET) webinar will provide participants with an overview of carbon monitoring for terrestrial ecosystems. This includes information about carbon estimation techniques and conducting accuracy assessments on these estimates. The course will draw on material from the GFOI's MGD and provide live demonstrations of tools for carbon monitoring.

GFOI released a second version of the Method and Guidance Document (MGD) and also launched REDDcompass, a web application to help countries develop national forest monitoring systems and procedures to measure, report and verify associated greenhouse gas emissions. REDDcompass helps users progressively work through the key themes, concepts and actions of REDD+ National Forest Monitoring Systems (NFMS) for Measurement, Reporting and Verification (MRV) gaining access to a suite of GFOI methods and guidance, space data resources, training materials and tools along the way.

GFOI partners hosted a 'Training the Trainers' workshop in Bangkok from 18-22 April, 2016. The workshop assembled a group of regional leaders and provided targeted training in the use of the GFOI's overarching REDDcompass, the training modules from the GOFC-GOLD source book, the World Bank's Decision Support Tool (DST) and various other linked products.

The GFOI Plenary and Open Forum meetings were held at the European Space Agency's (ESA) Centre for Earth Observations (ESRIN) in Frascati, Italy, from 22-25 February, 2016. With well over 100 registered participants bringing different backgrounds, expertise and perspectives from all over the world; the meetings were engaging and highly productive.

2.5 Global Observing System for Mercury (GOS4M)

Reference to the activity GI-04.

- Installation and operation of GMOS (Global Mercury Observing System) monitoring sites (more than 40 ground-based sites in both southern and northern hemispheres);
- Execution of oceanographic and tropospheric studies over major oceans and seas, and in the troposphere (including the UTLS);
- Design and development of GMOS Spatial Data Infrastructure (GMOS SDI - www.gmos.eu/sdi) for mercury in the environment and integration in the GCI (GEOSS Common Infrastructure);
- Quality control of collected datasets and uncertainty assessment performed through a transparent and inclusive process involving representatives of the mercury monitoring networks;
- Archiving and sharing of historical and up-to-date information on mercury;
- Monitoring database/information warehouse established.

2.6 AfriGEOSS 2016 Summary Progress Report

Reference to the activity GI-06.

- Held the first AfriGEOSS Steering Committee, hosted by South Africa in February 2016. The first AfriGEOSS Symposium was held from 27-29 April 2016, in Victoria Falls, Zimbabwe hosted on behalf of the Government of Zimbabwe, by the University of Zimbabwe and the Research Council of Zimbabwe. More than two dozen African nations committed to mobilize the Earth observation community to contribute to the implementation of GEOSS and the African Space Policy and Strategy. http://www.earthobservations.org/afrigeoss2016;

- Identified four thematic priority areas with leads, namely a) Food Security and Agriculture – to be implemented through the AfriGEOSS Agriculture Monitoring (AfriGAM) Initiative led by South Africa (ARC). b) Sustainable Forest Management led by Gabon (AGEOS) and COMIFAC; c) Water Resource Management led by Morocco (Chouaib Doukkali University); and d) Sustainable Urban Planning and Growth led by UNECA and South Africa (SANSA). In addition, RCMRD was identified as lead for the Capacity Development action area and an activity on Soil Moisture Mapping for Africa using satellite data was established led by GRSS;

- Reinforced country and regional institution participation in AfriGEOSS and increased GEO membership with two Africa based Participating Organizations joining GEO, the Arab States Research and Education Network (ASREN), contributing to the data and infrastructure action area and the African Regional Centre for Space Science and Technology Education - in English Language (ARCSSTE-E), contributing to the capacity development action area with a third (Sahara and Sahel Observatory - OSS) pending approval by the 38th Executive Committee Meeting in November 2016;

- Raised visibility and awareness of AfriGEOSS and GEO through participation in various international events such as the Joint Meeting of SADC Ministers of ET and STI, UNGGIM-Africa 4th High Level Forum, ESA Food Security and Sustainable Agriculture Workshop, EUMETSAT User Forum for Africa, etc.;

- Strengthened engagement and collaboration with existing initiatives in the continent such as MESA, SASSCAL, SERVIR E&S and West Africa, TIGER, GlobeWetlands Africa, WIGOS, Wetlands East Africa, GEO-CRADLE, UNGGIM-Africa and with policy institutions such as AMCOMET Secretariat, SADC Secretariat and the African Union Commission (AUC). In addition the Initiative continued consultation with GMES & Africa to foster synergies and coherence with AfriGEOSS;

- Secured a mandate for AfriGEOSS through the declaration of the 26th African Union Summit, urging "Member States, RECs … AfriGEOSS and the Commission to popularize space science and technology in socio-economic development, mobilize domestic resources and implement the Space Policy and Strategy." In support of this mandate, AfriGEOSS Data & Infrastructure team has co-developed with the African Union Space Working Group an EO infrastructure survey to be launched by the African Union Commission;

- Increased African resources brokered in the GEOSS Common Infrastructure (GCI): brokered those held by RCMRD and received approval to broker OSS Geoportal pending final development of the portal and initiated conversation with AUC for the MESA geoportal;

- Advanced engagement with African commercial sector enable innovative and showcased value added products in support of decision making in the continent.

2.7 Data Access for Risk Management (GEO-DARMA)

Reference to the activity GI-16.

- Following the publication of the Sendai Framework for Disaster Risk Reduction 2015-2030, CEOS proposed a new initiative, GEO-DARMA, at the end of 2015. After the approval of the GEO 2016 Work Plan by the 2015 GEO Plenary and the positive review of the GEO-DARMA proposal by the GEO Programme Board in 2016, the European Space Agency as current GEO-DARMA Lead (on behalf of CEOS) has further consolidated the GEO–DARMA implementation plan and set up a contract to get an initial two-year support from Industry to kick-off GEO-DARMA in the last quarter of 2016 and to foster the execution of the related activities.

2.8 Earth Observation for Ecosystem Accounting (EO4EA)

Reference to the activity CA-29.

- Recruited members to participate in the community and draft a proposal for an initiative.
- Held initial meeting to refine the concept and develop the Initiative proposal:
  - Hosted by Steering Committee member Conservation International in Washington, DC;
  - Initiative proposal developed with four work streams;
  - Many participants made commitments to contribute;
  - Several participants will work to identify additional resources.

2.9 GEO Carbon and Greenhouse Gas Initiative

Reference to the activity GI-05.

These are, among others, some of the major accomplishments over the past year:

1. The GEO Carbon Community of Practice worked together to write the GEO Carbon and GHG Initiative, that has been accepted by the GEO Programme Board. This is an important success, even if it is just a first step toward the implementation of a Global Carbon and GHG Observing System. A significant number of key players in the field of research and observations, from four continents, agreed to work together on a common plan for improving the observational efforts in support to climate relevant policy decisions.
2. In 2016, the Integrated Global Greenhouse Gas Information System (IG3IS), supported by WMO, started to prepare its Program Roadmap for an observation-based information system on trends and distributions of GHGs in the atmosphere. IG3IS will be coordinated with the GEO Carbon and GHG Initiative.
3. ICOS is a pan-European research infrastructure for observing and understanding the greenhouse gas balance of Europe and its adjacent regions that currently has 12 member countries (https://icos-ri.eu/). ICOS is part of the GEO Carbon Initiative and is, as a long-term and domain-overarching research infrastructure, well-equipped to address several of the GEO Carbon objectives and to foster interlinkage with other initiatives. The Integrated Carbon Observation System European Research Infrastructure Consortium (ICOS ERIC) was founded in November 2015, and obtained the status of a GEO Participating Organisation in 2016.

In terms of resources there is still a lack of widespread and coordinated support to climate-related observations at global scale, in particular in less developed areas.

2.10 GEO Cold Regions Initiative (GEO CRI)

Reference to the activity GI-11.

- GEOCRI meetings (one face-to-face meeting, telecons, co-leads telecons);
- Establishment and work of the GEOCRI co-leads team (GEOCRI Work Plan and related activities);
- Joint development of the GEOCRI Work Plan 2017-2019 and related goals, tasks and activities;
- Development of the implementation mechanism for GEOCRI Task Teams;
- Identification of the Task Teams to implement the tasks and activities of the GEOCRI Work Plan;

- Recommendation of GEOCRI as a Global Initiative to the Work Plan 2017-2019 by the Program Board;
- Identification of resources for GEOCRI implementation (financial and in-kind contributions);
- Networking, identification of potential new contributors to GEOCRI;
- Document re-analysis: importance and requirements for the polar and cold regions globally;
- Provision of the Fact Sheet to the GEO XIII Plenary;

2.11 GEO Global Ecosystem Initiative (GEO ECO)

Reference to the activity GI-14.

- The USGS, Esri, and a team of global marine ecosystem scientists collaborated to develop the first ever map of global ecological marine units (EMUs) produced from data collected over a 50-year period. The EMUs (Figure 1) represent 37 global marine ecosystems based on differences in temperature, salinity, oxygenation, and nutrient levels. The EMUs are intended to support marine biodiversity conservation assessments, economic valuation studies of marine ecosystem goods and services, and studies of ocean acidification and other impacts;

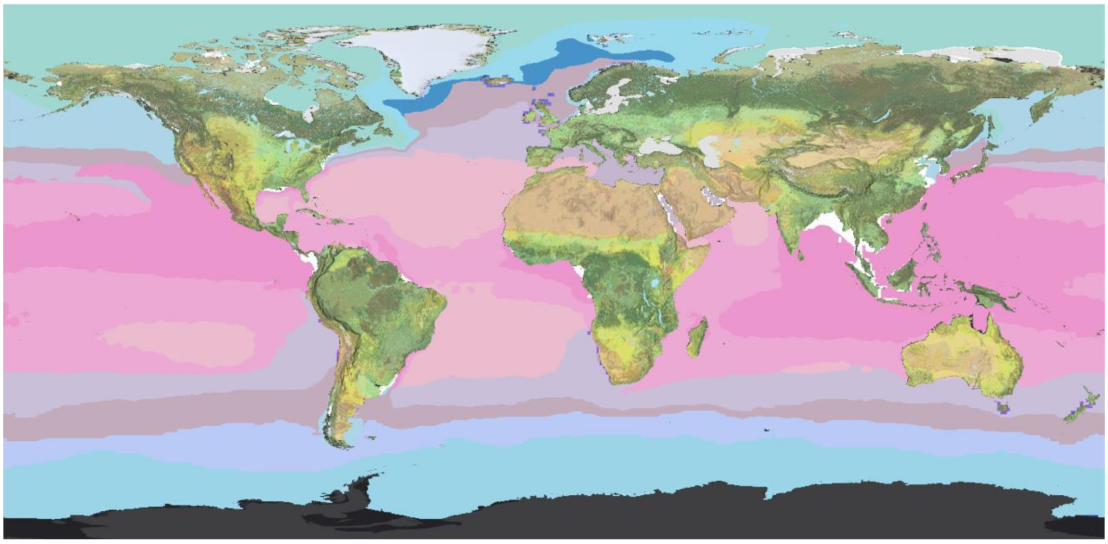

Figure 1. Surface view of the Ecological Marine Units

- In order to make full use of the Internet and EIA Big data visualization technology and to establish the system of statistical indicators of EIA, intelligent analysis and information release, the leader of the EIA big data visual platform based on RS-GPS -Web GIS, together with some younger IT technicians, set up Taiyuan Baiyu S&T Co. Ltd. With the application of Internet of things technology, the company combined that with sensor technology, ZigBee technology, and Android query technology to achieve real-time monitoring of environmental pollution. The company built a platform for sharing the configured information release server (Web server), the GIS server and database server for information publishing and online query;
- The H2020 project ECOPOTENTIAL Consortium defined the list and characteristics of the Protected Areas (PA) to be studied (pictured below), covering the range of European biogeographical regions and assessing the representativeness of the selected PAs. The main Essential Variables for selected PA studies have been identified and analyzed. Downscaling of climate drivers for the PAs was performed and the framework for future projections of the PA ecosystem status was established. A video explaining the aims of the project was prepared and

it will be shown at the GEO Plenary. The two European projects ECOPOTENTIAL and SWOS started interacting with the goal of completing each other's approach.

2.12 GEO Global Network for Observation and Information in Mountain Environments (GEO-GNOME)

Reference to the activity GI-15.

- Accurately delineating mountain regions is fundamental to and the first task of GEO-GNOME. Thus GEO-GNOME participants started comparing the extent and coverage of mountain regions so an effective mechanism for data access and visualization can be set up;
- GEO-GNOME participants worked together towards creation of the Unified High Elevation Observing Platform (UHOP), a global network of instrumented elevational transects aimed at quantifying and understanding Elevation Dependent Warming, a regional expression of global warming. An initial assessment will form the basis for the goal of a fully operational system within the next year;
- The Elevation Dependent Warming group met with the Land Surface Temperature satellite community in June to explore how the field-based efforts could be coordinated with the remotely-sensed efforts. The European Space Agency supported this collaboration.

2.13 GEO Global Water Security (GEOGLOWS)

Reference to the activities GI-20, CA-07, CA-08, CA-09, CA-10, CA-15, CA-17.

- GEOGLOWS consolidated seven GEO Community Activities in water into its programme framework for the 2017-2019 Work Plan;
- New GEOGLOWS projects and training sessions are being initiated in Colombia, Argentina, Europe and Canada as well as in the USA;
- GEOGLOWS held its first international Steering Committee meeting in August 2016 and is now initiating groups to undertake its 2017-2019 Work Plan.

2.14 GEO Vision for Energy (GEO VENER)

Reference to the activity GI-10.

- A Sensor observation service capacity for the Energy SBA has been set-up through the ConnectinGEO project for Enhancing GEOSS Webservice-Energy SD and is available at http://insitu.webservice-energy.org. It allows the visualization and processing of in-situ solar radiation measurements. It is also used for discussing the involvement of private solar companies within GEO as providers of in-situ solar irradiation and users of the GCI. A video showing the benefits of this new component of webservice-energy.org is available (in French subtitled in English) at https://www.youtube.com/
- The COPERNICUS CAMS Service for Solar Radiation (https://www.gmes-atmosphere.eu/) has been released as an operational service. The Copernicus Atmosphere Monitoring Service (CAMS) deals both with the ultraviolet part of the spectrum having an impact on human health and with the visible solar spectrum being relevant for solar energy usage. Global and direct irradiances are provided for Europe, Africa, the Middle East and Asia, providing the solar energy industry, the electricity sector, governments, and renewable energy organizations and institutions with suitable and accurate information of the solar radiation resources at the Earth's surface in easily-accessible formats and understandable quality metrics.
- Activities of the Federation of Earth Science Information Partners (ESIP) Energy & Climate Working Group included enhanced communication between data providers at US Federal

agencies and renewable energy decision makers. A workshop was organized in 2016 focused on new applications using NASA and other US agency Earth science resources for energy management decision making.

2.15 GEO-Wetlands Initiative

In 2015, a diverse partnership started discussing the establishment of a GEO-Wetlands initiative with the goal to advance the development of a Global Wetland Observation System (GWOS). This collaboration was based on prior activities of the Ramsar Convention on Wetlands, GEO BON and Wetlands International and supported by several on-going projects. The major achievements of the GEO-Wetlands partnership from 2015-2016 can be summarized as follows:

- Formation of a GEO-Wetlands core team that prepared a GEO-Wetlands implementation plan, proposing it as a new GEO Initiative for the 2017-2019 Work Programme;
- Establishment of close collaboration between different, wetland & EO related, projects to ensure cooperation under a common set of global objectives;
- Representation of GEO-Wetlands in several conferences and workshops; Publication of a conference paper, describing the idea behind GEO-Wetlands, in the proceedings of the ESA Living Planet Symposium 2016.

2.16 Global Drought Information System Global Initiative (GDIS)

Reference to the activity CA-16.

Existing network partners within GDISs include the North American Drought Monitor (NADM), the European Drought Observatory (EDO) and the Australian Bureau of Meteorology (BoM). A new continental partner drought network is being developed (as a GDIS activity) within Central and South America, also under the auspices of the World Meteorological Organization (WMO).

Global and regional pilots to be pursued, along with the addition of new content to the existing data portal:

- Develop a Regional Drought Association for South America (and Central America);
- Develop in conjunction with WMO of the "One Stop Shop" drought information service through the GDIS portal;
- Continue to develop the adaptation of the global precipitation monitoring system (for GDIS global drought monitoring) to recover global water availability maps for global water stress monitoring. Investigate space-based technologies for global water usage monitoring. Work with UN Water and FAO Aquastat's (and possibly GCOS) development of global water stress monitoring;
- Assess global drought prediction system based upon ECMWF SEAS (seasonal forecasts) and North American Multimodel Ensemble forecasts;
- Assess feasibility for establishing regional drought associations in South Asia with WMO and Middle East-North Africa (MENA).

2.17 Global Urban Observation and Information

Reference to the activity GI-17.

- Megacities Observation and Monitoring (MOM) program: Expanded from the Global Urban Supersites Initiative under GEO SB-04. These projects all focus on global urbanization of megacities and providing the data sets for municipalities for megacities in the world;

- Continued generation of Global Human Settlement Layers at various international and national levels and seeking of synergies among them;
- Implementing Virtual Global Urban Remote Sensing Laboratory through joint projects: The main objective is to develop an online tool to acquire, process, visualize, and share urban data sets;
- Initiate a joint project of Impervious Surface Mapping in Tropical and Subtropical Cities - ISMiTSC (Asia, Africa, and South America): This initiative focuses on urban mapping and providing datasets and EO technology services to developing countries.

2.18 Global Wildfire Information System (GWIS)

Reference to the activity GI-09.

The implementation of the Global Wildfire Information System follows the scheduled plan, which foresees for 2016 the following actions:

- M1 Workshop of GWIS partners – Q4 2016;
- M2 Consolidated prototype of the GWIS – Q4 2016.

Preparation of M1 is underway. The first meeting of the GWIS partnership will take place on 15 November, 2016, in the context of the ForestSAT2016, in Santiago de Chile (https://forestsat.blogspot.co.uk/2016/08/fire-sessions.html). Participants to this meeting include the members of the Global Observation of Forest Cover – Global Observation of Land Dynamics (GOFC-GOLD) Fire Implementation Team, including representatives of the regional networks, as well as other relevant national/international providers of fire monitoring information.

Development of the prototype of the Global Wildfire Information System prototype (M2) is progressing smoothly. This development is framed in the synergy between GEO activities and those of the EU Copernicus Program 2015-2020, which envisage the extension of the European Forest Fire Information System (EFFIS – http://effis.jrc.ec.europa.eu) to the global scale.

2.19 Oceans and Society: BLUE PLANET

Reference to the activity GI-07.

Over the past year, Blue Planet has made significant progress towards securing resources and moving forward as a GEO Initiative. In November 2015, Blue Planet established a distributed Secretariat. The Secretariat consists of a full time Scientific Coordinator supported by the U.S. National Oceanic and Atmospheric Administration (NOAA) and a part time Technical Manager supported by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). In 2016, Blue Planet has focused on the development of the Initiative Implementation Plan which was accepted by GEO. Through this process, Blue Planet has identified a formal governance structure and a plan for growing the network of Blue Planet participants and identifying priority pilot/prototype projects for the Initiative to focus on in the coming years. Blue Planet has also undertaken efforts to engage with stakeholders and users and expand community support for the Initiative.

A summary of these and other recent and on-going Blue Planet achievements are presented below:

- Secretariat established;
- Governance structure developed;
- Blue Planet Implementation Plan submitted and accepted by GEO;
- New website established (www.geoblueplanet.org);
- Communication and engagement strategy development and implementation underway;

- User and stakeholder engagement underway;
- 3rd Blue Planet symposium planning underway.

3 COMMUNITY ACTIVITIES

3.1 Introduction

GEO Community Activities allow stakeholders to cooperate flexibly in a community-led, bottom-up fashion, with a low initiation cost. Progress in 2016 represents a broad variety of activities with varying degrees of coordination. GEO Community Activities define user needs, explore new frontier applications, demonstrate technical possibilities and agree on specific observation or analysis protocols and data exchange. Naming of the activities is according to the new Work Programme (2017-19) with a reference to the name of the Community Activity according to the Transitional Work Programme, 2016.

3.2 Access to Climate Data in GEOSS

Reference to the activity CA-03.

- Observations for Model Intercomparisons Project (OBS4MIPs), the observational component of the Earth System Grid Federation (ESGF) dedicated to the evaluation of Model Intercomparison Projects, has now published more than 60 documented data sets and another 100+ are in preparation (see https://www.earthsystemcog.org/projects/obs4mips/ for details);
- ANA4MIPs, the reanalysis component of ESGF has also now published global reanalyses from all major producing centers (ECMWF, NASA, NCEP, JMA) (see https://esgf.nccs.nasa.gov/projects/ana4mips/ for details);
- The US National Operational Model Archive and Distribution System (NOMADS) continues to be a highly accessed model data archive service that provides more than 250 million individual downloads per year providing over 1.4PB of data to researchers, the private sector and the operational forecasting community;
- Teams from NCEI and NOMADS are implementing the most recent version of the ESGF software suite that has undergone an extensive security review led by NASA with participation across the international federation;
- WCRP and CA-03 are jointly advancing improved model data access within GEO to provide increased and easier access to advanced climate and weather models to and through the GEO community.

3.3 African Geochemical Baselines

Reference to the activity CA-25.

Due to the lack of funding, the activities carried out during 2015-16 were financed by China Geological Survey, the UNESCO International Centre on Global-scale Geochemistry and the IUGS/IAGC Task Group on Global Geochemical Baselines (as from August 2016, the IUGS/IAGC Commission on Global Geochemical Baselines). All the activities were concerned with capacity building.

- In 2015, the China Government provided funding of approximately US$ 200,000 for two training courses for Ethiopia, and French-speaking countries from Africa, i.e.,
  - Geoscientists from Ethiopia were trained in applied geochemical methods at the premises of China Geological Survey in Langfang, China (17-21 August, 2015);

- Geoscientists from French-speaking African countries were trained in applied geochemical methods in Chengdu, China (22-23 October, 2015).

- In 2016, the China Government, through the UNESCO International Centre on Global-scale Geochemistry in Langfang provided funds for the opening ceremony of the Centre (12-13 May 2016), the inaugural meeting of the Governing Board and Scientific Committee, and a three-day Training Course (14-16 May 2016) on "Global Geochemical Baselines". The course was attended by more than 50 geoscientists from China, Africa, Asia, Europe, Central and South America. The African participants were from Liberia, Madagascar, Namibia, South Africa, Zambia and Zimbabwe.
- In 2016, the IUGS/IAGC Task Group on Global Geochemical Baselines organised and sponsored a two-day Workshop on "Global Geochemical Baselines" on the occasion of the 35th International Geological Congress in Cape Town (27-28 August, 2016). The first day was devoted to lectures, and the second to training in sampling methods in the field. The course was attended by 19 people, mostly from African countries.

3.4 AquaWatch

Reference to the activity CA-14.

In 2016, AquaWatch hired a part time Secretariat staffer, generated a strategic plan that includes seven work packages, established and populated five working groups and held a workshop in Koblenz, Germany where the future of AquaWatch was discussed and specific projects were identified for work packages 3 and 4. AquaWatch has also identified a host for a new website with increased functionality (Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO)) and is working on the new site. An overview of specific progress for work packages 1-4 is outlined below.

Work Packages 1 & 2: Work package 1 (the initiation of the community of practice) has been completed and a first version of work package 2 (the project inventory) has been produced. The inventory is a living document that will be continually updated throughout 2017-2019.

Work Package 3: AquaWatch is beginning the development of a global 300m resolution baseline turbidity and reflectance product for freshwater and coastal areas. Where higher resolution data is available, the product will include additional layers with higher resolution information.

Work Package 4: The AquaWatch community is currently producing a booklet highlighting the functionality of prototype projects that include in situ data, remote sensing data and modeling. The deadline for project submissions for this booklet is September 15, 2016. The projects to be highlighted will then be selected in October and the booklet will be produced.

3.5 Data Analysis and Integration System (DIAS)

Reference to the activity CA-18.

- The Data Integration and Analysis System of Japan (DIAS) has opened a new English language website with easy access to the data archive and a wide range of tools. A new tool is available to access, visualize, analyze, subset, and download the data of the Coupled Model Intercomparison Project Phase 5 (CMIP5) for a specified time or space through simple screen operations;
- A new capability of the Water Cycle Integrator (WCI) function has been developed – the coupled land-vegetation data assimilation system (CLVDAS), which includes an eco-hydrological model and a satellite data assimilation scheme and is suitable for monitoring and predicting droughts in regions with scarce observation;
- The Asian Water Cycle Initiative (AWCI) activities included the Asia Water Cycle Symposium 2016 in Tokyo, 1-2 March 2016, which was organized in collaboration with the

Network of Asian River Basin Organizations (NARBO), the International Flood Initiative (IFI), and the International Drought Initiative (IDI). The Symposium focused on flood and drought issues in the Asia-Pacific region in the context of the Sendai Framework and in the relevance to Sustainable Development Goals, and on the role of science and technology for mainstreaming DRR and contributing to sustainable development in the Asia Pacific region. The deliberations contributed to the refinement of the New IFI Strategy for 2016–2022 and AWCI member countries discussed possible solutions to improve their operational flood warning systems to become truly early warning systems;

- A two-week International Summer Program on Sustainable Water Management in an Era of Big Data was organized by the University of Tokyo and ICHARM in Japan in 2015 and 2016, designated mainly for undergraduate students. The Program was designed to promote problem-solving capacity for water-related problems with an interdisciplinary approach and by exploiting various data and data integration functions of DIAS.

3.6 Digital GEOMUSEUM

- In August 2016 the GEOMUSEUM was exhibited in the archived collections at the International Geographical Union (IGU) congress in Beijing.
- In November 2016 the GEOMUSEUM will exhibit at GEO-XIII Plenary in St. Petersburg.

3.7 Earth2Observe

Reference to the activity CA-20.

Over the past year the following key activities have been performed:

- The results of the first water resources ensemble have been analysed using the tools from the International Land Model Benchmarking Project (ILAMB) and a paper describing the results is in preparation;
- An analysis of the error propagation through the entire modelling chain has been performed over the Iberian peninsula and the results have been reported in a project report;
- The outputs from the first global water resources ensemble have been used in all case studies and reporting on the results is on-going. A number of peer reviewed papers on the first results have already been published;
- For the second version of the global water resources ensemble we have prepared the new global meteorological forcing data at 0.25 degree resolution that includes a new global merged precipitation product (MSWEP, Beck. et. al. 2016). In addition, we have formulated the protocol for the second batch of model runs;
- An updated remote sensing dataset supporting the water resources estimate has been collected and made available through the data portal (wci.earth2observe.eu).

These activities contribute to our understanding of the applicability of global water resources estimates (and model results) at the local scale and will help to improve the on-going efforts by better quantifying errors in different water balance components at the global scale. Preliminary results show that cold region processes and evapotranspiration in general may be key target areas for improvement.

3.8 Earth Observations for Disaster Risk Management

Reference to the activity CA-27.

The Earth Observations for Disaster Risk Management activity helped kick-off the GEO-DARMA initiative, starting the first project phase aiming at identifying the Regional Institutions that will be requested to identify the most critical DRR-related issues that affect most of the countries in each one of the selected regions. A €140,000 contractual support to the GEO-DARMA Lead for an initial two-year period will kick-off in October 2016; the contract includes an option for two additional years.

3.9 Earth Observations for Geohazards, Land Degradation and Environmental Monitoring

The EuroGeoSurveys Earth Observation and Geohazards Expert Group (EGS EOEG) Annual Meeting was held in Bucharest from 24-25 May 2016. The main activities for 2016 were discussed and further activities were planned.

A joint abstract and proceedings paper were submitted for the 4th World Landslide Forum in which the results of a review on landslide and subsidence databases in the Geological Surveys of Europe were summarized.

The EGS EOEG partners have been working towards preparing an annual landslide report for 2016, led by Eleftheria Poyiadji, IGME, Greece, as well as creating a European landslide density map, led by Gerardo Herrera, IGME, Spain.

The EGS EOEG has an EO-Raw Materials Working Subgroup working towards submitting a new COST Action proposal to aim to build world soil/rock reflectance and emissivity libraries (the deadline is on 1 December, 2016). This activity is led by Veronika Kopackova (CGS) and coordinated together with the CA-06 Community Activity: EO data and Mineral Resources.

The idea of Supra-national Ground Motion Service has been recently pointed out at the Copernicus User Forum. EGS EOEG could play a role in the implementation of future ground motion Copernicus services pushing the involvement of Geological Surveys in such processes (quality of products, etc.).

The EGS EOEG report on Earth Observation National activities in the frame of Sentinel and Copernicus data and services has been elaborated by Michaela Frei (BGR).

On 5 September 2016, a Copernicus Workshop on Earth Observation for Raw Materials was held in Brussels. The objective of this event was to propose effective measures to support Copernicus uptake from private intermediate and end users, with a special focus on the area of raw materials and extractive industries as well as identifying potential research and development needs. Mr Gerardo Herrera (IGME) presented during this conference the Earth Observation activities on Raw Material.

3.10 Earth Observations for Managing Mineral Resources

Reference to the activity CA-06.

3.10.1 Activities

- First CA-06 meeting held at CSIRO in Perth (WA) through physical attendees (AU, JP, US) and WebEx (FR, UK, DE, IL, CN) on 3 February 2016.
- Issues and outcomes:
- Generation of a publicly available Global ASTER Geoscience map to be delivered to GEO.
- Definition of possible product standards for global, public hyperspectral satellite soil surface composition.
- Global spectral libraries of soils for future quantitative soil spectroscopy - from laboratory to spaceborne applications.
- Identification of a user community and their requirements related with energy and minerals.
- Submission (7 April, 2016) of a CA-06 General Comment on the consultation on the UNDP – WEF draft report on ‘’Mapping Mining to the Sustainable Development Goals’’.
- Potential contribution of EO to UNDP 2016 Sustainable Development Goals (SDGs).

- Submission (7 April, 2016) of a CA-06 proposal on the EU consultation on next Societal Challenge 5 Work Programme 2018-2020.
- Input from the GEO Community Activity on "Earth Observation Data in Mineral Resources" (CA-06)
- Oral presentation at the 35th International Geological Congress (Cape Town, South Africa) entitled ''towards a global mapping of Earth's Surface minerals". Abstract included in proceedings.

3.10.2 Resources

There is currently no specific resource (funded projects) available to CA-06.

3.11 Earth Observations for the Water-Energy-Food (W-E-F) Nexus

Reference to the activities CA-19 and CA-22.

This Community Activity is a collaboration between GEO, Future Earth and the Sustainable Water Future Programme (SWFP). A workshop on the Future Earth WEF cluster project was held in Kyoto Japan at the Research Institute for Humanity and Nature in April 2016. The workshop featured special sessions on Earth Observations with presentations on ESA and NASA services among others and another session addressing scaling issues. Workshop recommendations included actions to develop consistent terminology across the three sectors and the development of a proposal to use geospatial data to map the stresses and risks associated with the Nexus. Both ESA and the US National Science Foundation have started to support WEF Nexus projects including those that use Earth observations.

This WEF Stress mapping project has subsequently been formulated as the End to End (E2E) WEF Nexus project. The initial planning meeting for the study will take place in the Washington DC area possibly in December 2016 with support from the Sustainable Water Future Programme.

In addition, the final regional Project for the WEF Nexus project has been planned for South Africa from 21-23November, 2016. It will be followed by a two-day Science-Policy Dialogue. Earlier in 2016, an article related to this activity was published in the Journal of Environmental Studies and Sciences, on "the Present and Future of Primary Resources Nexus and the Role of the Community of Practice", which highlighted the role of a Community of Practice in the WEF Nexus based on the IGWCO COP experience.

Within the activity and through the efforts of Adrian Strauch the Community Activity managed to evolve the wetlands component into a new GEO Initiative (GEO-Wetlands) and developed the implementation plan for it in collaboration with other partners like the Ramsar Convention Secretariat, ESA and others.

3.12 Forest Biodiversity in Asia and the Pacific Region: Capacity Building Phase

Reference to the activity CA-33.

Significant progress has been made in initiating a review of National Forest Inventory (NFI) design, currently used by Forest Survey of India (FSI), the lead institution on the subject in the country. UN FAO has joined the initiative by approving a grant to provide international expertise during 2016-2017 to transform the design into a National Forest Monitoring System (NFMS), a new generation of national forest inventories, geared towards providing continuing information to meet national policy and planning needs for both forest and environment sectors including climate change, biological diversity and sustainable forest management. The first activity, in the form of an Information Needs Assessment (INA), was completed in August 2016. During the rest of the year, consultations will be organized with State Forest Departments regarding their acceptance of the NFMS.

3.13 Global Agricultural Drought Monitoring

- A project entitled Drought Mechanism is being implemented in Asia with partners from China, India, Sri Lanka and Mongolia. This project is promoted by UNESCAP. More countries in Asia are expected to be involved;
- Chinese partners prepared the five-day and ten-day composites of FY3A MERSI data for Sri Lanka partner and aims to help monitor the drought in Sri Lanka;
- Chinese and Indian partners are interested to initiate a proposal related to agricultural drought monitoring and are seeking partners from other BRICS countries. South African partners have expressed their interest and are willing to cooperate on this proposal that will be submitted to BRICS funds. Other partners from Brazil and Russia are welcome to join this proposal;
- Indian partners are proposing that our community draft a synthesis report from the ongoing drought monitoring program.

3.14 GFCS - GEO Collaboration

Reference to the activity CA-04.

- Support for GFCS implementation has been endorsed as a key collaboration area between WMO and GEO at the 68th Session of the WMO Executive Council;
- GEO Secretariat and GFCS Office are collaborating regarding the user and data needs processes to be established in both frameworks. In this regard, GEO has joined the new WMO Expert Team on Specific Data Requirements for the GFCS. Likewise, GFCS will be contributing to the GEO Foundational Task on SBA User Needs;
- A GEO-GFCS White Paper outlining the interlinkages and synergies between GEO and GFCS is under preparation.

3.15 Global Mangrove Monitoring

Reference to the activity CA-31.

- Monitoring methods were developed;
- Analysis of the entire continents of Africa, South Asia, and North America were completed;
- A paper on the monitoring of South Asia was published;
- A manuscript on the USA was submitted to a peer review journal;
- Analysis of other continents is in progress.

3.16 In Situ Observations and Practices for the Water Cycle

Reference to the activities CA-11, CA-12 and CA-13.

Over the past year the following key activities have been performed:

- The Global Terrestrial Network – Hydrology (GTN-H) held its Panel Session in June 2015 back to back with the Steering Committee meeting of the Global Runoff Data Centre (GRDC). Significant progress was reported by all federated global data centres, representing hydro-meteorological essential climate variables that are identical with the essential water variables in this regard;
- In April 2016, GTN-H and several of its federated data centres participated in the 18th session of the Terrestrial Observation Panel on Climate (TOPC) under the leadership of the Global Climate Observations System (GCOS). Here and in subsequent activities, GTN-H with its

partner data centres contributed significantly towards discussions to improve in-situ observation systems related to hydro-meteorological variables, including the development and update of the basic requirements tables that are the observational back-bone of the GCOS Implementation Plan to be presented during the upcoming meeting of the Conference of the Parties (COP);

- Major efforts were undertaken to improve the interoperability of the exchange of data as a milestone for enhanced efforts to develop tailored data products from a multitude of databases;
- Data centres continue to register datasets with the GEO-Common Infrastructure;
- In cooperation with the Open Geospatial Consortium (OGC) and HydroDomain Working Group the Community Activity made significant progress in matters related to standards and standardization of communication including the use of Water –ML;
- The database of Global Environment Monitoring System Water (GEMS-Water - GEMStat) that is hosted by Germany is nearing operational capabilities after its transfer from Environment Canada to Germany;
- Both, GRDC and GEMStat are migrating to a common new database system that enables the centres to use synergies and the development of joint data products related to water quantity and quality;
- The International Soil Moisture Network (ISMN), hosted by Austria is supported for one additional year through an ESA contract;
- The International Groundwater Resources Assessment Centre hosted by The Netherlands has expanded its Global Groundwater Monitoring Network including the strive to obtain critical groundwater information from major aquifers;
- The Global Data Centre for Lakes and Reservoirs (HYDROLARE), hosted by Russia intensified its cooperation with the French Space Agency (LEGOS-CNES) to ingest satellite-derived water levels of major lakes worldwide with the aim to jointly calculate water volume changes of major lakes.

3.17 Land Cover and Land Cover Change

Reference to the activity CA-01.

3.17.1 From GEO Secretariat

- The GEO Secretariat and UNGGIM co-organized a Land Cover workshop in Rotterdam from 23-24 May 2016, entitled “Towards a sustainable operational system for land cover classifications that meets varied user needs”. The outcome was general agreement on basic concepts which are being captured in a synthesis document. Presentations and key points are available at the Workshop website.

3.17.2 From GOFC-GOLD

- Researchers from Wageningen University (NL), IIASA (AT) and VITO (BE) are working on creating Dynamic Land Cover products as part of the C-GLOPS1 project funded by the EC-JRC. The validation strategy will focus on the flexibility and re-usability of the validation dataset towards multiple users and multiple land cover maps including higher resolution maps that are based on Landsat or Sentinel data;
- From JRC/Copernicus;
- Some services of the EC/Copernicus Global Land Service became operational;

- The Copernicus Global hot-spot monitoring task was launched with an initial focus on African Key Landscape Areas.

3.18 Land Cover for Africa

Reference to the activity CA-02.

3.18.1 Land cover product:

- RCMRD in collaboration with the Department of Resource Surveys and Remote Sensing of Kenya and Ethiopian Mapping Agency produced land use/cover change maps at a scale of 1:100.000 from Landsat data for Kenya and Ethiopia. The land use/cover maps are to be used for Green House Gases inventory estimation as required by the UNFCCC;
- Sahara and Sahel Observatory (OSS) has developed a land cover map using Landsat-8 acquired during 2014/2015 currently covering North Africa with a goal to cover the Great Green Wall action zone (12 countries) by the end of 2016;
- Through its BIOPAMA (http://rris.biopama.org/lcc) project the JRC is providing land cover change data in and around protected areas in Africa over the period 1990-2000-2010 using Landsat data;
- Tsinghua University completed a series of Landsat based 2014 multi-seasonal land cover maps for Africa with two classification systems.

3.18.2 Access to Data:

- A prototype web interface for the Africa Land Cover Inventory has been developed by the Centre de Suivi Ecologique (CSE), Senegal with financial support from US DOI. The tool will allow users to access information about available or in-work land cover datasets for specific countries and regions;
- SERVIR Eastern and Southern Africa, through its host institution RCMRD, developed a geoportal to share geographic information datasets (http://geoportal.rcmrd.org/layers). The geoportal contents are discoverable in the GEOSS Portal. Datasets include land cover maps developed by RCMRD through SERVIR E&S Africa for nine countries;
- OSS is currently developing a regional Atlas covering the Great Green Wall zone to be launched end 2016. Connections for brokering by the GCI have been made;
- Tsinghua University started the development of a web-based portal to support individuals interested in making local land cover maps at any location in Africa. At this year's GEO Plenary, a demo will be delivered.

3.18.3 Meetings and Workshops

- A thematic session on land cover was organized at the AfriGEOSS Symposium in Victoria Falls, Zimbabwe in April 2016 and a special session and workshop is organized for October 2016, at the AARSE conference;
- RCMRD and the National Administration of Surveying and Geoinformation of China organized a two-day workshop on Advanced Land Cover Information Technology and Applications from 18-19 April, 2016, in Addis Ababa, Ethiopia, as a side event of the UN-GGIM 4th High Level Forum;
- SERVIR hubs across the globe are helping the United Nations Food and Agriculture Organization (FAO) conduct a new pilot assessment of tree cover, forest, and land use around the globe. More than 400 experts are participating from institutions worldwide including RCMRD in Kenya and AGRHYMET (launched in July as SERVIR West Africa hub) in Niger. AGHRYMET participated in July 2016, while FAO and RCMRD collaborated in a

Forest Assessment Training and Validation Workshops from 9-26 August, 2016, in Nairobi, Kenya.

3.19 Space and Security

Reference to the activity CA-23.

In 2016 a number of activities were initiated with the main aim of promoting the GEO Space and Security Community Activity within suitable entities and stakeholders in order to build a relevant User Community and to look for cooperation. The Space and Security CA has been announced in a number of open events (e.g. the ESA-SatCen-JRC Big Data from Space Conference, the ESA Living Planet Symposium, the ESA EO Open Science Conference and the SatCen Big Data in Secure Societies Workshop) and in a number of restricted events (e.g. the SatCen Expert User Forum).

Moreover possible synergies with suitable H2020 projects (e.g. BigDataEurope and EVER-EST) have been explored and a major effort has been spent to ensure the SatCen participation in the H2020 NextGEOSS project (which will start at the end of 2016). NextGEOSS aims at implementing a federated data hub for access and exploitation of EO data, including user-friendly tools for data mining and discovery; SatCen will develop a pilot in the Space and Security domain (building on the results of the activities performed in BigDataEurope and EVER-EST) with the main aim of providing tools for the analysis of large amounts of heterogeneous data as well as of promoting within GEO the concepts and outcomes of the pilot fostering extensive exploitation of the GEOSS Data Hub.

3.20 Synergized Multi-Source Remote Sensing Products and Services

Reference to the activity CA-34.

To support global change studies and international cooperation in Earth Observation System of Systems (GEOSS), a series of products from the China National High-tech Research and Development Program (863 Program) were integrated to continually carry out and release Annual Report on Remote Sensing Monitoring of Global Ecosystem and Environment. Seven land regions and 12 ocean regions along “The Belt and Road” are selected as the monitored areas. A comprehensive analysis was conducted for the ecological environment, typical economic corridors, traffic and transportation channels, important nodal cities and ports based on the remote sensing data and products. The multisource and multi-spatial-temporal-scale remote sensing data were obtained by the standard processing and model operation from the Feng-Yun meteorological satellite (FY), Hai-Yang oceanic satellite (HY), and Huang-Jing environmental remote sensing satellite (HJ), high resolution satellite (GF), Terra/Aqua and Landsat during 2000-2015. The data products have relatively high currency, containing 31 ecological environment remote sensing products, such as land cover/land use, vegetation growth status index, agricultural condition, marine environment and so on. The data and the report were published on the website of National Integrated Earth Observation Data Sharing Platform (http://www.chinageoss.org/geoarc/2015).

3.21 TIGGE (THORPEX Interactive Grand Global Ensemble) Evolution into a Global Interactive Forecast System (GIFS)

Reference to the activity CA-05.

- Successful launch of the Subseasonal-to-Seasonal (S2S) database in May 2015, first for near real-time data, then of reforecast data towards the end of 2015. A great effort was put into the establishment of all the routine processes to ingest up to 10 models in the database. This effort is continuing up to the present day, as output data from the remaining one model (out of the planned 11 models) is close to being ingested to the S2S database;
- Continuation of data ingestion after NCAR stopped their involvement in TIGGE at the end of the THORPEX project (December 2014). This meant that a different institution (NCDC) had to deal with the conversion of NCEP data to TIGGE convention, and changed the way to

transfer to ECMWF. The adaption to different model changes and increases of resolution (namely, ECMWF's implementation of its new Octahedral grid) were some of the challenges that had to be dealt with.

4 GEO FOUNDATIONAL TASKS

Based on the outcome of the GEO Work Programme Symposium, May 2016 and on the day-to-day interaction of Secretariat Experts with the different teams, a summary of the progress achieved to date on the Foundational Tasks is reported in the set of tables contained in Attachment 1. The tables contain, for each Task, the key deliverables identified in the approved 2016 Work Programme and the summary progress as of September 2016.

It should be noted that there is some overlap with these tables and the Secretariat Operations Reports, regularly submitted to the Executive Committee, which, heretofore, has been the place where Secretariat activities are reported. This overlap is a consequence of the new implementing arrangements where all Secretariat resources and activities are devoted to the performance of Foundational tasks.

The following documents, related to the outputs of three Tasks, are attached for Plenary information, upon request of the relevant Task Teams:

Report	Task	Att
GEOSS Data Sharing Principles Implementation Guidelines 2016-2025	GD-01 Advancing GEOSS Data Sharing principles	2
Data Management Principles Implementation Guidelines (*)	GD-07 GCI Development	3
In Situ Observations: Coordination Needs and Benefits	GD-06 GEOSS non-space based Earth Observation Resources	4

Appendices

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APPENDIX 1. Foundational Tasks Progress against Work Programme

Appendix 1: Foundational Tasks Progress against Work Programme P2016 key Deliverables status June 2016

GD - Tasks GEOSS Development and GCI Operations

GD-01	Advancing GEOSS Data Sharing principles	Key deliverables 1. Hold at least one meeting of DSWG 2. Draft Implementation Guidelines on Data Sharing Principles for Plenary approval in 2016 3. Produce a report on international Open Data trends 4. Draft a summary on monitoring the progress of GEO Members in establishing and implementing Open Data Policies *Progress:* *As of September 2016, this task has been progressing steadily.* *1. A revised version of Implementation Guidelines for Data Sharing Principles has been drafted and is submitted to GEO-XIII Plenary, which conveys the necessary elements to guide both GEO Members and Participating organizations, as well as data managers and custodians to follow the revised Data Sharing Principles and pledged resources to GEOSS.* *2. The living document regarding developments in the area of Open Data is currently being updated to correspond to the new GEOSS Data Sharing Principles, and to contain relevant bases for comparison and analysis of regulatory and policy documents and other sources that introduce or develop Open Data in a given jurisdiction or an organization. A new version of the living paper is intended for presentation during the GEO Plenary.* *3. Additional cases are collected for the Value of Open Data Sharing paper. Compelling stories and reader-friendly designs are explored to convey impact to target readers.* *4. Requested by the DSWG, with consultation at the Executive Committee, the GEO Secretariat Director sent a letter of Request to Establish National Contact Points for Data Sharing within GEO Member Governments. Nominations have been received from countries that used to be not very active in GEO.*

GD-02	GCI Operations	Key deliverables 1. Continue GCI operations 2. Develop a concept paper on user desk will work by April 2016, with interactions and support by SIF. User desk should be operational in 2016 3. Start the configuration control of GCI 4. Improve capabilities of existing brokering providers in particular more accessibility 5. Connect new providers giving priority to those relevant to Flagships, Initiatives and Community Activities and key members and participating organizations 6. Definition of improvements of early next year to be incorporated in the next 3year WP 7. Test and release new GEOSS resource registration process, including the synchronization of the CSR and the DAB. *Progress:* *GCI Operations, are progressing well as planned, by the various GCI components:* *The GEODAB by brokering new data providers also to align with the needs of Flagships and Initiatives, and starting a preliminary quality check of existing brokered data providers to assess the discoverability, accessibility and utilization, as well as metadata completeness;* *The brokering of the new data providers takes into account user needs and thematic as well geographic balance of the resources brokered prioritizing those organizations who have open data policies to allow users to discover, access and use the resources* *A process of advocacy and knowledge transfer on the GEO DAB APIs has started to involve additional technical partners and expand knowledge and leverage the GCI resources.* *The GEOSS Portal is undergoing a re-styling and is including new additional functionalities to enable the user to have an easier and more successful experience in searching, accessing and use the required datasets. Development of thematic and regional Portals have been addressed with some examples, leveraging the GEO DAB APIs and GCI resources.* *A new simplified process for the registration of new data providers is being identified, with enhanced functionalities to provide more visibility to Data providers contributing with their data and resources as well as enabling a simpler and more effective registration process of their resources,* *GEOSS User Help desk concept note has been drafted and the plan is to have n incrementally operational GEOSS user desk operational in 2017.* *The challenge we see is the maintenance cost of GEODAB operation within the next 3/5 years, a proper funding plan needs to be agreed to ensure running costs and improvements.*

GD-03	Global Observing and Information Systems	Key deliverables 1. Resume coordination and consultations with Global Observing and Information Systems . In 2016, start leveraging and promoting WIGOS and WIS in GEO Community. Seeking other systems to take part in the task. 2. Start the development of a document describing GEO plans to support existing Systems and facilitate development of new ones, including their connection with GCI 3. Start the development of a report on "Inventory of Global Earth observation and information systems" with identifying potential gaps, duplications and synergies *Progress* *No major progress to report. There is a clear challenge to understand how to proceed; still under brainstorming mode and forming a team (at this point only WMO). There is need to involve other major Observation coordination bodies such as GCOS, GOOS, GTOS, GGOS, CGMS, CEOS, etc.* *The 37th Executive Committee discussed the document which the GEO Secretariat proposed a reassessment of progress towards the original vision of a Global Earth Observation System of Systems (GEOSS). The Committee requested that a subgroup, comprised of representatives from the Executive Committee, Programme Board and Secretariat, be formed to further frame issues and produce a two-page strategy for GEOSS comprising the broader aspects and implications for the GEOSS value chain: from federated observing systems to identification of gaps to use for policy and decision-making.*
GD-04	GEONETCast Development and Operations	Key deliverables 1. Continue GEONETCast operations 2. Test options for truly global coverage 3. Develop and test a GEONETCast planning tool and a friendly User Interface **(including a service desk)** 4. Develop a GEONETCast User Guide *Progress* *Following the reaffirmed commitments of further contributions by the three GEONETCast operators (EUMETSAT, NOAA and CMA) at the Mexico City Summit, active and on-going efforts have been made for increasing numbers of user stations (almost 20 stations per month), expanding bandwidth of EUMETCast and organizing training workshops for users.* *The team has initially engaged with GEO-GLAM, AmeriGEOSS and AfriGEOSS for the identification of possible, future use of GEONETCast in support of these initiatives.* *The team has also continuously engaged with International Charter for Space and Major Disasters to conduct initial test to disseminate data to their authorized users.* *A new GEONETCast website information page including Point of Contact, User Station Statistics, etc has been defined and agreed and it will be implemented into the new GEO website.*

GD-05	GEOSS satellite Earth Observation Resources	Key deliverables 1. Review the strategy and plans for the implementation of Virtual Constellations 2. Develop options on how better support the SBA's rolling processes on User Needs/Observation Requirements *Progress* *Steady progress on the implementation of CEOS Virtual Constellations continues to be made by CEOS, under the leadership of the CEOS Strategic Implementation Team. Regular reviews of Virtual Constellation implementation are conducted, allowing opportunities and issues, such as issues and potential gaps, to be addressed. There are currently no major issues, with a range of recent successful launches, and a strong forward schedule.* *CEOS is currently examining:* ** Options for increasing coordination of water cycle observations, in support of the CEOS Strategy for Water Observations. One option being considered is a 'Water Virtual Constellation'.* ** Its ongoing coordination of observations the carbon cycle, consistent with the CEOS Strategy for Carbon Observations.* ** In coordination with CGMS, opportunities to enhance coordinated observation of atmospheric CO2.* ** In coordination with CGMS, whether a proposal for a 'Polar Observations Virtual Constellation' should be developed.* *CEOS has also recently re-invigorated the Land Surface Imaging Virtual Constellation. The new focus of this group reflects the increasing availability of land surface imaging data, including global open datasets and specialised complementary (sometimes non-open datasets). This presents obvious opportunities, as the land is where much human activity takes place. However, the volume of data will present challenges for users. CEOS is working on topics such as 'Analysis Ready Data' and the development of a CEOS Data Cube, to help lower the technical barriers to the use of this data.* *CEOS has actively participated to the GD-08 User Requirement process definition. GD-08 will provide critical inputs to CEOS's efforts as the 'space arm' of GEO, coordinating long-term planning and development of the space segment of GEOSS. CEOS has started examining the processes and tools that it can adopt to make best use of the outputs of the GD-08 process as it matures. CEOS would like to see more progress on implementation of GD-08.* *Connections between CEOS and CGMS continue to be strong, as noted above, and through excellent ongoing cooperation in the frame of the Joint CEOS/CGMS Working Group on Climate.*
GD-06	GEOSS non-space based Earth Observation Resources	Key deliverables 1. Develop a plan of activities for the task, with defined leadership roles 2. Publish a report on the status of global non space-based coordination and frameworks, addressing also the sustainability of existing measurements, facilitating the transition from research to sustained long-term operations, and the integration of space-based and non space-based observations. *Progress* *A team is in place, providing a good representation from different Organizations/Communities, such as European Commission (Lead), European Environment Agency, France, GCOS, GGOS, GOOS, Germany, IEEE, I-BEC, Spain, WMO. According to the plans, a report on the status of global In Situ coordination and framework has been issued for information to the GEO-XIII Plenary.*

GD-07	GCI Development	Key Deliverables 1. Draft document of GEOSS Architecture 2. Consolidate/update a document "Evolution of GCI functionalities and architecture" including following topics: i. A report on "GCI Operations options" for 2016 ii. Plenary decision and implementation starting from 2017 3. Interact with GD08 (SBA process) and GD09 (Knowledge base) to collect requirements for designing the new functionalities 4. Implement new functionalities in 2016 to improve the accessibility and usability of GCI resources. 5. Report results on Demonstration pilot Projects 6. Approved Data Management Guidelines at GEO-XIII and draft a process of implementation with Flagships, Initiatives and Community Activities with training and workshops. 7. Organize a GEOSS Interoperability Workshop in 2016 and conduct virtually (arranged and managed by the SIF) 8. Publish new guidelines and tutorials in the Best Practices Wiki (The process is managed by the SIF.) 9. Deliver an updated version of the Community Portal Paper with specific recommendation based on interactions between community components and the GCI. *Progress* *The task includes a number of coordinated activities that are now structured in 6 subtasks and the entire team is in place. The team includes representation from different regions and different POs.* *Several subtasks have been initiated their activities such as:* • *Develop "Evolution of GCI functionalities and architecture",* • *Implement "Demonstration Pilots for supporting AmeriGEOSS and GEO-BON"* • *Improve "Data Management Principles Implementation Guidelines",* • *Plan "Data Providers Workshop"* • *Plan "Interoperability Workshop in the Standard Interoperability Forum" and* • *Develop "Community Portal Paper"* *With reference to deliverable 5), there has been no AIP (Architecture Implementation Pilot) this year. The team is planning for 2017, focusing on user-oriented demonstrations.* • *Conducted a workshop that was well attended by flagships, initiatives and activities to gather user requirements.* • *Developed a Draft GEOSS Service Framework (GSF) to support engagement, advocacy and delivery of Earth Observations for understanding and decision-making.* • *Developed prototypes and pilots working with flagships, initiatives and activities to test and evolve the GSF. The participants included GI-19 AmeriGEOSS, GI-20 GEOGLOWS, GI-07 BluePlanet, Aquawatch, Marine Bon, GI-18 SDG indicator development, CA-29 Ecosystems Accounts Framework*

		• *Through advocacy and engagement with these activities the GDWG completed a user needs analysis, gap analysis and developed solutions and services that resulted in the delivery of the following:* • *Capacity building efforts to advocate engage and deliver data, tools, products and services that are responsive to stakeholder needs.* • *Synergy between the identified participants to link efforts and activities for communication, coordination and resource sharing* • *Identification of data, tools, services and product needs* • *New commitments by providers to provide data to support gaps identified* • *Development of an AmeriGEOSS Community Platform for collaboration and co-creation of products and services* *Tested new functions and features using Application Programming Interfaces (API's) to make data discoverable, accessible and usable by community portals, through machine to machine interface to GCI, thus improving the quality of services. Four API's were integrated into community portals and are now operational improving the discovery, accessibility and usability of EO data. The conceptual technical architecture is evolving to include an API Component resource that will provide an accessible library of data, tools, and services that support the discovery, accessibility and usability of EO.* *A prototype using was developed to link non spatial open data with EO data, tools and services using the Comprehensive Knowledge Archive Network open source tool used by governments and institutions around the world. The tools is planned for use in the AmeriGEOSS community to link social, economic and other data with EO to support understanding and decision-making.* *DAB developments involved (GEO DAB APIs, advanced connection with GEOSS Portal) as well as other "European" activities that should be included –e.g. JRC MyGEOSS, GCI harvesting from China GEOSS via the DAB APIs, first GEOSS metadata analysis to recognize potential gaps (supported by H2020 ConnectinGEO).* *The Data Management Principle Implementation Guidelines has been updated and have been submitted to the Plenary. The team has also started to draft process of implementing the Guidelines.*

GD-08	**SBAs process: Systematic determination of user needs / observational gaps**	**Key deliverables** 1. Issue a document describing the process and how it will be run 2. Define initial plans for each SBA 3. Activate the process for at least three SBAs by 2016 ***Progress*** *A "ad-hoc" Working Group has been formed for the development of the document describing the process. The Group includes The Group met beginning of May in Geneva and, based on the meeting outcome, the Secretariat developed a first draft of the Document that is now undergoing a couple of iterations within the Group. The document should be issued in July and will also include recommendations on the two SBA to start with in the second half of 2016. The Group includes people with experience on similar processes coming from the following Institutions/projects: ConnectingGEO, EC-Copernicus, EARSC, ESA, GCOS, GFCS, IIASA, JAXA, NOAA, NASA, WMO.* *The report from the Group will be issued just before Plenary.* *Points 2 and 3 will be addressed, because of lack of resources.*
GD-09	**Knowledge Base development**	**Key deliverables** 1. Convene the team 2. Issue a report on GEOSS knowledge base concept and development approach 3. Start the compilation of available knowledge resources 4. Design and prototype a database to host GEO-developed knowledge ***Deliverable 1:*** *Two co-leads were identified. The Horizon 2020 Project "ConnectinGEO" contributed substantial human resources to the Task. The Task Team needs to be enlarged particularly with participants from outside Europe. The GEOSS Science and Technology Stakeholder Network is organizing the Fifth Workshop on December 9-10, 2016 in Berkeley, CA, USA with a strong focus on the Knowledge Base and the goal to bring new member to the Task team.* ***Deliverable 2:*** *The report is in a draft status mainly based on work carried out in the frame of the ConnectinGEO Project. Several deliverables of the ConnectinGEO project are relevant for the development of the GEOSS Knowledge Base both in terms of the concept, development, and methodologies used to generate new knowledge. The data model of the knowledge base has been fully defined. Two complementary approaches are used to link societal goals and activities to observational needs. Both approaches utilize the concept of Essential Variables widely used in GEO SBAs. The "expert-based approach" starts from the observation side and identifies the essential variables with a strong focus on feasibility and then links these variables to societal benefits. The "goal-based approach" starts at agreed-upon societal goals and targets and then identifies Essential Variables required for the monitoring of progress towards these goals and in support of goal implementation. ConnectinGEO also developed an approach to gap analysis and an approach for prioritization of gaps is under development. These approaches are all included in the knowledge base concept.*

		Deliverable 3: *An initial list /and definition) of what are the "knowledge resources" to be made accessible has ben drafted and the link with the GCI Team has been activated. This list includes the former GEOSS User Requirements Registry and several observational requirements registries. It also includes a comprehensive knowledge base on sustainable development programs and activities in the United Nations including the Sustainable Development Goals. The Midterm review of the ConnectinGEO project by the European Commission underlined the importance of integrating the project outcomes into the Knowledge Base.* ***Deliverable 4:*** *A prototype of the Knowledge Base is under development and very preliminary version is available at the URL http://www.seeinkb.net. It is expected that initial functionality will be available for community testing late in 2016. The prototype is developed as an open source utility with the aim to engage a broader community in the development. The rules implemented in the Knowledge base for the identification of Essential Variables, gap analysis, and prioritization will be reviewed during a ConnectinGEO workshop in October 2016. The functionality of the knowledge base as a platform to link the Sustainable Development Goals to data, models and capacity building will be further explored during the 5th GEOSS S&T Stakeholder Workshop in December 2016.*
GD-10	**Radio-frequency protection**	Key deliverables Actions will be activated to prepare GEO positions for the events requiring strong support to EO instruments working frequencies protection. *Progress* *After successful protection of 5GHz C-band issues in the WRC-15, the GEO Secretariat has sent a letter to GEO community asking if there are any key issues for advance coordination towards the WRC-19. The task is fully leveraged by the WMO Steering Group on Radio Frequency Coordination. The task activity would be "on demand", in case if any issues are raised by GEO Members and Participating Organizations. There were three requests received from the GEO communities in response to the letter as follows:* *1. The GEO Global High-Frequency Radar Network requested to raise awareness of the need for protection of 13MHz and 25MHz bands. The GEO Secretariat and WMO provided guidance and possible actions.* *2. The GEO Secretariat provided a quote to support a charter for establishing an OGC Spectrum Model Language Domain Working Group that will develop a standard data model for electromagnetic field data would be useful in efforts to mitigate interference between wireless communications and Earth imaging.* *3. The GEO Secretariat sent a support letter to a public notice issued in late April by the United States Federal Communications Commission seeking comments from affected user communities in response to a proposal by the wireless industry to share 1675-1680 MHz with GOES and future GOES-R downlink services.*

GD-11	Communica-tions Networks	Key deliverables 1. It is envisaged to hold a meeting with all contributors to exchange information and discuss on existing requirements, architecture and solutions and present the output to the GEO Programme Board. 2. Facilitate meeting with AfriGEOSS and the African NREN organizations to discuss existing communication infrastructure, requirements and developing activities in the region. 3. Participate in the 2016 activities of WMO's Expert Team on Telecommunications Infrastructure (ET-CTS) with an aim to refining the conceptual architecture. 4. Report on the initial progress and findings of this task to the 16th session of the Commission for Basic Systems (CBS) to be held in the second half of 2016, seeking further commitment to this GEOSS activity. 5. Activate a specific advocacy action with ITU for improvement of communication infrastructure in developing countries. *Progress* *A Meeting with all contributors took place in February 2016 focusing on the different communications infrastructures currently used by GEO. Given that the extremely complex picture of expectations and stakeholder requirements is still unclear, at this stage and also the scope and diversity of the GEOSS, the task agreed to start with "the known" focusing on improvements of existing infrastructure. WMO/WIS is actively involved to seek opportunities to utilize the Multicast across different infrastructure providers in WIS to investigate Single Sign On solution and follow and evaluate the results of a Cloud Pilot Project. A regional relationship in Africa has been established between AfriGEOSS, African Research and Education Networks and local EUMETSAT and WMO contacts. A formal component to the relationship has been added by ASREN, the regional network for R&E, becoming a member organization of GEO.The team further engaged with the GEO community at the European GEO workshop in Berlin, May 2016 to discuss the work of the task.*

Appendix 1: Foundational Tasks Progress against Work Programme P2016 key Deliverables

status June 2016

CD - Tasks Community Development

CD-01	Capacity Building coordination	Key Deliverables 1. Two meetings of the CB Working Group 2. Holding the GEO Capacity Building Symposium 3. Develop and maintain a database with resource providers, ongoing programmes and activities 4. Undertake brokering activities - match needs with capabilities starting from January 2016 5. Holding a Capacity Building Forum (with participation of GEO Initiatives and Flagships Representatives) 6. Annual report on capacity building needs *Progress* *The Task Team, made up of people who are passionate about Capacity Building and GEO, is in place.* *The capacity building activities in the 2016 GEO Work Programme were mapped. The results indicated that about 50% (35 of 71) of 2016 Work Programme Activities have or plan to include capacity building activities.* *A questionnaire was also circulated to all GEO activities having or planning a CB component. Responses were low, possible due to 2016 being a transition year and communities have not quite settled their plans and activities.* *Additional capacity building resources were contributed to the GEOCAB Portal and marketing of the portal has increased the visibility and use of the portal.* *The first GEO Capacity Building Forum meeting was held on 2 May 2016, during the Work Programme Symposium. Main outcome was the call / request from the community for a platform enabling dialogue and facilitating robust discussions between and among providers of CB and those who have CB needs.* *Outreach activities were undertook: a) Secretariat participated at the CEOS WGCapD 5th Annual Meeting, engaging the WG on its contribution to GEO Capacity Building; b) GEO Capacity Building activities were presented at the ESRI GIS User Conference held in May 2016 and c) Nancy Searby, United States, participated at the Eighth Meeting of the Virtual Laboratory (VLab) Management Group, the capacity building management group for the Coordinating Group for Meteorological Satellites (CGMS) and WMO, to explore coordination opportunities with their activities.* *The Capacity Building Symposium has been postponed to 2017-2019 to appropriately link with the 2017 – 2019 GEO Work Programme by then it is anticipated the description of capacity building activities in each of Work Programme activities will be more homogeneous across and more specific on how the envisaged capacity building will be carried out and when.*

CD-02	Reinforcing engagement at national and regional level	Key Deliverables 1. Issue Template for EO reports 2. Outreach to potential and new Members 3. Members/POs Earth observations reports 4. Issue guidelines for national coordination mechanism. 5. Support Members in preparation and publishing their national Earth observation reports. *Progress* *The task is suffering and will suffer in the next months from lack of resources.* *The Task Team has been established, comprising National GEO coordinators and representatives from Participating Organizations.* *The Task Team convened its first meeting during the GEO Work Programme Symposium in May 2016 and agreed to develop and publish a pilot Member / POs report for GEO-XIII Plenary in November 2016. A draft Table of Contents / template for the EO reports is under review by the Task Team.* *Outreach actions were performed, such as encouraging the strengthening/establishment of national GEO coordination mechanisms and improve national participation in GEO, during regional meetings (AfriGEOSS Symposium held on 27 – 29 April, Meeting of the Asia-Oceania countries aimed at establishing AO-GEOSS held in May during the GEO Work Programme Symposium and AmeriGEOSS meeting held in June) and .the to potential and new Members:* *The team engaged with GEO-CRADLE, a EC-Horizo2020 project, on the development of the national report, looking at alignment with their envisaged national EO "Score Cards". Regional coordination mechanisms are deemed important in supporting the development of national / PO reports, as they already have partner engagement activities.* *The Team, mainly being composed of national GEO coordinators, agrees that the benefits of this EO report outweigh the challenge on it being perceived as a burden by Members and POs. The Task Team recognize the need to adequately promote its value and is preparing engagement material to address this potential issue.*

CD-03	Assess the benefits from EOs and of their socio-economic value	Key deliverables 1. Define case studies for baseline analyses. 2. Holding an International Workshop at OECD in March 2016 3. Ensure presence at major international events (such as AGU in US and EGU Europe) 4. Publication of themes and discussions in Earthzine and other journals 5. Maintenance of a web site 6. Develop and coordinate the Linkedin virtual community 7. Update GEO website and keep it current based on inputs from the team *Progress* *The Task Team is in place, with a good mix of people from EO and Socio-Economic Communities.* *All the planned activities are ongoing, with some delays on those related to points 5 and 7.* *The international Workshop was held, it was well attended and it constituted a golden opportunity to better link the two communities and to improve the way of working together.* *The Task Team is in contact with the GEOGLAM team to develop and run a "case study".*

Appendix 1: Foundational Tasks Progress against Work Programme P2016 key Deliverables
status June 2016

SO - Tasks Secretariat Operations

SO-01	Management and Support	Key deliverables 1. Convene GEO Governance meetings (preparation and execution of GEO-XIII Plenary, Executive Committee meetings, documents preparation and reporting. 2. Support Program Board activities 3. Development of Work Programme 2017-19, 4. Development and operation IT tools (website, ftp, ..) 5. Organization of meetings to make the GEO cooperation framework working, such as the WP Symposium, AP Symposium 6. Perform all the internal activities to ensure a functioning Secretariat, such as Human and financial resources Management *Progress* *On item 1, beyond organization of the two Executive Committee Meetings in March and July, the Secretariat has started preparations for the GEO-XIII Plenary and associated events. A visit to possible locations took place in May, a concept for the GEO-XIII Plenary agenda drafted, a first call for exhibition and side events issued.* *On item 2, the requested support was provided to the Programme Board, three meetings were organized and supported, and all the follow-on activities performed, leading to the development of the PB Reports to the Executive Committee and Plenary.* *On item 3, the Secretariat has provided information and support to PB subgroup revising the articulation of Foundational Tasks and their priorities, as well as support to the PB review of the received proposals for GEO Initiatives and Flagships. Based on PB inputs, as endorsed by the Excutive Committee, the Secretariat has developed the final draft of the GEO Work Programme 2017-19 for Plenary approval.* *On item 4, a major revision of the GEO Website was undertaken* *On item 5, the GEO Work Programme Symposium was held in Geneva on 2-4 May, with about 150 participants, marking a slight increase in numbers but also in the representation of different GEO stakeholders.* *On item 6, considerable effort was required in reconciling initial expenditure and staffing plans with the actual availability of resources.*

<table>
<tr><td>SO-02</td><td>Communication and Engagement</td><td>Key deliverables
1. Perform communications campaign
2. Develop foundational materials/ communication channels
3. Develop and deliver targeted engagement messages
4. Assist in convening a limited number (2-3) of segments of the GEO community with interested stakeholders in face-to-face workshops, forums and one-on-one dialogues to identify stakeholder needs and potential GEOSS-based solutions, including developing partnerships between interested stakeholders and GEO experts to deliver the added-value of GEO and GEOSS directly to these “strategic partners”
5. Assist specific communities in engagement activities (Disasters - Sendai framework, GEO-Future Earth)
6. Strengthen/Develop partnerships to foster use of EO’s, with: Un Conventions, MEAs (including Environmental Ecosystem Accounting), Development Banks, NGOs, Foundations, Companies / Associations.
7. Assist in implementing Belmont Forum recommendations on e-infrastructure and data management
Progress
The task has suffered from lack of dedicated resources.
Advances were made on several of the key deliverable. Details in the relevant section of the Secretariat operations report. Some examples:
Developed a new set of GEO branding guidelines, through a consultation process with the Programme Board
Continued consolidation of the Engagement Strategy for ExCom review
Continuous update of the GEO website with greater focus on user cases
Convened, on 7-3-2016, the GEO/UN and International Organizations Roundtable on Supporting Implementation of the 2030 Agenda Through Knowledge, Data and Information
Initial engagement with the UNCCD (Convection to Combat Desertification) to define a framework to develop Land-related SDG indicators
Additional information is contained in the Secretariat Operations Reports provided to the Executive Committee (Ref. ExCom 36 doc_12, ExCom37_Doc_14, ExCom38_Doc to be issued on 25 October 2016)</td></tr>
</table>

SO-03	Monitoring and Evaluation	Key deliverables 1. Identify performance indicators for the Targets defined in the Strategic Plan, for ExCom endorsement 2. Track progress of Work Programme activities, including feedback on suitability of GEO implementation mechanisms development 3. Measure baseline values for performance indicators. 4. Propose 2020 and 2025 values for the performance indicators, for GEO-XIII approval *Progress* *A preliminary analysis of the performance indicators proposed in the Strategic Plan Reference document has been performed by the Secretariat and provided to the Programme Board in April. The analysis was qualitatively addressing the feasibility of each indicator, including the preliminary identification of the data and data sources needed to calculate each of them. An update was also presented to the Programme Board at its 3rd meeting in September. A dedicated PB subgroup is working to consolidate the overall M&E framework and clearly define the activities associated with the Evaluation function(here included indicators)* *The Secretariat has developed the 2016 Work Programme Progress Report, to be issued by the end of September*.
SO-04	Resource Mobilization	Key Deliverables 1. Define guidelines and practices for resource mobilization for GEO activities 2. Engage with **(2-3)** international funding organizations to define mechanisms to secure resources for specific GEO activities *Progress* *The task has not progressed as planned because of lack of resources.* *Developed initial ideas (in support to the Budget Working Group) on how to ensure increased contributions to the GEO Trust Fund.* *A targeted action is ongoing towards the World Bank to identify areas of action of common interest.*

APPENDIX 2. GEOSS Data Sharing Principles Implementation Guidelines 2016-2025

GEOSS Data Sharing Principles Implementation Guidelines 2016-2025

This Document is submitted to the GEO-XIII Plenary for information. Feedback from the GEO community, and in particular, from those who have responsibility for data sharing is being sought. These guidelines for implementing the GEOSS Data Sharing Principles in the period 2016-2025 will be updated in the future as appropriate.

Table of Contents

1. INTRODUCTION

Data Sharing constitutes a pre-requisite for building an effective Global Earth Observation System of Systems (GEOSS). It is the backbone of the abiding GEO vision of "*a future wherein decisions and actions for the benefit of humankind are informed by coordinated, comprehensive and sustained Earth observations and information.*"

Since inception, the Group on Earth Observations (GEO) has been a strong advocate for broad, open data-sharing policies and practices wherever possible, as well as for the increased use of Earth observation data and information. Data sharing has been recognised as one of the greatest successes of the first GEO decade (2005-2015).

As GEO starts implementing its strategy for 2016-2025, the GEO partnership will continue to encourage governments, scientific and technical organisations, and other institutions to create open access policies for as much of their data and information as possible, hence expanding the trend towards Open Data worldwide. GEO will broaden its engagement with relevant stakeholders and continue to advance the evolution of a Global Earth Observation System of Systems (GEOSS) which facilitates the sharing of environmental data and information collected and derived from the wide array of observing systems contributed by GEO member countries and participating organisations.

Success during the second decade of GEO will be measured by how much progress GEO demonstrates in supporting solutions to problems associated with the Societal Benefit Areas (SBAs). This will imply establishing the overall activity as a true "data commons" where data are shared openly and made actionable for collective innovation, including for trans-disciplinary applications. The full implementation of the GEOSS Data Sharing Principles is an essential step towards maximizing the net societal and economic benefits of the global investment by GEO Members and Participating Organisations in GEOSS.

Based on the analysis of relevant GEO documents, applicable international agreements and practice as well as on extensive consultation with experts on data policy from around the world, and on its own deliberations, the GEO Data Sharing Working Group (DSWG) proposes the following revised Data Sharing Implementation Guidelines. These guidelines should help data providers and others when they seek to implement the GEOSS Data Sharing Principles adopted in 2015 by the GEO Plenary as part of the "GEO Strategic Plan 2016-2025: Implementing GEOSS"[1]. They aim at providing context and practical guidance to help turn these principles into practice.

[1] Mexico City Ministerial Summit, 13 November 2015, Document 4

This paper is intended to update previous implementation guidelines adopted by GEO Plenary VI in November 2009. They should be seen as a living document that will evolve over time as more is learned about implementing the revised GEOSS Data Sharing Principles.

2. DATA SHARING IN THE GEO CONTEXT 2016-2025

GEO is contributing to and benefiting from the Open Data trend observed worldwide. GEOSS is also developing in a changing global landscape deeply affected by the (big) data revolution and the rise of new Information and Communication Technologies (ICT). Earth observation data acquired in situ and remotely are growing in volume, becoming faster, and more diverse than ever. There are huge opportunities for multiple reuse, including both for policy making and re-use by the private sector for innovative services, if GEO can mobilise these trends to address planetary challenges and support the 2030 Agenda for Sustainable Development.

While today's awareness of the benefits of sharing Earth observation data openly is stronger than ever, there is a continuous need to promote open data sharing, maintain dialogue with governments and organisations, and support further uptake and implementation of the GEOSS Data Sharing Principles.

At the dawn of the second decade of GEO (2016-2025), Ministers and other heads of delegations have reaffirmed their support for the GEOSS Data Sharing Principles. This is enshrined in the **Mexico City Declaration**[2] of 13 November 2015. In particular, they resolved to pursue the implementation of the GEOSS Data Sharing and Data Management Principles to the extent permitted by national laws and policies. They acknowledged the contribution of national and international Open Data initiatives in accordance with the GEOSS Data Sharing Principles. They also called upon the global Earth observations community to make, to the largest extent possible, Earth observation data available and accessible through the GEOSS.

As part of its "***GEO Strategy Plan 2016-2025: Implementing GEOSS***", GEO has defined three Strategic Objectives and established an Implementation Plan to chart its activities through 2025.

- Data sharing appears upfront in the first strategic objective: "*to advocate the importance of Earth observations as irreplaceable resources that must be protected, rendered* ***fully and openly accessible*** *(including through contribution to GEOSS), and integrated to provide maximum value in support of achieving national and international calls for resilient societies, sustainable economic growth, and a healthy environment worldwide*".
- One of the core functions for GEO is "*Advancing GEOSS and best practice in data management and* ***sharing***". This implies collaboration with GEO members and participating organisations to implement the GEOSS Data Sharing and Management principles and ensure

[2] Mexico City Ministerial Summit, 13 November 2015, Document 3

that Open Data is discoverable, usable, accessible and preserved for integrated use across multiple communities.

- The Implementation Plan (Part B of the GEO strategy) provides the full text of the revised GEOSS Data Sharing Principles adopted for the second GEO decade.

Data sharing is a common activity across **GEO Work Programmes**. Advocacy, engagement and delivery in the field of data sharing take place in various ways through activities which are of different scales and types. Community activities, global GEO initiatives and GEO flagships can all make valuable contributions to fulfil or achieve the core function and strategic objective mentioned above. This shall be done in collaboration with the GEO foundational task on Data Sharing. This task aims to continue promoting free, full, open and timely access to Earth observation datasets, products and services. It also aims to aintain dialogue and support the uptake and implementation of the Data Sharing Principles by GEO members and organisations.

3. THE GEOSS DATA SHARING PRINCIPLES POST-2015

In 2007, the Cape Town Ministerial Summit recognised the need to reinforce the principle of data sharing within the GEOSS. "*The success of GEOSS will depend on a commitment by all GEO partners to work together to ensure timely, global and open access to data and products*".

The success of GEOSS largely depends on the expansion of its global network of content providers and users. When joining the GEO partnership and endorsing the GEO Strategic Plan 2016-2025, governments and organisations also endorse the GEOSS Data Sharing and Data Management Principles. They set themselves the aim of promoting and complying on a best effort basis with those principles.

3.1. Towards revised Data Sharing Principles

Since 2005 when GEO was established, the situation with regard to data sharing has significantly improved, both within GEO and across the international Earth observation and environmental data landscapes.

The Open Data trend. The Open Data trend has considerably expanded compared to the time when the initial version of the GEOSS Data Sharing Principles was adopted in February 2005. The first implementation guidelines adopted by GEO predates by four years the signature of the G8 Open Data Charter[3] by the G8 leaders in July 2013. In 2015, building on these efforts, and through an open, inclusive and representative process, a number of Open Data champions from governments, multilateral organisations, civil society and private sector developed the

[3] https://www.gov.uk/government/publications/open-data-charter/g8-open-data-charter-and-technical-annex

International Open Data Charter[4] including the following six principles for the release of Open Data:

1. Open by default
2. Timely and comprehensive
3. Accessible and useable
4. Comparable and interoperable
5. For improved governance and citizen engagement
6. For inclusive development and innovation

The Earth observation data policy trend. During the first GEO decade (2005-2015), many GEO governments and organisations adapted their Earth observation data policies, leading to a significant increase of data and information becoming discoverable, accessible and openly re-usable.

- With CBERS-2 (China Brazil Earth Resources Satellite), Brazil decided to remove imagery charges. This change of data policy resulted in increased access from 1,000 images/year to 10,000 images per month with more than 10,000 new users registered in the first year. 98% of users surveyed agreed with the policy of open data access and reported the creation of many new jobs, the creation of new SMEs and improved research and teaching.
- The Landsat free and open data policy announced in 2008 by the US Geological Survey (USGS) has revolutionised the use of four decades of Landsat data, spurring innovation and triggering new science and applications. As a result the use of Landsat data increased with over 100 times more data downloaded in 2011 than in 2007.
- The ASTER Global Digital Elevation Model (GDEM) saw a reversal in fortunes following the introduction of charges in January 2006 with a substantial reduction in data distribution. A reversal in policy to no charge in June 2009 again provided a clear indication of dramatically increased usage of ASTER data worldwide (with over 6.5 million tiles distributed in FY 2009). Strong interest for the DEM was received by representatives of all GEO Societal Benefit Areas as well as other users
- The Copernicus programme[5] of the European Union entered into operation from 2014. This huge programme[6] includes six operational thematic services[7] and a dedicated constellation of EU-owned satellites, known as "*Sentinels*", as well as tens of third party satellites known as contributing space missions, complemented by local or on-site measurement data. The

[4] http://opendatacharter.net/
[5] Previously known as GMES (Global Monitoring for Environment and Security)
[6] "*Copernicus: Europe's eyes on Earth*" Copernicus Brochure by the European Commission, 2015: http://www.copernicus.eu/sites/default/files/documents/Brochure/Copernicus_Brochure_EN_WEB.pdf
[7] The six Copernicus thematic areas are land, marine, atmosphere, climate change, emergency management and security.

European Union decisions[8,9] in 2013-2014 to make its Sentinel data and Copernicus service products freely available represent major steps taken in Europe towards free, full and open dissemination of Earth observation data and information. Once fully deployed, the Copernicus constellation of Sentinel satellites will generate up to several Terabytes of data per day and several Petabyte of new open data per year.

- Another example of is the decisive step by France in 2014 to gradually provide open access to non-commercial use of 29 years of satellites images from the SPOT family as part of the opening of the SPOT World Heritage programme.
- Trends towards open access to Earth observation data are also observed in Asia and other parts of the world. These include the free access to data from the Chinese polar-orbiting meteorological satellite Fengyun-3 (launched in 2008), and the decision by Japan in 2013 to guarantee free and unlimited access to low to medium resolution satellite data constellations operated by the Japan Aerospace Exploration Agency (JAXA).

Creation of the GEOSS Data-CORE. The GEO Ministerial Declaration in Beijing in 2010 announced the creation of the GEOSS Data Collection of Open Resources for Everyone (GEOSS Data-CORE). This data collection consists of GEO-tagged data contributed by the GEO community that can be shared without any restrictions on use. Since then, the commitment to sharing data as part of the GEOSS Data-CORE has increased and a growing number of GEO members and participating organisations adhere to and benefit from full and open data sharing without restrictions on re-use. Between 2012 and 2015, the number of systems brokered by the GEOSS information system increased from 10 to more than 190 systems. At the same time, the number of GEOSS data resources has boomed from only a few hundreds of thousands to more than 190 million resources. More than two-thirds of these data resources are flagged as GEOSS Data-CORE. They largely consist of satellite images as well as other Earth observation data records, documents and maps.

A new GEO decade with revised principles. In 2014, the Data Sharing Working Group decided to draft a revised version of the GEOSS Data Sharing Principles for the post-2015 period. The main motivation was to equip the GEO strategy 2016-2025 with principles better reflecting the rising Open Data trend and elevating the status of the GEOSS Data-CORE as the default standard for sharing data through GEOSS.

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[8] Regulation (EU) No 377/2014 of the European Parliament and of the Council of 3 April 2014 establishing the Copernicus Programme and repealing Regulation (EU) No 911/2010, accessible from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0377&from=EN

[9] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL establishing the Copernicus Programme and repealing Regulation (EU) No 911/2010, accessible from http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013PC0312&from=EN

3.2. The revised GEOSS Data Sharing Principles

The current GEOSS Data Sharing Principles have been included in the GEO Strategic Plan 2016-2025 and adopted by GEO Plenary XII in November 2015. GEO aims to implement the following GEOSS Data Sharing Principles:

1. Data, metadata and products will be shared as Open Data by default, by making them available as part of the GEOSS Data Collection of Open Resources for Everyone (Data-CORE) without charge or restrictions on reuse, subject to the conditions of registration and attribution when the data are reused;
2. Where international instruments, national policies or legislation preclude the sharing of data as Open Data, data should be made available with minimal restrictions on use and at no more than the cost of reproduction and distribution;
3. All shared data, products and metadata will be made available with minimum time delay.

3.3. Associated commitment

All GEO members are required to endorse the GEO Strategy 2016-2025 including the above data sharing principles. Such endorsement implies the aim of all GEO members and participating organisations to promote and comply on a best effort basis with those principles. At the same time, it is important to highlight that GEOSS welcomes all data contributions and is composed of voluntarily contributed systems and data which are governed by pre-existing laws, policies and practices that may not be fully compatible with these principles. The association of GEO members and participating organisations, and their adherence to the Data Sharing Principles, is not legally binding. It is expected that the principles will gain acceptance and importance through voluntary adherence in good-faith, which may also be accompanied by legal and policy changes at the national or international levels.

Data providers have to document - at the registration stage - any restrictions applicable to the exchange of their data, metadata and products. GEO as a whole does not own the data sets that are made discoverable and accessible through GEOSS. These data sets remain located in the data repositories of the data providers and under the responsibility of those data providers. Data sets that are made available in conformity with the GEOSS Data Sharing Principles can be flagged in GEOSS as Open Data as part of the GEOSS Data-CORE.

3.4. New features of the GEOSS Data Sharing Principles

The revised GEOSS Data Sharing Principles[10] have been drafted to advance GEO's vision and improve the wording compared to the initial version of 2005[11].

[10] GEO-XI – 13-14 November 2014 Document 8
[11] GEOSS 10-Year Implementation Plan 2005-2015, page 12

The reference to **Open Data** in *the first principle* provides context and sets unrestricted sharing as the default sharing mechanism for GEO. It further includes interpretation of the concept of Open Data by specifying that the data are shared without charge, with no restriction on reuse, and the possibility to impose only the conditions of registration and attribution when the data are reused. Open Data was chosen to be reflected in the Principles as it is gaining considerable traction as a simple, transparent concept, in particular with regard to data held or produced by governments. More and more authorities declare Open Data as the default principle for sharing some of their data, which above all excludes restrictions on re-use and charges for access to data for any purposes. This evolving context explains the shift from using the term '*full and open*' in the version 2005 of the GEOSS Data Sharing Principles to the term "*open by default*" in the revised version of the principles.

The first principle elevates the status of GEOSS Data-CORE to the default standard of data sharing through GEOSS. The GEOSS Data-CORE is presented as a mode of sharing Open Data as it rules out restrictions on use, while keeping conditions of attribution and user registration that per se do not affect re-use. The inclusion of the GEOSS Data-CORE in *the first principle* recognizes and emphasizes its value for GEOSS and the GEO community.

The second principle includes (as an exception) the possibility of sharing data with restrictions on re-use. This *principle* recognizes that restrictions may be imposed by "international instruments, national policies or legislation", and welcomes sharing of such data as well. However, as opposed to the initial version 2005 of the DSPs, the option of sharing data through GEOSS with restrictions on use is presented as a deviation from the default mechanism, with the emphasis on imposing as few restrictions on the use of shared data as possible. This shift in emphasis better recognizes the motivations for GEOSS: encouraging and facilitating reuse of EO data and products, as well as helping make informed decisions in the societal benefit areas targeted by GEO. The second principle encourages members and participating organisations to keep restrictions to a minimum and refrain from imposing charges that exceed cost of reproduction and distribution.

The third principle puts emphasis on the provision of data through GEOSS with minimum time delay. This part of the Principles does not differ from the initial 2005 version of the DSPs. By contrast to the initial version, it broadens the application of free of charge data provision beyond the sole case of "*research and education*".

3.5. Interpretation of key expressions

While the rise of Open Data trend is very encouraging, Open Data users are often confronted with different practices and interpretations by the governments and organisations implementing open access. The main issues relate to varying terminologies and interpretations between jurisdictions and organisations[12].

Expressions like "open data access" or "full and open access to data" might encompass different access and use conditions (e.g. registration, attribution conditions, free access for the research use only, etc.). Open Data policies rarely specify timing aspects such as the minimum time period from data acquisition to effective Open Data availability at the point of access. Some data policies allow for the possibility of a reasonable return on investment when making data accessible. Some terms commonly used suffer from a lack of homogenous interpretations. Moreover, the definition of "Open Data access" or "full and open access to data", if or when used, is most often limited to a specific type of data[13]. Altogether, these elements add another level of complexity when data from various sources are combined.

The following provides additional documented interpretation of the key terms or expressions used to define the GEOSS Data Sharing Principles.

- "*Open Data*": means that data are shared without restriction, free of charge, for any purpose and with any user. Anyone is free to use, reuse, and redistribute Open Data, subject only, at most, to the requirements to register and attribute.
- "*Without restriction*" means without discrimination against, for example, individuals, groups, nationality or fields of endeavour. Registration and/or attribution may be required.
- "*Free of charge*" means at no more than the cost of reproduction and delivery, without charge for the data itself.
- "*Free to redistribute*" implies that there are no restrictions as to selling or giving away the data either on its own or as part of a package made from works from many different sources.
- "*Free to reuse*" implies that modifications and derivative works are allowed.
- "*GEOSS Data-CORE*" refers to the GEOSS Data Collection of Open Resources for Everyone. This data collection was adopted by GEO-VII Plenary in November 2010 as part of the GEOSS Data Sharing Action Plan[14]. The GEOSS Data-CORE is a distributed pool of documented datasets pledged by GEO Members and Participating Organisations which is made available to the GEOSS community with open and unrestricted access (at no more than the cost of reproduction and distribution).
- "*Unrestricted access*" means that no restrictions are placed on the access to, or use and redistribution of, the data in the GEOSS Data-CORE. It should be noted that the following two conditions may be placed on data registered in the GEOSS Data-CORE by data

[12] "Interpretation of the full and open access to and use of (geographic) data: existing approaches" - Living paper of the GEO Data Sharing Working Group, October 2013

[13] Public data, research data, government-produced or –held data, other types of data as per relevant policy or legislative regulation.

[14] GEO-VII Plenary – 3-4 November 2010 Document 7(Rev2)

providers: (i) attribution and (ii) user registration. These are not considered to represent restrictions on the access to, or use and redistribution of, the data.

- "*GEOSS Data-CORE tag*": the GEOSS Data-CORE concept is intended to highlight - within the whole constellation of GEOSS datasets - those data and products that can be exchanged without restrictions. Technically speaking, this is performed by placing GEOSS Data-CORE metadata tags in the metadata in order to: (i) allow users to discover and identify the GEOSS Data-CORE data, and (ii) inform the data users of any conditions attached to the use of the data.
- "*Minimal restrictions on use*": GEO Members and Participating Organisations may have specific restrictions on the dissemination and use of certain data, metadata and products based on international instruments, national policies and legislation. Such restrictions apply mainly to concerns regarding the protection of: national security, financial viability, proprietary interests, privacy, confidentiality, indigenous rights, and conservation of sensitive ecological, natural, archaeological, or cultural resources. All participants in GEOSS are required to respect such restrictions when providing access to their data, metadata, and products. GEO Members and Participating Organisations are encouraged to establish flexible policy frameworks ensuring that a more Open Data environment is implemented.
- "*Cost of reproduction and distribution*": pricing of GEOSS data, metadata and products should be based on the premise that the data and information within GEOSS is a public good. GEO, together with its GEOSS data providers, should work to share their data as much as possible as Open Data by default with the only allowable cost for data being either that of reproduction and distribution, or the marginal cost of fulfilling the user request.
- "*Minimum time delay*": GEO should promote minimal time delay to data within GEOSS, depending on the type of data and application and the need for appropriate quality control, and data should be transmitted on a real-time basis whenever necessary or practicable.

3.6 Links to the GEO Data Management Principles

A number of significant reports and policy documents have argued that it is not sufficient simply to make data available, but that they need to be managed and presented in such a way that makes them usable and trustworthy. This has resulted in definitions of Open Data that comprise a number of additional attributes. The fullest is perhaps that given in the G8 Science Ministers' Statement on open scientific research data: "*Open scientific research data should be easily discoverable, accessible, assessable, intelligible, useable, and wherever possible interoperable to specific quality standards.*"[15] In the light of this definition, the GEOSS Data Management

[15] G8 Science Ministers' Statement (on Open Scientific Research Data), 13 June 2013 https://www.gov.uk/government/news/g8-science-ministers-statement

Principles can be seen as a high-level description of what is preferable in terms of data management to allow data to be shared through GEOSS as Open Data.

In 2014, a common set of ten GEOSS Data Management Principles was proposed by the GEO Data Management Task Force. They address the need for discovery, accessibility, usability, preservation, and curation of the resources made available through GEOSS. They are described in the Reference Document[16] accompanying the GEO Strategic Plan 2016-2025. In addition, Guidelines[17] for their implementation have also been provided to GEO Plenary XII in 2015 and are being regularly updated. These guidelines provide explanations for each of those data management principles, guidance on their implementation (with examples), metrics to measure the level of adherence and resource implications.

4. GUIDANCE FOR GEO GOVERNMENTS AND ORGANISATIONS

Our planet is being monitored by land, sea, air and space-based Earth observation systems. However, the current systems for collecting, storing, analysing and sharing the resulting observations still remain fragmented, incomplete (or even redundant) and difficult to integrate.

The Geneva Ministerial Declaration of 2014 highlights how the GEO vision agreed in 2003 remains relevant for the second GEO decade. As recalled in the GEO Strategic Plan 2016-2025, this vision "*is to realize a future wherein decisions and actions for the benefit of humankind are informed via coordinated, comprehensive and sustained Earth observations and information*".

To achieve this vision, GEO Members and Participating Organisations are contributing the resources from their respective Earth monitoring systems to GEOSS and interlinking these systems so that they work better together. The collective potential of GEO is huge given that GEO gathers the largest amount of publicly funded environmental data in the world. By some estimates, the data controlled by GEO's Members and Participating Organisations exceeds many petabytes in the aggregate, and is rapidly growing to the exabyte level[18]. A significant increase of the number of data sets being made available through GEOSS can be observed, particularly since 2012. It is expected that this trend will continue in the period 2016-2025 with more data to be shared as Open Data as part of the GEOSS Data-CORE.

[16] GEO-XII – 11-12 November 2015 Document 11 (Rev1)
[17] GEO-XII – 11-12 November 2015 Document 10
[18] Mazzetti, Paolo; Nativi, Stefano; Santoro, Mattia; Boldrini, Enrico. Big Data challenges and solutions in building the Global Earth Observation System of Systems (GEOSS). EGU General Assembly 2014, held 27 April - 2 May, 2014 in Vienna, Austria.

4.1. Benefits of Open Data Sharing via GEOSS

> "*All public data should be 'open by default*"[19]

There are many diverse opportunities to be derived from transitioning from restricted data policies to more open policies for government data. Providing open Earth observation data through GEOSS for unrestricted use worldwide leads to economic, societal and educational benefits, stimulates research and innovation and improve governance.

This was analysed, documented and reported in a White Paper[20] entitled "*The value of Open Data Sharing*" prepared for GEO Plenary-XII by the GEO Participating Organisation CODATA with involvement of members of the Data Sharing Working Group. This paper marshals the evidence for the participants in GEO to adopt the revised GEOSS Data Sharing Principles. More particularly, it identifies and illustrates the following main benefits of Open Data sharing via GEOSS.

Economic: Public data openly available through GEOSS have been shown to be economic enhancers, creating value many times over and providing much greater returns on the public investment than have restrictive, proprietary approaches. The effects generated by Open Data on digital networks are siginificant in this regard.

Societal: Social benefits are enhanced for both individuals and society at large. Open data meet society's expectations for appropriate management of public digital resources, provide diverse reputational benefits, and incorporate ethical principles for accessing and using public data.

Research and Innovation: Public research and private innovation opportunities expand when there is a policy of openness for upstream data resources. Such data can substantially reduce unproductive barriers to interdisciplinary, inter-institutional, and international research. They enable data mining for automated knowledge discovery in a growing sea of big data. Open Data are essential for the verification of research results and in generating broad trust in them. They avoid inefficiencies, such as the unnecessary duplication of research and allow the identification of erroneous results. They promote more and new types of research. They permit the legal interoperability of data when multiple sources of data are combined to produce new knowledge. Citizen scientists and "crowdsourcing" approaches, which are promoted by GEO, are facilitated. Open public upstream data contribute to and stimulate downstream commercial research and applications that benefit Member economies and society at large.

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[19] "A World that Counts: Mobilising the Data Revolution for Sustainable Development". Report prepared at the request of the United Nations Secretary-General, by the Independent Expert Advisory Group on a Data Revolution for Sustainable Development, November 2014

[20] GEO-XII – 11-12 November 2015 Document 9

Educational: GEOSS open data promote the education of new students and the public, whether at school, in higher education, or increasingly at home. They also support important studies of data collection methods and management. This is why non-profit research and education were given special status in GEO's first Data Sharing Principles.

Governance: Finally, there are key advantages for improved governance. Public data made openly available through the GEOSS portal support improved decision-making and transparency in government and society. Access to those data through GEOSS demonstrates leadership at home and abroad, thereby enhancing influence and legitimacy. For less economically developed countries, open data policies promote capacity building and help to implement "repatriation" objectives. Last but not least, open public data generally build societal freedom and trust in governance and its many functions.

The White Paper concludes that GEO Members and Participating Organisations stand to gain much more than they lose from making their public Earth observation data available on a full and open basis, freely and without reuse restrictions, as promoted by the GEOSS Data-CORE. They will also avoid all the negative effects that come with attempts at narrow cost recovery and policing leakage in the restricted uses of such data. It is thus imperative for GEO to seize the opportunity to benefit from publicly generated Earth observation data now, as the revised GEOSS Data Sharing Principles are being implemented for the coming decade. It is the primary organisational *raison d'être* of GEO to make those benefits a reality.

4.2. How to report data sharing progress?

All GEO members and Participating Organisations are invited to identify and nominate an active data sharing focal point to promote, implement, and monitor data sharing within his/her country/organisation. It is envisaged that this national focal point will:

- Report on data sharing activities within his/her country/organisation and support the GEOSS Data Sharing Working Group in preparing annual reports on data sharing activities
- Work with the DSWG to distribute information on matters related to the benefits of broad, open data sharing

The DSWG considers the amount of time needed for a data-sharing focal point to spend on these tasks to be less than a few hours per month. The focal point could already be a DSWG member, or would be welcome to join the DSWG. The minimum request, however, is that the data sharing contact point responds to occasional requests of the DSWG in assembling the annual report.

Name and contact information of new data-sharing focal points should be communicated by GEO Principals to the GEO Secretariat (secretariat@GEOSEC.ORG)

5. GUIDANCE FOR GEO DATA MANAGERS

5.1. How to register new GEOSS data sets?

From a data infrastructure point of view, GEOSS consists of a system of distributed systems of which common interoperability relies on (i) a brokering technology, called the Data Access Broker (DAB) and (ii) a Components and Services Registry (CSR). Each GEOSS constituent system remains fully autonomous. However, in order to be brokered effectively via GEOSS, each system is invited to follow a set of technical guidelines.

The registration process for new GEOSS data sets aims to get general information on: (a) the Provider organisation; (b) the shared datasets; (c) the enterprise system to be brokered; (d) the interoperability interfaces/APIs published by the enterprise system.

The registration of new GEOSS data sets comprises two successive phases:

1. Administrative registration: During this phase, the Provider shares a set of *administrative* information[21] related to the provider and the data sets foreseen to become discoverable and accessible via GEOSS. The Provider gets feedback on completeness and format of the received information. At the end of this process, the data set is described in the appropriate GEOSS registry or catalogue (a sort of yellow pages).
2. Technical registration (and effective GEOSS brokering): During this phase, the Provider supplies the GEOSS team with a set of *technical* information[22] related to the data sets to be shared via GEOSS. Interoperability is tested between GEOSS and the Provider's enterprise system and its interoperability interfaces/APIs. According to the required brokering pattern, the development by the GEOSS team of a mediation and or transformation module might be required for establishing interoperability. An interoperability test report is then provided. If an interoperability issue persists, further technical interaction with the Provider takes place in order to solve this issue.

The Provider must have accomplished both phases in succession in order to get its data sets exposed via GEOSS. As very first step, new data providers should contact the GEO Secretariat to start the process of administrative registration and to get any clarification they require, whether on GEO, GEOSS, the DAB and CSR or the GEOSS Data-CORE.

[21] Examples of administrative information include the Provider's name and its eventual GEO affiliation, the administrative and technical points of contact, the data category and data type, the type of data policy and data accessibility applied by the Provider.

[22] Examples of technical information include the Web service(s)/Web API(s) published by the Provider enterprise system to share datasets, the metadata re-harvesting time, the account to be used to access data and other optional fields.

The GEO Secretariat (secretariat@GEOSEC.ORG)
is the main contact point to initiate this two-phase registration.

The GEOSS brokering technology supports the large majority of protocols used by GEOSS Providers to share Earth observation data sets on the web (e.g. OGC/ISO protocols, W3C protocols, INSPIRE protocols, TDWG protocols, WMO protocols, OAI protocols, DCMI protocols, UNIDATA/UCAR/NCAR specifications, CKAN, etc.). Providers are encouraged to implement international standards for interoperability.

5.2. Instructions to tag data as GEOSS Data-CORE

In the case where a provider wants to share his data as Open Data by default through GEOSS, there are four pieces of information identifying data as part of the GEOSS Data-CORE. This information has to be expressed as special character strings (tags) and placed in the metadata (metadata tags). In the following sections, there is a description of the tags, their placement in the metadata, how to register data and data catalogs in the GEOSS Data-CORE, and how to discover these data using GEOSS.

Metadata Tags

GEOSS Data-CORE metadata tags must be placed in the metadata in order to:

- allow users to discover and identify the GEOSS Data-CORE data, and
- inform the data users of any conditions attached to the use of the data.

The four metadata tags that describe the data in the GEOSS Data-CORE are:

1. *geossDataCore* – this tag identifies the data that belong to the GEOSS Data-CORE. Thus, data without this tag will not be identified by data users as GEOSS Data-CORE data.
2. *geossNoMonetaryCharge* – this tag identifies the data that are available at no cost, (i.e., the cost for reproduction and distribution has been waived by the data provider, and the data are made available for free access and use).
3. *geossUserRegistration* – this tag identifies the data requiring data user registration and login in order to gain access to the data.
4. *geossAttribution* – this tag identifies the data requiring or recommending attribution. The data user should make sure that attribution is provided whenever the data is used, redistributed, derived from, etc. Data providers requiring attribution should ensure that the information they want to be used for attribution is included in the metadata.

Metadata Tag Placement

The metadata tags are not case-sensitive. There are a variety of metadata standards used by various data providers and scientific communities. Although placement in any free-text searchable field of the metadata will result in the tags being discovered via GEOSS, and made known to the data users, here follow specific examples of preferred metadata fields can be obtained from the GEO Secretariat for the following standards:

- ISO 19139 metadata
- Dublin Core metadata
- OpenSearch
- WCS, WFS, WMS, WPS metadata
- GBIF metadata
- THREDDS metadata
- NetCDF metadata
- DIF metadata

Metadata and Catalogues

For the purposes of the metadata tags discussed above, a homogeneous catalogue is a catalogue where every metadata record in the catalogue is associated with the same metadata tags. For example, if all records (in a catalogue) are meant to reflect the *geossDataCore* tag and none of the other metadata tags discussed, then the catalogue is considered homogeneous, and can be registered as GEOSS Data-CORE. Similarly, if all records in a catalogue are meant to reflect both the *geossDataCore* and *geossAttribution* tags and no other tags, then the catalogue is considered homogeneous, and can be registered as GEOSS Data-CORE with attribution. On the other hand, if all records in a catalogue are meant to reflect the *geossDataCore* tag, but only some of the records are meant to reflect the *geossUserRegistration* tag, then the catalogue cannot be considered homogeneous.

One way to achieve easy and fast metadata updating for each dataset being contributed to the GEOSS Data-CORE is to use homogeneous catalogues. Only homogeneous catalogues, with respect to the GEOSS Data-CORE metadata tags, can be registered in GEOSS to avoid tagging individual metadata records. Thus, for example, if a catalogue being registered in GEOSS will be associated with the *geossDataCore* tag, then all records in the catalogue will be considered as tagged with the *geossDataCore* tag.

Not all catalogues will be homogeneous with respect to the GEOSS Data-CORE metadata tags. However, one possible way to allow an easy and fast metadata updating if there is a non-homogeneous catalogue, is to split the catalogue up into two or more homogeneous catalogues. This process of splitting requires taking an original catalogue and creating one or more additional catalogues so that the metadata records of the original catalogue can be placed in the new catalogues in such a way that, in the end, there are catalogues that are homogeneous, as desired.

5.3. Recommendations for data quality documentation

It is essential for users to understand the quality of data sets and to combine this quality information with other metadata components in order to determine the appropriateness, or fitness, of these data sets for the users' applications and/or purposes. What makes a data set valuable for one purpose may be to the detriment of its use for another purpose. Data quality information should help the multitude of Earth observation users to choose the best data for their own purpose. Thorough documentation of data characteristics and data quality will support a wider scope of use than the purpose for which the data resources[23] were originally acquired[24].

GEOSS Data Providers are invited to:

- Identify, establish and exploit a "reference standard" for instruments used to collect Earth observation data as a means of evaluating performance or compliance for a particular activity. Ideally this should be undertaken as part of an internationally harmonized Quality Assurance procedure. For many data providers using commercial instruments, this may mean expressing the means by which the instruments are calibrated by the manufacturer, including the schedule followed for recalibrations.
- Provide data resources lineage, also called provenance, recording the data collection and/or generation, including auxiliary information used, in detail sufficient to allow reproducibility.
- Provide information about the quality of the data resources, and any quality assurance procedures followed in producing the data.
- Specify what purposes the data resource was collected or created for, or is known to be useful for, and any known caveats.
- Provide data quality assessments in a manner that ensures the quality information is supplied alongside the data resource itself, such as via associated metadata or documentation tightly coupled to the data.
- Provide quality control information at product level, taking into account instrument characteristics, environmental characteristics at the time the observation is made, and any algorithmic and ancillary data characteristics.
- Address the multiple dimensions of quality. The purpose is not to judge or rank data resources, but to describe the characteristics needed to be known in order for the user to decide whether he/she should use them.

Core metadata and quality tags for fitness-for-purpose assessment include:

* Coverage, including both spatial and temporal dimensions
* Consistency, including long-term consistency
* Uncertainties estimated and documented, including both spatial and temporal dimensions
* Attribution of error sources
* Validation information, i.e. how the data was assessed for uncertainties by comparison with alternative measurements
* Latency from time of observation
* Resolution, including both spatial and temporal dimensions

[23] Data Resources are defined for purposes of these guidelines to include observation data, derived products, information, models, and research results.
[24] The GEOSS Data Quality Guidelines of 19 June 2013

* Usability, in the sense of being in form and content convenient to use for the specific purpose
* Simplicity, such that the data and the underlying data model are not unnecessarily complicated or difficult to understand or manipulate.

While above recommendations are essentially tailored for data providers, further areas of work within GEOSS should also consider mechanisms to gather user feedback about fitness-for-purpose.

5.4. Recommendations for legal interoperability of GEOSS Data-CORE resources

The GEOSS Data-CORE terms and conditions can best be achieved through any of the following mechanisms: statutory, regulatory or policy created public domain (including government contract or grant provisions), a private-law waiver of rights, or a common-use attribution-only "Open Data" license. The GEO Data Sharing Working Group recommends the use of only standard instruments to help assure legal interoperability of data.

Definition of legal interoperability

Legal interoperability[25] among multiple datasets from different sources occurs when:

- Use conditions are clearly and readily determinable for each of the datasets
- The legal use conditions imposed on each dataset allow creation and use of combined or derivative products
- Users may legally access and use each dataset without seeking authorization from data creators on a case-by-case basis, assuming that the accumulated conditions of use for each and all of the datasets are met.

Public domain status: the best legal option

Public domain status is the best legal option for promoting the various social benefits and goals intended by GEO through making available data as the GEOSS Data-CORE by enabling and securing unrestricted re-use, re-dissemination, and legal interoperability. Public domain may be created formally by public laws through national legislation that excludes certain categories of data and information from copyright protection or prohibits impositions of restrictions on their use. The public domain may also be created through regulation or policies that place publicly-funded data in the public domain, as well as through national funding mechanisms, such as grants or contracts. Rights under copyright or '*sui generis*' database protection arise automatically and last until the term of protection expires, or unless expressly excluded or waived. For this reason, express legislative, regulatory, policy or funding mechanisms are needed, to make the data excluded or waived from protection, or to make the re-use and re-dissemination of data unrestricted. Alternatively, organisations can explicitly waive all such rights through a private law alternative to the extent that is allowed by the national statutory law.

[25] GEO-XI – 13-14 November 2014 Document 8 - APPENDIX 2: Draft White Paper: Legal Mechanisms to Share Data as Part of GEOSS Data-CORE

Ideally, datasets already having public domain status should include a notice in their metadata or on the database owner's server informing potential users of their public domain status. The Creative Commons Public Domain Mark serves this purpose. Such a notice could help to overcome the incorrect assumption by some potential users that the data are subject to protection and have attendant restrictions on reuse. Such a notice would thereby promote the further use of the data and legal interoperability through the GEOSS Data-CORE.

Waivers and Open Data common-use licenses as alternatives

Many datasets, however, do not have public domain status and are protected in whole or in part under statutory intellectual property laws. In those cases, a legally valid waiver of rights can achieve a private-law equivalent of public domain status, or a common-use Open data license (for example, the Creative Commons Attribution licence) can incorporate the Open data requirements and attribution conditions allowed by the GEOSS Data-CORE.

Open Data common-use licenses and waivers help promote the contribution of databases through the GEOSS Data-CORE, because most jurisdictions do not have public domain status for the data compilations relevant to GEOSS. Such a step is also be helpful for the Members and Participating Organisations that are willing to share data as part of GEOSS Data-CORE as it will economise the resources they would need to spend on developing such licences themselves.

Custom waiver or common-use Open Data licenses

If standard waivers or common-use licenses cannot be used, the data provider may consider adopting a custom waiver or data license. Such waiver or license must be compatible with the GEOSS Data-CORE principles being free of restrictions on re-use, with user registration, attribution conditions and marginal cost recovery charges permitted. In addition, it should be:

- Valid under the laws of as many different jurisdictions as possible;
- Clear and understandable to the data provider or user;
- Easy to find and recognize
- Embeddable in the data as machine readable metadata whenever possible;
- Available in different languages, at a minimum in the language(s) of the country/organisation making the data available, as well as in English;
- Kept under the legal control of the data providers, and not GEO or GEOSS.

A custom waiver or licence may contain any other terms and conditions, such as a disclaimer of warranty and liability, that do not restrict the user or conflict with any of the terms and conditions summarized in the list above.

Custom licenses that have the same terms and conditions as the characteristics listed above can also be used to provide data through the GEOSS Data-CORE. The decision as to the compliance of such custom licenses with the conditions of the GEOSS Data-CORE data access and use, however, will be determined solely by the data provider. Use of licences or other permissions beyond those listed above significantly risk diminishing the legal interoperability of data published under the standard licences.

Conclusion

Legislative, regulatory or administrative and other government measures placing all data and information produced by government entities in the public domain are considered as the best approach. Until relevant government measures are adopted and enforced in the jurisdictions of GEO Members, waivers and common-use Open Data licenses can be adopted on a voluntary basis for the data, metadata and products that they control. They may also apply open access conditions into public grants contracts, or use other mechanisms to ensure full and open sharing and use of data. Based on the characteristics set forth in the list immediately above, the GEO Members and Participating Organisations should consider adopting one of the following existing voluntary waivers or standard common-use licenses compatible with the GEOSS Data-CORE mechanism:

- Creative Commons Public Domain Mark;
- Statutory waiver of copyright;
- Creative Commons Public Domain Waiver (CC0);
- Open Data Commons Public Domain Dedication and License (PDDL);
- Creative Commons Attribution License (CC BY 4.0).

Any of the mechanisms recommended above will advance the goal of promoting access to Earth observation datasets as part of GEOSS Data-CORE data. It will reinforce the interpretation of the GEOSS Data Sharing Principles favouring open access and unrestricted re-use of the data.

5.5. GEO contact for assistance

For any assistance related to the implementation of the Data Sharing Principles, please contact the GEO Secretariat (secretariat@GEOSEC.ORG) who will dispatch your question to the appropriate GEO team.

APPENDIX 3. Data Management Principles Implementation Guidelines

GROUP ON EARTH OBSERVATIONS

Data Management Principles Implementation Guidelines

This is a revision of the Document submitted to GEO-XII Plenary (Doc. N. 10). It is submitted to the GEO-XIII Plenary for information. Feedback from the GEO community, and in particular, from those who have responsibility for data management is being sought. Principles will be further elaborated and updated next year.

GROUP ON EARTH OBSERVATIONS

Table of Contents

Metrics to measure the level of adherence to the DMP; and

- Resource implications of implementing the DMP.

A compilation of terms appears in Appendix A. A list of references appears in Appendix B.

This paper is intended to be a living document that will evolve over time as more is learned about implementing the GEOSS DMPs.

1 INTRODUCTION

The GEO Data Management Principles Task Force was tasked with defining a common set GEOSS Data Management Principles. These principles address the need for discovery, accessibility, usability, preservation, and curation of the resources made available through GEOSS. To support the implementation of the principles the Task Force has drafted the following guidelines that data providers and others can use as they seek to implement the principles, and to provide a basis for assessing how well the principles are being adhered to in practice.

Each Data Management Principle (DMP) has an associated implementation guideline for data providers to follow. The following topics are covered in the guidelines for each DMP:

- Terms used to describe the principle and its implementation;
- Explanation of the DMP;
- Guidance on implementation with examples;

2 DMP-1: METADATA FOR DISCOVERY

DMP Category: Discovery.

DMP-1: Data and all associated metadata will be discoverable, through catalogues and search engines and data access and use conditions, including licenses, will be clearly indicated.

a. Terms

The following terms, as they relate to this guideline, are defined in Appendix A:

Broker, Catalogue, Clearinghouse, Core Elements, Discovery, Discovery Services, License, Metadata, Metadata Element, Network Services, Queryable, Search Engine, Use Conditions

b. Explanation of the principle

A visitor to a library should be able to find a desired book without having to look at every book in the library. The library's catalogue allows the visitor to search information about the books (e.g. author, ISBN number, genre), to discover where to find the book and under what conditions or restrictions the book might be read or borrowed. This "information about the book" is its metadata. Likewise, a user looking for Earth Observation resources (data, web services, models, etc.) should be able to find what s/he wants by searching the metadata associated with that resource, including information on how the resource can be accessed and whether there are restrictions or conditions placed on its use. GEOSS maintains a catalogue of resource descriptions and, like a library catalogue, does not keep copies of resources, but manages the metadata that facilitates discoverability, allowing users to locate and access the resources.

Not all users begin a search for resources by going to a catalogue. Instead they may use general purpose search engines. For this reason catalogues may link to portals, such as a geoportal, for use by humans, as well as programmatic interfaces (APIs) meant for access by search engines, metadata harvesters and the portals of other communities. Syntactic and semantic interoperability can also enable discovery.

Syntactic Interoperability: this defines the way in which data services will be invoked (Hugo 2008). In many cases, such standards make provision for query parameters and sub-setting of data sets. OPeNDAP has started working on an additional refinement, in that requests for derived data ("offerings"), for example based on statistical analysis, can also be included into the service syntax. Such concepts, which allow requests for processing to be sent to data, instead of the other way round, is a major requirement in the field of Big Data applications (Fulker and Gallagher 2013). Definition of the parameters depend to some extent on semantic interoperability and conventions.

Semantic Interoperability ensures that the content of the schema (the data itself) can be understood by humans or machines (Heffin and Hendler 2000). It is the most complex of the interoperability requirements, and attempts to establish common ontologies, vocabularies, and frameworks such as "essential variables" (OOPC 2015), are all designed to address semantic interoperability. A subset or refinement of semantic interoperability concerns the protocols or methodologies used to gather the data – sometimes critical for valid collations or combinations. Some frameworks for essential variables in Earth and environmental observation science attempt to provide such protocols and methodologies.

In practice, true semantic interoperability is difficult to achieve, often requiring brokering and mediation to align with a standard. A future consideration is the extent to which it will be possible to persist such mediations for re-use. Agreement on a workable set of syntactic (service), schematic, and semantic standards for the typical data families in use by the community can help in some cases.

c. Guidance on Implementation, with Examples

The following types of metadata are particularly important for discoverability and reuse:

- a descriptive title and a description;
- identity and contact information (e.g. ORCIDs) for the individuals responsible for the creation of the resource;
- identity and contact information for the individuals responsible for the management of the resource;
- geographic location or boundaries;
- temporal coverage;
- keywords describing the resource and the scientific or practical domain to which it applies;
- information on conditions and restrictions on use, in particular license information; and
- web links to the resource and to further information about the resource.

The following guidelines will help ensure that data and services are discoverable and usable. Adherence to these guidelines is checked and assessed through certification of the data repository or service using baseline certifications, such as the Data Seal of Approval, the World Data System certification, or ISO 16363 certification.

- Catalogue entries should be in accordance with an accepted international or community agreed upon standards (e.g. DataCite, Dublin Core, ISO 19115, etc.), and all core elements of the standard should be completed;
- The catalogue should be accessible via an accepted international or community agreed upon standard protocol (e.g. OAI-PMH, OpenSearch, OGC CSW, etc.), including search capabilities where results of user queries display in relevance-ranked order;
- The metadata kept in the catalogue should be periodically checked for validity and to ensure that accessibility is maintained through valid links from persistent identifiers to the resources (Rauber et al., 2015), as described in DMP 10, Persistent Resolvable Identifiers. If metadata are maintained in the catalogue for resources that no longer

exist, a mechanism should be provided to point to updated versions, if any, or suitable explanations should be provided for why resources no longer exist;

- GEOSS Data/Resource Providers are encouraged to register catalogues that describe individual resources, where multiple resources are to be made discoverable;
- As an alternative to creating a catalogue with a search interface, a data provider may post metadata, with unique and persistent identifiers that link to the associated data, in a web-accessible location which can then be harvested by search engines or metadata aggregators (also see DMP 10); and
- Since some resources may have restrictions or other conditions of use; these should be clearly indicated in the metadata. Examples include limits on distribution, intended use, as well as licenses.

See also Data Management Principle 4 ‘Data Documentation’, which offers additional guidelines regarding documentation that allows data to be used, understood and processed.

d. Metrics to measure level of adherence to the principle

Appropriate metrics relate to: 1) whether the metadata provides appropriate information for discovery and about reuse conditions; 2) whether the system providing the catalogue information follows established practices in terms of standards and performance; and, 3) whether the repository is certified as a trustworthy digital repository in accordance with ISO 16363, the World Data System, the Data Seal of Approval, or other certification efforts.

There are many projects and components that contribute to the implementation and measuring of metrics. Some examples of these include:

- Projects:
  - The GeoViQua project utilizes metadata quality indicators.
- Service checkers, either existing or to be developed:
  - FGDC Service status checker;
  - JRC Service checker.
- Performance indicators and availability:
  - A catalogue data discovery service should be engineered so that it:
    - Contains no single points of failure;
    - Implements reliable cross over;
    - Detects failures as they occur.
  - Communities indicate the need for tools for validation (metadata, service, data – resources):
    - Some tools interpret standards differently;
    - Compliant resources should have undergone the certification process;
    - Need for reference implementations and consistent, widely publicized and well-known community-accepted implementation guidelines.
  - There should be a mechanism for data users to supply feedback as to the level of metadata adoption. In many cases, this is best known by the data user, and can serve as a qualitative metric.

e. Resource Implications of Implementation

Efforts to enable discoverability can be key resource consumers and include activities such as metadata authoring and maintenance, and standing up and maintaining a catalogue service. Creating metadata can be a labor-intensive activity, which can be more costly if corrections must be completed (Palaiologk, et al., 2012). Metadata reviews and automated checking can reduce such costs. Examples of cost estimates to cover these activities have been made by many data management organizations, such as the Italian National research Council (CNR) and various EC member states. In particular, CNR have made cost estimates for operating the GEO Discovery and Access Broker (DAB), as well as other EC member states having cost estimates to operate a Spatial Data Infrastructure (SDI).

3 DMP-2: Online Access

DMP Category: Accessibility

DMP-2: Data will be accessible via online services, including, at a minimum, direct download but preferably user-customizable services for access, visualization and analysis.

f. Terms

The following terms, as they relate to this guideline, are defined in Appendix A:

Authentication/Authorization, Online, SSO (Single Sign-On)

g. Explanation of the principle

The storage and distribution of data has evolved dramatically in recent decades. These developments include the vast increases in the availability of data online and the speed of transfer, as well as the ability to run queries over numerous datasets using Application Program Interfaces (APIs). Users now expect data to be available on demand, via online services. Currently, this mainly means a URL responding to HTTP, HTTPS, or FTP based protocols.

To meet a wide variety of use cases, particularly analysis at scale, users expect data to be usable to a human via a user interface (providing at least download but also tools for visualisation and analysis) and to be 'machine-usable' via an API. Tools for accessing the data should be described to foster use. Access services and tools must be comprehensively described in order to be useful.

There are several types of online services. A few of these are:

- Direct access service, allowing the user to download data to their computer;
- Direct Web service, providing capabilities for interoperability among services;
- Browse services, which allow users to inspect representations of candidate data sets before ordering;
- Visualisation services allowing a user to view images of data and possibly to superpose it on other data. For geospatial data this would typically be via a Web Map Service (e.g. OGC WMS / WMTS);
- In place processing of the data:
  - Since the volume of data is increasing dramatically, it is desirable to perform processing and analysis of the data in place, i.e. before downloading the source data;
  - The OGC WPS provides a standardized way to remotely execute processing.;
  - In order to ease the transfer of the processors, some techniques can be used: e.g. virtualization, or docker techniques.

h. Guidance on Implementation, with Examples

1. **Simple architecture**: The data access architecture should be simple to implement.
2. **Use of standards**: The data access system should rely on standards. Examples of standards are :
   - HTML
   - Traditional geospatial (OGC WxS),

- Near-continuous raster and/or Multidimensional (NetCDF/ HDF5/ OPeNDAP,
- Time Series (Sensor Observation Services), and
- Simple multipurpose tables (CSV).

3. **Archived data repackaging/reformatting:** Data should be provided in the standard formats that are needed by the designated communities and in exchange formats to facilitate interchange between archives.

In order to ease the work of the user, the URL for accessing the data should be present within the metadata provided by the catalogue service. The use of a standardized interface (like OPeNDAP OpenSearch, OGC, etc.) is preferred. This allows the use of existing tools and also helps resources to be more widely used.

Many data repositories require some knowledge of the identity of those requesting data. For this reason it is desirable to enable automatic user authentication and authorization. SSO is recommended to open data more widely and ease use. As several SSO protocols exist, a common protocol or a federation of interoperable protocols is recommended.

i. Metrics to measure level of adherence to the principle:

Online data accessibility using a standard browser or web service indicates adherence. Service availability and quality should be measured for throughput (speed), and causes of failure (processing error / request error / no data / ...), etc.

j. Resource Implications of Implementation

Providing simple accessibility for small numbers of users to access low volumes data that have been prepared in advance can be accomplished with minimal cost using freely available resources and can be aided by the availability of free and open source software that can reduce the cost of deploying standardised data services. Offerings range from spatial databases (PostgreSQL), through data servers (GeoServer, Sensor Observation Services, OPeNDAP) to visualisation tools (Global Imagery Browse Services, OpenLayers).

Costs increase when preparing and curating data and when providing and maintaining access to additional tools, services, and related information. Large scale data storage and access services are offered commercially (e.g. Amazon cloud) and from public and public-private service providers (e.g. EUDAT, Helix Nebula). In practice, few of these ideal aspects of interoperability are likely to be realised without brokering or mediation. The target of such brokering or mediation can be any of the three types of interoperability. A major consideration is the extent to which it will be possible to persist such mediations for future re-use.

4 DMP-3: Data Encoding

DMP Category: Usability

DMP-3: Data should be structured using encodings that are widely accepted in the target user community and aligned with organizational needs and observing methods, with preference given to non-proprietary international standards.

k. Terms

The following terms, as they relate to this guideline, are defined in Appendix A:

Community-Approved Standards, Documented, International Standard

l. Explanation of the Principle

Usability of data, and especially automated use, depends strongly on the extent to which end users (both human and machine) can rely on standardized encoding as tools, applications, and algorithms are typically designed to work with such. Use of standardised encodings brings benefits to the end user and limits the amount of time spent on transforming data, and therefore is a key to ***interoperability***.

Complete interoperability needs three conditions to be met (Hugo 2009):

Schematic Interoperability defines the structure (schema) in which the data will be offered by a service. For many applications, this schema is critical for correct binding, but schema are likely to vary within a common framework depending on specific applications.

m. Guidance on Implementation, with Examples

The availability and acceptance of ***syntactic encoding standards*** are at a high level of maturity, and these standards cover the majority of data families that the GEO community uses routinely. Examples include the map and sensor services defined by OGC SWE (2011), OPeNDAP and NetCDF services (OGC Network Common Data Form 2015; Common Data Model 2015), and the work done by WMO in respect of globally available meteorological data (WMO Information System 2015). The extent to which the community has implemented these standards is, however, highly variable, with implementation of Sensor Observation Services lagging seriously behind Web Mapping Services and the use of OPeNDAP and NetCDF. Practitioners should select the standards and open-source implementations of these appropriate to their community, internal information technology platforms, and capabilities, as a preferred means of providing access to publicly available data sets.

Communities have also developed a portfolio of content standards in support of ***schematic interoperability***. Examples include the provision of KML (OGC KML 2008), GML (OpenGIS® Geography Markup Language 2007), GeoJSON (GeoJSON Format Specification 2015), and other similar standards for the encoding of spatial data, and the SensorML (OGC® SensorML 2014) suite for encoding of time series and sensor observations. Interoperability practices, for spatial data sets, whether vector data sets or raster data sets, are highly mature and it is common for applications and web components to support a wide variety of data schema. Best practice and guidance should stress the application of these widely adopted standards whenever possible.

The most diverse landscape is found in respect of ***semantic interoperability***, as described under DMP-1, Metadata for Discovery, and content standard encoding to support it. Some communities have access to mature content standards (for example the Biodiversity community through TDWG (TDWG Standards 2015), the Climate Modelling community through essential climate variables (GCOS Essential Climate Variable(s) 2015), and WaterML(OGC® WaterML 2015)), and there are significant efforts to establish ontology, vocabularies, and name services for a wide variety of disciplines. A major concern is centered on this diversity, and it is often difficult for implementers and end users to select from the large number of options available. GEO is in a position to address this problem – firstly through creation of definitive registries of available resources, and by fostering community consensus on the most appropriate resources to use. In general, best practice in the absence of such guidance will be to use any published vocabulary, ontology, linked data capability, and name service appropriate to the field of study rather than none at all.

n. Metrics to measure level of adherence to the principle

Measuring adherence to a schema offered by a data service depends on the data format (MIME type): in the case of XML encodings, the structure and vocabulary (in other words, both schematic and to some extent semantic interoperability) can be tested against the XSD (XML Schema Document). Other encodings (GeoJSON, text, or binary encodings) do not support such automated validation and have to be explicitly tested.

It will often only be possible to evaluate or test the compliance of a data set and/ or service by submitting such a data set or service to a validation service, but to our knowledge only a few such services exist or are in practical use. OGC makes several test services and suites available (OGC Validator 2007). Metrics also might relate to the amount of data available in a well defined and documented format (% of the whole data holding) and to the availability of data format specifications offered by a particular service.

o. Resource Implications of Implementation

Implementation requires experience and knowledge in the domain of interest, spatial data, and computing. There is a growing need for this combination of skills, as seen in the emergence of careers in data science. Their contributions range from systems development, configuration, and maintenance to content publication and standardisation. They may also provide assistance with development of vocabularies, name services, and content standards.

From this, we deduce that a truly interoperable environment can only be realised if communities of practice converge towards a workable set of syntactic (service), schematic, and semantic standards for the typical data families that the community uses, and that brokering and mediation services and definitions are visible and available to practitioners.

5 DMP-4: DATA DOCUMENTATION

DMP Category: Usability

DMP-4: Data will be comprehensively documented, including all elements necessary to access, use, understand, and process, preferably via formal structured metadata, based on international or community-approved standards. To the extent possible, data will also be described in peer-reviewed publications referenced in the metadata record.

p. Terms

The following terms, as they relate to this guideline, are defined in Appendix A:

Community-Approved Standards, Documented, International Standards

q. Explanation of the Principle

Data documentation should enable users and potential users to determine whether the data will meet their needs and help them to access, use, understand, and process the data. Usability of data is maximized when data documentation is complete to enable understandability of the data and all appropriate elements of metadata are utilized. Partial documentation of data negatively impacts its usability in two main ways. First, one or more aspects of documentation can be handled partially, while others are handled completely and can happen when not all appropriate metadata elements have been populated for a given aspect of documentation. Second, one or more aspects of documentation can be ignored completely, meaning none of the metadata elements have been populated for that aspect of documentation.

The purpose of using formal standards-based metadata for data documentation is to maximize the use and reuse of the metadata across community and disciplinary boundaries and to support the reproducibility of science. Standards facilitate the sharing of metadata between data providers and data users, either directly or via mediation technology.

When applicable, data producers should publish, in the peer-reviewed open literature, the methods used in creating and validating the data. These and other descriptions can assist users in understanding various aspects of the data in ways not easily captured by formal metadata and should reference the data. However, publications are not a substitute for formal metadata, which should reference such works to enable discovery of additional documentation contained in referenced publications.

r. Guidance on Implementation, with Examples

Implementation requires populating metadata elements with appropriate content. Formal metadata standards for comprehensive data documentation include, among others, ISO 19115-1 (Standards ISO 2014), ISO 19115-2 (Standards ISO 2009), ISO 19139 (Standards ISO 2007), ISO 19157 (Standards ISO 2013), Dublin Core (Standards ISO-2 2009), Darwin Core, Directory Interchange Format (DIF), DataCite, and Climate and Forecast (CF) metadata conventions.

Each metadata standard contains a set of suggested elements, or fields, which should be populated to cover three categories of metadata, including Descriptive, Structural, and Administrative metadata. It is the responsibility of the data providers to create and populate the metadata according to the standard used. Data users should have an expectation that, if the standard is followed, the dataset metadata can be read and utilized appropriately. In the absence of a usable community standard, the documentation should describe the data, their quality, how they were produced, the instruments and variables employed, and how the data can be accessed and used.

s. Metrics to measure level of adherence to the principle

Measuring consistent adherence to metadata creation and population guidelines can be very problematic. It is relatively easy to determine if the suggested metadata fields have been left empty or populated, but it is much more difficult to determine if populated metadata fields have been populated properly, or in a meaningful way. For example, a metadata field used to point to where the associated data can be found may be populated incorrectly or populated with a link that resolves to a location where access or use of the data may not be possible. The question then becomes whether the link was wrong or outdated, or whether the metadata expressing the manner in which the data can be accessed and used is incomplete or wrong. Finally, following the example just mentioned, even if a link to data, and the associated metadata fields that explain how to access it, are populated correctly, it is still possible for the data to be misunderstood if appropriate semantic metadata is not available.

Four levels of metrics should be used to determine adherence to DMP-4:

- Measure the completeness of the suggested metadata fields for the standard used, reporting the percentage of fields meaningfully populated;
- Count the number of metadata references to other sources of documentation that describe the associated data;
- Measure whether links work correctly, reflecting dependencies between metadata fields and information on the accessibility of other documentation; and
- Measure the semantic success of the metadata, indicating the level at which the associated data can be understood and used in a meaningful manner, including metrics on Linked Open Data references and keywords selected from formal vocabularies.

t. Resource Implications of Implementation

Organizational, administrative, financial, technical, and operational resources are needed to implement the guidelines and the metrics necessary for measuring adherence to DMP-4. Organizational resources include policy formulation to reflect adherence and the value of adherence to the organization. Administrative resources include workflow definitions and review to validate adherence. Financial resources include budgets for people, software, and hardware for implementation. The hardware costs may be minimal compared to resources for professional development on metadata generation, software creation and maintenance, process improvement, and evaluation. Technical resources include tools and documents to implement the metadata generation, its testing, and adherence metrics. Operational resources include the time and people needed to integrate the metadata generation and adherence metrics into routine processes of the data provider. Tools for capturing metadata are available, both commercially and in open source.

6 DMP-5: Data Traceability

DMP Category: Usability

DMP-5: Data will include provenance metadata indicating the origin and processing history of raw observations and derived products, to ensure full traceability of the product chain.

u. Terms

The following terms, as they relate to this guideline, are defined in Appendix A: Provenance, Traceability

v. Explanation of the principle

Provenance information is provided by data producers and stewards, as part of the metadata , to record sources of the data, any changes to the data, and the chain of custody of the data. Some provenance information can be captured automatically by the process step tools involved and accumulated in the metadata of the resulting dataset. Ideally, a process step will inherit the provenance of data sources and add information about the current process step. Other elements of provenance can be captured manually, including names of parties that created, updated or maintained the dataset.

Provenance is a necessary complement to data quality information. In the absence of quantitative information about the uncertainties of the data, expert users can infer data quality estimations from the uncertainties of the sources and from the confidence in the process steps applied. In addition, evidence, describing the processing steps or the results of any tests that were conducted on the data, can provide an indication of the uncertainties of the data, as further described in DMP 6.

The accessibility of the original data source's metadata and processing algorithm descriptions is also a metric of the usability of the provenance information. If provenance is describing sources and processing tools that are not available (or at least have some available documentation), such information cannot be effective in the end. Provenance should include persistent links to such sources.

Provenance can help users identify a problem in a basic dataset or improve it. Provenance information about other products can help to identify which products were derived from the affected dataset. Provenance can help to recreate (or reproduce) the dataset when the problem in the basic dataset is fixed or an improved version is available. Provenance information can also be used to assess the homogeneity of a dataset series where some members of the series originated from sources with different time extents or different versions of the processing algorithms. Provenance can be provided at different levels such as collection, dataset series, dataset, feature, attribute type, attribute etc. For example, this is useful to determine the source of features of even attribute values in the case that a dataset is the result of merging elements features from different sources. Provenance at the dataset level is usually stored in the dataset metadata (that, in the case of GEOSS, it is accessible by the Discovery and Access Broker) while provenance at the feature and attribute level is usually stored in the dataset itself as additional properties of the feature, requiring data access to get them. Assigning version numbers to each release and providing access to earlier versions of the dataset also is recommended, especially if the earlier version has been published with a persistent identifier and could have been cited previously. Some metadata schemas, such as ISO and DataCite, offer capabilities for linking metadata entries on the basis of versioning and progressions in a series.

w. Guidance on Implementation, with Examples

1. **Automatic metadata creation**: Tools that create and manipulate the data also should produce provenance documentation automatically to avoid losing steps or incorrectly documenting metadata. Tools need to inherit the provenance from previous sources. References to algorithms and versions need to be added. Descriptions of methodology

and protocols are sometimes published separately and referred to via URL or persistent identifier, especially when they apply to multiple metadata records.

2. **Provenance metadata presence and completeness**: Datasets should be tested for the presence of metadata about provenance information, which should include a clear sequential description of all sources, processing steps, and responsible parties.
3. **Provenance metadata and provenance data correctness**: Ensure that data sources are documented using universal identifiers (many times local file names are documented) and ideally pointing to accessible sources, that processing algorithms are well maintained and accessible, and that responsible party information is current and points to an accessible party.
4. **Provenance Visualization**: Provenance information can sometimes be very complex. Tools for interpreting provenance and generating graphs can enhance understanding.

x. Metrics to measure level of adherence to the principle

1. Presence of information about data sources, process steps, and responsible parties in the metadata distributed with the data. This can be done by verifying the sources and process steps documented in the lineage model of ISO 19115 and ISO 19115-2" Geographic Information – Metadata" that the Discover and Access Broker provide for each GEOSS resource.
2. The accessibility of the original data source's metadata, processing codes, and processing algorithm descriptions is a metric of the usability of the provenance. For sources, this can be obtained by checking the source URI and finding out if they are available for downloading.

y. Resource Implications of Implementation

This is part of the metadata process and the costs can be absorbed in this concept. There are two associated costs:

1. Implementing automatic metadata procedures in the processing tools and processing chain;
2. Complementing the automatic tools with a manual edition and review.
3. Implementing automated assessment of metrics.

7 DMP-6: Data Quality-Control

DMP Category: Usability

DMP-6: Data will be quality-controlled and the results of quality control shall be indicated in metadata; data made available in advance of quality control will be flagged in metadata as unchecked.

z. Terms

The following terms, as they relate to this guideline, are defined in Appendix A: Data Quality Indicator, Quality Control

aa. Explanation of Principle

The quality-control of data is necessary to enable use of the data, especially by individuals who were not involved in the creation of the data. A data quality review should verify consistency, accuracy, and precision of values, fitness for use, completeness and correctness of documentation, and validity and fullness of metadata (Peer et al., 2014), as well as other aspects of the data, including uncertainty and any limitations on use. Ideally, the data quality review should be conducted prior to dissemination so that prospective user communities can determine the potential for using the data by consulting the results of the data quality review in a timely manner. Prospective users should be able to easily determine the potential for use for their own purposes by assessing data quality review results recorded in data quality indicators of the metadata that describe the data. Results of data assessments also can inform decisions on whether to invest resources in the data. The absence of values for data quality indicators in metadata is an indication that a data quality review has not been conducted.

bb. Guidance on Implementation, with Examples

One or more tiers of data quality assessments should be completed, either independently or in succession. The review also can be conducted as an internal review, an open review, a blind review, or a double-blind review, depending on community practices. An internal quality review may be officiated by the data producer, either manually or automatically. External open reviews offer opportunities for the research community to review and comment on data quality. Blind or double-blind data quality reviews also may be conducted externally by members of the research community. Ideally, an external party, such as a data center, archive, repository, or publisher will officiate an external review to ensure that it is conducted independently of the data producer. The officiator facilitates the review by providing access to the data, any dependent tools, services, related information, and documentation. They specify the review criteria, recruit reviewers, ensure the integrity of the process, receive commentary, and report the results using terminology that is understandable by the community so that the results of the data quality assessment are available and usable. An assessment of the data also may be conducted as part of the peer-review of the article that describes the data.

Officiators should enable reviewers to determine the extent to which the data meet each criterion. Besides providing context by describing the profile, purpose, scope, collection period, phenomenon studied, and lineage or provenance, documentation should describe collection methods, processes, each variable measured, instrumentation, meaning of each variable value, any input data, previous versions, reasons for missing values, descriptions of uncertainties, and post-collection processing and the location of processing codes, if applicable. Sources of support for data collection should be described as well as any considerations for interpretation or restrictions for collection, storage, transmission, access, or use, including any approvals or licenses received with regard to such conditions or restrictions. Names and affiliations of data producers and contributors should be documented for the review process, except for double-blind reviews. Officiators also should report needed corrections to ensure that they are addressed in subsequent data releases.

The data quality review should evaluate the data, in terms of relevant criteria that are applicable to a variety of uses of the potential user community. Data quality indicators should distinguish between the dataset level and the individual file level. In consultation with the community, established practices, or standards, the data quality review officiator should define each criterion to be used for the review. Archives, data centers, and publishers may consult with their respective community representatives to define the criteria for data quality reviews to be conducted on data acquired for their collections.

cc. Metrics to measure level of adherence to the principle

When assessing valuable scientific data products, the officiator of the data quality review provides capabilities to ensure that the results of and justification for each reviewer’s decisions, including area of expertise, are documented to complete the data quality report and determine the score for each data quality indicator. The results should record each reviewer’s decisions, the criteria used for the data quality review, a definition for each criterion and the meaning of each value, and the extent to which the data met each criterion within data quality indicators to clearly communicate the results determined for each criterion. The officiator should resolve discrepancies between decisions of individual reviewers for a particular criterion to provide a decisive determination about the quality of the reviewed data. For example, the officiator may request clarification from individual reviewers or request a review by an additional reviewer to break a tie vote for any particular criterion.

The value of the data quality indicator should be included in the metadata that describe the data along with the definition of the indicator or a reference to the definition. If a data quality review was not conducted prior to metadata creation, the metadata should state that the data quality review was not completed. If a particular criterion was not included in the data quality review, the indicator for that criterion should state that the data quality review was not completed. Other possible indicators might describe the quality assessment framework or the kind of review that was completed, such as internal review, metadata completeness, formal review for a peer reviewed article, and end-user feedback.

dd. Resource Implications of Implementation

Ideally, except for automated reviews and processes that produce multiple datasets, at least two reviewers should be recruited to conduct independent data quality reviews. Each data quality reviewer should possess expertise relevant to the use of the data and their type of use should be recorded. Candidate data quality reviewers must report to the officiator, any potential conflicts of interest prior to accepting a review assignment and recuse themselves from the review process when conflicts exist. Determinations of conflicts of interest should be completed prior to conducting the review.

Each reviewer should be provided with access to the review criteria, the data, documentation, metadata, and any tools or services needed to access or use the data (Callahan, 2015). Associated products, tools, or services should be accessible by the reviewers and described to enable inspection and use. Each reviewer should be provided with capabilities for rendering and inspecting these resources and with instructions to enable unimpeded use of the data and related resources.

8 DMP-7: Data Preservation

DMP Category: Preservation

DMP-7: Data will be protected from loss and preserved for future use; preservation planning will be for the long term and include guidelines for loss prevention, retention schedules, and disposal or transfer procedures.

ee. Terms

The following terms, as they relate to this guideline, are defined in Appendix A: Archive, Digital Migration, Long Term, Long Term Preservation, Succession Plan

ff. Explanation of the principle

Data are valuable assets for reuse and underpin the scholarly record. The preservation of data in digital format requires certain actions to be performed: this includes preservation planning, scheduled transformation of file-type to avoid obsolescence, system backup and recovery plans for the possibility of system failures and corruption, and plans for asset transfer in the eventuality that the repository is obliged to close. These actions are detailed in the Reference Model for an Open Archival Information System (OAIS) (CCSDS, 2012). Repositories which through their mission, organisational setup and business processes are able to fulfill these actions in a sustainable way, may qualify as Trustworthy Digital Repositories (TDRs).

A TDR:

- Has an explicit mission to provide access to and preserve data in its domain or in accordance with a stated collection policy;
- Has a continuity plan ensuring ongoing access and preservation of holdings;
- Assumes responsibility for long-term preservation and manages this function in a planned and documented way; and

- The repository enables reuse of the data over time, ensuring that appropriate metadata are available to support the understanding and use of the data, and that obsolete data formats and services are updated as required.

gg. Guidance on Implementation, with Examples

- **Archived data refreshment**: Periodically perform or automate migration of the archived data ("media refreshment") to the most adequate proven technology for data storage, to ensure data access preservation. Technology selection should not only be based on technical and cost aspects, but should also aim at the minimization of environmental impact (e.g. in terms of power consumption, thermal dissipation, etc.). Additional copies also can be created and stored in a simple human readable format;
- **Archived data formats description**: Provide formal description of old archiving formats to automate or allow the conversion to new standard formats, which will increase technical compatibility and reduce diversity of formats and interfaces between archives;
- **Archived data duplication**: Maintain identical copies of all archived data applying one of the security levels defined below:
  a. Dual copy in the same geographical location (but different buildings) to avoid data loss due to media degradation or obsolescence, or
  b. Dual copy in the same geographical location (but different buildings) based on different technology to avoid technology based principle failures, or
  c. Dual copy in two different geographical locations to safeguard the archive from external hazards (e.g. floods, other natural and technological hazards, etc.), or
  d. Dual copy in two different geographical locations, based on different technologies to avoid technology based principle failures.

Archive system components migration (hardware): Perform periodical migration of archive system components to new hardware platforms.

Data contributed to GEOSS should be preserved for the long term and protected from loss for future use in trustworthy digital repositories (TDRs). Each requirement above is accompanied by guidance text—as part of the certification criteria for the Data Seal of Approval, the ICSU World Data System[1] or the joint DSA-WDS Criteria[2] currently under development—to assist GEOSS data contributors to conduct a self-assessment.

The guidance below indicates the types of evidence required to certify the trustworthiness of a data repository.

- TDRs are responsible for stewardship of digital objects, ensuring that they are stored in an appropriate environment for required durations and that the holdings are accessible and available, both currently and in the future. Depositors and users must understand that preservation of, and continued access to, the data is an explicit role of the repository;

- The repository, data depositors, and Designated Community need to understand the level of responsibility required for each deposited item in the repository. The repository must have the legal authority to complete their responsibilities and must document procedures to assure their completion; and

- Repositories must ensure that data can be understood and used effectively into the future despite changes in technology. This Requirement evaluates the measures taken to ensure that data are reusable.

[1] WDS Certification criteria and guidance: https://www.icsu-wds.org/services/certification

[2] DSA–WDS Partnership WG Catalogue of Common Requirements: https://goo.gl/WnAau0

a. Metrics to measure level of adherence to the principle

Recommended compliance levels for each of the requirements in the section above:

0 -- Not applicable;

1 -- The repository has not considered this yet;

2 -- The repository has a theoretical concept;

3 -- The repository is in the implementation phase; and

4 -- The guideline has been fully implemented in the repository.

Recommended metrics for the evaluation of a trustworthy data repository:

i. Mission/Scope

- Explicit statements of the long-term preservation role within the organization's mission, with approval by the governing authority.

ii. Continuity of access

- The level of responsibility undertaken for data holdings, including any guaranteed preservation periods.
- Medium-term (3-5-years) and long-term (> 5 years) plans ensure continued availability and accessibility of the data. Descriptions of contingency plans and responses to rapid changes of circumstance and long-term planning indicate options for relocation or transition of activities to another body or return of data holdings to their owners (i.e., data producers). For example, what will happen in the case of cessation or withdrawal of funding, a planned ending of funding for a time-limited project repository, or a shift of host institution interests?

iii. Organizational infrastructure

- The repository is hosted by a recognized institution (ensuring long-term stability and sustainability) appropriate to its Designated Community; and
- The repository has sufficient funding, including staff resources, IT resources, and a budget for attending meetings when necessary. Ideally these resources should be budgeted for in three- to five-year periods.

iv. Appraisal

- What is the repository's approach if the metadata provided are insufficient for long-term preservation?

v. Documented storage procedures

- How is data storage addressed by the preservation policy?
- Does the repository have a strategy for redundant copies? If so, what is it?
- Are data recovery provisions in place? What are they?
- Are risk management techniques used to inform the strategy?
- What checks are in place to ensure consistency across archival copies?
- How is deterioration of storage media handled and monitored?

vi. Preservation plan

- Is the 'preservation level' for each item understood? How is this defined?
- Does the contract between depositor and repository provide for all actions necessary to meet the responsibilities?
- Is the transfer of custody and responsibility handover clear to the depositor and repository?
- Does the repository have the rights to copy, transform, and store the items, as well as provide access to them?
- Is a preservation plan in place?
- Are actions relevant to preservation specified in documentation, including custody transfer, submission information standards, and archival information standards?
- Are there measures to ensure these actions are taken?

vii. Data reuse

- Are plans related to future migrations in place?
- How does the repository ensure understandability of the data?

b. Resource Implications of Implementation

The Common Requirements described above reflect the basic characteristics of trustworthy repositories based on the Catalogue of Common Requirements developed by the DSA-WDS Partnership Working Group on Repository Audit and Certification, a Working Group (WG) of the Research Data Alliance. Their goal is to create a set of harmonized common criteria for certification of repositories at the **basic level**, drawing from the requirements already put in place by the Data Seal of Approval (DSA) and the ICSU World Data System (WDS). The ultimate aim is to build a global framework for repository certification that moves from the basic level to the extended level (nestor-SEAL DIN 31644) to the formal (ISO 16363) level.

As should be expected of a comprehensive accreditation process, providing sufficient evidence is somewhat involved and the amount of time and effort needed for the self-assessment depends on the level of maturity of the repository. Entities with existing business process and records management procedures or experience with audits or certifications should spend less time preparing the self-assessment. In general, while very well-prepared repositories may only need a few person-days to complete the assessment, the process usually takes two weeks to three months.

Several individuals may need to contribute to the assessment, which can require discussion with other data management and technical experts in the organization. Thus, it is difficult to estimate resource requirements for the self-assessment phase.

9 DMP-8: Data and Metadata Verification

DMP Category: Preservation

DMP-8: Data and associated metadata held in data management systems will be periodically verified to ensure integrity, authenticity and readability.

a. Terms

The following terms, as they relate to this guideline, are defined in Appendix A:

Authenticity, Integrity, Readability

b. Explanation of the principle

Important among the actions performed by TDRs described above in DMP-7, is periodic checking and transformation (file migration) of data to ensure that they do not become obsolete. Constant and careful maintenance of the preserved data sets (data and associated knowledge) is necessary to ensure data integrity, authenticity, readability and thus usability over the long term. Archive and Data Management Systems' curation and maintenance consist of all the activities aimed at guaranteeing the integrity, authenticity and readability of the archived and preserved data. While also pertinent to DMP 7, Data Preservation, this covers the storage of equipment, media and hard disk arrays in secured and environmentally controlled rooms, and a set of defined activities to be performed on routine basis, such as migration to new systems and media, in accordance with the technology and consumer market evolution, data compacting and data format/packaging conversion. Data holders and archive owners need to design a maintenance scheme for their Archives and Data Management System to guarantee the integrity of the archived and collected data. Verification should include routine tests for resolvability of persistent identifiers, readability, fixity, and provenance.

c. Guidance on Implementation, with Examples

1. **Media readability and accessibility tests:** Perform periodical test for media readability and accessibility on a representative set of the archived data.
2. **Archive content integrity:** Periodically verify the integrity of the archive collection/content through integrity check on a representative set of the archived data.
3. **Data content integrity:** Ensure that archived content and associated information remains unchanged and, if changes are made, that these are documented, and that this documentation is preserved and made available as well (provenance information).

d. Metrics to measure level of adherence to the principle:

Measures for the level of adherence include the Data Preservation Guidelines in point C above or to **ISO 16363:2012 - Space data and information transfer systems - Audit and certification of trustworthy digital repositories** (CCSDS 652.0-M-1), the standard used to assess the trustworthiness of a generic digital repository.

e. Resource Implications of Implementation

Estimating the cost in terms of resources for long-term digital preservation has received much attention from many organisations (e.g. companies, digital libraries, research data centres) interested in preserving their data and depends on the organization and on the data to be preserved (e.g. volume, format, etc.) and can therefore only be modelled here. Cost modelling techniques are used to estimate the costs involved in digital asset preservation and their economic impact on the organisation. Generic Cost models follow two main steps:

1. *Identifying resource costs and activities;*
2. *Assigning resource costs to activities and Assigning activity costs to cost objects*.

1. *Identifying resource costs and activities*

Activities identified for the Archiving process include managing storage, refreshment, migration, reporting, back-up, reformatting/repackaging, test and integrity verification, and reporting on archived data formats. Resources needed to complete the cost analysis include human resources and equipment, office/work space, IT services and technology, and other utilities. Usability and integrity are core parameters for quantifying impact.

Activities	Parameters	Impact
Manage Storage	• Usability (Readability, Authenticity); • Integrity.	This activity is very important in order to ensure the physical preservation of digital data and consequently the physical access to it, that is to maintain data and technologies (HW, SW) used for accessing the data. If this activity is incorrectly performed, the risk of losing the data, as well as the ability to access the data, is very high.
Manage Refreshment Manage Migration Manage Reporting Manage Back-up Manage Reformatting/ Repackaging Manage Test and Integrity Verification	• Usability (Readability; Authenticity) • Integrity	It is very important in order to ensure the physical preservation of digital data and consequently the physical access to it, and its availability over time. Without such activities, the data can be lost in the long term, without the possibility to recover it or, if not correctly managed, the access to data could be lost.
Report on archived data format	• Integrity	These activities are relevant in order to ensure the traceability of each action on the data. This can support the integrity and completeness of data and information provided to the data users.

2. *Assigning resource costs to activities and Assigning activity costs to cost objects*.
The aforesaid step should be done with simulation and estimation value.

10 DMP-9: Data Review and Reprocessing

DMP Category: Curation

DMP-9: Data will be managed to perform corrections and updates in accordance with reviews, and to enable reprocessing as appropriate; where applicable this shall follow established and agreed procedures.

a. Terms

The following terms, as they relate to this guideline, are defined in Appendix A: Data Curation, Data Reprocessing, File Format, Format Conversion

b. Explanations of the principle

Curation, normally [4] implies most, if not all the activities of DMPs 1 to 10. Thus, its meaning as one of the 5 foundational elements of the DMPs is narrower than its usual meaning, focusing exclusively in activities beyond appraisal/selection of data and data preservation (DMPs 7 & 8) and other activities intended to ensure discoverability (DMPs 1 & 4), accessibility (DMP 2), and usability (DMPs 3 to 6). In particular it focuses on correction, updating and reprocessing of data records (DMP 9) and the use of unique and persistent identifiers (DMP 10).

Most data management planning ends with its ingestion and the processing and interpretation of raw data. But, since data processors, who preserve the integrity and authenticity of the data, are well versed with software developments, advancements in computing technology, and processing algorithms, it has produced, as a natural development, the practice of extracting more and more information from the available data. This coincides with the key "social" and "scientific" goals of providing data to distinctive communities: long-term data sets and their usability by multiple stakeholders and communities. Combining such technological processes with scientific knowledge has led to the addition of new essential elements, adding value to data records, such as a) review [leading to corrections and updating] and b) reanalysis [with or without reprocessing i) when new technologies, including new formats for presentation, emerge, or ii) when data are reviewed by other communities using different processing tools].

Updates and Corrections have increasingly become a major purpose of databases in order to facilitate comparisons between different sets of data (e.g. between in situ observations -regionally, temporally, by technique, by investigator, etc.-, as well as between in situ and remotely sensed observations). Updating and correcting processed data can be time consuming, resource intensive, and constrained by time and interpreter choices to meet user needs. When possible, automated techniques should be created to reduce the amount of manual review required for data and metadata.

Reprocessing can produce higher quality data (in particular fidelity images of multiple datasets of different categories of earth observations) than those created during initial processing. Data reprocessing is often necessary and can include, e.g., updating of the instrument calibration, taking account of current knowledge about sensor degradation and radiometric performance; or applying new knowledge in terms of data correction and/or derived products algorithms. Reprocessing also can change the output file format. F**ormat conversion** or **reformatting** might be an additional and usual consequence not necessary linked to reprocessing.

c. Guidance on Implementation, with Examples

Updates and corrections to submitted data sets is encouraged. Records of updates and corrections should be maintained as well as the original data; summaries of updates should be posted in the database, and users should be notified as part of the provenance information. Whether it should be the provider's or the data curator's responsibility to ensure that the current data in the archive is identical to the data used in the most recent publications or current research is open to debate. But such responsibilities should be stated in data provision arrangements and transparent to users. Corrections might initiate debates (e.g. the July 2015 NOAA corrections of the dataset questioning the hiatus and slowdown of 21st century global temperature rise) but should not prevent implementation of correction policies and methodologies and results from being open to the designated communities along with continued access to the previous versions of the data, especially those that were provided a persistent identifier and possibly cited.

Reprocessing should be strongly considered when 1) the quality of the end product from processing does not meet the objectives of the designated community and there is technology (whether new or from another community) available to improve it; 2) the data were processed with different objectives or with objectives appropriate only at the time of its processing; 3) when acquisitions of more data in adjoining areas or in the same area (with new parameters or type), necessitates reanalysis; 4) when new techniques and processing steps are more suitable to tackle the problem in the issue-area; 5) when new software is more suitable for processing the data; and/or 6) when new processing skills, experience and knowledge offer improvements.

Reprocessing has limitations. It can strain resources, including time, personnel, and expertise, requiring more quality control, interpretation, data handling and additional computer resources. Dataset or collection-specific limitations include software or hardware (e.g. processing systems and algorithm differences in various data sets limit or enhance ultimate quality), geographic-bound or time-bound data sets with bad data quality that are not suitable for reprocessing with the new technologies, and when new reprocessing techniques cannot overcome errors made during acquisition etc. Ideally, reprocessing should deliver new data products that are part of a very long time series. At times, data reprocessing needs a previous phase as a proof of concept before it becomes a broader initiative or a consolidated policy. Communication of strengths, limitations and uncertainties of reprocessed observations and reanalysis data to the developer community and the extended research community, including the new generations of researchers and the decision-makers, is crucial for further advancement of observational data records.

d. Metrics to measure level of adherence to the principle

i. Substantive metrics:

Since usability is the main purpose of curation, metrics have traditionally been linked to citation metrics. Other metrics also are being considered (e.g. US NAS analysis of indicators of STI activities in the US and abroad that NCSES should produce; metrics on socio-economic benefits of interdisciplinary data curation from the Use of Earth Observations [5]). Concerning GEO, CEOS has made an unprecedented effort to develop a roadmap with specificity, actionability, responsibility, and desired outcomes in terms of quantitative metrics of ECVs, and there are ongoing exercises to provide metrics for the EBVs by the GEOBPN Leipzig Center. Qualitative descriptions also are valuable and should not be abandoned. See, e.g., Conway *et al*, describing impact of curation of data on disasters, health, energy, climate, water, ecosystems and agriculture [6]. Agreement on universal metrics may be difficult.

ii. Process-based metrics:

Metrics for institutional processes that guide updating, correction, and reprocessing should include:

- existence of a process (logic) for update and reprocessing of holdings
- existence of appropriate metadata structures to capture update and reprocessing information

e. Resource Implications of Implementation

Both updating and corrections, as well as reprocessing, are detailed, labor intensive, time-consuming, and prone to errors. Each reusable data set or collection requires specific reprocessing steps or techniques appropriate for the specific data set or group. Many variables impact the effectiveness of reprocessing, such as reprocessing challenges at individual facilities (time, expertise, computer equipment, quality and completeness of reprocessing instructions) and change due to technological evolution, since reprocessing requires precision, as well as periodic retraining to assure staff competence.

Reprocessing is still not considered strictly necessary in many areas. Climate change related observations are the paradigmatic data sets that need reprocessing since a major difficulty in understanding past climate change is that most systems used to make the observations on which climate scientists now rely were not designed with their needs in mind. Current observation system requirements for climate monitoring and model validation such as those specified by GCOS are rarely aligned with the capabilities of historical observing systems, emphasizing continuity and stability. It is no surprise that the GEO 2009-2011 Work Plan has only one task specifically addressing reprocessing: CL-06-01a on Sustained Reprocessing and Reanalysis of Climate Data. But even in this area, e.g. in the CEOS 2014-2016 Work Plan considers that only the data from the TOPEX/Poseidon mission ended in 2006 -VC-13-, although it admits -CMRS-3: Action plan (first version)- that it is necessary to create the conditions for delivering further climate data records from existing observational data by targeting processing gaps/shortfalls/opportunities (e.g., cross-calibration, reprocessing).

Alternatives to reprocessing such as OTFR (on-the-fly reprocessing) that generate real-time new data products or other dynamic data processing techniques (as well as migration to intermediate XML for file format conversions or e-streaming technologies) are still in their initial research or development phases.

11 DMP-10: Persistent and Resolvable Identifiers

DMP Category: Curation

DMP-10: Data will be assigned appropriate persistent, unique and resolvable identifiers to enable documents to cite the data on which they are based and to enable data providers to receive acknowledgement for use of their data.

a. Terms

The following terms, as they relate to this guideline, are defined in Appendix A: A persistent, unique and resolvable identifier, Persistence, Resolution to Location, Unique Identity

b. Explanation of the principle

Assigning a persistent, unique and resolvable digital identifier to data allows researchers and other users to communicate unambiguously about the data that were used in the published research and contributes to the transparency and reproducibility of research. Persistent, unique and resolvable identifiers are an important component in the mechanism and practice of citation. They remove ambiguity about which work or data has been cited and easily allow citations to be counted and used as a metric for research contributions.

Data citations allow the user to locate the evidence underpinning a research statement, which is critical for scientific practice and the process of verification, and they provide acknowledgment of a source, which has become culturally important in the practice of attributing intellectual debt and as one of the metrics for assessing research contributions.

Improving data citation practice is an important step to ensure that contributions of data creators and data curators are acknowledged. In turn, such recognition should lead to proper financial support for data sharing and data stewardship, which are essential research lifecycle activities.

Thus, the Joint Declaration of Data Citation Principles [https://www.force11.org/group/joint-declaration-data-citation-principles-final] states:

Sound, reproducible scholarship rests upon a foundation of robust, accessible data. For this to be so in practice as well as theory, data must be accorded due importance in the practice of scholarship and in the enduring scholarly record. In other words, data should be considered legitimate, citable products of research. Data citation, like the citation of other evidence and sources, is good research practice and is part of the scholarly ecosystem supporting data reuse.

All the Data Citation Principles are relevant to this Data Management Principle.

Relatedly, the San Francisco Declaration on Research Assessment (DORA) [http://www.ascb.org/dora/] calls for metrics relating to the value and impact of all research outputs, including datasets and software, to be included in the assessment of research contributions.

c. Guidance on Implementation, with Examples

The persistence, resolvability and uniqueness of an identifier depend on responsibility being taken to enact and maintain a series of key functions.

- **Persistence and uniqueness of the identifier:** a registration authority must ensure that the identifier is unique and that information is maintained that unambiguously associates the identifier with the resource. The identifier itself (the string of numbers or letters in whatever format) must be maintained and must not change;
- **Persistence of resolution of identifier to location:** a mechanism must be provided that enables the resource to be found at a specific location on a network. As noted above, this will generally be to a freely accessible 'landing page' providing detailed metadata relating to the data resource. If the data resource is moved, steps must be taken to ensure that the identifier resolves to the new location;
- **Persistence of metadata on landing page:** If for whatever reason the data holder needs to remove (de-accession or destroy the data itself) the landing page must be maintained and must provide information that this step has been taken. The identifier and metadata must persist even if the data resource has been destroyed;
- **Persistence checking:** to maintain these functions regular checking of link resolution, resource persistence and location should be undertaken;
- **Maintaining arbitrary views of data:** For arbitrary views of data, such as those generated via a query, provide continuing access by versioning and timestamping the data and by storing executable queries to access the timestamped data and assigning persistent identifiers to those queries.

Organizations that maintain and provide access to data resources should ensure that these functions are carried out, whether by the organization itself or by a third party.

The key words here are persistence and responsibility. The authors of Clark et al. 2015, recommend that all organizations endorsing the Joint Declaration of Data Citation Principles adopt a "Persistence Guarantee':

[Organization/Institution Name] is committed to maintaining persistent identifiers in [Repository Name] so that they will continue to resolve to a landing page providing metadata describing the data, including elements of stewardship, provenance, and availability.

[Organization/Institution Name] has made the following plan for organizational persistence and succession: [plan].

The capacity to deliver such a guarantee corresponds to some of the criteria for being a Trusted Digital Repository (TDR) [see above, DMP-7 and reference DSA/WDS]

iii. Persistent Identifier Schemes

A number of persistent identifier schemes exist. The principal ones, summarized in Clark et al. 2015, include PURLs (Permanent Uniform Resource Locators), the Handle System, ARKs (Archival Resource Keys), CrossRef and DataCite DOIs (Digital Object Identifiers). Some databases and data archives use their own identifier system and maintain the resolution between these identifiers and a location themselves.

DOIs are built on the Handle System. CrossRef and DataCite are Registration Agencies that provide services for registering and resolving DOIs and ensure persistence by requiring specific commitments from registering organizations and by actively monitor compliance.

The following table is adapted from Clark et al. 2015 and summarises the approach of the most important identifier schemes used for identifying data to maintain persistence. Additional information about these schemes and others is available from the DataCite Metadata Working Group (2016).

Scheme	Authority	Resolution URI	Achieving Persistence	Enforcing Persistence	Action on Removal of Data Resource
PURL	Online Computer Library Centre (OCLC)	https://purl.org	Registration	None	Domain owner responsibility
ARK	Various Name Assigning or Mapping Authorities	http://n2t.net; Name Mapping Authorities	User-defined policies	Hosting server	Host-dependent; metadata should persist
Handle	Corporation for National Research Initiatives (CNRI)	http://handle.net	Registration	None	Identifier should persist
DataCite DOI	DataCite	http://dx.doi.org	Registration with contract	Link checking	DataCite contacts owners; metadata should persist

Data contributed to GEOSS should be assigned appropriate persistent**, unique** and resolvable identifiers. Both the organisation holding the data and GEOSS should indicate clearly how the data should be cited by those using the data in published work.

d. Metrics to measure level of adherence to the principle

Measures of adherence are as follows:

1. Assigning appropriate, persistent, unique and resolvable identifiers to data sets contributed to GEOSS;
2. Resolution of the identifier to the data landing page;
3. Clear statement on the landing page and in the GEOSS entry of how to cite the data; and
4. Good practice data citation in the GEO community.

e. Resource Implications of Implementation

Data archives should subscribe to a service that generates unique persistent identifiers for data and should assign an identifier to each data product that is released to the public. The data identifier assignments may be initiated automatically or manually by the archive. The recommended citation for each data product should include the data product identifier.

APPENDIX A

DEFINITIONS OF TERMS

Access Rights Information: The information that identifies the access restrictions pertaining to the Content Information, including the legal framework, licensing terms, and access control. It contains the access and distribution conditions stated within the Submission Agreement, related to both preservation (by the repository) and final usage (by the Consumer). It also includes the specifications for the application of rights enforcement measures. [From DMP-7]

Archive: An organization that intends to preserve information for access and use by a Designated Community. [From DMP-7]

Authentication: Authentication is the process of giving users access to systems based on their identity. Authentication merely ensures that the user is who he or she claims to be, but says nothing about the access rights of the user. Usually it is based on a username and password. [From DMP-2]

Authenticity: The degree to which a person (or system) regards an object as what it is purported to be. Authenticity is judged on the basis of evidence. [From DMP-7]

Authenticity: *the property of authentic data and associated metadata as being what they purport to be — reliable assets that over time have not been altered, changed or otherwise corrupted.*

Assuring continued authenticity is an essential but intransigent preservation consideration for digital data and records. Authenticity verification requires the use of metadata. The critical change for IT practices is that metadata is now very important and must be safeguarded with the same priorities as the data. Authenticity must involve the entire process from submission of information to a repository, creation of the data record containing the necessary metadata, and security and reliability of the stored information record. Validation of the information at the time of submission is crucial. This includes secure transmission and authentication but may also extend into requirements on the processes producing the information, such as ensuring who is the author or owner of the information (Context and Provenance information). [From DMP-8]

Authorization: Authorization is the process of granting or denying access to a resource that can be a web service or a dataset. [From DMP-2]

Broker: Transforms a dataset from one standard into another. A broker can read and mediate among the many standards and specifications used by different communities of practice.[3] [From DMP-1]

Catalogue: A data catalogue is a collection of metadata about datasets. [From DMP-1]

Clearinghouse: In general a clearinghouse provides a central access point for value-added topical guides that identify, describe, and evaluate Internet-based information resources. A clearinghouse is a system of servers located on the Internet that contain field-level descriptions of available digital data. This descriptive information, known as metadata, are collected in a standard format to facilitate query and consistent presentation across multiple participating sites. A clearinghouse uses readily available Web technology for the client side and uses standards for the query, search, and presentation of search

[3] http://www.eurogeoss.eu/broker/Pages/TheEuroGEOSSBrokeringPlatform.aspx

results to the Web client. A clearinghouse provides information about who is providing which authorized geoinformation for which application (GETIS).[4] [From DMP-1]

Community-Approved Standards: Standards that are typically narrowly focused, and published and maintained by scientific or disciplinary communities, such as official Communities of Practice, or more informal groups that represent a certain discipline or area of interest. [From DMP-4]

Consumer: The role played by those persons, or client systems, who interact with repository services to find preserved information of interest and to access that information in detail. This can include other repositories, as well as internal repository persons or systems. [From DMP-7]

Core Elements: the minimum subset of metadata fields that need to be maintained for a dataset. [From DMP-1]

Curation[5]: Activities required to make deposited data preservable or usable now and in the future. Depending on technological changes, curation may be required at certain points in time throughout the data lifecycle. [From DMP-7]

Data: A reinterpretable representation of information in a formalized manner suitable for communication, interpretation, or processing. Examples of data include a sequence of bits, a table of numbers, the characters on a page, the recording of sounds made by a person speaking, or a moon rock specimen. [From DMP-7]

Data Curation: is the active and on-going management of data through its lifecycle of interests and usefulness to scholarship, science, and education. These activities should "enable data discovery and retrieval, maintain its quality, add value, and provide re-use over time" and include "authentication, archiving, management, preservation, retrieval, and representation" [1] [From DMP-9]

Data Quality Indicator: Values specifying the level of quality determined for each data quality criterion. [From DMP-6]

Data Reprocessing: Treatment of data reclaimed from existing data sets to obtain new data products. [From DMP-9]

Designated Community: An identified group of potential Consumers who should be able to understand a particular set of information. The Designated Community may be composed of multiple user communities. A Designated Community is defined by the Archive and this definition may change over time. [From DMP-7]

Digital Migration: The transfer of digital information, while intending to preserve it, within the repository. It is distinguished from transfers in general by three attributes: a focus on the preservation of the full information content that needs preservation; a perspective that the new archival implementation of the information is a replacement for the old; and an understanding that full control and responsibility over all aspects of the transfer resides with the repository. [From DMP-7]

Digital Object: An object composed of a set of bit sequences. [From DMP-7]

Discovery: the act of finding or learning something for the first time (Merriam-webster). [From DMP-1]

Discovery Services: making it possible to search for data sets and services on the basis of the content of the corresponding metadata and to display the content of the metadata.[6] [From DMP-1]

[4] http://cordis.europa.eu/project/rcn/60644_en.html

[5] Term not present in the OAIS glossary

[6] http://inspire.ec.europa.eu/documents/Network_Services/TechnicalGuidance_DiscoveryServices_v3.0.pdf

Documented: Data that has associated metadata, where the metadata elements contain information necessary to assist data users in accessing the data, using the data, understanding the data, and processing the data. [From DMP-4]

Encoding: TBD. [From DMP-3]

Essential Variables: TBD. [From DMP-3]

File Format: The internal structure and encoding of a digital object, which allows it to be processed, or to be rendered in human-accessible form [2]. [From DMP-9]

Format Conversion: copying the digital content from one type of storage medium to another, in a permanent attempt to outrun the obsolescence of one generation after another of data carriers and their associated hardware; frequently, format conversions rather involve translation from one data format (or file format) to another, to outrun the obsolescence of the format and its associated software [3] [From DMP-9]

GeoJSON: TBD. [From DMP-3]

Identifier: a Persistent, Unique and Resolvable Identifier: A maintainable digital identifier that allows a digital object (a file or set of files) to be referenced. [From DMP-10]

Ingest[2]: The process of entering data and associated metadata into a data repository. [From DMP-7]

Integrity[2]: Internal consistency or lack of corruption of digital objects. Integrity can be compromised by hardware errors even when digital objects are not touched, or by software or human errors when they are transferred or processed. [From DMP-7]

Integrity: *the property of safeguarding data and associated metadata accuracy and completeness. Integrity refers to the assurance that data and associated metadata are not lost or damaged as a result of malicious or inadvertent activity.*

The most important measure to ensure integrity of stored digital information is access control. Additional protection is provided by checksums that may be applied to individual records, files or disk structures. The best protection is to store however several copies of each data record in separate systems under separate administration and possibly also in separate locations. At least three copies should exist in order to enable a majority vote to determine the correct version and to grant the Data Preservation. [From DMP-8]

International Standards: Standards that are published and maintained by recognized international Standards Development Organizations, such as IEEE, ISO, OGC, etc. [From DMP-4]

License: A permission or a set of permissions regarding whatever is licensed. When I give someone a license to do something, I give them the permission to do it. I have rights that I license. [From DMP-1]

Long Term: A period of time long enough for there to be concern about the impacts of changing technologies, including support for new media and data formats, and of a changing Designated Community, on the information being held in a repository. This period extends into the indefinite future. [From DMP-7]

Long Term Preservation: The act of maintaining information, Independently Understandable by a Designated Community, and with evidence supporting its Authenticity, over the Long Term. [From DMP-7]

Metadata: information describing data sets and data services and making it possible to discover, inventory and use them - alternative: data about data. [From DMP-1]

Metadata Element: a discrete unit of metadata, in accordance with ISO 19115 and 19139. [From DMP-1]

Network Services: computing services that make it possible to discover, transform, view and download data and to invoke data and e-commerce services. [From DMP-1]

Open Archival Information System (OAIS): An Archive, consisting of an organization, which may be part of a larger organization, of people and systems, that has accepted the responsibility to preserve information and make it available for a Designated Community. It meets a set of responsibilities, as defined in section 4, that allows an OAIS Archive to be distinguished from other uses of the term 'Archive'. The term 'Open' in OAIS is used to imply that this Recommendation and future related Recommendations and standards are developed in open forums, and it does not imply that access to the Archive is unrestricted. [From DMP-7]

Persistence: the identifier and the resolution are persistent in that some entity, depending on the system involved, takes responsibility for ensuring that the information 1) defining the identifier's relationship to a specific resource and 2) the resolution to a given location are maintained. [From DMP-10]

Preferred Formats: Formats that a repository can reasonably assure will remain readable and usable. Typically, these are the de facto standards employed by a particular discipline. [From DMP-7]

Producer: The role played by those persons or client systems that provide the information to be preserved. This can include other repositories or internal repository persons or systems. [From DMP-7]

Provenance: *Part of the metadata that documents the history of the content information. This information tells the origin or source of the content information, any processes and changes that may have taken place since it was originated, and who has had custody of it since it was originated. It is sometimes referred to as lineage.*

Complete provenance information is part of the information required for assessing the validity and fitness for purpose of a dataset or product. It is composed of references and descriptions of the data sources, data processes and algorithms used. It also includes a description of responsible parties involved in all the steps of the process chain. [From DMP-5]

Provenance Information: The information that documents the history of the Content Information. This information tells the origin or source of the Content Information, any changes that may have taken place since it was originated, and who has had custody of it since it was originated. The Archive is responsible for creating and preserving Provenance Information from the point of Ingest; however, earlier Provenance Information should be provided by the Producer. Provenance Information adds to the evidence to support Authenticity. [From DMP-7]

Quality-Control: Data quality-control is conducted by reviewing data to assess their potential for use. [From DMP-6]

Queryable: a metadata element that can be queried upon or that is part of a query. [From DMP-1]

Readability: *the property of assuring data and associated metadata usage over the long term.*

All activities such as reformatting, data refreshment and duplication, etc., aim to grant that the data and the associated metadata are accessible and readable for the entire retention period, and that they are viewed and understood. [From DMP-8]

Reference Model: A framework for understanding significant relationships among the entities of some environment, and for the development of consistent standards or specifications supporting that environment. A reference model is based on a small number of unifying concepts and may be used as a basis for education and explaining standards to a non-specialist. [From DMP-7]

Resolvable: The identifier contains information that enables access (e.g. via browser click) to a specific location on a network, even if the location of the metadata or data has changed. Most often this will be to metadata presented on a landing page that acts as a proxy for the data resource. [From DMP-10]

Search Engine: Computer program that can search indexed topics. [From DMP-1]

SSO – Single Sign-On: Single sign-on (SSO) is an authentication process that allows a user to access multiple servers with one set of login credentials. With SSO, a user logs in once and gains access to different servers, without the need to re-enter log-in credentials each time. [From DMP-2]

Succession Plan: The plan of how and when the management, ownership and/or control of the repository holdings will be transferred to a subsequent repository in order to ensure the continued effective preservation of those holdings. [From DMP-7]

Traceability: Property of a measurement result whereby the result can be related to a reference through a documented unbroken chain of process steps and source each contributing to the measurement of the uncertainty.

In other words, it is the capability to trace back the data to its origins. Traceability implies that provenance information is complete enough for the user to assess the uncertainty of the data. This is one of the aims of documenting provenance. Another term that is relevant to provenance is *reproducibility*, which would require the provenance information to be complete enough, and in a clear sequence, to enable recreation of the data from its sources by applying the process steps. [From DMP-5]

Unique Identity: The identifier communicates unique information confirming that it refers to, and only to, a given object - in other words, the identifier itself is unique, while the thing it is identifying may not be. The uniqueness is maintained by the registration authority. [From DMP-10]

Use Conditions: something that limits or restricts the use or reuse of a resource; a qualification. [From DMP-1]

Web-Service: The W3C defines a Web service generally as: "a software system designed to support interoperable machine-to-machine interaction over a network." [From DMP-2]

APPENDIX B

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      http://www.iso.org/iso/catalogue_detail.htm?csnumber=39229http://www.iso.org/iso/catalogue_detail.htm?csnumber=39229 .
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3. ISO 19157:2013 Geographic information -- Data quality http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=32575 ;
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5. Dublin Core http://dublincore.org/http://dublincore.org/ ;
6. Darwin Core http://rs.tdwg.org/dwc/http://rs.tdwg.org/dwc/ ;
7. DIF :

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APPENDIX C

ACRONYMS AND ABBREVIATIONS

API – Application Programming Interface
ARK – Archival Resource Key
CCSDS – Consultative Committee for Space Data Systems
CEOS – Committee on Earth Observation Satellites
CF – Climate and Forecast
CNR – National Research Council
CNRI – Corporation for National Research Initiatives
CSW – Catalogue Service for the Web
DAB – Discovery and Access Broker
DCC – Digital Curation Centre
DIF – Directory Interchange Format
DMP – Data Management Principle
DOI – Digital Object Identifier
DORA – Declaration on Research Assessment
DSA – Data Seal of Approval
EBV – Essential Biodiversity Variables
ECV – Essential Climate Variables
FGDC – Federal Geographic Data Committee
GCOS – Global Climate Observing System
GEO –Group on Earth Observations
GeoJSON – Geographic JavaScript Object Notation
GEOSS – Global Earth Observation System of Systems
GeoViQua – Quality Aware Visualization for the Global Earth Observing System of Systems
GETIS – Geo-Processing Networks in a European Territorial Interoperability Study
GML – Geography Markup Language
HW – Hardware
ICSU – International Council for Science
IEEE – Institute of Electrical and Electronics Engineers
ISO – International Organization for Standardization
JRC – Joint Research Centre
JSON – JavaScript Object Notation
KML – Keyhole Markup Language
MIME – Multipurpose Internet Mail Extensions
NAS – National Academy of Sciences
NCSES – National Center for Science and Engineering Statistics
NetCDF – Network Common Data Form
NOAA – National Oceanic and Atmospheric Administration
OAI-PMH – Open Archives Initiative Protocol for Metadata Harvesting
OAIS – Open Archival Information System
OCLC – Online Computer Library Centre
OGC – Open Geospatial Consortium
OPeNDAP – Open-source Project for a Network data Access Protocol

OTFR – On-the-Fly Reprocessing
PURL – Permanent Uniform Resource Locator
SDI – Spatial Data Infrastructure
SensorML – Sensor Model Language
SSO – Single Sign-On
STI – Science, Technology, and Innovation
SW – Software
SWE – Sensor Web Enablement
TDR – Trusted Digital Repository
TDWG – Taxonomic Databases Working Group (also known as Biodiversity Information Standards)
TOPEX – Ocean Topography Experiment
URI – Uniform Resource Identifier
WaterML – Water Markup Language
WDS – World Data System
WMO – World Meteorological Organization
WMS – Web Map Service
WMTS – Web Map Tile Service
WPS – Web Processing Service
XML – Extensible Markup Language
XSD – XML Schema Definition

GROUP ON EARTH OBSERVATIONS

APPENDIX D

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APPENDIX 4. In Situ Observations: Coordination Needs and Benefits

In Situ Observations: Coordination Needs and Benefits

Report Compiled by
GD-06 Task Team

PREAMBLE

Earth observations from diverse sources, including satellite, airborne, in situ platforms, and citizen observatories, when integrated together, provide powerful tools for understanding the past and present conditions of Earth system components, as well as the interplay between them. GEO is a facilitator of policy-level dialogue on the importance and coordination of Earth observation systems (including ground-, air-, water- and space-based sensors, field surveys, and citizen observatories).

Systems for in situ observations (i.e. all ground, water- and airborne observations excluding space-borne observations) are diverse and there is no single global group responsible for their overall coordination. One of the key recommendations in the GEO Evaluation Report for the first GEO decade recommended the "*Creation of a high-level task force to promote the incorporation of in situ data into GEOSS.*" Subsequently, the GEO Strategic Plan 2016-2025 underlined the importance of coordination and improvement of in situ observation networks. Based on the guidance and recommendations, the GEO In Situ Task GD-06 "GEOSS In Situ Earth Observation Resources" was defined in the GEO 2016 Work Programme.

Coordination of in situ Earth observations is not an easy task. Even a simple survey of in situ coordination groups leads to a large, incomplete and very complex system. During the preparation for the Task, a brief report was prepared and finalized in early 2016. This report summarizes the state of in situ Earth observation community, discusses the benefits of coordinating in situ observations, identifies challenges for this coordination, and provides recommendations on how to proceed. The recommendations were taken into account in developing the team and work plan for GD-06. As an initial activity, the GD-06 Task Team decided to prepare a report on the status of global in situ observation networks and existing frameworks for their coordination, include options for new in situ measurements and coordination scenarios. The present document is the initial outcome of this activity, which has been conducted during 2016. It is planned to continue this assessment in the next years and to prepare a more comprehensive and conclusive report.

SCOPE AND OBJECTIVE OF THE DOCUMENT

This report attempts to describe the main characteristics of in situ observation networks and their coordination across domains and regions and to outline steps that could lead to improved coordination. Due to the limited time available for the preparation of the document, the report focuses on example regions, domains, and areas. The conclusions and recommendations may therefore not all generalizable to a global level.

CONTENTS

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1 INTRODUCTION

Efforts to develop a framework for the harmonization of Earth observations (EOs), both in situ and from space, have a history that goes back several decades. Here, in situ refers to all land, water, and air based observations, independent of the observing technology and methodology, excluding only space-based observations.

In 1984, G7 initiated the Integrated Global Observing Strategy (IGOS) as a framework for EOs with the goal to identify the essential variables that need to be observed in order to document the changes that are happening on the planet and to ensure that these observations were made available. In 1998, major organizations in the scientific and EO fields established the IGOS Partnership (IGOS-P) in an effort to first identify what needs to be monitored and then to implement the corresponding observing systems. IGOS-P used a well-defined theme approach to define the overall strategy, which "recognises that in reality it is impossible, in one step and for all eventualities, to complete the exercise of defining all the necessary observational requirements and hence the observational systems, data handling, processing and analysis infrastructure for a comprehensive global system. The theme approach allows the coherent definition and development of an overall global strategy whilst recognising the different state and stage of development in different areas. Themes have not a priori been defined, rather it is anticipated that the user communities will identify areas that require action and bring forward themes for agreement and action." (IGOS-P, 2003). The resulting IGOS-P theme reports were excellent outcomes defining observational needs for societally relevant themes. Many of the identified observational needs required in situ observations (see, e.g., Marsh et al., 2004; IGOS, 2006).

In 1984, G7 also gave the mandate to coordinate space-based observation to the Committee on Earth Observation Satellites (CEOS), and CEOS has been the space-based global coordination body since then. No such mandate has been given for in situ observation, and no group for global coordination across the wide range of domains has emerged.

The ad hoc Group on Earth Observations (GEO) was initiated in 2003 (again by the then G8) with the mandate to develop an implementation plan for the Global Earth Observing System of Systems (GEOSS). In the resulting 10-Year Implementation Plan (GEO, 2005a) and the associated Reference document (GEO, 2005b), the importance of in situ observation is emphasized in many places. After being fully established in 2005 with a ten-year mandate to build GEOSS, GEO developed a work plan, which was updated on an annual basis. Unlike IGOS-P where themes emerged from a community and expert-based approach, the GEO Work Plan was structured according to nine pre-defined Societal Benefit Areas (SBAs). In more recent years, additional Societal Benefit Tasks were added to emphasize large areas that the nine SBAs did not sufficiently cover, including those focusing on Oceans and Society: Blue Planet, Global Land Cover, Global Forest Observation, Global Urban Observation and Information, and Impact Assessment of Human Activities. In several SBAs and SB Tasks, the concept of Essential Variables (EVs) was adopted to identify variables that should be prioritized for observations (see Bombelli et al., 2016). Many of the EVs identified so far require in situ observations either directly or indirectly as groundtruth for space-based observations.

During the first decade, in situ coordination for GEOSS was included in the GEO Work Plan Task IN-01: Infrastructure. This task included coordination of both the space-based and in situ observations. During the transition into the second decade, a dedicated Foundation Task GD-06 "GEOSS In Situ Earth Observation Resources" was defined (see GD-06, 2016) with the mission to assess the needs for coordination of in situ observations and to enable improved cross-domain coordination.

As the first activity, the GD-06 Task Team is reviewing the levels of coordination in regions and EO domains with the goal to make detailed recommendations on what coordination is needed, what the benefits of improved coordination could be, and what option for coordination should be considered. In the next section, an overview is given of regional in situ observations with a focus on existing coordination mechanisms. Section 3 reviews the current status of in situ observations in selected domains. Section 4 discusses in greater depth issues that require more coordination. Finally Section 5 provides recommendations for both the work to be carried out by GD-06 and for coordination activities by GEO in general.

2 REGIONAL ACTIVITIES

The current organisation of in situ data provision worldwide is very complex and resulting from often uncoordinated initiatives driven by both science and policy-oriented projects, established on different time-scales and involving many different stakeholders. An exhaustive description of the current landscape would therefore be extremely demanding and not achievable within the scope of GD-06. In this section, the current status of in situ observations and their coordination on regional to continental scales is reviewed for selected regions with a focus on data sharing, the relationship between these activities and the SBAs, and the need for additional regional and global coordination. It is planned to add sections for additional regions including North America, Africa, and Oceania in the next version of the document.

2.1 Europe

The European landscape of in situ observation networks, research networks and research infrastructures is very diverse and complex. The complexity is indicated in Figure 1 in Section 2.4.1 below. Over the last 20 years, major efforts have been made to overcome fragmentation due to national boundaries, disciplinary fields, and societal sectors. Although today many initiatives exist or are developing that focus on coordination, there is still an urgent need for integration of networks, research initiatives and research infrastructures, and improvements of the links between those providing data and products and those needing the information for decision and policy making.

2.1.1 Non-profit organisations and networks

There are several non-profit organisations and networks in Europe dealing with coordination of in situ data collection, analysis and distribution. The list of organisations provided below is far from being exhaustive, but represents prominent European networks of, typically public, institutions covering a broad range of thematic themes. It is characteristic that these networks often have a legal mandate and a clear operational perspective implemented via, e.g., establishment and operation of infrastructure, observing systems, and standards.

EuroGeographics: EuroGeographics (http://www.eurogeographics.org/) is the membership association for 60 European National Mapping, Cadastre and Land Registry Authorities from 46 countries. The main objective of EuroGeographics is the further development of the European Spatial Data Infrastructure through collaboration in the area of geographic information and the representation of its members and their capabilities. EuroGeographics' activities focus on supporting relevant European policies, exchange of knowledge in the field of geo-spatial and related information, and harmonising and making available members' national topographic, cadastral and other land information.

EuroGOOS: EuroGOOS (http://eurogoos.eu/) is a grouping of oceanographic institutes in Europe with the objective of fostering, promoting, and implementing cost-efficient operational oceanographic services in Europe. EuroGOOS has 40 members from 19 European countries providing operational oceanographic services and carrying out marine research. EuroGOOS coordinates European contributions to sustained marine observing systems and plays a key role in establishing the European Ocean Observing System (EOOS). EOOS will deliver a vision, roadmap and a common focal point for European ocean observing research and technology. EOOS will provide a flexible coordinating framework to help manage and improve the existing observing effort, making it more efficient and effective at different geographical scales, and for different end-users.

EUMETNET: EUMETNET (http://eumetnet.eu/) is a network grouping of 31 European National Meteorological Services. EUMETNET provides a framework to organise co-operative programmes between its members in the various fields of basic meteorological activities such as observing systems, data processing, basic forecasting products, research and development, and training. Through its programmes, the members intend to develop their collective capability to serve environmental management and climate monitoring and to bring to all European users the best available quality of meteorological information.

Eurogeosurveys: Eurogeosurveys (http://www.eurogeosurveys.org/) is an organisation of 37 National Geological Surveys and some regional Surveys in Europe representing national Geological Surveys of the European countries. It promotes the contribution of geosciences to European Union affairs and provides a permanent network between the Geological Surveys and it pursues activities that lie exclusively in the public interest or in the interest of public administration that will benefit from the combined and coordinated expertise of its members and in the direct interest of the EU. One of the key objectives of the Eurogeosurveys is to set up the European Geological Data Infrastructure (EGDI).

Eionet: The European environment information and observation network (Eionet, http://www.eionet.europa.eu/) is a partnership network of the European Environment Agency (EEA) and its 33 member and 6 cooperating countries, aiming to provide timely and quality-assured data, information and expertise for assessing the state of the environment in Europe and the pressures acting upon it. Eionet consists of the EEA itself, six European Topic Centres and a network of around 1000 experts from countries in over 350 national environment agencies and other bodies dealing with environmental information. The Eionet partnership supports the collection and organisation of data and the development and dissemination of information.

EUREF: The Reference Frame Sub Commission for Europe of the International Association of Geodesy (IAG) focuses on the definition, realization and maintenance of the European Geodetic Reference Systems. It engages in the promotion and assistance of the adoption and use of European Terrestrial Reference System (ETRS89) and European Vertical Reference System (EVRS) and the development and maintenance of the EUREF GNSS Permanent Network (EPN), which is the ground based GNSS infrastructure for scientific and practical applications in positioning and navigation. EUREF provides all its products on the “best effort” basis and free of charge to the public. The EPN is a voluntary federation of over 100 self-funding agencies, universities, and research institutions in more than 30 European countries. They work together to maintain ETRS89, which is the single Europe-wide standard coordinate reference system adopted by the European Commission (EC). In addition, the Infrastructure for Spatial Information in the European Community (INSPIRE) Directive 2007/2/EC of the European Parliament and of the Council as regards interoperability of spatial data sets and services established - among other requirements - that the ETRS89 shall be used for the referencing of spatial data sets in INSPIRE. The ETRS89 geodetic reference is widely used in continental Europe. Furthermore, the increasing use of GNSS networks incline countries to use the ETRS89. In addition to its key role in the maintenance of the ETRS89, the EPN data are also used for a wide range of scientific applications such as the monitoring of ground deformations, sea level, space weather and numerical weather prediction. In response to evolving user needs and the changing GNSS landscape, EUREF is working for the continuous development of new applications and products through Working Groups and Pilot Projects.

2.1.2 Other examples of European/EU initiatives

In Europe a major development has been the entering into force of the INSPIRE Directive in May 2007, establishing an infrastructure for spatial information in Europe to support Community environmental policies, and policies or activities which may have an impact on the environment. INSPIRE aims to create an EU spatial data infrastructure, enabling the sharing of environmental spatial information among public sector organisations and better facilitate public access to spatial information across Europe. A European Spatial Data Infrastructure will assist in policy-making across boundaries. Therefore the spatial information considered under the directive is extensive and includes a great variety of topical and technical themes. INSPIRE is based on the infrastructures for spatial information established and operated by the 28 Member States of the European Union. The Directive addresses 34 spatial data themes needed for environmental applications, with key components specified through technical implementing rules. This makes INSPIRE a unique example of a legislative “regional” approach.

In February 2008, the EC Communication 'Towards a Shared Environmental Information System (SEIS)' proposed a solution to Europe's environmental information challenge (http://www.eea.europa.eu/about-us/what/shared-environmental-information-system-1). Since then, SEIS has become a collaborative initiative of the European Commission together with the EEA and the 39 countries of Eionet. SEIS is a key driver for the growth of the knowledge base, and it integrates a wealth of information from Eionet and other networks and partners, citizen science, crowd sourcing, and new environmental information gathering initiatives such as Copernicus. A key cross-cutting goal of SEIS is to provide access to environmental information, and maximise and expand its use.

The European Marine Observation and Data Network (EMODnet, http://www.emodnet.eu/) consists of more than 100 organisations assembling marine data, products and metadata to make these fragmented resources more available to public and private users relying on quality-assured, standardised and harmonised marine data which are interoperable and free of restrictions on use. EMODnet is currently in its second development phase with the target to be fully deployed by 2020. EMODnet is a long-term marine data initiative from the European Commission Directorate-General for Maritime Affairs and Fisheries (DG MARE) underpinning its Marine Knowledge 2020 strategy. The main purpose of EMODnet is to unlock fragmented and hidden marine data resources and to make these available to individuals and organisations (public and private), and to facilitate investment in sustainable coastal and offshore activities through improved access to quality-assured, standardised and harmonised marine data which are interoperable and free of restrictions on use.

The United Nations' initiative on Global Geospatial Information Management (UN-GGIM) aims at playing a leading role in setting the agenda for the development of global geospatial information and promoting its use to address key global challenges. In addition to a global committee of experts, UN-GIMM is developing a regional structure, and UN-GGIM: Europe's aim is to ensure that the national mapping and cadastral authorities and national statistical institutes in the European UN Member States, the European Institutions and associated bodies work together to contribute to the more effective management and availability of geospatial information in Europe, and its integration with other information, based on user needs and requirements. UN-GGIM: Europe provides support to the further implementation and alignment of existing legislation, to support relevant ongoing initiatives and proposing actions, to be implemented as far as possible within Europe's existing legal, institutional and operational frameworks addressing issues of geo-information management. The regional intention is to: (a) avoid duplication of efforts; (b) improve the joint response to user needs and requirements; (c) encourage geospatial data interoperability, harmonisation and sharing; and (d) optimise the overall management of geospatial information in Europe.

2.1.3 Research networks and infrastructures

In Europe, the landscape of in situ data provision has been established mostly during the last 30 years, in response to policies-related treaties on the one side and research requirements on the other side. For many years, policy- and research-driven initiatives were ran with very limited degree of interaction and/or coordination. While policy and treaty-driven in situ observation networks are often organized at Environmental Ministry level, research-driven in situ observations are instead supported at Research Ministry level using the European Research Infrastructure (RI) funding scheme. It is only over the last decade that more integrated and synergetic approaches were developed to bridge the different initiatives.

The concept of infrastructure supporting environmental research was developed in Europe over the last decade to meet the needs expressed by the scientific communities for continuous observation of natural and anthropogenic processes affecting the environment. Environmental research infrastructures comprise major scientific equipment or sets of instruments, as well as knowledge-containing resources such as collections, archives and thematic data infrastructures and the associated expertise and human resources. They provide support to access data, services and facilities within their own domain.

Each environmental research infrastructure has its own particular set of scientific questions, has identified the stakeholders and the communities to engage and has designed its services for contributing to tackle environmental challenges. Indeed, every RI is designed to provide data and services to a wide range of user communities and as such contributing to cross- and inter-disciplinary research regardless of its own particular field of interest. Research infrastructures are established in the long-term (>20 years) but the process to reach a legal organization (for example as a European Research Infrastructure consortium – ERIC) is complex and can take more than a decade. At present, very few consortia formally exist in the environmental science: ICOS (Integrated Carbon Observing System), IAGOS (In-Service Aircraft for a Global Observing System), EURO-ARGO (European Component of broad-scale global array of temperature/salinity profiling floats), EISCAT-3D (European Incoherent Scatter Scientific Association). Others initiatives, in the different environmental domains, are currently on the European roadmap preparing their long-term sustainable organisation : ACTRIS (Aerosol, Cloud and Trace Gases Research Infrastructure), SIOS (Svalbards Integrated Observing System), EPOS (European Plate Observing System) EMSO (European Multidisciplinary Seafloor and water-column Observatory) , DANUBIUS (International Centre for Advanced Studies on River-Sea Systems), EMBRC (European Marine Biological Resource Centre) or ANAEE (Infrastructure for Analysis and Experimentation on Ecosystems). The landscape will continue to evolve in the next years with different updates of the roadmap scheduled in 2018 and 2020. The research infrastructure program is clearly shaping the European Earth observing system for the upcoming decades and will address identified parameter gaps and long-term commitments/sustainability since a very large fraction of observations are still based on short term research funding.

Despite consistent progress, the landscape of European environmental research infrastructures is still too fragmented (see Figure 1 below) and will benefit from further integration and collaborative work. Most of the RIs have similar elements in their structure, e.g. they have instrumentation (such as sensors or laboratories) and have dedicated data systems including elements for data acquisition, management, access, processing, and community support. Therefore, whilst the short/medium-term goal of each RIs is to foster common solutions for promoting integrated use of data through interoperability within its own domain of interest, it is also imperative to find robust yet lightweight means to integrate data and RI services across RIs to serve an increasingly multidisciplinary scientific community and progress toward the holistic understanding of planet Earth and its behaviors.

When applicable, integration of research Infrastructures and policy-driven networks is key to enhanced use of data and services, in particular for developing the various segments of the European Copernicus programme framework of Copernicus services. An excellent example is the close cooperation between the European Monitoring and Evaluation Program (EMEP) and ACTRIS. EMEP is a science-based and policy-driven instrument for cooperation in atmospheric monitoring and modelling, emission inventories and projections, and integrated assessment to help solve transboundary air pollution problems in Europe. In order to achieve its mission, EMEP coordinates a long-term network of stations monitoring concentrations and deposition fluxes of various pollutants to test the effectiveness of European policies for air quality. The network includes different type of monitoring stations with most numerous (>100) level 1 sites providing basic chemical and physical measurements of the traditional EMEP parameters, 20 to 30 level 2 sites providing additional physical/chemical speciation of relevant components that is necessary for assessing long-range transport of air pollutants, and <20 research-oriented level 3 stations nominated as “EMEP supersites”. Level-3 activities are research-oriented to improve the scientific understanding of the relevant physical-chemical processes in relation to regional air pollution and its control. The research infrastructure for atmospheric research ACTRIS is the funding scheme to ensure long-term sustainability of level-3 activities within EMEP. ACTRIS is central to providing the required tools for calibrating measurements and harmonizing procedures throughout the EMEP network by operating relevant calibration centers. When applicable, ACTRIS and EMEP data are managed using identical procedures and accessible through the same data center. ACTRIS is also the tool to providing guidance for optimizing the observation network by, for example, developing new standard operation procedures for atmospheric parameters. This is a excellent example of integration of existing programs and projects that will help building the European component of an evolving Integrated Global Observing System and GEOSS in a coordinated and more sustainable way.

2.1.4 Examples of cross-cutting coordination

Copernicus: The European Earth Observation flagship programme, Copernicus (http://copernicus.eu/), encompasses three components: Space, In Situ and Services. In situ data are an essential and integrated part of Copernicus, and are used extensively every day by the Copernicus services and the space component to produce products, and deliver services requested by end users. In the context of the Copernicus programme the term ‘in situ data’ covers a wide range of data: observation data from ground-, sea- or air-borne sensors as well as reference and ancillary data licensed or provided for use in Copernicus.

The primary objective of the Copernicus in situ component is to provide reliable and sustainable access to in situ data to the Copernicus services, relying on existing capacities operated at national and European level, and global observing systems. The component is primarily implemented by the six Copernicus services, and, when overall coordination is required, by the European Environment Agency.

The Copernicus services are mainly responsible for the day-to-day operational managing and processing of data in accordance with their requirements, and for specific data access and cooperation agreements with data providers. Whereas the European Environment Agency focuses on maintaining an overview across all the services regarding in situ data requirements, in situ datasets used by the services, and critical in situ data gaps. To avoid duplication of work, the European Environment Agency is also supposed to deliver data access solutions targeted multiple services, such as the Copernicus reference data access portal, CORDA.

It is the joint effort of the Copernicus services and the European Environment Agency that operationalise the Copernicus in situ component, but it is the indispensable in situ data contributions from the EU Member States, International and European networks and other data provides that make it possible for the Copernicus services to deliver high quality products to end users.

ENEON: The European Network of Earth Observation Networks (ENEON) is a network of networks aiming to provide an integrated and harmonized perspective on EOs, forecasting and projecting, helping to reduce redundancies and detect gaps in the European EO arena. ENEON is funded by the EC through the H2020 ConnectinGEO project. Main goals are to better coordinate mainly non-space networks, to provide integrated observations and products for resolving interdisciplinary problems, to be a common voice for the observation networks, to facilitate a link between the networks and policy and decision makers, and to improve the sustainability of network. ENEON engages in gap analysis and the prioritization of gaps focusing on in situ data in Europe. ENEON will improve the European in situ participation in GEO and focus the networks on support for the implementation and monitoring of the UN Sustainable Development Goals (SDGs). As an initial activity, dynamic in situ Earth Observation network topography is being compiled and made available both as a JSON file and as a graphical interface available at http://www.eneon.net/graph. Figure 1 shows the networks and their interrelations based on the information currently in the ENEON network topography database.

ENVRI: In Europe, environmental research infrastructures provide key tools and instruments for the researchers to address specific challenges within their own scientific fields. However, to tackle the grand challenges facing human society (for example climate change, extreme events, loss of biodiversity, etc.), scientific collaboration across the traditional fields will be more and more necessary. The Earth system is highly interlinked and the area of focus for environmental research is therefore our whole planet. Initiatives such as the Environmental Research Infrastructure (ENVRI) EU project bring together Environmental and Earth System Research Infrastructures, projects and networks together with technical specialist partners to create a more coherent, interdisciplinary and interoperable cluster of Environmental Research Infrastructures across Europe. ENVRI was first created in 2011 to avoid the fragmentation and duplication of efforts, making the Research Infrastructures' products and solutions easier to use with each other, improving their innovation potential and cost/benefit ratio of the Research Infrastructure operations. ENVRIplus is another EU project that continues the efforts in this direction.

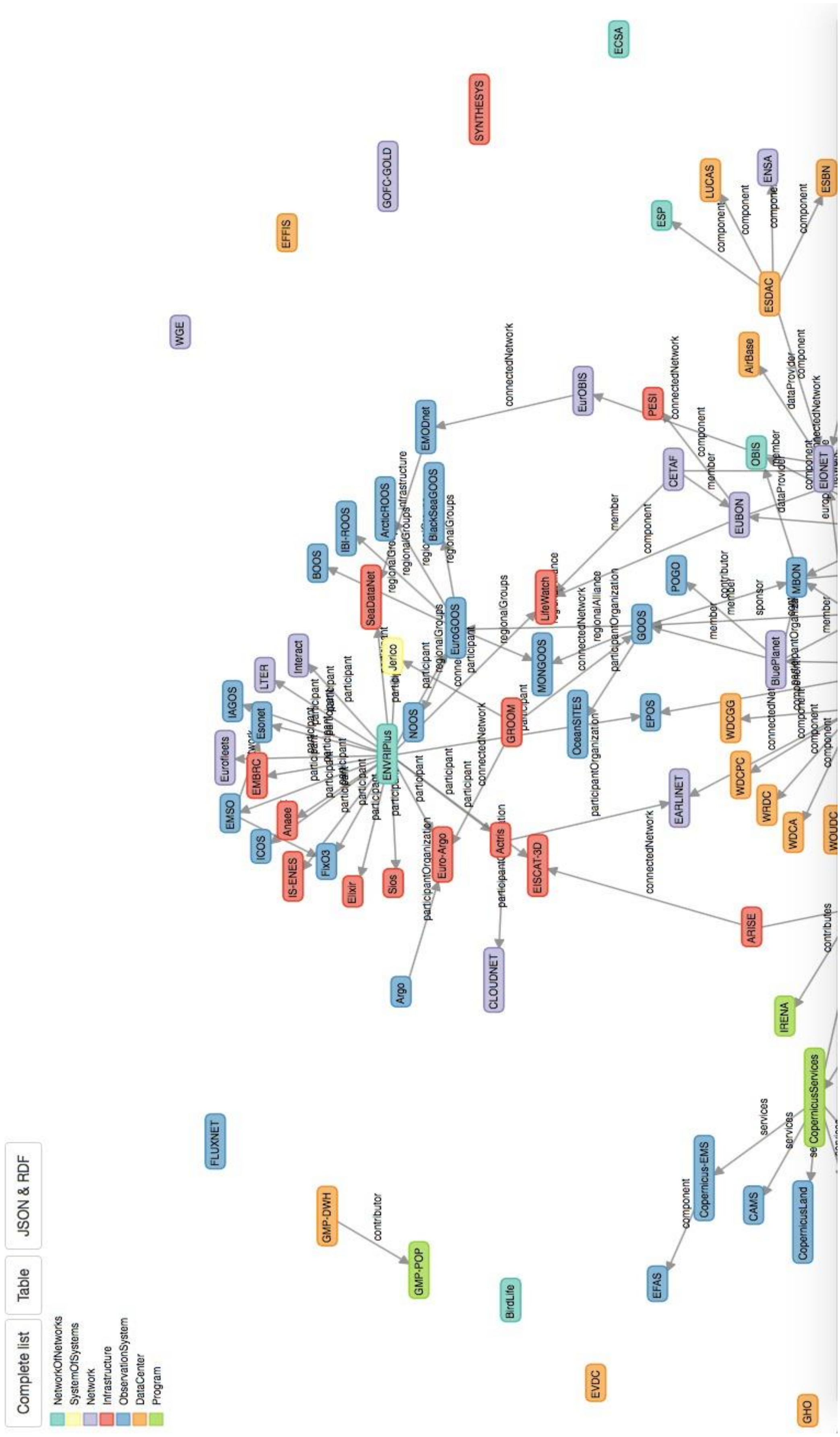

Figure 1: Topography of European Earth observation networks. The topography is continuously revised and updated. For lower part of the diagram, see next page. See text for details.

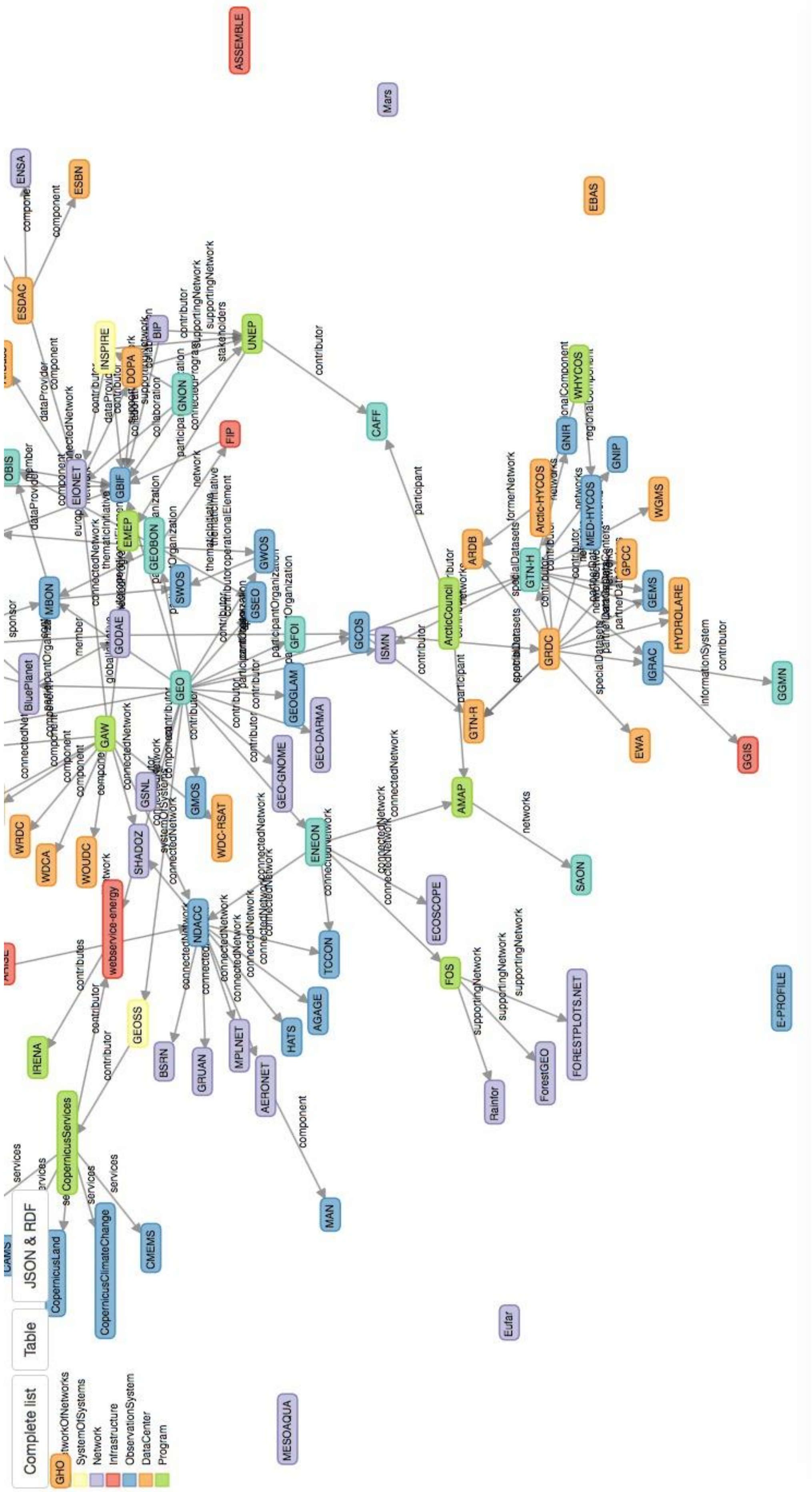

Figure 1 continued.

2.2 Asia

In this section, initially only two domains have been selected as examples. There are many more areas that will be covered in a future version of the document.

2.2.1 Asia-Pacific Biodiversity Observation Network (AP-BON)

Responding to the call of GEO BON, AP-BON (Asia-Pacific Biodiversity Observation Network) was organized in 2009, one year earlier than CBD COP 10 in 2010. The history of AP-BON until 2012 is summarized by Yahara et al. (2014). The first AP-BON workshop was held from 21–22 July 2009 in Nagoya, and the second workshop was held from 10-11 December 2009 in Tokyo.

Through discussion in those workshops, participants agreed on the following AP-BON visions, which are slightly modified from GEO BON visions:

- To establish a coordinated Asia-Pacific network that gathers and shares information on biodiversity and ecosystem services,
- To provide tools for data collection, sharing/exchange, analysis, and synthesis/integration, and
- To contribute to improving ecosystem management, sustainable use of biodiversity, and human well-being.

Participants also agreed on the following AP-BON missions:

- Observing and analyzing changes in biodiversity over time.
- Improving delivery of biodiversity information and services to users, particularly decision makers.
- Facilitating linkages among many countries, organizations, and individuals contributing to biodiversity observations.
- Identifying gaps between existing biodiversity observation systems and promoting mechanisms/projects to fill them.

Since 2009, AP BON made good progress in achieving those missions including contributions to the success of CBD COP10 in Nagoya in 2010. As for the first mission, significant progress has been made from 2011 to 2015 through a project "Integrative observations and assessments of Asian biodiversity" sponsored by the Environment Research and Technology Development Fund of the Ministry of Environment Japan. An example of the progress is a series of plot-based surveys on vascular plant richness in Vietnam, Cambodia, Thailand, Myanmar, Malaysia and Indonesia where a total of 115 plots with the same size of 100 m x 5 m have been placed in collaborations with botanists in those countries. In each plot, all the vascular plants including trees, shrubs, herbs, climbers and epiphytes have been recorded, photographed, and collected. The specimens obtained from those surveys have amounted to 24,259 and the number of operational "species" recorded is approximately 19,000. For all specimens, silica-gel dried samples for DNA isolation have been collected. Taxonomic studies of those specimens, using both morphological observations and DNA barcodings, are now in progress and studies until today have resulted in publications of more than 50 new species. In Cambodia, where 22% of forest coverage was lost between 1990 and 2010, permanent plots with historical records were re-surveyed and significant species richness loss was documented (Toyama et al. 2015).

Another example of observing biodiversity is a series of fish survey in Mekong Basin. Kano et al. (2013) developed fish distribution data database that integrated information on freshwater fish specimens collected between 2007 and 2014 from 1571 sites in Cambodia, Laos, Thailand, and Vietnam. Using this database, Kano et al. (2016) assessed risks of hydropower dams and global warming on freshwater fish diversity loss. Projections from scenarios assuming the synergistic effects of dams and global warming showed 10-20% higher impact on fish diversity than the scenarios assuming additive effects.

As for the second mission, three volumes of books were published on states and trends of biodiversity in the Asia Pacific region (Nakano et al. 2012, 2014, 2016). Volume 1 includes overviews of biodiversity observations in the Asia-Pacific region, introductions to some useful databases, reviews of new tools and methods, and summaries of states and trends in biodiversity and ecosystem services in the Asia-Pacific region. Volume 2 includes documentations on achievements and challenges of AP BON since Volume 1, introductions to advanced methods of integrated biodiversity observations and reviews of socio-economic aspects of biodiversity. Volume 3 focuses on states and trends of freshwater biodiversity in the Asia-Pacific region.

As for the third mission, an active network of biodiversity observation in the Asia-Pacific region was developed through seven workshops and additional related meetings. Participants of those meetings are from Japan, Mongolia, Korea, China, Taiwan, Vietnam, Laos, Cambodia, Thailand, Myanmar, India, Nepal, Malaysia, Singapore, Brunei, Indonesia, Philippines, Fiji, Palau, Samoa, Papua New Guinea and Australia (as an observer).

The seventh workshop was held from 19-20 February 2016. In this most recent workshop, participants discussed about the following questions;

- Why, what, where do we observe?
- What is APBON's niche?
- How do we promote the organization of BONs in the AP Region?
- How do we strengthen the link of APBON to GEOBON?
- How do we align the biodiversity initiatives that are in the region?

Also, the participants discussed about future plans of AP BON including the publication of AP BON Book Volume 4, training courses of taxonomy and data sharing, summary of national red lists etc. We will continue our efforts to achieve those plants by which we can strengthen our activity of biodiversity observations in the Asia-Pacific region, including data collection, sharing, analysis, and synthesis, and contribution to sustainable use of biodiversity.

2.2.2 AsiaFlux

AsiaFlux is one of regional research networks under FLUXNET (http://fluxnet.ornl.gov/, Figure 2) bringing together scientists from universities and institutions in Asia to study the exchanges of carbon dioxide, water vapor, and energy between terrestrial ecosystems and the atmosphere across daily to inter-annual time scales. Its mission is to bring Asia's key ecosystems under observation to develop and transfer scientific knowledge to ensure quality and sustainability of life in Asia. The purpose of the network is to develop collaborative studies and datasets on the cycles of carbon, water and energy in key ecosystems in Asia, to organize workshops and training on current and related global change themes, and to cultivate the next generation scientists to become informed leaders and stewards with skills and perspectives to address global climate change in Asia.

AsiaFlux was established in 1999, and up to now it has held 11 international scientific conferences and workshops in Japan, Korea, China, Thailand, Taiwan, Malaysia, the Philippines, and India. One of the highlighted activities within AsiaFlux is the capacity building program based on short training courses, training workshops, and joint field practices. The program started in 2006 with financial supports from two projects, namely "Standardization and Systematization of Carbon-Budget Observation in Asian Terrestrial Ecosystems Based on the AsiaFlux Framework" by the Asia-Pacific Network for Global Change Research (APN), and "Initiation of the next-generation AsiaFlux" by the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT). The main objectives of the program were originally to initiate eddy covariance measurements for energy, water vapor, and CO_2 flux sites and to grow research communities for the sites in each country and region.

Capacity building programs have been planned and conducted depending on each target and need from different countries and regions. The targeted groups have been, among others, beginners in the field, i.e., persons with observation experience of 2-3 years, and young scientists who seek to conduct excellent science and write better papers. The training courses for beginners have been effectively supported by sensor production companies attending the annual meetings of AsiaFlux. The training workshops for students and researchers with limited observation experience have been usually conducted with relatively small numbers of participants (< 15-20 persons) focusing on their own needs, e.g. long-term measurements and data analysis. Such small-scale training courses have been independently held in countries such as Malaysia, Vietnam, and Bangladesh, to raise the scientific level of targeted regions.

Another essential part of AsiaFlux is data sharing based on the AsiaFlux database, which was officially established in 2007, starting from sharing datasets provided by about ten flux sites in Asia. The number of data shared in AsiaFlux database has steadily increased since then. Contributions from domestic and international science projects for various kinds of synthesis studies are indispensable. The participants have shared their quality-controlled datasets to the AsiaFlux database after the synthesis had been completed. In particular, CarboEastAsia (2007-2012), the international joint project among ChinaFlux, KoFlux, and

JapanFlux (national networks for China, Korea and Japan) has compiled datasets throughout Asia, and the number of sites has reached approx. 30 including forests, grassland, and agricultural fields. The project has also produced gap-filled datasets, and almost all the data have been shared in the AsiaFlux database. So far, a total of 104 sites across Asia have been registered in AsiaFlux, and the number of sites whose datasets have already been shared in AsaiFlux database is 36 (as of July 2016).

- Continue expanding observation sites and communities in serious 'blank area' in Asia such as in south and southeastern Asia, central Asia, Siberia, and etc.
- Improve new observation techniques and skills, and other trace gas emissions, and their QC/QA, and standardization
- Improve scientific level of Asian-scale international synthesis studies and contribute to global communities more directly.

For more details, see http://asiaflux.net/.

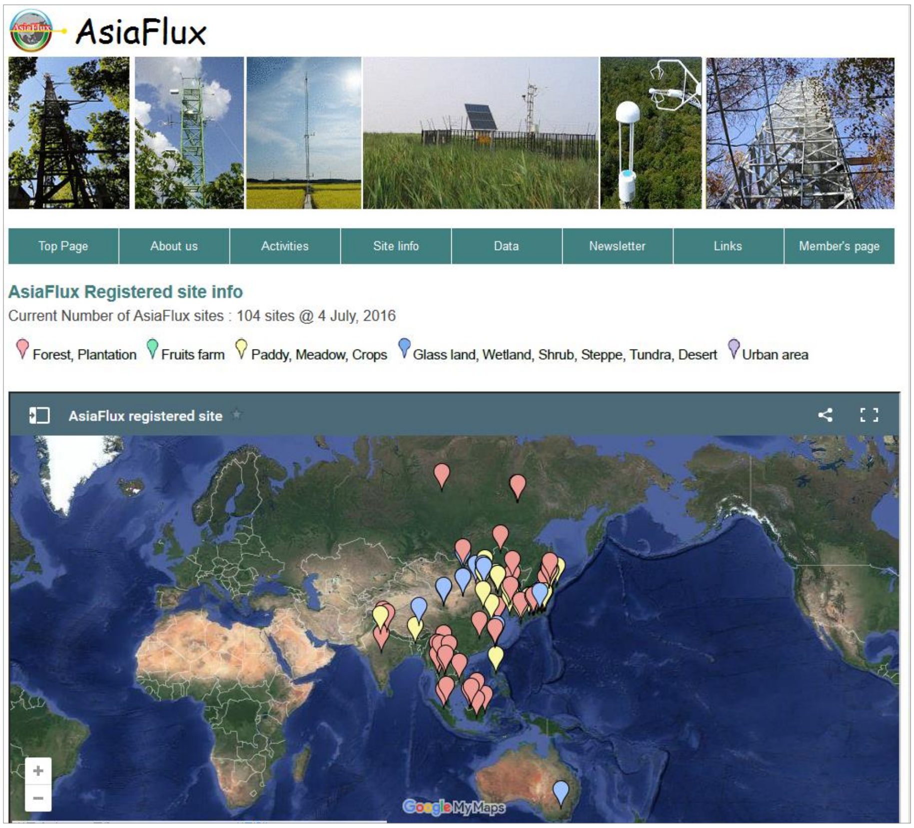

Figure 2: AsiaFlux registered site information (http://asiaflux.net/).

3. ACTIVITIES IN DOMAINS AND SOCIETAL BENEFIT AREAS

In this Section, activities related to in situ observations and their regional to global coordination for selected areas such as Geodesy (Section 3.1) and Climate and Atmospheric composition (Section 3.2) are described as good practices. It is planned to add other areas, such as oceans, meteorology, and land applications. Sections 3.3 to 3.5 describe emerging in situ implementation challenges, which should meet requirements of GEO.

3.1 Geodesy

3.1.1 The Dynamic Earth

The Earth is a dynamic system—it has a fluid, mobile atmosphere and oceans, a continually changing global distribution of ice, snow, and water, a fluid core that is undergoing some type of hydromagnetic motion, a mantle both thermally convecting and rebounding from the glacial loading of the last ice age, and mobile tectonic plates. In addition, external forces due to the gravitational attraction of the Sun, Moon, and planets also act upon the Earth. These internal dynamical processes and external gravitational forces exert torques on the solid Earth, or displace its mass, thereby causing the Earth's shape, gravity, and rotation to change. These dynamical processes also cause natural hazards like earthquakes, tsunamis, volcanic eruptions, tectonic deformations, landslides, deglaciation, sea level change, floods, desertification, storms and storm surges, global warming and many others.

The world's growing population needs to cope with the consequences of the dynamic Earth system. Towns and cities are spreading into areas of high risk from natural hazards. Major infrastructure is being built in potentially hazardous areas, thereby increasing the vulnerability of society to natural hazards. This infrastructure is increasingly being lost in natural disasters, affecting economies on national and global levels, with severe societal impacts. In addition, the growing demand for access to food, water, energy, and materials is stressing the finite resources of planet Earth. Clearly, dynamic Earth system processes have a major impact on society, both now and in the future. In order to minimize the impact of these processes and to preserve natural resources for future generations, a better understanding of the processes is needed. This better understanding can only be achieved through observations. Only through observations will the predictive capabilities of models be improved, allowing impacts to be assessed and informed decisions to be made.

EOs are needed not only for scientific research but also for societal applications such as disaster prevention and mitigation, managing resources like energy, water, and food, mitigating the effects of climate change, and protecting the biosphere, the environment, and human health. Geodetic observations provide the metrological foundation for EOs and provide the means to determine mass transport in the Earth system. Geodetic observations are therefore a cornerstone of the Earth observing systems needed for scientific research and societal applications.

3.1.2 Geodetic Observations

Geodesy is the science of the Earth's shape, size, gravity and rotation, including their evolution in time. A number of different measurement techniques are used to observe the geodetic properties of the Earth including the space-geodetic techniques of Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR), Global Navigation Satellite Systems (GNSSs) like the US Global Positioning System (GPS), and the French Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) system. These space-geodetic observations also provide the basis for the realization of the reference systems that are needed in order to assign coordinates to points and objects and thereby determine how those points and objects move in space and time. For this purpose, the global network of tracking stations is crucial (Figure 3).

The International Association of Geodesy (IAG), a founding association of the International Union of Geodesy and Geophysics (IUGG), is the international scientific organization devoted to the advancement of geodesy. Its origin dates to 1862 when the Prussian General Johann Jacob Baeyer formed the Central European Arc Measurement project with the ultimate goal of precisely determining the size and shape of the Earth. Today, more that 150 years later, the IAG continues to pursue this goal by collecting, analyzing, modeling and interpreting observational data, by advancing geodetic theory through research and teaching, by stimulating technological development, and by providing a consistent representation of the shape, rotation, and gravity field of the Earth and planets including their temporal variations.

With the objective of determining global properties of the Earth like its shape and size, geodesists have always cooperated with each other, both nationally and internationally. To determine global Earth properties, observing stations must be globally distributed, by necessity requiring them to be located in different countries. The organizations operating the stations in the different countries must then cooperate with each other in order achieve the geodesists' objective. This cooperation is accomplished under the auspices of the IAG.

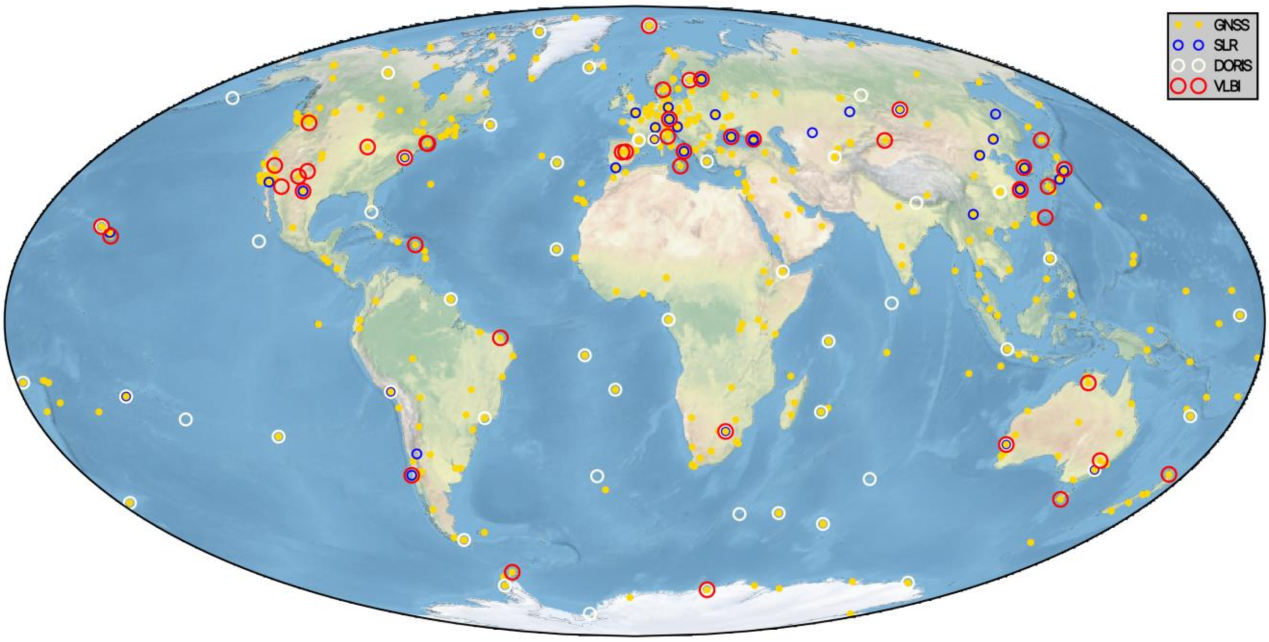

Figure 3. The GGOS network. Locations of the currently operating GNSS (solid yellow circles), SLR (hollow blue circles), DORIS (hollow white circles), and VLBI (hollow red circles) stations in the GGOS network.

The IAG accomplishes its mission to advance geodesy through the activities of its operating components, including its Commissions, Services, and the Global Geodetic Observing System (GGOS). The Commissions represent the major fields of activity in geodesy and represent the IAG in all relevant scientific matters, promoting the advancement of science, technology, and international cooperation in these fields. The four IAG Commissions are: (1) Reference Frames, (2) Gravity Field, (3) Earth Rotation and Geodynamics, and (4) Positioning and Applications.

The IAG Services organize the collection and reduction of geodetic observations and generate the geodetic products needed for scientific research and societal applications. There are currently 14 Services spanning the relevant geometric, gravimetric, oceanographic, and related properties of the Earth. Included amongst these Services are the geometric Services of the International GNSS Service (IGS), the International DORIS Service (IDS), the International Laser Ranging Service (ILRS), the International VLBI Service for Geodesy and Astrometry (IVS), and the International Earth Rotation and Reference Systems Service (IERS). Figure 3 shows the locations of the currently operating stations in the IVS, ILRS, IGS, and IDS networks.

Recognizing the increasingly important role that geodesy plays in scientific research and societal applications, the IAG established the Global Geodetic Observing System (GGOS) in 2003, first as a Project and then, in 2007, as a full component of the IAG. GGOS is meant to be the observing system of the IAG, organizing its technique-specific Services under one unifying umbrella, thereby forming a comprehensive geodetic observing instrument integrating the hitherto separate pillars of geodesy (shape, rotation, and gravity) into one consistent observing system. GGOS works with the other IAG components to provide unique, mutually consistent, and easily accessible geodetic constants, data and products for science and society. In addition, GGOS represents the IAG in the GEO and is IAG's contribution to GEOSS that is being constructed by GEO.

GGOS provides the basis on which future advances in the geosciences can be built. By considering the Earth system as a whole (including the geosphere, hydrosphere, cryosphere, atmosphere and biosphere), monitoring Earth system components and their interactions by geodetic techniques and studying them from the geodetic point of view, the geodetic community provides the global geosciences community with a powerful tool consisting mainly of high-quality services, standards and references, and theoretical and observational innovations.

Observations of the Earth’s shape, rotation, and gravity provided by the IAG’s GGOS and its Services show that they change on a wide range of timescales reflecting the wide range of processes affecting them, from external tidal forces to surficial processes involving the atmosphere, oceans, and hydrosphere to internal processes acting both at the core-mantle boundary as well as within the solid Earth itself. Measurements of the Earth's shape, rotation, and gravity can therefore be used to gain greater understanding of mass transport within the entire Earth system, from tracking water in its various phases as it cycles through the atmosphere, oceans, and land, to crustal deformation associated with tectonic motions and glacial isostatic adjustment, to torsional oscillations of the core.

3.1.3 Terrestrial Reference Frame

Geodetic observations of the Earth’s variable shape, rotation, and gravity also provide the basis for realizing the reference systems that are required in order to assign coordinates to points and objects in space and time and to describe the motion of the Earth in space. Two such reference frames are realized by geodetic observations: the terrestrial reference frame and the celestial reference frame. Since the terrestrial reference frame is attached to the Earth and the celestial reference frame is fixed in space, these two reference frames are linked to each other by the Earth’s rotation in space.

The most accurate global celestial and terrestrial reference frames available today are the International Celestial Reference Frame (ICRF) and the International Terrestrial Reference Frame (ITRF) that are produced under the auspices of the IERS. The ICRF is represented by a set of estimated positions of extragalactic reference radio sources; the ITRF is represented by a set of estimated positions and velocities of globally distributed reference marks on the solid Earth’s surface associated with the VLBI, SLR, DORIS, and GNSS observing stations.

The TRF determined by geodetic measurements is the indispensable foundation for all the sustainable EOs that are used by science and society for so many purposes, including navigation, mapping, surveying, construction, land development, natural resource management and conservation—in fact, all decision-making activities that have a geo-related component. It allows different spatial information, such as imagery from different space and airborne platforms, to be geo-referenced and aligned with each other. And it plays a key role in modeling and estimating the motion of the Earth in space, in measuring change and deformation of all components of the Earth system, and in providing the ability to connect measurements made at the same place at different times, a critical requirement for understanding global, regional and local change. Providing an accurate, stable, homogeneous, and maintainable terrestrial reference frame to support numerous scientific research and societal applications is one of the essential goals of the IAG’s GGOS.

The advent of space-geodetic techniques enabled a rapid increase in the accuracy of at least five orders of magnitude of the reference frames mentioned above over the last four decades, and this has contributed to the economic and social development of a modern global society. Many applications of considerable economic value are enabled by precise positioning in a stable reference frame ranging from determining real-estate boundaries efficiently and with high accuracy (particularly in high-value urban areas), mapping subsurface infrastructure, operating heavy equipment (including mining equipment), navigating human-controlled and autonomous vehicles, improving resource efficiency of agriculture, increasing safety of air traffic, to the docking of large ships in harbours, to name a few. Likewise, many scientific studies depend on observations that require high-accuracy positioning, including, for example, studies of natural and human-made hazards and disaster risk reduction, understanding global and climate change, monitoring sea level rise and groundwater level changes. EO from space and in situ observations depend crucially on the access to long-term stable, accurate reference frames. The importance of the reference frames has been acknowledged in a number of national and international resolutions, most recently in the United Nations General Assembly resolution on Global Geodetic Reference Frames (69/266).

Geodesy uses a range of space-geodetic and traditional techniques with specific strengths and weaknesses to maintain the reference frames. Co-location of in situ components provides the means to interconnect the techniques and to reduce the individual weaknesses and exploit the strengths. Of particular interest are geodetic core stations, which are fundamental for the accuracy and long-term stability of the global celestial and terrestrial reference frames and the Earth orientation parameters (including time keeping) that link these two frames together. The core stations are those where several techniques are co-located allowing the combination of the available techniques for the best possible products. A global tracking network of several hundred stations with one or more of the geodetic techniques is used to realize the global reference frames. The number and spatial distribution of the core stations has a major impact on the overall accuracy and stability of the reference frames and the performance of many societal applications and scientific studies.

Besides the need for co-location to interconnect the techniques, a unique aspect of the geodetic in situ networks is that several techniques depend on coordinated observations of instruments distributed globally and joint analyses of data from the global networks. This need has made global coordination and data sharing an inherent characteristics of geodetic in situ observations. Joint observations, data management, analysis, and product delivery are coordinated by the global geodetic community active in the services of the IAG.

3.2 Climate and Atmospheric composition

The Global Atmosphere Watch (GAW) Programme was created by WMO in 1989 in response to the growing concerns related to human impacts on atmospheric composition and the connection of atmospheric composition to weather and climate. GAW's mission is focused on the systematic global observations of the chemical composition and related physical characteristics of the atmosphere, integrated analysis of these observations and development of predictive capacity to forecast future atmospheric composition changes. These observations and analyses are needed to advance the scientific understanding of the effects of the increasing influence of human activity on the global atmosphere as illustrated by such pressing societal problems as: changes in the weather and climate related to human influence on atmospheric composition, particularly, on greenhouse gases, ozone and aerosols; impacts of air pollution on human and ecosystem health and issues involving long-range transport and deposition of air pollution; and changes in UV radiation as consequences of changes in ozone atmospheric content and climate, and subsequent impact of these changes on human health and ecosystems. The new GAW implementation plan was published in 2016.

The mission of GAW is to reduce environmental risks to society and meet the requirements of environmental conventions, to strengthen capabilities to predict climate, weather and air quality, and to contribute to scientific assessments in support of environmental policy. For this purpose, GAW supports global, long-term observations of the chemical composition and selected physical characteristics of the atmosphere at different sites around the World, emphasizing quality assurance and quality control, and delivering integrated products and services of relevance to users, in particular for the study of climate change and its impacts.

In providing a comprehensive set of high quality and long-term observations of atmospheric composition GAW supports the United Nations Framework Convention on Climate Change (UNFCCC), especially by contributing to the implementation plan for the Global Climate Observing System (GCOS), the Intergovernmental Panel on Climate Change (IPCC) and to the development of Global Framework for Climate Services (GFCS).

The program is operated through the support of different stakeholders organized either at WMO member state level or, at regional level, as in the case of Europe with the research infrastructure consortia (ICOS, ACTRIS). The importance of atmospheric composition in the above matters was emphasized in resolutions from the Seventeenth World Meteorological Congress, which stressed the need to enhance the capacity of NMHSs to deliver on their mission by developing and improving competent human resources, technical and institutional capacities and infrastructure; particularly in countries where the capability to maintain high standards of observations, data and metadata is problematic. It also included Resolution 60 of the 17th Congress, which urges members to strengthen their support to the framework of the GCOS Essential Climate Variables (ECVs) in the collection and supply of data and products to support the GFCS on a free and unrestricted basis. Among others, GCOS ECVs include data on the composition of the atmosphere including aerosols and their precursors, greenhouse gas and atmospheric ozone data together with climate relevant cryosphere data, including glacial monitoring.

3.3 Food security

The growing global population - coupled with changing patterns of consumption - is increasing the demand for food. Food security relies on various elements related to the availability of safe foods, such as water abundance, vegetation stresses, yield variance and soil quality. Today, with increasingly limited land available for agricultural activities due to it depends mainly on soil fertility and its relationship with the other ecosystems, more intensive food production is resulting in a heightened environment impact. To that end, severe threats linked to agricultural production, as soil degradation and desertification, together with deterioration of water quality and water balance, are widely reported.

Eliminating such effects and guaranteeing food security requires a sustainable intensification of agricultural production that is beneficial in order to minimize yield gap, by identifying the potential scope for raising average yields via optimization of spatially explicit irrigation, fertilization and application of pesticides. Aligned with this rationale is the long-term monitoring of cultivations, soils and food security essential parameters (e.g. soil degradation/acidification/moisture as well as their protection against the water extremes regimes (floods & drought). The collection of high-resolution information about key soil properties, the amount of plant available water, nutrients and others which largely affect crop growth remains a challenging task in order to facilitate reduced input agriculture applications.

The improved provision of EO services and improved access to that data, should be at the core of GEO activities. The systematic integration of EO data with high resolution (e.g. spatiotemporal and spectral) relying also on adequate modelling will greatly impact the level of acquired information, enable the evaluation of new service chains and methods and extraction of actionable agricultural knowledge for assessing sustainable agricultural development and food security. As a concrete, sustainable action towards improved access to space borne but also to in situ derived EO data, higher level products, and descriptive metadata, as well as knowledge on existing service chains and processing tools, could act as a catalyst for end-users to preserve soil and water resources from further degradation and adapt the appropriate agro-technical activities accordingly to microclimatic conditions, securing the abundance of healthy crops and yield production yearly. All these will facilitate further the perspective of variable rate application, according to which, agricultural inputs are applied in controlled amounts to the specific parts of the field that requires them.

3.4 Climate Change

Climate change is now affecting every country on every continent. People are experiencing the significant impacts of climate change, which include changing weather patterns, rising sea level, and more extreme weather events. The poorest and most vulnerable people are being affected the most. It is disrupting national economies and affecting lives, costing people, communities and countries dearly today and even more tomorrow. Climate Change is one of the sustainable development goals of UNEA and the recent COP21 Paris climate conference adopted the first-ever universal, legally binding global climate deal to set out a global action plan to put the world on track to avoid dangerous climate change by limiting global warming to well below 2°C. The agreement is due to enter into force in 2020.

The greenhouse gas emissions from human activities are driving climate change and continue to rise, reaching every year unprecedented levels. Affordable technology-based or not solutions are now available to enable countries/regions/cities to engage in more resilient economies: renewable energy and other measures can substantially reduce emissions and better predicting capacity can lead to efficient adaptation strategies.

Emissions of pollutants driving atmospheric composition are affecting climate Worldwide and people everywhere. Solutions to reduce emissions therefore require an international level of coordination by widest possible number of countries. Some cooperation is already undertaken within the International Panel for Climate Change and various international treaties. Recently, COP21 agreement in Paris in December 2015 called for “strengthening scientific knowledge on climate, including research, systematic observation of the climate system and early warning systems, in a manner that informs climate services and supports decision-making”.

A suitable observing system allows for informed decisions in a wide range of policy areas, including climate change and air quality, but also for health, international protocols and research requirements. Such an observation strategy therefore responds to political, societal and economic challenges and to the development of scientific knowledge. The challenges in promoting an observation strategy for the future are therefore tremendous and range from technical issues like the instrumentation to be applied, how to treat data etc. to more political matters like funding and sustainability.

3.5 Sustainable Development Goals

In 2015, the United Nations agreed on the Agenda 2030, which aims to reach seventeen SDGs addressing almost all societal, economic and environmental issues impacting the sustainability of the modern global society. Each of the goals comes with a set of up to ten specific targets. In order to monitor progress, a monitoring framework consisting of currently 240 indicators has been developed by the Interagency and Expert Group on SDG monitoring (IAEG-SDGs) and accepted by the United Nations Statistical Commission in 2016 as a starting point for the monitoring. The governments of the world are now challenged with the development of policies and the implementation of actions that would lead to progress towards these ambitious goals and their associated targets.

Science and technology support is needed to inform policy development and to monitor progress (Figure 4). Geospatial data including observations of the natural and build environment and data on the socio-economic system will be crucial for both the monitoring of progress towards the targets and the planning of actions to make progress. The formal monitoring of progress towards the targets is based on the monitoring framework defined by the IAEG-SDGs. The monitoring framework has up to two indicators for each of the targets. A first review of the indicator framework by the GEO Initiative 18 (GI-18) showed that many of the currently 240 indicators traditional EOs are required for quantification (Figure 5), and GI-18 is developing methods for the quantification of those indicators that depend on EOs for quantification (A in Figure 4). The Horizon 2020 Project "ConnectinGEO" developed a goal-based approach to the identification of EVs (Plag et al., 2016a) and applied this approach to the SDG indicators (A in Figure 4). This research revealed that a minor fraction of the SDG Indicators requires traditional EOs of the natural environment for quantification, while many of the EVs of the SDG monitoring framework are related to the built environment (Figure 6). A considerable challenge is in the collection of more information on the build environment. This brings up the question to what extent some of these EVs could be extracted from available EOs or gathered by using Big Data analysis, in situ observations, citizen scientists, the Internet of Things and other forms of crowd-sourcing. The Internet of Things, crowd-sourcing, and citizen scientists are promising developments to get the necessary observations. Creating collaborations that lead to the integration of the new data, including data from human sensors, into an integrated database available for analysis and models appears to be a necessity, but developing the concepts and infrastructure remains a challenge.

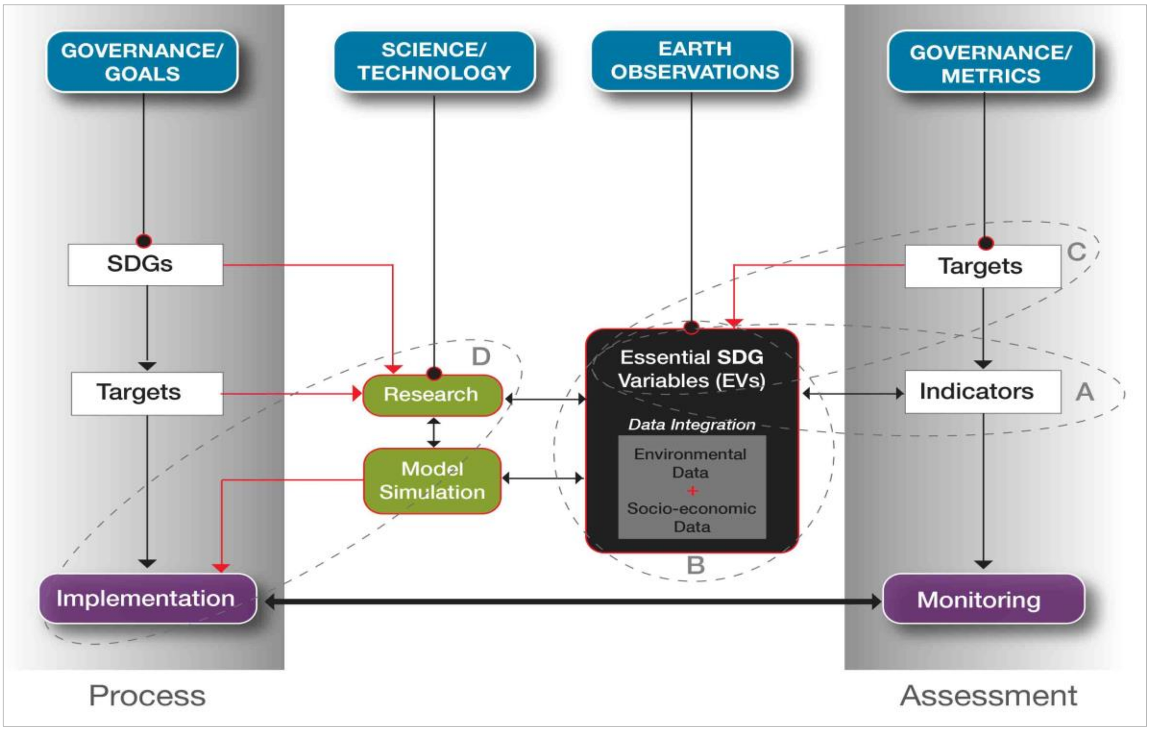

Figure 4: Earth observations and SDGs. Relevance of Earth observations and science and technology support for the implementation and monitoring of progress towards the SDGs and associated targets. See text for details. From Jules-Plag and Plag (2016a).

For many of the indicators, the integration of socio-economic statistical data with environmental data, including in situ observations, is of importance (B in Figure 3). GEO has the convening power to bring the communities together, but to actually achieve the integration, infrastructure is required that provides tangible incentives for working in a cross-domain environment. It is anticipated that GEO could use its convening power to facilitate this integration and develop GEOSS toward the platform for this integration.

Figure 5: Dependence of SDG indicators on Earth observations. From GEO (2016).

In the ConnectinGEO project, the goal-based approach was also applied to the SDG Target (C in Figure 4), and this analysis revealed that many of the Targets would benefit from indicators that are directly related to the environment. An example is SDG-3 “Ensure healthy lives and promote well-being for all at all ages” and the associated Target 3.9: “By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.” The Indicators included for this target in the current monitoring framework are 3.9.1 “Mortality rate attributed to household and ambient air pollution” and 3.9.2 “Mortality rate attributed to unsafe water, unsafe sanitation and lack of hygiene (exposure to unsafe WASH services).” These indicators are focusing on the impacts and outcomes in terms of mortality. However, mortality is not a good indicator for progress towards the target because there is an accumulative effect of air quality that generates a huge time delay between changes in air quality and mortality rates. For example, a decrease in mortality can happen even if pollution is increasing in the short term. The existing SDG indicators for Target 3.9 do not account for the time-lagged relation between pollution and mortality. Adding indicators for the state of the system (e.g., long-term changes in air quality) would reduce the time lag between actions taken to make progress towards the targets and a change in the indicators. A similar situation is found for many other Targets. Many of the more environmentally focused indicators would require in situ data for quantification. A revision of the monitoring framework could take this finding into account and account for the linkage of the socio-economic and environmental aspect reflected in the SDGs.

Besides supporting the monitoring, there is an urgent need to support the planning of actions and the development of policies that would facilitate progress towards the SDG Targets (D in Figure 4). For many of the SDGs, research is needed to better understand the causes of the current problems and to develop options that could lead to more sustainability. Both space-based and in situ EOs are important for most of this research. Tools to assess the impact of actions and policies are lacking for most of the SDGs and models capable of answering "What if" questions need to be developed. In order to capture the complexity, these models need to embrace a hybrid approach and require data assimilation. To capture the complexity, agent-based models will be crucial. The development and validation of these models depend on a number of factors. The former depends on how well the real world has been modeled and applied to the agent-based model. It has to be ensured that the best available modeling parameters and framework is applied by coupling the agent-based model with existing environmental models. In applications associated with the built environment it would be prudent to couple a Geo-Design model with the agent-based model. Data and knowledge integration can be achieved using the already developed concepts of Geo-Design. A Geo-Design hub can be a starting point for the integration of built and natural environment with socio-economic data and support policy development. To promote such interdisciplinary and cross-domain tools, relevant stakeholders need to see benefits that they cannot achieve on their own.

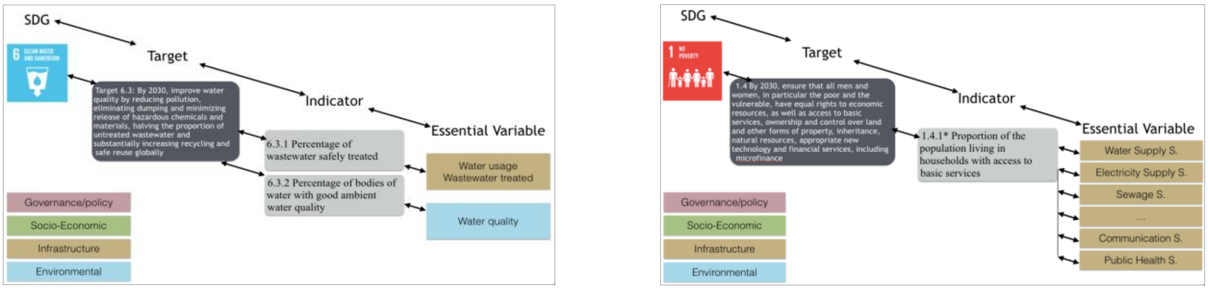

Figure 6: Using the goal-based approach of ConnectinGEO to identify EVs for SDG indicators. For several indicators, traditional EOs are required for quantification (e.g., Indicator 6.3.2; left example), while most indicators require statistical data or observations related to the built environment (e.g., Indicators 6.3.1, left, and Indicator 1.4.1, right). Modified from Jules-Plag and Plag (2016b).

The GI-18 is strongly focusing on the development of training and capacity building programs directly related to the use of EOs for the monitoring of the SDGs. The implementation plan of GI-18 includes a number of tangible goals to be achieved by 2020. We are considering including also the development of toolboxes supporting the implementation of SDGs. The global nature of GEO allows for actions that lead to capacity building on a global scale. The role of in situ observations for the quantification of SDG indicators should be emphasized in the capacity building activities.

An important aspect of the SDGs that is often overlooked is the interdependency of the SDGs. Many of the individual SDGs depend on actions focusing on other SDGs, and capacity building needs to take this into account. For example, restoring ecosystems under several Targets of SDG 15 may be in conflict with SDG1 and SDG2. The example of Mangroves shows that they are connected to several SDGs (Figure 7). As a consequence, cross-goal coordination of data collection and integration, including the in situ observations, would have significant benefits for a cross-goal consistent quantification of the indicators.

Figure 7: Cross SDG links. Many of the SDGs are linked to other SDGs and actions to improve progress towards one target may have negative or positive impacts on others. The example of mangroves shows that restoring ecosystems could negatively impact food security or increase inequality or help to reach targets under SDG 14. Modified from Jules-Plag and Plag (2016b).

4 ISSUES REQUIRING GLOBAL COORDINATION

In this section, issues identified so far are summarized for a very limited set of selected areas. It is planned to review more areas in the coming years. The issues addressed include sustainability of existing observation infrastructure, investments for new infrastructure, and emerging technologies and new approaches.

For in situ observation, many observational networks are initially established for research purposes with a limited lifetime. Facilitating the transition from research to sustained long-term operation is an issue recognized by GEO from early on but no process has been developed to identify suitable candidate infrastructures and to facilitate the transition. Another issue requiring more attention is the coordination of the integration of space-based and in situ observations. The analysis of requirements resulting from SDG monitoring also revealed the need for integration of environmental and socio-economic (statistical) data – a need recognized by GEO from the start, however, without sufficient progress being achieved for this integration. These issues will be addressed by GD-06 in the coming years.

4.1 Sustainability of Existing Measurements for Climate

According to IPCC's latest assessment report, the human influence on the climate system is clear and continued emissions at the current rate will cause changes to all components of the climate system. The universally accepted Sustainable Development Goal 13, calls for urgent actions to combat climate change and its impact; the thrust area 13.3 talks about improved education, awareness and human and institutional capacity for mitigation, adaptation, impact reduction and early warning. A sound base of knowledge and information, derived from high quality climate data is key to tackle the challenges associated with climate change. Systematic long term monitoring of the climate system is not only a fundamental prerequisite to understand both the change and resulting consequences, but is also a prerequisite for making decisions at all levels. The World Climate Conference in 2009 decided to establish the Global Framework on Climate Services (GFCS) as a UN initiative, spearheaded by WMO. The five components (pillars) of GFCS are user-interface platforms, climate service information systems, observation and monitoring, research, modelling and prediction and capacity development. It is clear that the demand from governments, institutions and citizens for more useful and reliable information, products and services is increasing, placing the World Meteorological Organization (WMO) and its Members' National Meteorological and Hydrological Services (NMHSs) in the forefront for the provision of these products and services. Conclusions from the Seventeenth World Meteorological Congress stresses the need for enhancing the capacity of NHMSs to deliver on their mission by developing and improving competent human resources, technical and institutional capacities and infrastructure, particularly in countries where capability to maintain high standards of observations, data and metadata is problematic.

As mentioned in the report, the Earth global observing system has improved substantially in the last decades but efforts still are needed to address current gaps and shortcomings, and to continue building on existing observational, data management and exchange systems, adding enhancements where needed to support provision of climate services. Analysis of gaps in the geographical coverage of WMO/GAW climate observations shows that numerous in situ stations have been recently closed or are facing difficulties in reporting information. Many of these stations are actually located in regions where information is crucially lacking. It is important to address the reasons why long-term programs for the provision of ECVs are rarely established in the long-term in many countries. Many hydro-meteorological institutions in charge of weather prediction may not have yet integrated the new GFSC framework in their priority actions, which is perhaps a cause for some of the difficulties. Sustainability of the observing system will require that UN member countries, with their own climate change policies, strategies and action plans, engage in concerted and systematic efforts for integration of climate risk management in development efforts. Use of climate information at the national level plays an important part in the capacity and willingness of countries to maintain and further develop systematic observation and monitoring of climate variables.

The spread and intensity of this engagement varies depending upon the contexts, national circumstances, programs, needs and capacities of different national entities to efficiently make use of data and services provided by GFCS. For the sustainability of the in situ observing component, it seems essential to ensure that climate observations are put to good use in the national level communications on climate change (national adaptation plan, national adaptation plan of action, national mitigation plan, national communications to UNFCCC etc.). This implies that stimulating the demand for climate observations/climate information at the user level in the countries and also raising the expertise of potential beneficiaries would be effective tools to motivate national support of in situ observations for climate. Global cooperation and bilateral partnership between countries are essential to achieving this goal.

4.2 Investigating new in situ measurements

The prioritization of new investments for new in situ measurements is a challenging task, given the limited resources and rapidly increasing demands for new observations resulting from societal challenges. An example is the problem of monitoring progress towards the SDGs, where the SDG Indicators require additional information on the natural and built environment (see Section 3.5 above). Prioritization should be based on a thorough gap analysis and agreed-upon criteria to assess the societal benefits of addressing certain gaps identified in this analysis. In GEO, a number of approaches to gap analysis have been discussed in several Tasks and components, but a thorough gap analysis has not be performed so far. The Task US-09-01 carried out a detailed survey of user needs and identified a list of prioritized observational requirements (GEO, 2012). In Europe, several EC-funded projects have attempted domain specific (e.g., GAIA-CLIM, see van Weele, 2015) and cross-cutting gap analyses (e.g., ConnectinGEO, see Plag et al., 2016b).

In support of prioritizing investments for new in situ measurements, it is important for GD-06 to facilitate a comprehensive gap analysis with respect to available and required in situ observations. Such an analysis could be carried out step-wise for regions and specific societal and research challenges.

Here we provide an initial description for selected areas including agriculture, global change, and climate, and we discuss steps toward improved access to data, identifying gaps, and building capacity.

4.2.1 Improving Agricultural Monitoring

Agriculture monitoring and yield assessment need low-cost efficient methods based on EO technology in conjunction with agro-meteorological modelling. Therefore, new service specifications have been given for deriving EVs relevant for food security. Diversified EO data sets (e.g. imagery) and soil spectra libraries together with their metadata can be exploited for identifying soil and crop attributes and their spatial interrelations in a rapid, precise and inexpensive way for the benefit of all potential users.

Sensors based on visible, near- and mid-infrared spectroscopy enable the collection of encoding values of soils that are represented in the spectra as absorptions at specific wavelengths of electromagnetic radiation. These can be utilized to describe soil both quantitatively and qualitatively. Currently, advanced technologies are being used to produce miniaturised instruments that are rugged and cheap and that can be used to help extract useful information from the spectra and to enhance our understanding of soil. These recently developed innovative sensors have the potential to be applied to online scanning of soil by a tractor or robot mounted sensor-frame simplifying the laborious and times consuming static sampling procedure. The advancements in utilising mobile proximal soil sensing (PSS) for site-specific crop management show that there are advantages in the PSS technologies, including their ability to enable a range of applications in a variety of operational environments (e.g. ability to operate even during the night due to their own stable lighting conditions). Moreover, the progressive miniaturisation and increased speed of the spectral sensors will enable their use on small-sized airborne autonomous vehicles, such as quadcopters, making spectroscopy even more attractive. Hence, soil and crop spectra can be recorded by imaging from remote sensing platforms with typical super spectral, or hyper spectral capabilities (Figure 8).

Figure 8: Measuring soil and crops. Soil and crop vis-NIR spectra are measured at points or by imaging from various developed platforms by i-BEC

Knowing the spatial and temporal variation of soil properties and nutrients and crop stresses through the availability of hyperspectral georeferenced data allows the establishment of an integrated monitoring and awareness system for assessing yield, water availability and food security via variable rate strategies for crop production.

In this respect, the high spatial and spectral accuracy of the data recorded by the in situ sensors, covering a wide region of the spectral range, can be used to calibrate sensors onboard planes (airborne) or satellites (space-borne) that are used for the development of prescription maps. Hence, the challenge of using multiple satellite missions, together with a large dataset of field spectral measurements will be addressed in the near future.

4.2.2 Coordinating observing strategy for measuring global changes: from networks to flagship stations

Observations and monitoring are key elements of the emerging Global Framework for Climate Services and, more generally, are fundamental support to climate research, assessment of climate change, and development of policy responses. Observations are fundamental to advancing scientific understanding of climate and to delivering timely and purposeful climate information needed to support decision making in many sectors.

Progress in the understanding of atmospheric composition changes and its drivers is therefore strongly linked to the availability of these observations. The coordinated efforts in the last decade to facilitate access to data have been extremely beneficial but more needs to be done. While today reasonable harmonization exists within specific networks, it is not necessarily the case between them, even for networks measuring similar compounds. As a result, international networks sometimes collect information in a relatively uncoordinated manner and the overall location of sites for measuring atmospheric composition from the ground is not organized in the most optimal manner. The Global Atmosphere Program of WMO has favoured coordination of networks worldwide with the concept of Global, Regional and Contributing stations reflecting somehow the degree of concurrent and co-located measurements of key atmospheric species of interest to air quality and climate studies from background sites (Figure 9). This strategy was backed by regional programs such as ACTRIS or ICOS in Europe, GMD-NOAA in the US, and others although some regions in the World do not have regionally organized programs. A similar approach was implemented in the USA as part of the supersite program for urban areas that led to significant advancements in measurement methods, atmospheric characterization, and understanding of source-receptor relationships.

A step further for GEO would be to address the need for a higher-level coordination across networks relevant to different domains, i.e. atmosphere, terrestrial ecosystems, ocean, biodiversity. The concept of a hierarchical in situ observation system consisting of networks of measurement sites having increasing complexity from standard single-domain stations to flagship multi-domain stations may be an interesting option. Flagship stations would consist of instruments making comprehensive observations of the environmental character of the surrounding area from local to regional to global relevance. Examples of flagship stations already exist in both natural and urban environments. Operating a comprehensive observation station together with multi-scale modelling and satellite remote sensing will provide unique data of relevance to global grand challenges and will enable novel insights into their solutions.

4.2.3 Facilitating access to data including ECVs

In the 1990s, gaps in knowledge of climate and declining core observational networks in many countries led to calls for systematic observation of a limited set of critical variables. To provide guidance, the Global Climate Observing System (GCOS) program developed the concept of ECVs, which has since been broadly adopted in science and policy circles as described by the IGACO report more than a decade ago. Adequate observation capacity together with easy access to ECVs are therefore essentials to implementing the IGACO strategy. Even if ECVs from single networks are easily accessible, integration across networks or, worse, across domains is far from being implemented. This is a clear limitation to inter-disciplinary research in the concept of GEOSS. This will require common policies, models and e-infrastructure to optimize technological implementation, define workflows, and ensure coordination, harmonization, integration and interoperability of data, applications and other services between the different networks and programs providing observations of ECVs. A key challenge for GEO will be to facilitate data discovery and use, and to provide integrated end-user information technology to access heterogeneous data sources. It is clear that implementing of the GEO e-environment will require addressing the necessary resources needed in order to meet end-user requirements.

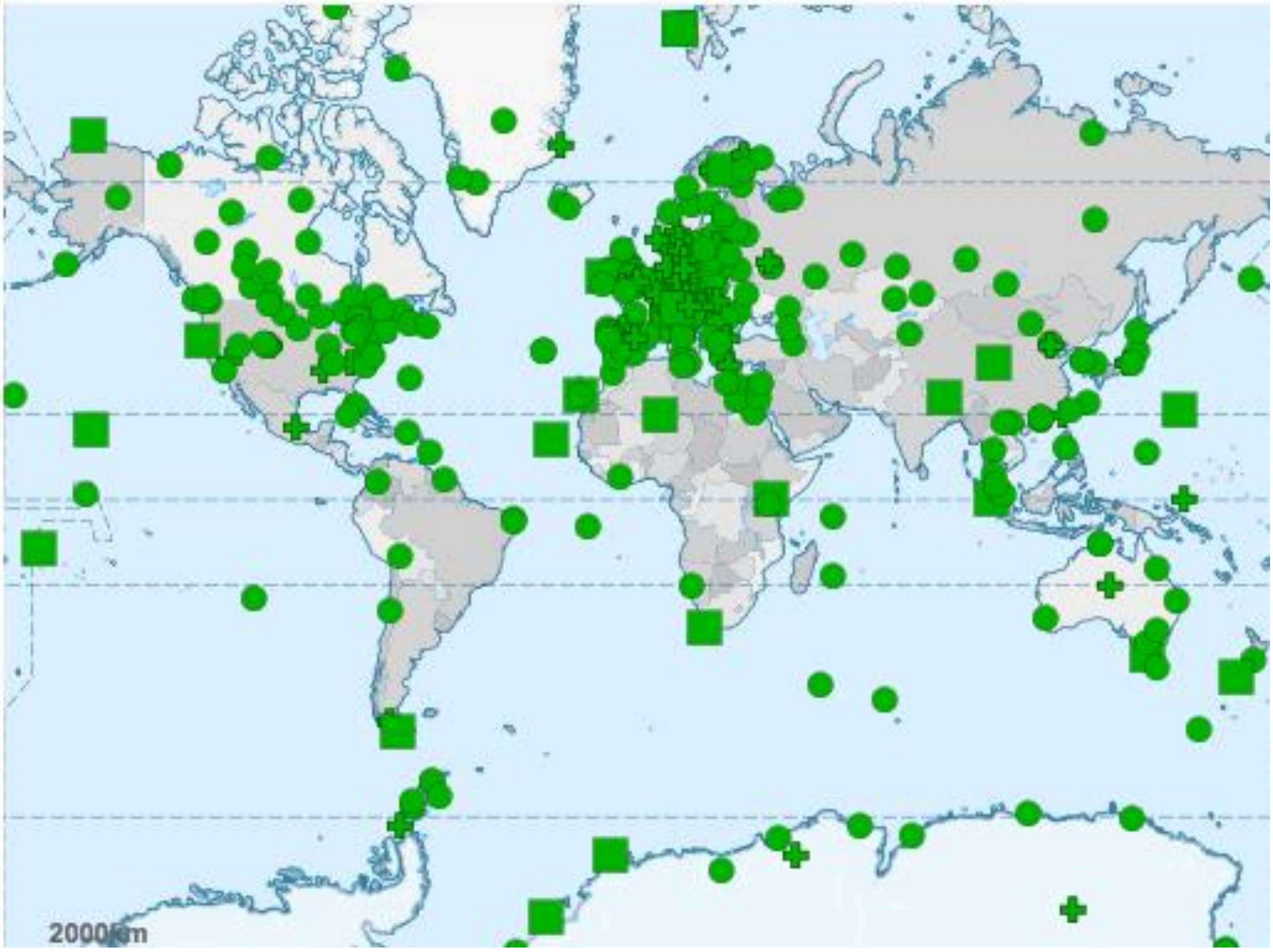

Figure 9: The network of operational in situ stations with the Global Atmosphere Watch program. Global stations (square), regional (circle) and local (cross) stations are indicated. As discussed in the report, while observation density is adequate for some World regions, there are still important areas where provision of ECV is still crucially lacking.

4.2.4 Filling gaps in observations

Gaps in in situ observations have many different aspects: technological gaps, geographical coverage gaps, gaps in computing resources, and more. Not all can be covered within this report.

Evolution of observation strategies will have to consider emerging technologies in sensors and their suitability to respond to the needs of the users. The scientific community is facing technological revolution with key-enabling technologies that will provide the basis for innovation in a wide range of products.

Uneven global and regional coverage of climate observations is still limiting our ability to adequately predict global change. This is due to a number of geographical, economical and political/legislative reasons. In the past, the main regions of focus of climate observations have been Europe and North America, and the marine territories traditionally influenced by them. While the main problem in Western and Northern Europe as well as in North America now appears to be one of network integration, in other parts of the world the main problem is the very limited geographical coverage. Observations in continental Asia are improving but the area is still under-sampled. Clear gaps remain in polar and equatorial regions, and generally in the southern Hemisphere. This is partly due to the predominance of oceans there but also due to the lack of monitoring stations on land and to the restricted number of dedicated field campaigns in many parts of the Southern Hemisphere. One of the drawbacks of ground-based observations is the need to locate the instruments on land surfaces. Although data are generated at a few island sites, monitoring over the oceans, which cover about 70% of the globe, is sparse. New technologies may contribute to fill these gaps in geographical coverage.

4.2.5 Favouring regional cooperation, including training centres

Capacity building constitutes one of the strategic priorities for improving the observing system as a whole.

Developing and improving competent human resources, technical and institutional capacities and infrastructure, particularly in developing and least developed states is crucially needed. Developing the capacity to use and develop services provided with the GFCS is similarly important. GEO must include elements of capacity building in its activities from providing assistance with operational activities to organizing topical/specialized workshops and formal training programs to facilitating direct partnering or twinning between more experienced and less experienced countries and encouraging the establishment of outreach programmes. A regional approach for cooperation in training may provide the proper scale for organizing the training of technical staff on the operation of instruments, data handling and data quality assurance. A strong recommendation is to promote partnership between Europe and countries in the Southern part of Asia, America and Africa to ensure joint implementation of monitoring networks in these areas.

4.3 Emerging Techniques and new Approaches

Aerial EO has been historically considered to be expensive. Even if it can provide better resolution than satellite data, the revisiting time is much lower as it is limited by the costs of operation. Unmanned Aerial Vehicles (UAVs), also called drones, are much easier to fly and can be programmed to cover some areas automatically. They can carry small sensors, cameras or even LIDAR scanners. They cannot provide the same data quality and coverage that aerial surveys using precision sensors can but they can be very useful in emergency response, infrastructure and crop monitoring.

There are an increasingly large number of citizen science projects active around the world involving the public in environmental monitoring and other scientific research activities.

Many citizen science projects are grassroots initiatives formed in response to local concerns, but a few have a more global scope. However, for citizen science to have maximum impact on scientific research and public policy, data collected from local projects must also be re-usable on national and global scales (beyond the purpose for which they were originally collected) and complement official sources. In that respect, the EC is financing projects in the context of GEOSS that should demonstrate the capacity of existing citizen observatories to achieve broader scope and to integrate them as another source of valid EO. To do so, these projects have to base their systems on rigorous data quality protocols, trusted and secure systems, standard data models, open data access and data curation and preservation.

In the Internet of Things a deep network of sensors is automatically contributing information to the network, mainly in populated areas (this time connected with is so-called smart cities) but also in rural areas. These networks produce vast amounts of information that need to be analyzed and integrated with other EO data types.

Another form of citizen participation is crowd-sourced information. In some cases, systems are harvesting the activities of citizens in social networks to, for example, generate early warnings of hazards or to study human distribution and social patterns. More intrusive methods can record and analyze the use of communication networks. This data is particularly useful for describing human activities and monitoring infrastructures.

4.4 Coordinating the integration of space-based and in situ observations

The integration of space-based and in situ observations may be accomplished in at least two ways: a) by using modelling to integrate and optimise the impact of combined and simultaneous use of space and surface observations; and b) by applying the concept of Integrated Observing Systems when designing and managing composite observing networks.

Effective integration of space-based and in situ observations is key for many application areas including weather and air quality forecast models and operational oceanography. The combined use of surface and space-based observations is considered essential to meeting end users requirements for information about, for example, the environment, climate, and weather at national, regional, as well as global scales. As a consequence, the European Earth Observation programme Copernicus is composed of three components (space-based observations, in situ observations, and services) to ensure proper integration and coordination of inter alia data availability, observational requirements, and interoperability.

Integrated Observing Systems, consisting primarily of existing surface and spaced-based observing capacities, may provide an over-arching framework for the coordination and optimised evolution of these capacities that will continue to be owned and operated by a diverse array of national, regional, and global actors.

The advent of Integrated Observing Systems may be viewed as fundamental to meeting future observational requirements, avoiding duplication of work, achieving the necessary level of interoperability, and ensuring cost-effective solutions.

The WMO Integrated Global Observing System (WIGOS) may serve as an excellent example of this. The development of WIGOS is requirements-driven with a clear orientation to inter alia public health, disaster risk reduction, water resource management and food security, renewable energy, tourism, travel, and insurance. WIGOS is building upon and adds value to the existing surface and space-based subsystems, while providing a foundation for the integration of new and emerging observational technologies. Space-based components of WIGOS will play a key role in the composite network design and in filling the gaps of data sparse areas, such as oceans and Polar Regions. The interoperability of WIGOS component observing systems will be achieved through utilisation and application of internationally accepted standards and recommended practices and procedures. Data compatibility will also be supported through the use of data representation standards.

WIGOS is addressing all observational needs of the weather, climate, water and environmental services of its members, and acts as an integrator of all WMO observing systems and WMO contributions to co-sponsored systems. Together with the WMO Information System (WIS), WIGOS is a WMO contribution to GEOSS.

5. CONCLUSIONS AND RECOMMENDATIONS

The limited scope of the report, which is due to the limited time and resources available for the preparation, does not allow for final conclusions concerning a comprehensive state of in situ observations and the needs for improved coordination across national, domain, and sector boundaries. However, the material presented in this report exemplifies the need for coordination on regional levels and across disciplinary boundaries. It provides a basis for planning the future work of an in situ working group in GEO that continues the work of GD-06 in the next Work Programme and allows for initial recommendations to GEO and the identification of the building blocks of a road map towards improved coordination and exploitation of in situ observations.

5.1 Benefits of Coordinating In Situ Earth Observations

There are many societal and research challenges that need to be addressed to make progress towards environmental, social and economic sustainability and to support prosperous societies and the safe-guarding of the Earth's life support system (see e.g., Griggs et al., 2013). For many of these challenges, information derived from in situ observations is crucial both for a better understanding of the relevant processes, the development of policies, the planning of actions, and the monitoring of progress, as well as a support for space-based observations. Examples are the implementation and monitoring of the SDGs, the documenting of global change and its impact on humanity, the sustainable use of resources, governance of risks and the reduction of disasters, and the prediction of environmental conditions (such as air quality, weather, droughts, floods, seasonal climate in support of agriculture, sea level, and changes in environmental health). Providing the full range of information that could be derived from in situ measurements often would require cross-discipline coordination and data integration and coordination across national boundaries. In the regions surveyed so far, there is still a need to improve this coordination, despite considerable progress in recent years. Without having performed a detailed analysis for other regions not consider in this report, it can nevertheless be assumed that in those regions the lack of coordination limits the exploitation of in situ observations significantly, too. Economic activities aiming to utilize the potential of the available in situ observations by providing value-added services are often hampered by factors such as use restrictions and the lack of access to data.

5.2 Challenges of Coordinating In Situ Earth Observations

The regional landscape of in situ observation networks, research networks, and research infrastructures is complex and there are many stakeholders involved in maintaining networks, archiving data, processing data and generating products, and using observations for value-added activities. Many users are benefiting from information and knowledge derived from in situ observations, and many more could benefit if the providers of this information and knowledge would be better connected to the users and have better knowledge of their needs. The networks and organizations are to some extent fragmented along national, disciplinary, and sectorial boundaries. On global level, coordination is well developed for some discipline-focused networks (e.g., meteorological and geodetic networks) and to some degree by in situ components of the space agencies, while for the rest no global coordination mechanisms exist. The increasing societal needs for information derived from in situ observations is likely to also increase the need for in situ observations complementing the classical expert collection with new and emerging technologies and approaches such as the Internet of Things, citizen scientists, and crowd-sourcing. A particular challenge with the increasing variety of in situ networks and the new methodologies/technologies is in the integration and interoperability of the different data types, which requires special attention to the coordination of semantics and standards as well as guarantying coverage that includes remote areas.

Continuity and long-term time series are key, but in some cases, the sustainability of observation and processing infrastructure is not easily ensured, and decisions on discontinuing funding to networks are often made without a thorough analysis of the societal and scientific benefits of the observations. A coordinated, detailed gap analysis based on well-defined user needs could help to ensure that the societal benefit of networks can impact the decisions to continue or discontinue the networks. A gap analysis can also provide a basis for prioritization of investments on new infrastructure. In that sense, defined sets of EVs provide a basis for a holistic cross-domain gap analysis and prioritization. However, the approaches used to determine domain specific EVs show a broad range of variability and a cross-domain coordination of the development of sets of domain-specific EVs is urgently needed. GEO could play an important role in convening this coordination process.

5.3 Recommendations to GEO

The Task Team of GD-06 recommends that

- a process to coordinate the development of sets of domain-specific Essential Variables be convened by GEO and those EVs that require in situ observation be identified;
- the need for regional trans-boundary and cross-domain coordination of in situ Earth observations, including semantic harmonization, adoption of standards, processing of data to generate information products of value for societal users and the adherence to GEO data sharing and management principles, be emphasized and covered with the needed resources in the GEO Work Programme;
- a comprehensive gap analysis to identify gaps in the in situ networks vis-à-vis GEO programmes' requirements for in situ observations be convened by GEO with the goal of providing guidance for the maintenance of existing and the development of new in situ networks.

5.4 Recommendation to the GEO in situ working group in the next Work Programme

The Task Team of GD-06 recommends that

- the survey of the state of in situ observations and their coordination be further detailed and extended to include Africa, the Americas, and Oceania and also add additional domains in Asia;
- existing and potential new coordination models be assessed;
- the role of the private sector as provider and user of in situ observations be considered;
- efforts be made to provide a more complete picture of the risks of loss of observational continuity and issues that reduce the sustainability of in situ networks, impact the cross-domain integration and coordination, and hamper the full exploitation of the societal benefits of these observations;
- the in situ working group take an active role in collecting relevant in situ data requirements and a gap analysis and prioritization process that can provide guidance to the in situ communities with respect to unmet user needs and the prioritization of existing and new networks.

5.5 Road Map Toward Increase Coordination of In Situ Earth Observations

The following steps could facilitate progress towards improved coordination of in situ EOs:

- Complete the descriptive analysis of the regional state of in situ observations with a focus on (i) observation networks; (ii) data processing and access facilities; (iii) linkage between providers and users.
- Analyse the coordination mechanisms in terms of capabilities to facilitate regional cross-domain coordination and coordination across sectorial boundaries.
- If necessary, develop new coordination approaches and propose these to GEO.
- Convene regional and global conferences/workshop to promote coordination in the in situ communities.
- Identify research observation networks that should be transitioned to an operational state and the facilitation of this transition in GEO.

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ACRONYMS

ACTRIS:	Aerosol, Cloud, and Trace Gases Research Infrastructure
ANAEE:	Infrastructure for the Analysis and Experimentation on Ecosystems
AP-BON:	Asian-Pacific Biological Observation Network
APN:	Asia-Pacific Network for Global Change Research
CBD:	Convention on Biodiversity
COP:	Conference of the Parties
CEOS:	Committee for Earth Observation Satellites
ConnectinGEO:	Coordinating an Observation Network of Networks EnCompassing saTellite and IN-situ to fill the Gaps in European Observations
CORDA:	Copernicus reference data access portal
DANUBIUS:	International Cneter for Advanced Studies on River-Sea Systems
DORIS:	Doppler Orbitography and Radiopositioning Integrated by Satellites
EC:	European Commission
EEA:	European Environmental Agency
EGDI:	European Geological Data Infrastructure
Eionet:	European environment information and observation network
EISCAT-3D:	European Incoherent Scatter Scientific Association
EMODnet:	European Marine Observation and Data Network
EMBRC:	European Marine Biological Resource Centre
EMEP:	European Monitoring and Evaluation Programme
ENEON:	European Network of Earth Observation Networks
ENVRI:	Environmental Research Infrastructures
EO:	Earth Observation
EPN:	EUREF GNSS Permanent Network
ERIC:	European Research Infrastructure Consortium
ETRS89:	European Terrestrial Reference System
EU:	European Union
EV:	Essential Variable
EVRS:	European Vertical Reference System
ECV:	Essential Climate Variable
EURO-ARGO:	European Component of broad-scale global array of temperature/salinity profiling floats
GAIA-CLIM:	Gap Analysis for Integrated Atmospheric ECV Climate Monitoring
GAW:	Global Atmospheric Watch
GCOS:	Global Climate Observing System
GEO:	Group on Earth Observations
GEOBON:	GEO Biological Observation Network
GEOSS:	Global Earth Observation System of Systems
GFCS:	Global Framework for Climate Services
GGOS:	Global Geodetic Observing System
GNSS:	Global Navigation Satellite System
GOOS:	Global Ocean Observing System
GPS:	Global Positioning System
IAEG-SDGs:	Interagency and Expert Group on SDG Monitoring
IAG:	International Association of Geodesy
IAGOS:	In-Service Aircraft for a Global Observing System
ICOS:	Integrated Carbon Observing System
ICRF:	International Celestial Reference Frame
IDS:	International DORIS Service
IERS:	International Earth Rotation and Reference System Service
IGACO:	Integrated Global Atmospheric Chemistry Observations

IGOS:	Integrated Global Observing Strategy
IGOS-P:	Integrated Global Observing Strategy Partnership
IGS:	International GNSS Service
INSPIRE:	Infrastructure for Spatial Information in the European Community
IPCC:	Intergovernmental Panel on Climate Change
ITRF:	International Terrestrial Reference Frame
ITRS:	International Terrestrial Reference System
IVS:	International VLBI Service for Geodesy and Astrometry
IUGG:	International Union of Geodesy and Geophysics
LIDAR:	Light Detection and Ranging
NMHS:	National Meteorological and Hydrological Services
NOAA:	National Oceanic and Atmospheric Administration
QA:	Quality Assurance
QC:	Quality Control
SBA:	Societal Benefit Area
SDG:	Sustainable Development Goal
SEIS:	Shared Environmental Information System
SLR:	Satellite Laser Ranging
UAV:	Unmanned Aerial Vehicle
UN:	United Nations
UNFCCC:	United Nations Framework Convention on Climate Change
UN-GIMM:	UN Global Geospatial Information Management
VLBI:	Very Long Baseline Interferometry
WIGOS:	WMO Integrated Global Observing System
WIS:	WMO Information System
WMO:	World Meteorological Organization