Results-Oriented GEOSS: A framework for transforming Earth observation data to knowledge for decision making

This document is submitted to the GEO-XVI Plenary for discussion.

This document describes a framework for evolving the implementation of GEOSS towards an information and processing system to improve delivery of knowledge, services and products, as referenced in the GEO Strategic Plan 2016-2025: Implementing GEOSS. This framework suggests ways in which advances in hardware technologies, software tools and cloud computing resources needed for handling, processing and delivering big data from the Earth observation systems may be maximized to deliver results for informed decision-making.

1 INTRODUCTION

Following the 44th Session of the GEO Executive Committee, the GEO Secretariat (GEOSEC) established the Expert Advisory Group (EAG) composed of invited experts to develop a strategy document for advancing a "Results-Oriented GEOSS (Global Earth Observation System of Systems)". The main task of the EAG has been to provide expert advice on how best to design a GEOSS capable of addressing the EO needs of monitoring frameworks for global policy initiatives and conventions. Over the past twelve months, the EAG held a number of brain-storming meetings, consulted with a variety of representatives from Member states, participating organizations, the GEO Programme Board, Flagships, Initiatives, GEOSS EVOLVE, GEOSS Platform team members and others as appropriate to develop a proposed framework for a Results-Oriented GEOSS.

In this framework document, the EAG, in consultation with the GEO Programme Board, proposes an instrumental framework to advance a Results-Oriented GEOSS that includes foundational pillars, goals, objectives, and actions to transform the current data-focused GEOSS to a knowledge-based GEOSS that delivers decision-ready products and services. Recognizing the need for adjustments, the EAG recommends this instrumental framework be considered an adaptive approach that will incrementally improve over time, guided by tangible results, community feedback, lessons learned, and improved processes and methods. To facilitate implementation of the framework, the EAG supports a limited proof of concept that includes development of a knowledge hub to facilitate the delivery of knowledge-based products and services.

The EAG presented this framework for advancing a Results-Oriented GEOSS to the 48th Session of the GEO Executive Committee. The Executive Committee approved the development of the proof of concept of the GEO Knowledge Hub, as outlined in the Plenary document, GEO-XVI-6.2 Proposed Design of the GEO Knowledge Hub.

2 MOTIVATION

As stated in the Group on Earth Observations (GEO) Strategic Plan 2016-2025, a central part of GEO's Mission is to build the Global Earth Observation System of Systems (GEOSS). GEOSS facilitates the sharing of environmental data and information collected from the large array of observing systems contributed by countries and organizations within GEO. GEOSS increases our understanding of Earth processes and enhances predictive capabilities that underpin sound decision-making: it provides access to data, information, and knowledge to a wide variety of users. Thus, GEOSS furnishes decision makers with sound scientific data, knowledge, and tools to make informed decisions for the health, welfare, and safety of communities under conditions of ongoing environmental change.

The Strategic Plan emphasizes the importance of involving all key stakeholders across the provider-user spectrum in a process of co-design to ensure that GEOSS data is transformed into useable knowledge and information to address societal needs[1]. **This**

[1] GEO Strategic Plan 2016-2025 : Implementing GEOSS : GEOSS, the Global Earth Observation System of Systems

original vision of GEOSS as a "system of systems" continues to be essential to GEO.

The Strategic Plan emphasizes that the scope of GEO includes an "end-to-end process of identifying needs, ensuring the availability of data with which to develop information for addressing societal challenges, and transforming that information into knowledge through the generation of products and services for end-users." The GEOSS Platform provides the foundational infrastructure and capabilities necessary to link and make Earth Observation(EO) resources available for discovery and access by the GEO community. However, key challenges for GEO remain knowledge and technical diffusion––the ability to transform data into fit-for-purpose and fit-for-use knowledge-based products and services that support decision-making.

3 HOW CAN GEO ACHIEVE TANGIBLE RESULTS FROM GEOSS?

The development of knowledge-based tools and products for understanding the Earth system and informing decision-making requires the integration and aggregation of complex Earth observation data and information products from a variety of sources, formats, spatial/temporal scales and resolutions. Additionally, quality assurance is essential to produce robust datasets that can be used for analysis, synthesis and modelling, while open access to the underlying data, models, algorithms is essential in order to accelerate co-design/production. GEO must adopt a results-oriented organization framework that supports knowledge and technical diffusion to commoditize EO data for evidence-based decision-making.

Given these challenges, this document from the EAG outlines a framework to create a policy-driven, country-relevant open-science environment that transforms data into fit-for-purpose knowledge-based products and services. Moreover, an open-science environment allows GEO Member states and Participating Organizations better connect people, processes, and technologies in order to establish a next-generation GEOSS Infrastructure that supports diffusion of knowledge and technical expertise, thus increasing the value and use of Earth observations worldwide.

4 AN ILLUSTRATIVE EXAMPLE

GEO assists Member States, particularly developing nations, increase the benefits they derive from Earth observations through their application in support of decision-making across a wide spectrum of domains. We consider the case where an expert in Mali is working to address a mandate from her government to assess the status of the health of certain agricultural crops being cultivated across the country.

She then enters the GEO Knowledge Hub. After being recognized by the system, she has access to a large network of resources provided by the GEO community. In her particular case, the GEO Secretariat has facilitated access to the Sentinel-2 for Agriculture

https://www.earthobservations.org/documents/GEO_Strategic_Plan_2016_2025_Implementing_GEOSS.pdf

(Sen2Agri) products, developed within the GEOGLAM Flagship, which integrates data from Sentinel-2 and Landsat 8 satellites to operationally produce indices of crop development, from local to global extents. Additionally, she has access to the African Data Cube which hosts a data set of ground-truth data for the Sahel region of Africa. Due to restrictions by the in-situ providers, the ground-truth data set is not yet public, but GEO and the African Data Cube have secured its use by GEO-authenticated users.

Through the open-science environment of the GEO Knowledge Hub, the expert has access to the data, reports, methodologies and software produced by the Sen2Agri development team[2] on best practices for crop monitoring using big EO data. In particular, she will receive detailed instructions on the construction and use of Normalized Difference Vegetation Index (NDVI) for vegetation monitoring, Leaf Area Index (LAI) to determine plant canopy, and Phenology indices which provide parameters related to the growing season. If needed, she can then use GEOSS programming environment to derive the indices, which she can subsequently verify with ground truth data. The result is an end-to-end solution to operationally produce near-real-time crop condition assessment at 10m resolution for each satellite overpass (phenology indices at the close of the growing season), without her government having to invest in extensive computational infrastructure to process and store big EO data. Facilitating the application of Earth observation data through lowering the technology barrier and promoting cost-saving solutions, especially for developing countries, are some of the added value aspects of the GKH.

5 OPERATIONALIZING THE CONCEPT

The scenario described above is not futuristic, but reality. GEO and its collaborators should consider not only how knowledge about the Earth is created but also disseminated as effectively as possible. This issue is best framed from the perspective of reproducibility.

All successful Earth observation applications have different components: policy mandates, national priorities, satellite and in situ observations, collaborators, methods and algorithms, and deployment strategies. GEOSS must be organized to ensure that these components are visible and accessible, and that others can share their knowledge and experience in a codified manner for country-relevant, evidence-based decision-making. Doing this, we will capture a significant portion of the knowledge embedded in each EO application while lowering barriers for developing countries to use EO and deliver tangible results. In so doing, we will transform GEOSS and the GEOSS Infrastructure from a principally discovery-and-access facility to an evidence-based decision platform–user interfaces with intelligent capabilities, analysis-ready data, co-creation capabilities and decision-ready services to produce evidence-based products and services that inform policy and decision-making.

[2] Université Catholique de Louvain (BE), the Centre d'Etudes Spatiales de la Biosphère (FR) and the companies CS – Systèmes d'Information (FR) and CS Romania (ROU), working in close collaboration with 18 organizations, centers, universities or companies belonging to the agriculture monitoring communities, funded by the European Space Agency (ESA).

The EAG recommends a whole systems end-to-end approach to address current gaps, and to link the people, process and tools required to achieve a results-oriented GEOSS.

6 PILLARS TO ACHIEVE A RESULTS-ORIENTED GEOSS

The proposed results-oriented framework is based on four pillars that provide a consistent approach for GEO to identify, select, evaluate and implement actions towards a results-oriented GEOSS. These four pillars will underpin the GWP with activities guided by **policy- and country-relevant** objectives, using **project-based** methodology to deliver **knowledge-based** tangible results for decision-support.

6.1 Policy-Relevant:

A results-oriented GEOSS that supports decision-making must include Earth observation applications that are policy-relevant, in alignment with defined national/global policy objectives and societal benefit areas. These applications need to be carried out by the Member States, with support from the GEO community. The results-oriented approach will be particularly relevant to GEO Flagships and Initiatives that have policy-relevant mandates. Much progress on the Flagships and Initiatives will result from finding a trusted and consistent set of methods that can be applied to the big data sets that are openly available to inform policy-relevant decisions.

GOAL:	**Key Measures/Outputs:**
Engage, Advocate and Deliver Policy-Relevant knowledge-based services	a. Identify specific policy indicators where the application of EO has the potential to increase understanding leading to decision-making by Member states. b. Delivery of policy-relevant and actionable products and services. c. Policy related interventions and actions that result from Member state application of EO.

6.2 Country-Relevant

In a results-oriented approach, the involvement of the concerned Member state is paramount. In keeping with the principle of co-design, GEO needs to engage with Member country institutions that provide in situ observations to ensure that these institutions benefit from full and unrestricted access to the results to which they contribute. Instead of having a large number of small-sized case studies, Flagships and Initiatives need targeted actions that support the development of country-relevant results. For example, instead of answering the question "what data does agriculture monitoring need?", GEO needs to respond to the demand: *"what are the components of a successful agricultural monitoring application to support food security for GEO Member States and how can GEOSS organize knowledge-based services required to build it?"*.

GOAL:	**Key Measures/Outputs:**
Deliver fit-for-purpose country-relevant knowledge-based products and services	a. Member states advocate national open data policies. b. Member states implement GEOSS Data Sharing and Management Principles. c. Member states advocate and engage in capacity development and communities of practice. d. GEO community delivers policy/country-relevant fit-for-purpose products and services that support member state understanding and decision-making.

6.3 **Project-Based**

A results-oriented organization is better managed by having a portion of its work to be *project-driven*. In this context, we define projects as fixed-term activities that are approved as part of the GEO Work Programme, managed, properly financed and staffed by sponsoring GEO Members and Participating Organizations so as to achieve policy and country-relevant results. Projects with fixed terms and clear objectives will provide a foundation to keep GEO focused on results and to ensure that those who finance them get what they expect. A main focus of the GEO projects will be to bring the benefits of EO to Member states, in particular developing nations.

GOAL: Improve management and accountability in the GWP towards a result-oriented GEOSS	**Key Measures:** a. Approved in the GWP that will be fundamental in both providing methodologies for solving problems and identifying potential end users. b. Properly managed, staffed, resourced and financed. c. Clearly defined/aligned with policy/country-relevant indicators. d. Defined schedule with clearly defined products and services. e. Monitoring and reporting GEO governing bodies and the community.

6.4 **Knowledge-based**

GEO has the mission of improving the capacity of all its Member States to use Earth observation data for decision-making. To achieve this goal, we need to go beyond data. Broadening the global access to knowledge-based products and services that support decision-making is essential for delivering tangible results. Achieving this goal requires combining best practices from the GEO community with long-term capacity development.

The GEO community produces many useful and relevant results, which it aims to share globally. Such resources will be of different types to reflect the entire information flow of the research and knowledge pertaining to a domain. Linked documents that contain relevant information for Earth observation applications that provide access to the underlying data, models, methods and algorithms are necessary to promote dissemination of knowledge and technical expertise for reproducibility, scalability, and co-design/co-production.

Engaging developing nations as providers and users of in situ data requires a change in attitude from the data analysis and modelling community. All models and analysis methods that use such data should be made public. In case of complex models such as numerical weather predictions or climate change models, at a minimum, all results from these models that can benefit developing nations need to be public.

GOAL:	**Key Measures:**
Deliver fit-for-purpose country-relevant knowledge-based products and services	a. Member States adopt and implement GEOSS Data Sharing and GEOSS Data Management Principles. b. Establishment of communities of practice for dissemination of knowledge and technical expertise. c. Curated and linked data that contain relevant information to promote reproducibility, scalability, and co-design/co-production. d. Advance the creation and co-development of analysis ready and decision-ready data and knowledge. e. Establishment of knowledge-based products and services that lower the barriers for developing countries to use EO.

7 ACTION PLAN

The EAG assessed the current state of capability, considered the proposed architecture from GEOSS Evolve and recommends the establishment of a GEO Knowledge Hub (GKH) to close current gaps in the GEOSS Platform to facilitate the implementation of the framework as proposed.

The primary goal of the GKH is to advance transformation of Earth observation data into knowledge-based services for evidence-based decision-making. The GKH is envisioned to provide linkages to policy mandates, the Work Programme with related project and task workflow alignment, task monitoring, and to implement dissemination of knowledge and technical expertise capabilities as integral part of a results-oriented GEOSS. Implemented, the GKH will effectively extend the GEOSS Platform to achieve the optimal state described in the Strategic Plan. The GKH will serve as a component of the GEOSS Infrastructure, and its development is part of the GEOSS Infrastructure Development Foundational Task, which will be part of the 2020-2025 GWP. This proposal for this Foundational Task has been endorsed by the GEO Programme Board, GEOSS Evolve, and the GEOSS Platform.

The EAG recommends that the GEOSS Implementation Development Task Team carry out a proof of concept demonstrating the GKH, based on data, methodologies and other information from the GEOGLAM. This demonstration will provide valuable lessons learned, best practices, recommendations on architecture, scaling and long-term implementation and operational requirements for the GKH. The following governance structure and activities are proposed:

a) The GEOSS Implementation Development Task Team will oversee the development of the proof-of-concept to ensure that the GKH is consistent with the other components of the GEOSS Platform;
b) This proof of concept will be built in consultation with the GEO Programme Board, GWP Leads, and external consultation as appropriate;
c) GKH will be developed using only free and open source software, drawing as much as possible on existing community solutions for Open Science and on accepted best practices for knowledge sharing;
d) Progress developing the proof-of-concept will be demonstrated at the 48th and 49th GEO Executive Committee meetings;
e) The proof of concept will be demonstrated at the GEO-XVI Plenary in 2019, Canberra, Australia. Based on the response of the GEO community to this proof of concept, the GEOSS Implementation Development Task Team will propose a plan for further development of the GKH, to be presented for decision to the GEO Executive Committee, at their March 2020 meeting.

8 CONCLUSION

To realize the GEO 2025 vision and maximize the use and application of Earth observations, GEO must address the effective dissemination of knowledge and technical expertise – the ability to transform data into fit-for-purpose and fit-for-use knowledge-based products and services that support decision-making. Implemented, this framework has the potential to support GEO Member states' ability to advocate, engage and accelerate the delivery of tangible knowledge-based products and services for decision-making. Recognizing the need for adjustments, the EAG recommends this instrumental framework be considered an adaptive framework approach that will incrementally improve over time, guided by tangible results, community feedback, lessons learned, and improved processes and methods. To support the framework the EAG supports a limited proof of concept that includes development of a GKH to facilitate the delivery of knowledge-based products and services.

Annex A
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