# WP23_25: GEO Global Water Sustainability

1244,254

## Basic Information

### Full title of the Initiative

GEO Global Water Sustainability

### Short Title or Acronym

GEOGloWS

### Current category in the 2020-2022 GWP

GEO Initiative

### Proposed category in the 2023-2025 GWP

GEO Initiative

### Points of Contact

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## Purpose

### Objective

To pioneer scientific and global collaboration to provide relevant, actionable water information and to promote the use of earth observations in the decision-making process.

### Please provide a short description of the Initiative

https://www.youtube.com/watch?v=v8FhgV4cBnI

The Global Water Sustainability (GEOGloWS) Initiative under the Group on Earth Observations (GEO) is a user-driven initiative that seeks to enable scientists and organizations to solve multidisciplinary challenges associated with achieving global
water sustainability while promoting activities providing equitable solutions. The core innovation of the GEOGloWS effort is its combination of modern computing technologies with hydrologic sciences and satellite datasets enabled by web services and cloud computing. With an operational focus and innovations, GEOGloWS provides a space for the engagement of multidisciplinary and transboundary organizations and provides a forum for government-to-government collaboration and engagement with academia, non-profit organizations, and private sectors. GEOGloWS provides access to actionable water data, information, and knowledge to bridge the digital divide and promote global equity through a service.

## Why is this Initiative needed?

https://www.youtube.com/watch?v=2a4oleT-ChQ

In climate change response and disaster preparedness and mitigation, accurate streamflow indicators and forecasts play an increasingly important role in flood and drought control, reservoir operation, watershed planning, water resource management, and mitigation of the impacts of climate change by providing critical information in advance on various timescales. The GEOGloWS - ECMWF flow forecasting service responds to the global need for streamflow forecast information. The forecast service also provides a solution to the lack of data sharing in transboundary watersheds as neighboring countries do not share information.

In prosperous economies, the benefits of adopting cloud computing are already recognized for improving security and optimizing operations. On the other hand, governments and organizations in developing nations have lower budgets with priorities requiring early-win demonstrations before long-term adoption and investing in cloud computing. The core innovation of the GEOGloWS effort is its combination of modern computing technologies with hydrologic sciences and satellite datasets enabled by web services and cloud computing.

### What evidence is there to support this need?

Honduras: https://www.youtube.com/watch?v=l3Gjy2ZAV8E
Guatemala : https://www.youtube.com/watch?v=JfibcGBoKDE
Israel : https://www.youtube.com/watch?v=j_UxUk6z7aQ
Transboundary solutions - Africa: https://player.vimeo.com/video/565756335?h=dee5bf427a

The majority of flood exposed people, about 1.36 billion, are located in South and East Asia; China (329 million) and India (225 million) account for over a third of global exposure. Of the 1.47 billion people exposed to flood risk, 89 percent live in low- and middle-income countries. According to the reinsurance agency Swiss Re Institute, losses to the global economy due to flooding were more than $82 billion in 2021. Since 2012, the World Meteorological Organization has been developing HydroSOS. As of 2022, the WMO states on the hydroSOS page: "Global hydrological conditions of floods and droughts and potential conflicts in water use are some of the most significant challenges and threats facing the world's population. There is currently no global operational system capable of assessing the current status of surface and groundwater hydrological systems or predicting how they will change in the coming weeks and months. "

## Is this Initiative open to participation by representatives of any GEO Member, Participating Organization, and GEO Associate?

Yes

## Are you aware of other projects or initiatives at a global or regional scale (both in GEO and externally) that provide similar products or services?

Yes

### Please describe.

In many countries, there are military applications not open to the public. There are also PLANS for the WMO Global Hydrological Status and Outlook System (HydroSOS), which will directly build on existing and planned WMO initiatives in relation to hydrological monitoring, data sharing, and sub-seasonal to seasonal meteorological forecasting to deliver a unique operational system providing up-to-date hydrological information and products from National Meteorological and Hydrological Services to a range of end-users. The responsibility for implementing the HydroSOS has been left to the WMO Regional Associations. While the system’s information and products will be global, they will also be provided at regional and national scales. The operational HydroSOS system will support the activities of the National Meteorological and Hydrological Services and will provide easily accessible hydrological information and products that can be accessible to government bodies, regional and international aid agencies and the general public.

### How is this Initiative unique?

The goal of the Initiative is to provide viable solutions to global problems related to water sustainability through innovation and multidisciplinary collaboration.

The Initiative's first objective was to break the paradigm of how the flow of information is created and disseminated. Thanks to public-private collaboration, the GEOGloWS ECMWF streamflow forecast service resulted from this effort, becoming one of the most important contributions to the social need for information on water. The service became the hub around which complementary projects contribute to service improvement. Some of these projects include flood mapping forecast, tools like the Water Data Explorer with in situ observations, Met Data Explorer with gridded time series data like CHIRPS, GRACE, and the new HydraFloods application, among others. In 2022, GEOGloWS, through NASA funding, is partnering with The National Centre for Space Studies (CNES; French: Centre national d'études spatiales) to bring time series of water levels in the rivers and lakes around the world processed from satellite altimetry and stored in the Hydroweb database. Hydroweb is operated by the company Collective Localisation Satellites (CLS) under the coordination of LEGOS, IRD, and CNES. Water levels from Hydroweb will be used to develop the bias correction, commonly derived from in-situ monitoring data, for the local application of the GEOGloWS ECMWF service.
The advances of GEOgloWS are approached with an integral perspective. GEOGloWS' technological developments within the OGC climate change services pilots accelerate readiness to access, merge and analyze multidisciplinary data to contribute to the global push for climate resilience. GEOGloWS is implementing technology and standards to improve its interoperability to be one of the first global implementations of the Environmental Data Recovery (EDR).
GEOGloWS is also partnering with cloud providers to optimize the cyberinfrastructure necessary to support GEOGloWS portal implementations worldwide.
From the human perspective, GEOGloWS promotes global equity through the GEOGloWS-ECMWF streamflow forecast service, with data, knowledge, and actionable information that is open, free, and accessible to the world.

## Please identify the most important actual and/or intended outputs (products, services, etc.) produced by the Initiative, along with their intended and/or actual users. This list does not need to be comprehensive but should identify the outputs which are most used and are expected to have the greatest potential impact.

| Output | Status | Users | Additional info |
|---|---|---|---|
| streamflow forecast | Regularly updated | | |
| water fraction maps using in-situ streamflow data | Planned | | |
| VIIRS-generated water fraction map | Planned | | |

### If needed, please provide additional comments or explanation to accompany the outputs table

- no answer given -

## What kinds of decisions are the outputs of this Initiative primarily intended to support?

Flood preparedness and contingency plans; evacuations; water management; climate change impact to food security; Flood impact; ecosystems health.

### How will these decisions benefit from the outputs of this Initiative?

Streamflow Indicators and streamflow forecasting will increase confidence and more accurate outcomes for decisions related to planning water storage and release, agricultural planting, irrigation, ecosystem health, water quality, evacuations, disaster mitigation, hydro-electricity production, insurance, and reinsurance cost, etc.

## What kinds of impacts (for example, reduced loss of life, monetary savings, conservation of biodiversity, etc.) are anticipated as a result of the use of the outputs

### of this Initiative?

Reduce loss of life, monetary savings, conservation of biodiversity,

### Has this Initiative been asked to provide specific information (for example, reports, data, services) on an ongoing basis to an international convention, organization, or other multilateral body?

Yes

#### Please identify the requesting organization.

The GEOGloWS ECMWF Streamflow forecasting service runs on ECMWF's private cloud computing infrastructure. It has run 24-7 without interruptions for the last 18 months. Recently, the data service has averaged around 30 thousand requests for data each week.
Malawi : https://earthobservations.org/geo_blog_obs.php?id=546
INDRHI DR: https://indhri-hydro-apps.westus2.cloudapp.azure.com/apps/
Inamhi Ecuador: https://tethys-inamhi.westus2.cloudapp.azure.com/apps/
Senamhi Peru: https://senamhi.westus2.cloudapp.azure.com/apps/
Cemaden Brazil: https://cemaden.westus2.cloudapp.azure.com/apps/
IDEAM Colombia: https://tethys-ideam.westus2.cloudapp.azure.com/apps/

#### Describe the nature of the request.

Streamflow (forecast and historical data).

#### Please provide supporting documentation of the request.

- no supporting documents provided -

## Technical Synopsis

### Please provide a brief description of the methods used by the Initiative to produce its (actual or planned) outputs.

Methods and publications are provided through the GEO Knowledge Hub : https://gkhub.earthobservations.org/ https://gkhub.earthobservations.org/search?q=GEOGloWS&l=list&p=1&s=10&sort=bestmatch

### If you would like to provide further details on the technical methods, you may upload one or more documents here.

- no supporting documents provided -

### Are there any significant scientific or technical challenges that need to be resolved by the Initiative during the 2023-2025 period?

Yes

#### Please describe these challenges and the steps being taken to solve them.

Considering the current capabilities of GEOGloWS and the challenge of climate change preparedness and adaptation to address multiple hazards and the potential for chained threats, GEOGloWS needs to advance its connectivity with multidisciplinary environmental data resources. More than 50 years of historical streamflow obtained through retrospective analysis, the streamflow forecast, and environmental data will provide comprehensive knowledge and the first global glimpse of water nexus interactions with other sectors. With this in mind, we are partnering with the USGS and OGC to demonstrate the potential impact of integrating an Environmental Data Retrieval (EDR) API standard and the PYGEOAPI implementation into the GEOGloWS ECMWF Streamflow Service REST API. As different organizations prepare to focus on accelerating open science practices in the scientific community, OGC and GEOGloWS seek to demonstrate the use of defined standards for data services to improve data accessibility and interoperability worldwide.

This demonstration will be deployed in collaboration with the Earth Science Information Partners (ESIP) group. A report documenting the guidelines and challenges for migrating an existing data service to compliant standards and the potential benefits of such effort will be included in the GEOGloWS public documentation. The USGS already funded this activity under the OGC Climate Pilots 2022.

As the data is increasing in frequency, resolution, and application, there is a need for the earth science community to have a flexible analysis environment that empowers them to explore, analyze, and model big data in a software-as-a-service “cloud” environment. GEOGLoWS needs to develop a Cloud-based Platform for Rapid Deployment of GEOGLOWS Water and Food Security Decision Support Apps. This Cloud-based Platform, also known as the GEOGloWS toolbox, was developed with funding from NASA in 2019. In 2022, new funding was obtained to advance the capabilities of the toolbox and to incorporate New web apps for workflow-based hydrologic modeling and water level analysis. This new capability will allow GEOGloWS to use satellite data and existing tools developed by the National Center for Space Studies (CNES France) to address the lack of in-situ data in many regions and to produce the bias correction needed for the global forecast. The bias correction is necessary to localize the streamflow forecast. This activity is already funded by NASA 2022-2025.

Cloud infrastructure is becoming more critical for government organizations as they explore digital modernization and offer government agencies more flexibility than traditional IT infrastructures. No more worries about limited resources, buying and housing servers and hardware, updating software, or data protection with a cloud service provider. The GEOGLOWS-ECMWF is a Cloud-based Streamflow Estimation and forecast that incentivizes organizations to explore cloud infrastructure adoption in their organizations. We are exploring possibilities to partner with Cloud providers who, through credit donation for two years, will allow government organizations in developing countries to experience the benefits of the Cloud Infrastructure and services.

Flood Mapping: GEOGloWS needs to implement FIER (Forecasting Inundation Extents using REOF analysis) to the GEOGloWS-ECMWF streamflow forecasting. The initial pilot was funded by NASA ROSES in 2017 using the Mekong region. In 2020, NOAA provided funding to implement the methodology in NOAA's operational environment and to apply it to the US using VIIRS-observed water fraction maps. The implementation of FIER and the GEOGloWS- ECMWF streamflow forecast needs to be at the local scale, and countries or organizations can use SAR, optical, or both to develop inundation extents. Funding is required to provide training and capacity development.

## Does the Initiative expect to complete any key new outputs, improvements to existing outputs, or improvements to the methods of producing outputs, in the 2023-2025 period?

Yes

### Please describe these new outputs or improvements.

We expect to make GEOGloWS OGC compliant.
We expect to establish a partnership with cloud providers to establish a no-cost 2-year program to enable organizations in developing countries to access computing resources to implement and customize GEOGloWS Toolbox on a local scale to access GEOGloWS hydrological forecasting and enable organizations to improve safety and optimize operations.

### Please identify the key tasks that must be implemented to ensure delivery of these changes, with target dates for completion.

| Task | Task description | Expected completion (month/year) |
|---|---|---|
| Interoperability | EDR instance based on PygeoAPI that provides standards-based access to GeoGLoWS model outputs. | 07/2022 |
| Proof of concept | use of satellite data for bias correction | 06/2023 |
| app development in GEOGloWS toolbox | Bias correction using satellite data (water level) | 06/2024 |

## Resources

### Have all resources required to implement the Initiative's planned work in the 2023-2025 period been secured?

- Gap in financial resources

#### What is the estimated funding gap for the 2023-2025 period?

US $ 1'000,000

#### What actions is the Initiative taking to obtain the required resources?

While funding from scientific proposals provides funding for innovation and research, funding for service improvement, training, capacity development is needed. It may help to work on a resource mobilization plan once the new RM lead at the GEOSEC comes on board. The initiative could greatly benefit from a formal Secretariat or Secondee.

### Please list all financial and non-financial contributions to the Initiative (other than in-kind, voluntary participation by individual contributors) having a value of more than USD 50,000.

| Contributing Organization | GEO Status | Type of Resource | Value | Currency |
|---|---|---|---|---|
| NASA | United States | Financial | 3'500,000 | US |
| CNES | France | Financial | 1'000,000 | US |
| OGC | OGC - Open Geospatial Consortium | Financial | 35,000 | US |
| World Bank | The World Bank - The World Bank | Financial | 200,000 | US |
| NOAA | United States | Financial | 600,000 | US |
| Esri | Esri - Environmental Systems Research Institute, Inc. | Financial | 250,000 | US |
| Brigham Young University | United States | Other | 50,000 | US |
| ECMWF | European Commission | Data | | |

## Lessons from the 2020-2022 Period

### Were all planned activities for the 2020-2022 period implemented as expected?

No

#### Please describe which activities were delayed or not implemented and how has this affected plans for 2023-2025.

Of the four projects funded for GEOGloWS by NASA in 2018, only two are fully integrated in the Initiative activities. The research from these two projects were migrated to operational environments with implementations in various organizations and countries. The four projects are as follows:
Risk and Capacity Development for two Indian River Basins
Optimizing the Indus River Basin Irrigation System
AmeriGEOSS Cloud-based Platform for the deployment of GEOGLOWS (BYU): Dan Ames from Brigham Young University
Surface Water Changes over the Lower Mekong (inundation areas): Dr. Hyongki Lee from the University of Houston

The science and technology developed by Brigham Young University were implemented at ECMWF and constitute the core of the GEOGloWS ECMWF streamflow forecast service. The interoperability architecture of the streamflow service is being further developed to make it OGC compliant. The project from the University of Houston was advanced to the operational environment in NOAA through the following task: “Forecasting Inundation Extents using VIIRS and SAR Imagery with Streamflow Forecasts from NOAA’s River Forecast Centers/National Water Model and GEOGloWS.”

### Were there any key challenges faced by the Initiative in the 2020-2022 period?

Yes

#### Please describe.

Not having a formal secretariat is a challenge to maintaining fluid communication with members of the Steering Committee. The co-chairs have taken responsibility for the initiative's administration and have held the presence of GEOGloWS in GEO and non-GEO events. The GEO Secretariat and the regional AmeriGEO and AfriGEO assist from time to time with outreach activities. The initiative could greatly benefit from a formal Secretariat or secondee.

## Were there any impacts or changes to operations due to COVID-19?

No

## Please describe the key changes proposed for the 2023-2025 period, for example, new projects, new areas of focus, or adjustments to the activity governance.

Considering the role of GEOGloWS in Climate Change, GEOGloWS will be working with the Open Geospatial Consortium (OGC) to test data sharing standards and interoperability to improve the information value. GEOGloWS 2.0 will seek to become OGC compliant. Aquaveo, an SME partner in GEOGloWS, is participating in the 2022 OGC Pilots to contribute to best practices for GEOGLoWS + EDR and will deliver an EDR instance based on PygeoAPI that provides standards-based access to the GeoGLoWS model outputs. These open-source capabilities will benefit organizations and GEO member countries as they can be freely adopted.
During the period 2019-2022, The National Centre for Space Studies (CNES) led the improvement of the global network of water elevation data over rivers and lakes in preparation for the SWOT data. GEOGloWS 2.0 will be using this satellite data from more than 12,000 virtual stations to develop the bias correction needed to convert the global streamflow forecast into a local forecast. The use of satellite data will be an essential contribution to areas in which in-situ monitoring doesn't exist or is limited in the number of stations.
GEOGloWS seeks to accelerate sustainability research and innovation by minimizing the cost and time required to acquire and analyze large sustainability datasets. We are exploring possibilities with Cloud providers to establish collaboration so that organizations have the possibility to experience the benefits of the streamflow forecast service through the cloud environment.
GEOGloWS will continue expanding its activities to include flood map inundation using the FIER (Forecasting Inundation Extents using REOF) to perform hindcast/forecast of inundation extents based on a correlation between historical water levels (or streamflow) and inundation extents derived from satellite imagery, such as Sentinel-1 SAR. analysis). These methodologies will be made operational in the GEOGloWS toolbox.

Governance: We need to establish a Secretariat who maintain better engagement with members of the Steering Committee. We also need to renew some of the members as some are not longer with the sponsored institutions.

## Does the Initiative have outputs (products, services, etc.) available to users now, even if only on a pilot or testing basis?

Yes

### Please provide any available information describing this usage (for example, user statistics, results of user testing) and/or feedback from users (for example, user comments, evaluations).

- no answer given -

### Please provide supporting documentation if available.

- no supporting documents provided -

## Do you have evidence of any impacts that have occurred in part as a result of using the outputs of the Initiative (for example, policy decisions taken, behaviour changes by users, risks mitigated)?

Yes

### Please provide examples, with evidence where available.

In 2020, the National Electric Energy Company of Honduras (Empresa Nacional de Energía Eléctrica: ENEE) used data from the GEOGloWS ECMWF streamflow forecast service to reduce loss and damage in the Sulla Valley. Equipped with forecasts, ENEE made controlled water discharges from a reservoir between two significant hurricanes: category 4 Hurricane Eta on 2 November 2020 and Category 5 Hurricane Iota on 16 November 2020. The Earth observation-based analysis was also shared with the country's National Disaster Risk Reduction agencies, informing decisions on community evacuations. The damage to Sula Valley was considerably reduced by the decisions made by ENEE based on its EO enhanced analysis. Compared to the estimated economic losses caused by Hurricane Mitch (Category 5) in 1998 (US $3,793.6 million), the combined losses of Hurricanes Eta and Iota (US $2,171 million) were reduced by 40%. Considering that El Cajón Dam is the only structure capable of controlling the massive volume of runoff (39% of total water discharge) to the Sula Valley, ENEE's reservoir management made a significant impact during the two hurricanes using the GEOGloWS ECMWF Streamflow Forecast service. This was a collaborative effort with AmeriGEO.

In January 2022, Cyclone Ana hit Malawi, which caused severe flooding across the country. Thanks to resources that included the GEOGloWS-ECMWF streamflow forecast service deployment and cooperation with local authorities and international partners, losses and damages were limited. The integrated CBFEWS system combines real-time data from telemetry sensors and forecasted data obtained from the GEOGloWS-ECMWF streamflow services to provide timely and reliable forecasts and flood warning information to the vulnerable communities across the eight flood-prone districts. On 24 January 2022, Cyclone Ana lashed the Southern and Central Districts of Malawi, bringing strong winds and heavy rains to an area already suffering from floods due to the rainy season. The Southern districts of Chikwawa, Phalombe, and Nsanje were the worst affected, with over a million of the population at risk. According to the Government of Malawi, the Department of Disaster Management Affairs (DoDMA), about 37 people were reported dead, 22 missings, and 158 injured as of 31 January. The flooding affected over 193,558 households and destroyed over 740 hectares of croplands, pushing the already vulnerable communities into food insecurity in the coming months. This was a collaborative effort with AfriGEO.
https://earthobservations.org/geo_blog_obs.php?id=546

### Please provide supporting documentation if available.

- malawi_cbfews_geoglows_ecmwf_integration.pdf (link)
- use_case_1_geoglows_streamglow_forecast_service_in_honduras.pdf (link)

## Have there been any internal or external reviews or evaluations of the Initiative since 2019?

No

## Please indicate any GEO Work Programme activities with which you have ongoing collaboration.

- AFRIGEO - African Group on Earth Observations
- AMERIGEO - Americas Group on Earth Observations
- EO4DRM - Earth Observations for Disaster Risk Management

## Please indicate any additional GEO Work Programme activities with which you would like to establish new collaborations.

- AOGEO - Asia-Oceania Group on Earth Observations
- EO4EA - Earth Observations for Ecosystem Accounting
- EO4WEF - Earth Observations for the Water-Energy-Food Nexus
- GEO BON - GEO Biodiversity Observation Network
- GEO-EV - GEO Essential Variables
- GEOGLAM - GEO Global Agricultural Monitoring
- HUMAN-PLANET - GEO Human Planet
- GEO-MOUNTAINS - Global Network for Observations and Information in Mountain Environments
- BLUE-PLANET - Oceans and Society: Blue Planet
- GEO-VALUE - Understanding the Impacts and Value of Earth Observations

# Stakeholder Engagement and Capacity Building

## Are there specific countries or organizations that your Initiative would like to engage?

Yes

### Please list these countries, regions or organizations.

Expand our engagement in collaboration with AfriGEO and AOGEO

### What are your plans to engage them?

Seek the support of the regional GEOs and GEO partners' projects.

## Does your Initiative engage users in the work of the Initiative (for example, consultation, testing, co-design)?

Yes

### Please briefly describe the Initiative's approach to engaging users.

GEOGloWS has leveraged activities within SERVIR, a joint venture between NASA and the U.S. Agency for International Development to engage government organizations in developing nations. GEOGloWS also leverage activities from the World Bank in Africa and Latin America, and leverage social media (Facebook, Linkedin, Youtube, VIMEO) outlets and the global GEO web page with blog publications. Participation in GEO events, including those from the regional GEOs; we leverage other organizations' events to showcase projects.
We organize training and capacity development activities in collaboration with GEOGloWS partners.

## Does the Initiative have a user engagement strategy or similar kind of document?

No

## Are there categories of users that are not represented at this time, but you would like to engage?

Yes

### Please list these user categories or regions.

Once we complete the activities related to interoperability, we expect to engage stakeholders from many sectors that can benefit from using the streamflow forecasting information.

### What are the plans for further engagement of users in the Initiative?

GEOGloWS works with multidisciplinary GEO partners and regional GEOs in Asia (AOGEO), Africa (AfriGEO), and the Americas (AmeriGEO). GEOGloWS is seeking collaboration with cloud providers to enable organizations in developing countries to access computing resources to implement and customize GEOGloWS Toolbox on a local scale to access GEOGloWS hydrological forecasting and would allow organizations to improve safety and optimize operations free of charge for two years. Preliminary tests indicate that the cost per year of running the GEOGloWS toolbox and accessing the GEOGloWS-ECMWF streamflow forecast in the Cloud is relatively low, on the order of ten thousand (US)/year.

## Does the Initiative have a documented capacity development strategy?

Yes

### Please upload it.

- no supporting documents provided -

## Are there any commercial sector organizations participating in this Initiative?

Yes

### Please list the commercial sector organizations.

| Organization name | GEO Member/PO/... | Country in which the organization is based | City in which the organization is based |
|---|---|---|---|
| Esri | United States | United States | Seattle |
| Aquaveo | United States | United States | Provo |
| Mineros | Colombia | Colombia | Medellin |
| ENEE | Honduras | Honduras | Tegucigalpa |
| EPAGRI | Brazil | Brazil | Santa Catarina |

## Are there opportunities for commercial sector uptake of the outputs of the Initiative?

Yes

### Please describe these opportunities.

GEOGloWS has recently developed capabilities that provide standards-based access to GeoGLoWS-ECMWF (EDR) model results. These capabilities are based on OGC's Environmental Data Retrieval (EDR) API service using PygeoAPI. (https://pygeoapi.io). This specification addresses two fundamental operations; discovery and consultation. These new capabilities will make it possible to integrate a large amount of heterogeneous data and develop simulation models considering socio-environmental interrelationships in parallel. The integration offered by these capabilities makes GEOGloWS an essential information service in areas where there may be a demand for knowledge about possible data interrelationships.

### Is there already commercial uptake occurring?

Yes

### Please describe the nature of this uptake and the relevant commercial sector organizations.

1. Mining: https://mineros.com.co/en/ This is a company dedicated to responsible production and exploration of gold, with more than 47 years of experience. Its headquarters are located in the city of Medellín, Colombia, and have operations in four different countries including Colombia, Nicaragua, Argentina, and Chile. Mineros use GEOGloWS for the planning of extraction operations and in compliance with environmental restrictions. Trends of inflows and water levels are analyzed to generate alerts in the operations.

2. Energy Production: Empresa de Energia Electrica (ENEE) http://www.enee.hn/ Since Hurricane Eta and Iota, ENEE is using GEOGloWS information to manage the resource for electricity generation in Honduras. Testimonial : https://vimeo.com/564820620

3. Flood Risk Preparedness and Response in the City of Tel Aviv, Israel. https://www.youtube.com/watch?v=j_UxUk6z7aQ

4. Tourism: https://vimeo.com/564822331 municipalities and small businesses around Lake Atitlan, Guatemala use the information provided by the Global Nature Fund which accesses GEOGloWS information to forecast water quality in the lake.

5. Aquaculture: EPAGRI a public research and rural extension company in southern Brazil, uses GEOGloWS as input for a hydrodynamic model to support the aquaculture industry in Santa Catarina, Brasil. https://ciram.epagri.sc.gov.br/rios-online/

### Are there opportunities for further commercial sector participation in the Initiative?

Yes

#### Please describe these opportunities.

The core innovation of the GEOGloWS effort is a combination of modern computing technologies with hydrologic sciences and satellite datasets enabled by web services and cloud computing. The GEOGloWS ECMWF Streamflow forecasting service runs on ECMWF's private cloud computing infrastructure. It has run 24-7 without interruptions for the last 2 years. Recently, the data service has averaged around 30 thousand requests for data each week. The data services, including the ongoing forecasts and historical simulation data results, are currently housed in the ECMWF cyberinfrastructure. It would be optimal to have this replicated by a cloud provider and be optimized.

Over the past five years, Esri has been collaborating with Brigham Young University (BYU), the European Center for Medium Range Weather Forecasting (ECMWF), the GEO Global Water Sustainability (GEOGloWS) program, and others on a vision to provide global streamflow forecasts and historic flow through easy-to-use web maps. Esri has implemented the service within the ArcGIS Living Atlas, and users with Esri licenses can access the service directly from the package.
Esri has been working on the cartography in Alignment with Industry Standards. There is a precedent pattern already in place from NOAA and GloFAS for the progression of colors from low (yellow) to high flood risk (purple). This layer is also offered within a web map that contains two customized vector tile base maps created from the World Terrain Reference Local Language and Dark Gray Canvas Base, two of Esri's signature base maps. The base map layers were customized with Esri's Vector Style Editor, allowing users to make custom modifications to these maps and then save them to their organizations and share them publicly.

### Does the Initiative have a plan for commercial sector engagement?

No

## Governance

### Please describe the roles of each of the key leadership positions, as well as any team structures involved in day-to-day management.

The co-chairs are Dr. Phillip Maisongrande from the National Centre for Space Studies (CNES-France) and Dr. Angelica Gutierrez from the National Oceanic and Atmospheric Administration (NOAA- US).
There are three working groups who lead research, outreach, and capacity development activities under their projects.

### Is there a steering committee or other governance bodies that advise the Initiative but are not involved in day-to-day management?

Yes

#### Please describe the roles of each body. If there are multiple governance bodies, please describe the relationships among them (such as through a governance structure diagram).

The GEOGloWS Steering Committee comprises individuals from both Country Members and Observers. The Steering Committee is led by two Co-Chairs (NOAA and CNES), who carry the duties of the administrative Secretariat, including one nominated and selected from within the ranks of the Members and the other by USGEO. The GEOGLOWS Steering Committee convenes once per year in person and/or via teleconference, with logistics arranged by the GEOGloWS Co-chairs/Secretariat on a six-month basis.

The current members of the Steering Committee are:
Dr. Nagaraja Rao Harshadeep (Harsh) - World Bank;
Dr. Toshio Koike, Director of the International Center for Water Hazard and Risk Management under the

auspices of UNESCO (ICHARM) - Japan;
Dr. Selma Cherchali Centre National D'Etudes Spatiales CNES - France;
Dr. Peter Salamon Directorate-General Joint Research Centre Disaster Risk Management Unit. - European Commission;
Dominique Berod, M. Sc., PhD. Head a.i. of the Earth System monitoring Division at the World Meteorological Organization (WMO).

- no supporting documents provided -

### What methods does the Initiative use to communicate with its participants?

- Email / e-newsletters
- Website
- Regular events

### Please describe the key risks that could delay or obstruct the completion of the planned activities and outputs of the Initiative, along with any actions taken to mitigate these risks.

| Description of the hazard | Description of the possible impacts | Scale of impact | Likelihood of occurrence | Mitigation measures |
|---|---|---|---|---|
| Loss of cochairs funding | GEOGloWS cochairs have carried with the Secretariat's responsibilities and have set the initiative's strategic direction. Activities are presented and discussed with the Steering Committee, but this occurs yearly, so cochairs rely on the few Steering Committee members who actively engage in the activities' decisions. Cochairs make frequent decisions based on their experience, knowledge, and consultation with the technical groups. | Severe | Not very likely | GEOGloWS needs to implement a more robust Steering Committee, ensuring the members have a stake in the GEOGloWS activities. Cochairs will seek funding to establish a formal Secretariat for the Initiative that provides the needed support for outreach and communication activities. |

### What methods are used by the Initiative to monitor its effectiveness?

- Informal discussions with users / beneficiaries
- Consultations or events

### Would the Initiative be interested in assistance from the GEO Secretariat for developing an impact plan?

Yes

### How are the results of the monitoring and evaluation activities shared with participants and the wider GEO community?

GEOGloWS did not participate in the mid-term evaluation due to the lack of bandwidth to submit responses to the survey. However, we have taken the general findings and applied corrective measures as needed.

### Are any monitoring or evaluation activities required by funders/contributors?

No

## Participants

### Please list the active individual participants in the Initiative

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## Other information

### Please provide any other comments or information that was not included in the previous sections, but you would like to appear in the Implementation Plan.

"Additional clarification on the cloud-based nature of the GEOGloWS streamflow forecast service would be helpful along with existing connections with the GEO Knowledge Hub": As EO data increase in frequency, resolution, and availability, there is a growing need within the earth science community for flexible analysis tools that empower users and developers to explore, analyze, and model big data in a software-as-a-service “cloud”

environment. A collaboration among NASA, NOAA, and GEOGloWS partners, has developed a prototype open-source software system called the GEOGloWS Toolbox to meet this need. The GEOGloWS Toolbox includes a collaborative web application development and management platform, the GEOGloWS App Warehouse, and several modular web applications for discovering, visualizing, and analyzing EO and locally collected water data to support on-the-ground decision-making for flood management, drought preparedness, food security, and energy planning. The GEOGloWS Toolbox was developed to overcome storage capacity limitations, processing speed, transmission bandwidth, and platform dependency associated with desktop computing. Data are provided to the GEOGloWS Toolbox web apps from several data sources, including the Global Earth Observation System of Systems (GEOSS) data broker (Nativi et al., 2013), the European Centre for Medium-Range Weather Forecasts (ECMWF) Global Streamflow Services (Qiao et al., 2019; Sanchez Lozano et al., 2021), WaterOneFlow data services from local government agencies (Valentine et al., 2007), and NASA Earth Observing System Data and Information System (EOSDIS) Distributed Active Archive Centers (DAACs). Combining data from various data sources with their distinct and often incompatible file formats and data structures into usable, functional, decision support tools for local and regional water managers is the hallmark of the GEOGloWS Toolbox effort. New web apps for workflow-based hydrologic modeling and water level analysis will be added to the GEOGloWS Toolbox (2022-2025) based on existing tools developed by the National Center for Space Studies (CNES France) and our software development partners, Aquaveo, LLC and Hydro-Engineering Solutions.
Documentation of this development is already available through the GEO Knowledge Hub, the GEO repository.

Lastly, clarification on long-term funding sustainability and any associated risk factors with identified funding gaps can be added to the IP to explain the current state and any future challenges:
The data services, including the ongoing forecasts and historical simulation data results, are currently housed in the ECMWF cyberinfrastructure. We rely on the contribution of ECMWF to provide the service. It would be optimal to have the streamflow forecast replicated in the cloud and optimize its use.

Regarding the following question: "The IP did list existing collaborations across the GWP and potential future collaborations; however, there was no place in the template to describe these planned activities and future goals. If this is available, it would be helpful to include it as supplemental information and other relevant links."
GEOGloWS is one of the few operational services within GEO, and we have been working on the interoperability aspect of the service. For GEOGloWS to collaborate across the GWP, these activities must go through the same process and establish interoperability within their services/data/products.

- no supporting documents provided -

## Co-Editor Management

### List of co-editors for this initiative

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