GEO In-Situ Data Strategy

This document is submitted to Plenary for decision, following a decision by the Executive Committee at its 69th session on 25 May 2026 and its endorsement by the Executive Committee at its 67th session on 29 October 2025. It is presented for Plenary's consideration and final approval.

Executive Summary

GEO's Member governments, Participating Organizations and Associates work together to develop and implement Earth observation (EO) projects and initiatives that address global environmental and societal challenges and help decision-makers understand and act on global environmental challenges. EO data, both in-situ and satellite-based observations / measurements, are fundamental components of these actions and essential for GEO to achieve its mission of Earth Intelligence for All.

This document responds to the need for an In-Situ Data Strategy that has been acknowledged within successive GEO Ministerial Declarations e.g. Canberra Declaration (2019). Building on a significant body of work by GEO Members spanning several years, the In-situ Data Strategy aims to provide a framework for GEO that addresses the specific challenges associated with the acquisition and use of in-situ measurements and observations. It also provides a set of objectives, and potential roles that will enhance integration of all forms of EO data to support GEO's ongoing mission.

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INTRODUCTION

Background

In-situ data refers to Earth observations and measurements collected directly at or near the Earth's surface, as opposed to remote sensing (RS) data that is gathered from space-based systems, e.g., satellites. In-Situ data encompasses, but is not limited to, observations and measurements obtained from ground-based monitoring systems, maritime platforms, airborne sensors (excluding satellites), field surveys, and citizen science (Strobl, 2024).

In contrast to satellite-based observations, in-situ data are usually direct measurements of selected variables, often in specific and fixed locations, which are likely to be more precise and therefore considered as the "ground truth". Satellite-based observations and measurements tend to be more indirect but systematically cover the Earth's surface.

Together, in-situ and RS data are complementary, providing a comprehensive suite of observations and measurements of the planet. For this reason, both satellite and in-situ Earth observations are equally important in order for GEO to deliver its stated mission, especially with respect to data, knowledge and Earth Intelligence for all.

The significant value of in-situ data is demonstrated through various applications, including the GEO Work Programme activities, because it:

- is essential for realizing GEO's key global priorities as defined in the GEO Post-2025 Strategy;
- enables evidence-based policy and governance-based processes. It helps assess the effectiveness of regulations, identify areas of concern, and guide investments in infrastructure and conservation;
- is essential for the calibration and validation of remote sensing products and Earth system models (including training Artificial Intelligence and as input for Machine Learning modules);
- provides measurements in difficult to access locations, e.g., within the global oceans, in areas affected by clouds, smoke or aerosols, or other areas that are not accessible to space-based observing systems;
- often measure significant variables in the Earth system that are directly impacted by human activities;
- has a temporal and spatial distribution that allows more accurate and frequent measurements. In-Situ measurements tend to be tied to a specific location and taken at a greater frequency, which provides higher resolution data than can be achieved by space-based systems;
- potentially provides long time series based on repeated historical measurements that can, in some cases, be over a period of more than 100 years;
- is the only legally admissible form of Earth observation data that can be used to prove illegal activities in some Member States e.g. destruction of protected natural habitats.

Due to the diversity and nature of the various in-situ data acquisition activities spread across a wide range of different disciplines, e.g., hydrology, climatology, oceanography, biodiversity, etc., the current associated data landscape is highly heterogeneous. Despite some limited efforts to standardize monitoring protocols and aggregate in-situ datasets to generate more general coverage, the landscape remains fragmented in many sectors with significant gaps in some areas. A situation that is further exacerbated by inconsistent data policies at the national and local level, including those related to data archiving, preservation, and reuse, which leads to loss of critical data and knowledge. Actually, the diverse nature of in-situ data necessitates significant investment of resources in its curation and archiving to ensure its usability and accuracy for specific user applications. Significant data management efforts in terms of standardization, harmonization, and interoperability are also critical to effectively consolidating different datasets to fulfil the needs of users.

In addition to the already existing efforts by observational research infrastructures, some of which are included in the GEO Work Programme), achieving the necessary level of in-situ data integration requires new and existing in-situ data systems and networks to implement common data frameworks, metadata standards, and quality control processes to ensure consistency and reliability across different sources. This should include encouraging wider adoption of recognised data management practices, the GEO Data Sharing and Management principles, the Data Licensing principles as well as other relevant best practices, e.g., the FAIR, CARE, and TRUST Principles.

Challenges associated with in-situ data

The specific challenges associated with the in-situ data landscape, such as its heterogeneity, lack of coordination, geographical variations, large and diverse range of stakeholders, and barriers to data access, have been recognized in successive Declarations from GEO Ministerial Summits (Cape Town 2007, Beijing 2010, Geneva 2014, Mexico City 2015). Reinforcing this message, the Canberra Declaration (November 2019) states that the Ministers:

- Recognise the critical role that data collected from the atmosphere, land, and water (in-situ data) plays in achieving GEO's mission;
- Note that the sharing of such data is limited, and significant gaps remain for a global observing system;
- Note that such data has specificities in its nature, governance, technical management, financing,
- Call upon the GEO community to develop a strategy to address the challenges in this area and to demonstrate progress in implementation.

GEO Members, Participating Organizations and Associates work together to develop and implement Earth observations projects and initiatives that address global environmental and societal challenges and help decision-makers understand and act on the global environmental challenges. To address these challenges and their impacts at different geographical scales, GEO is the result of connecting major thematic global activities with those regional and national stakeholders (most of whom are participants in the GEO work program) that share, manage, [1]use in-situ data such as WMO[2], EEA[3], NOAA[4], FAO[5], GCOS�, etc.

GEO has a convening power to coordinate and foster best practices for management and sharing of all forms of EO data, which are fundamental for creating the synergies necessary for GEO to achieve its mission of Earth Intelligence for All. A critical element of putting into practice is the development of an in-situ data strategy for GEO that responds to the Canberra Declaration (2019) and seeks to address the specific challenges associated with in-situ data, which are identified below.

The following are some of the challenges at Global, Regional and National levels:

- highly heterogeneous data landscape that lacks coordination in some areas;
- inconsistent spatial and temporal distribution, including critical gaps in some geographical and thematic areas;
- barriers to sharing / reuse caused by variances in data policies across Member States;
- concerns about sharing unvalidated data resulting in low observation data latency;
- lack of adoption of common standards, vocabularies, and access protocols;
- available data with inadequate metadata, unsuitable format, lacks quality indicators and / or suitable user licensing;
- lack of data stewardship procedures at local level for long-term storage and preservation, leading to loss of data, especially from short -term projects or research field campaigns;
- sustainability, including consistent funding for key observing systems, leading to uncertainties for ongoing data availability and preventing long-term monitoring and as a consequence.

Acquisition, management, and preservation of in-situ data are significantly different from those required for space-based data. For this reason, GEO requires a targeted and distinct strategy that acknowledges and addresses the specific challenges associated with in-situ data. Furthermore, the highly heterogeneous landscape and diverse range of stakeholders require that the GEO membership

[1] WMO: World Meteorological Organisation

[2] EEA: European Environment Agency

[3] NOAA: National Oceanographic and Atmospheric Administration

[4] FAO: Food and Agriculture Organisation

[5] GCOS: Global Climate Observing System

take a very specific approach to in-situ data that differs from that adopted for space-based Earth observation data.

The GEO strategy should build on the existing in-situ data landscape and the experiences of current activities and initiatives, e.g., GEO Working Groups and Work Programme activities. Several examples already exist that demonstrate the critical importance of in-situ data for GEO initiatives (e.g., GEOGLAM, GEOGLOWS, GEO Mountains, TWIGA-TAHMO, GEO Aqua Watch, and others). Efforts should also be made to engage the wider GEO community, e.g., regional GEOs, Participating Organizations, including private sector partners, that maintain and promote in-situ data networks that are potential data providers in GEO. Many of these thematic initiatives are coordinating existing in-situ data networks on a regional or global scale, which can provide key insights into the challenges associated with in-situ data systems and how these can potentially be resolved.

Addressing fragmentation of the in-situ data landscape also requires coordination among existing frameworks such as the World Meteorological Organization (WMO) Global Observing System, the Global Climate Observing System (GCOS), and regional initiatives such as Copernicus. In this context, GEO must play a key role in bridging the different efforts to promote cross-sectoral integration.

Potential roles for GEO community within the in-situ data landscape are:

- **Advocate**: actively seeking opportunities for implementation of new in-situ observing systems and ensuring the sustainability of existing key monitoring networks;
- **Promoter**: highlight availability, quality, and value of in-situ data, products, services, and systems;
- **Coordinator**: actively engaging with relevant stakeholders to encourage greater (re)use of in-situ data, reduce duplication of effort and address specific data gaps; Foster adoption of consistent standard data management practices, including the GEO Data Sharing and Data Management Principles, and implementation of the FAIR, CARE, and TRUST Principles;
- **Facilitator**: initiating community dialogue to address specific issues associated with in-situ data, e.g., prioritisation of the creation or continuation of selected in-situ observing systems;
- **Custodian**: providing guidance for archiving and preservation of in-situ data, especially “orphan” data that might otherwise be lost;
- **Redistributor**: supporting discovery and access of in-situ data through the GEO infrastructure;
- **Capacity builder**: supporting user upskilling to enhance exploitation of in-situ data. GEO tools such as the Knowledge Hub (GKH) can be used to deliver the necessary materials to train and educate users, including the next generation of researchers.

Goals and Objectives

The **mission** of this strategy is to coordinate in-situ data providers, such as research infrastructures, such as the ones that make up the ENVRI cluster, mobilize GEO members and participating organizations, engage in-situ data users, and advocate for in-situ open knowledge. It aims to foster a change in the mindset of the GEO community by ensuring in-situ data sharing and management are an integral part of all relevant activities and support this approach by delivering the tools needed for in-situ data sharing and integration. GEO will also actively complement and align with efforts led by WMO and GCOS.

The strategic objectives are as follows:

- Encourage the GEO community to identify and monitor data users (as defined by the GIDTT second deliverable) requirements for discovering, accessing and re-using in-situ data. Determine the barriers to delivering in-situ data that respects the relevant data management principles e.g. FAIR, CARE etc. as open access;
- Foster the GEO community to coordinate with existing national and regional in-situ data networks across different geographical areas and by domains with the aim of:
    - Defining and describing the existing in-situ data landscape;
    - Promoting sustainability and improving observing networks in data-sparse regions and focus areas;
    - Identifying existing gaps in the observation systems, supporting data providers that can close those gaps, and promoting new harmonized observing networks;
    - Supporting implementation of a GEO infrastructure that can serve as a gateway for in-situ data and stimulate the adoption of appropriate tools for data management;
    - Incorporating novel sources of in-situ data such as from citizen science, Internet of Things (IoT), and drones (UAVs).
- Support the GEO community to advocate and monitor the implementation of the GEO Data Sharing and Data Management Principles for in-situ data applications at the national and regional scale. GEO serves to bridge the gap between sector-specific data practices. It offers overarching guidance that is suitable for multi-sectoral and cross-cutting applications. GEO should focus on:
    - Taking a leading role in promoting good data stewardship (e.g., with the adoption of DSDMP, FAIR, CARE, TRUST principles);
    - Encouraging the use of flexible and common data licenses;
    - Illustrating the use of in-situ for increasing environmental knowledge;
    - Minimizing and avoiding loss of in-situ data, including through the adoption of relevant archiving and preservation best practices.

Conclusion

The GEO In-situ Data Strategy provides a framework for the open sharing of ground-based observations of our Earth System. This approach provides clear guidance on different aspects of in-situ data management with the aim of overcoming the specific challenges associated with the acquisition, (re)use, and long-term archiving of this type of Earth Observation data. Critical elements of the implementation of this strategy are the tools and services that are necessary to support the open access and sharing of in-situ data, such as those that make up the GEO infrastructure, e.g., GEO Knowledge Hub (GKH), G-REQS, libinsitu, etc.

To maximise the impact of the In-situ Data Strategy, a comprehensive and coherent set of actions will be put in place to foster its adoption and implementation throughout the GEO community and beyond. Such an implementation plan will demand a strong commitment at the national, regional, and global levels to ensure the availability of the resources necessary to raise awareness and encourage adoption of the In-Situ Data Strategy, which has been identified as a priority for GEO.

This document has been developed through a collaborative effort by current and previous members of the In-situ Data subgroup and the Data & Knowledge Working Group in GEO. The main authors of the document are listed in Table 1 below.

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Table 1: Main authors of the GEO In-situ Strategy document (September 2025)

Annex A
Existing tools

GEO supports the community with a set of tools that are regularly reviewed and updated based on the evolving needs of users. The tools currently available are:

1 GEO INFRASTRUCTURE

2 GEO DISCOVERY AND ACCESS BROKER (GEO-DAB): HTTPS://WWW.GEODAB.NET/

The GEO-DAB acts as a bridge between contributing data providers and users, providing the necessary functionalities to link existing and planned observing systems worldwide. It serves as the enabler for connecting and establishing interoperability among the various in-situ data providers.

2.1 GEO Knowledge Hub: https://gkhub.earthobservations.org/

A key element of the GEO tools and services is the Geo Knowledge Hub (GKN) that acts as a digital library providing access to Earth Observation (EO) Applications developed by the GEO Work Programme activities as well as other resources supporting the GEO mission towards open data and knowledge.

3 G-REQS: HTTPS://G-REQS.GRUMETS.CAT/

The Geospatial Requirements tool (G-reqs) captures identified user needs for in-situ data in a standardized form that builds into a comprehensive requirements database (Maso et al., 2023). The resulting database can be used to match requirements with existing datasets, identify gaps in in-situ data coverage/ availability, and provide the basis to define new in-situ observing systems where necessary.

4 LIBINSITU: HTTPS://LIBINSITU.ORG/

The libinsitu tool is an open-source python library (BSD licence) to transform heterogeneous time series of in-situ measurements into well-formed binary NetCDF files, compliant with Climate and Forecast (CF) convention, ready for sharing (see Blanc et al., 2022). The aim is to push for FAIR principles and the usage of interoperable and self-describing data, easing the scientific community to leverage open dataSelf-assessment for FAIR compliance (Findable, Accessible, Interoperable, and Reusable (FAIR) Data): https://fair-data.netlify.app/ able designed to facilitate the assessment of data compliance with the FAIR principles. It has been adapted by Lionel Menard and Kalamkas Yessimkhanova as an outcome of the deliberations and collaborative efforts within the GIDDT group meetings. The original source is from the GO FAIR Initiative:

5 GEO DATA MANAGEMENT PRINCIPLES IMPLEMENTATION GUIDELINES: HTTPS://GKHUB.EARTHOBSERVATIONS.ORG/RECORDS/GG85H-X8466

Set of recognised GEO principles covering discovery, accessibility and usability of data, among other topics. They can be applied to the entire data management lifecycle, and are complimentary to the FAIR principles, which focus primarily on aspects of metadata, and the TRUST Principles, which primarily focus on the curation and preservation of data and related resources.

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