(Draft)

March 31, 2022 report on actions to address the recommendations from the GEOSS Water Strategy Report January 12, 2022

(Inputs invited from all IGWCO members)

Compiled by
Integrated Water Cycle Observations (IGWCO)
Community of Practice (CoP)
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Appreciation is also expressed to the many other people who provided inputs to these regular updates including members of the IGWCO CoP.

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Introduction:

This report is one of a series of updates prepared by the Integrated Global Water Cycle Observations (IGWCO) Community of Practice (CoP) to outline the steps being taken with regards to recommendations in the GEOSS Water Strategy (GWS) and the overall status of the implementation of the Strategy. The Group on Earth Observations System of Systems (GEOSS) Water Strategy (GWS) was released in 2014. Since then periodic updates have been provided to recognize advances in implementing the Strategy and to reflect the changing context within GEO and other agencies as new program structures emerged. It also allows the authors to cull the recommendations for those which are completed or unlikely to be carried out within or influenced by the implementation team.

The recommended actions from the GWS have served as a focus for water initiatives and activities in the Integrated Global Water Cycle Observation (IGWCO) Community of Practice (CoP), Group on Earth Observation Global Water Sustainability (GEOGloWS), Committee on Earth Observation Satellites (CEOS), and Global Terrestrial Network – Hydrology (GTN-H). In terms of CEOS activities the principals at the recent CEOS-SIT 35 meeting reviewed their inputs to these recommendations and concluded that, from its perspective, the CEOS responses are now complete.

The IGWCO CoP is committed to providing periodic updates on the progress in addressing GWS recommendations. A mid-term report was developed for June 2020 which gave a more comprehensive accounting of the various projects. This report identifies those activities which can be considered complete; those which may have gone beyond the capabilities and mandates of groups contributing to the response to GEOSS Water Strategy and which ones still are looking for an appropriate leader. In cases where the IGWCO CoP and the implementation team lacks access to resources and/or expertise the recommendation will be passed to a body that is more capable of addressing the issues and producing the results

desired by the GEOSS water community. Since the completion of the GWS Report in 2014 the structure of GEO has evolved. The GEOGloWS Initiative has developed and taken over a number of the GEO Water activities. The leadership of GTN-H has changed to the International Centre for Water Resources and Global Change (United Nations Educational, Scientific and Cultural Organization [UNESCO] category 2 centre hosting the Secretariat of the German Intergovernmental Hydrological Programme of UNESCO (IHP)/Hydrological and Water Resources Programme of WMO (HWRP) German national committee). Within the Committee on Earth Observation Satellites (CEOS) a number of new experts and priorities have replaced those present when the report was being written. In addition, GEO has modified its program framework and terms like Societal Benefit Area (SBA) are no longer used. Initiatives and flagships as documented in the current GEO Work Plan are the foundation for the GEO Programme and to the extent possible these updates refer back to the work plans for the GEO initiatives.

This body of the report is divided into three sections.
Section A: Recommendations which require action (9 recommendation)
Section B: Recommendations for which action has been initiated but they must be monitored to ensure it meets the intent of the recommendation (17 recommendations)
Section C: Recommendations which should be transferred to a willing agency that is better equipped in terms of resources and expertise to take on the effort. (14 recommendations)

The 17 recommendations that have been addressed by the Implementation Team or by agencies and are no longer under consideration for further action are listed in Appendix A. Appendix B includes a list of acronyms.

The primary leads for responses to these recommendations have been CEOS, GTN-H, and GEO (through its GEO Water initiatives primarily GEOGloWS but also including AquaWatch, and the IGWCO CoP). A number of the actions included here are also part of the GEO Work Plan for 2020-2022. The GTN-H actions are now being tracked and inputs have been drawn from the GCOS sponsored 9th meeting of the GTN-H Panel.

In reality, the resources available for addressing many of these recommendations are only a fraction of what would be required to fully address the

recommendations. Consequently, the focus of this discussion is on recognizing the progress that has been made and try to see what could be reasonably done to move toward the goal implied by each recommendation within these resource constraints.

The recommendations address the following areas of concern:
EUE - Enhancing User Engagement
DAS - Expanding Data Acquisition Strategies
SDA - Advancing Satellite Data Acquisition
SIDA - Strengthening In Situ Data Acquisition
RPD - Encouraging and Conducting Research and Product Development
DSS - Facilitating Data Sharing and Common Standards
ECD - Expanding Capacity Development

A new numbering system is introduced for tracking purposes. The first letter (A to D) indicates the status of the recommendation. It is followed by a number which indicates the recommendation order. This is followed by the three or four letter indicator for the area of concern (see the listing above). In parenthesis the number of the recommendation from the GWS is given to connect this new listing with the listings in the original GWS report and the previous updates.

Section A: Recommendations requiring Further Action:

This section includes those recommendations which have been discussed but no group or individual has put forward a viable plan or taken responsibility for fully addressing the recommendation. These recommendations are identified as requiring action.

A1.EUE (A.1). A study of the methods for assessing the requirements and needs of users should be undertaken by identifying precisely how different observational data types and derived information products for end-user applications are used in decision-making. Based on the results of this study, an analysis should be carried out to design the best available integrated observing technology and data analysis systems that deliver data products in a form that satisfies the data-based information requirements for end-user decision-making processes. This would entail some well-designed workshops, with strong representation of the user community.

Relevant Actions and Plans: A Stakeholders meeting to examine data requirements is seen as an opportunity to gain insights into how different data are

used in decision-making. The GEOGloWS Essential Water Variables (EWVs) exercise and the GEO Water-Energy-Food (W-E-F) Nexus Community Activity can both contribute to this goal. Discussions regarding a stakeholders meeting have been held with Goddard Earth Sciences Data and Information Services Center (GSFC DAAC) experts, with users and stakeholders in the U.S. portion of the Red River Basin, with experts at Agriculture and Agri-Food Canada, and with the Global Water Institute to assess applications in the Saskatchewan River Basin. Although interrupted by COVID, this discussion is continuing.

Recommendation: This is an important area of development, especially for this phase of GEO, and it is anticipated that this GEO connection will remain with both GEOGloWS and the EO4WEF Community Activity and other energy and water initiatives. The possibility of holding a virtual stakeholders meeting should be explored. Developments in this area should also be linked to the World Climate Research Programme (WCRP) Grand Challenge on Water for the Food Baskets of the World, for which GEWEX is the lead.

Status: Action Needed

A2.EUE (Merger of former A.6 and E.12): A review of the water resource managers' needs should be undertaken to gather water cycle information related to extreme values. This would include the needs for data to assess changes in the frequency and probability distributions in the extremes in water-related variables and parameters, especially those that impact the availability of freshwater resources. Data collection and information systems should be assessed to ensure these data are available for research activities.

Relevant Actions and Plans: Terms of Reference for a study of extremes were introduced at a recent and GEOGloWS and IGWCO CoP meetings. A proposal for a paper addressing extremes paper to be developed was adopted at the second annual GEOGloWS and IGWCO meeting in 2018. GEOGloWS agreed to host the effort. In a separate effort, papers on precipitation extremes have been developed based on studies of the satellite data record. More recent discussions within GEOGloWS indicate that this project should be merged with the GEOGloWS EWV activity and treated as part of that initiative.

Recommendation: Given the possible link between discussions on extremes and EWVs, the pros and cons of merging Recommendation A.5 and A.6 should be reviewed, possibly by the Task Group mentioned under Recommendation A.5. In

addition, the principals from both studies should be consulted before making a decision.

Status: Action needed.

A3.EUE (**A.8).** GEO should develop a strategy to ensure that future water cycle integration activities develop, implement, and utilize acceptable techniques to quantify uncertainty in various products delivered to end-users, and engage with these end-users to provide them with information on the use and understanding of these supplemental error and uncertainty products to a risk-based approach to water management.

Relevant Actions and Plans: GEO could advance this activity by compiling and disseminating materials to facilitate efforts to assess the uncertainties in different data products. NASA land data assimilation systems and the Land Information System have developed methods for assessing uncertainties that could help to address this issue. However, no action has been taken on this recommendation by water activities within GEO, suggesting that this is not an urgent priority for GEO.

Recommendation: If this is a priority for the research community, it might be more appropriate for WCRP to oversee and promote the action. More discussion is needed.

Status: Action needed to assess the future of this specific recommendation.

A4.SIDA (D.1) In situ observational networks (for EWVs) should be strengthened to ensure that the required data are collected and made freely available to the international community. GEO and WMO members should engage in assisting countries to assess gaps in their national networks and to develop plans for addressing those gaps. As an operational research activity, approaches should be studied to take advantage of supplemental observational networks (for selected variables) that are maintained by volunteers, research networks, education systems, and local governments.

Relevant Actions and Plans: Through GTN-H representation, GEO Water has been contributing to a GEO in-situ data committee. **<Is there actually someone on this committee representing IGWCO?>** While the in-situ committee reports to the GEO Secretariat, it appears that they have not produced reports or

recommendation that relate to GTN-H needs. It may be feasible to launch a collaborative study with GEO, GEOGloWS, IGWCO COP, WMO, UNESCO, and GTN-H to explore the potential of observations from volunteers, research networks, education systems, and local governments. However, it would not seem feasible to undertake such a study without additional resources. On the other hand, the objectives of the new Knowledge Hub would seem to require access to in-situ data, and it may stimulate a shorter-term action within GEO. GTN-H is working on a discovery service to support WMO's WHOS program and GEOSS.

Recommendation: Without stronger interactions with the GEO in Situ Committee water-related activities, it appears that relevant action is not likely in the near future. A more productive approach would be to ask **GTN-H?** to undertake the development of the Terms of Reference for a study to be undertaken by other interested groups (GTN-H, WMO, WHOS, GCOS, GEO, GEOGloWS, GEMS/Water).

Status: Action required.

A5.SIDA (D.3). National precipitation gauge networks should be strengthened and all measurements should be collected, archived, and made available to the international community. Special attention should be given to strengthening the gauge networks at high latitudes where more accurate snowfall information is needed for evaluating changes arising from climate change. A study should be undertaken of approaches to take advantage of the supplemental gauge networks that are maintained by volunteers, education systems, and local governments.

Relevant Actions and Plans: GEOGloWS indicated an early interest in this effort but has not included it in the 2020-2022 Work Plan due to lack of funding for the activity. GEOCRI, GEOGloWS, IGWCO CoP, WCRP Climate and Cryosphere (CliC), GEWEX, WMO, and GTN-H should consult to determine the state of cold region precipitation measurements and to propose enhancements for cold region precipitation databases.

Recommendation: Through the Global Precipitation Climatology Centre (GPCC) and the National Snow and Ice Data Center (NSIDC), GTN-H should work jointly with GEOGloWS, WCRP (CliC) and GEOCRI to strengthen cold region precipitation observational networks and data archives. GPCC has indicated they would be willing to have a explore this with the Global Cryosphere Programme.

Status: Action required.

A6.ECD (G.4). GEOGloWS, IGWCO CoP (and other groups) should undertake a feasibility study to determine how Earth observations can be integrated with other data types to produce a system for monitoring water use.

Relevant Actions and Plans: Water use is an input for the monitoring system for SDGs. GEOGLOWS has introduced a regional water use product as one of its deliverables. In addition, FAO operates a water productivity programme (FRAME), UNESCO-IHE is developing a water use model, and SWFP's COMPASS is assessing ways to estimate water use. In addition NASA has funded several GEOGloWS studies aimed at improving the information and data available to users making decisions related to water use. These include a study of Earth Observations to improve the management the reservoirs in the upper Indus River by improved snowmelt estimates, developing a system for monitoring Surface Water Storage Changes over the Lower Mekong by integrating various satellite products with MODIS data and an overview of the water resources assets in India and their changes over time. The FAO AQUASTAT Centre has been added to the GTN-H federation of data centres.

Recommendation: GEOGloWS should be encouraged to explore the needs and capabilities for producing a global water use product based on its regional efforts. Collaborations with other programs such as UNESCO and the FAO FRAME programme should also be explored. This task should be merged with B.5 (DAS B.1).

Status: Action required.

A7.ECD (G.5). [Not in the original GWS report] The GEOSS Water Strategy recommendations should be mapped with the efforts of WMO Hydrology activities to identify specific capacity building areas where collaboration is possible and to focus on coordinated standards and systems. Similar actions should be taken to coordinate with ESA, NASA, and COSPAR.

Relevant Actions and Plans: A preliminary discussion on the possibility of mapping these recommendations against WMO plans was held with Dominique Bérod of WMO.

Recommendation: Terms of Reference for this analysis should be developed through discussions with WMO. A sponsor to support the cost of this mapping should be sought.

Status: Action needed.

Section B: Recommendations where commitments have been made and the follow-up actions need to be monitored:

This section includes those recommendations which are being addressed by a group or individual and are being monitored to ensure that they are progressing toward the goal outlined in the GWS recommendation.

B1.EUE (A.2). GEO Water should develop and launch a continuous process to identify, articulate, and further refine user needs in the various water communities from the local scale to the global scale. The process should build upon existing work by GEO such as the Water SBA Needs report; utilize existing draft taxonomies of user types such as the one developed by the former GEO User Interface Committee; interact with communities of users in professional organizations such as the International Water Resources Association and with UN agencies such as UNESCO and United Nations Environmental Programme (UNEP); identify needs and water-related information from other relevant GEO focus areas, networks, projects, and Work Plan activities; publish findings regularly; and prepare a sustainability strategy.

Relevant Actions and Plans: A component of this activity has grown into the EWV activity. At a recent GEO Plenary, GEOGloWS committed to GEO that it would undertake the development of a consultative process for the EWVs activity. ICWRGC plans to host a virtual workshop on in-situ data in late 2021 or early 2022 related to EWVs and other applications. <Plans have not emerged – what can we do differently?> CEOS also discussed this activity at its November 2018

Freshwater from Space Workshop. GTN-H has also committed to developing inputs to the EWVs and liaising with WMO on its rolling review of user requirements.

Recommendation: This activity is progressing in GEO with a GEOGloWS lead and it should be encouraged. In an update of the strategy, this overall goal should be adjusted to reflect the focus on EWVs.

Status: Monitor progress and support as appropriate.

B2.EUE (A.3). A global-scale coordinated initiative should be developed and implemented to advance the future use of satellite remote sensing for water quality applications. Factors such as the community requirements for continuity of existing satellites, development of new and improved sensor/platform technologies, algorithm development, calibration/validation activities, and improvements in open and free data accessibility should be part of this initiative.

Relevant Actions and Plans: AquaWatch is taking the lead in developing an operational system for making satellite-based information available to users. AquaWatch continues to work toward the delivery of an information system for users. CEOS also produced a report on this action, through a report addressed to GEO (see Recommendation C.10) with some suggestions. Other assessment activities on a regional scale with the potential to assess water quality are being planned as pilot projects under the SWFP COMPASS Project. The essential water quality variables will be part of the GEOGloWS EWV review. They are therefore part of the delivery in this recommendation.

Recommendation: AquaWatch should continue to deliver on its operational global system.

Status: Monitor progress and intervene as necessary.

B3.EUE (A.4). An inventory of current data services supporting GEO Water should be developed. This inventory should include information on the characteristics of available services and their data needs.

Relevant Actions and Plans: Initially, within GEOGloWS a deliverable was formulated to address this recommendation. However, in discussions with NASA

GSFC DAAC and associates of the European Union (EU) and European Space Agency (ESA) Copernicus programme, it was determined that there are online inventories currently available that address this need and the requirement really seems to be distributing this information more effectively to users. GTN-H is planning to develop a maturity matrix that could inform users about the characteristics and capabilities of data services of the federated data services as well as other services supporting GEO, GCOS and WMO activities.

Recommendation: GTN-H's plan to develop a maturity matrix is welcomed. On the larger scale (all data services) there is a potential duplication of efforts that should be assessed. A small team, possibly convened by the GEO Secretariat and including representation from CEOS, GTN-H, GEOGloWS, IGSCO CoP, GSFC DAAC, ESA and other organizations such as UCAR hosting relevant data services should assess the extent to which existing inventories address this need and how these inventories could supplement the GTN-H maturity matrix.

Status: Encourage GTN-H to proceed with its maturity matrix and monitor their progress,

B4.EUE (A.7). GEO members should support the development of integrated water cycle solutions in order to meet the needs of water resource managers and other end-users by translating water cycle observations into actionable products.

Relevant Actions and Plans: The Japanese government is supporting the University of Tokyo to develop the decision-making component of the Asian Water Cycle Initiative (AWCI). This activity could be supplemented by SWFP (which has developed a solutions lab concept through a research centre in Bengaluru, India), the National Oceanic and Atmospheric Administration (NOAA) (National Climate Program Office), and NASA, which also supports work related to the closure of the water cycle and solutions to water management issues through their applications program. In addition, GEWEX, GCOS and GTN-H are contributing to a study of consistent monitoring of the global water cycle. (Further clarity in the wording of the recommendation would help GEO members understand the benefits of this activity and how they could engage in it.)

Recommendation: The plans and progress on this work should be reviewed and an assessment made to explore whether this fits best under GEO or WCRP, and whether the groups working on it need to be expanded. The recommendation is formulated as a general guidance rather than a specific task. It needs a specific user

community and some specific project funders. If it remains in GEO, it should be rewritten as an actionable recommendation and efforts should be made to secure sponsors.

Status: Monitor progress and support as appropriate.

B5.DAS (B.1). An integrated monitoring system should be developed to track consumptive and non-consumptive water use and its changes using satellite and in situ observations along with models that relate water use to land cover and demographic information.

Relevant Actions and Plans: This recommendation has become more important as a result of Target 6.4 of the Sustainable Development Goals (SDG) and its focus on water productivity. In its 2020-2022 Work Plan, GEOGloWS adopted an action to develop a water use product for South America. The question of scaling up to the global level will still remain. In a related SWFP study, COMPASS will also assess water use as part of its national water assessments. The UNESCO Delft Institute for Water Education (IHE) has already developed a preliminary global water use product that uses some data inputs. NASA projects that produce evapotranspiration (ET) products on a regional, national, and global scale also support this goal. GTN-H has expanded its centres to include the Food and Agriculture Organization (FAO) AQUASTAT database, which contains national estimates of water use based on its national reports. FAO operates the FRAME project on water productivity; it should also be coordinated with this activity.

Recommendation: The GEOGloWS activity related to this topic should be supported and encouraged. **<This item could be merged with A.6.>**

Status: Monitor progress and intervene if necessary.

B6.DAS (B.2). Based on the principles of participatory monitoring for assessing the state of groundwater and its changes, International Groundwater Resources Assessment Centre (IGRAC) should be encouraged to further develop the Global Groundwater Monitoring Network (GGMN). The project should be accelerated and it should be linked to the validation of remote sensing data. Special attention and support should be directed at developing a global hydro geodetic repository that provides additional groundwater data and information and that links directly to the GGMN.

Relevant Actions and Plans: GTN-H will continue to cooperate with IGRAC. Continued resource limitations, staff changes, and reluctance in some countries for data sharing makes progress on this recommendation challenging.

Recommendation: GTN-H continues to monitor and report progress on this issue. No clear resolution of IGRAC's challenges is evident.

Status: Monitor progress and advise if necessary.

B.7.DAS (B.3). The Global Climate Observing System's (GCOS) participants should be invited to undertake a joint study with GEO to assess the current prioritization of observational and modelling efforts for water cycle variables as part of its support to the United Nations Framework Convention on Climate Change (UNFCCC).

Relevant Actions and Plans: At the 2018 GEO Plenary, GEOGloWS committed to developing a strategy for EWVs that will provide a basis for engaging GCOS in this action. A workshop on this topic was planned for 2019 but did not take place due to circumstances beyond GEOGloWS's control. GTN-H operates under the auspices of GCOS and will support IGWCO by obtaining further information of the status of the priorities for Essential Climate Variables (ECVs) in securing global water cycle variables for UNFCCC. GTN-H is leading an effort to develop a paper on consistent monitoring of the global water cycle in support of GCOS. Steps should be taken to ensure IGWCO is involved in the review of observational requirements for climate change monitoring. CEOS has also been engaged through its November 2018 Freshwater from Space Workshop. <No workshop report prepared>

Recommendation: Continue to press forward with this action through GEOGloWS and other GEO Water Initiatives, including IGWCO as well as partners, such as CEOS, GCOS and GTN-H.
<GTN-H activities supporting GCOS should be updated>

Status: Monitor progress and intervene if necessary.

B8.SDA (C.4). The coverage and quality of satellite observations should be improved to a constellation providing three-hourly (or more frequent) revisit times

over the entire globe by a combination of GMI/AMSR2-class multi-channel conically scanning microwave imagers and ATMS-class multi-channel cross-track microwave sounders. These instruments are identified because they provide input data for a wide range of applications.

Relevant Actions and Plans: These issues have been considered by CEOS and by the latest Decadal Survey. The METOP Second generation satellite series will host MWI and MWS radiometers, and JAXA is studying the development of an AMSR3 for launch on a future GOSat.

Recommendation: The deployment of these additional sensors should be supported and other space agencies should be encouraged to develop similar missions.

Status: Monitor and intervene or promote when appropriate

B9.SDA **(C.5).** Space-borne precipitation radar should be made operational and next-generation precipitation radar with advanced technology should be developed. The success of the Tropical Rainfall Measuring Mission precipitation radar demonstrated that space-borne radar observations are among the most valuable multi-purpose observations of precipitation. Although the Global Precipitation Measurement (GPM) Dual-frequency Precipitation Radar is expected to extend this result, a long-term plan is needed for using these radars operationally and a long-term commitment is needed by GEO members to ensure a continuity of supply for these instruments.

Relevant Actions and Plans: This issue has been considered by CEOS and by the latest U.S. Decadal Survey. The International Precipitation Working Group (IPWG) is preparing a white paper on satellite radars. The NASA Aerosols, Clouds, Convection, and Precipitation (ACCP) Decadal Survey study team has various satellite radars in its architecture study

Recommendation: Potential users should be consulted and if none are ready to be supportive, this recommendation can be closed. For example, the Global Precipitation Climatology Project; the producers of the current generation of high-resolution precipitation products (Climate Prediction Center morphing technique [CMORPH], Global Satellite Mapping of Precipitation [GSMaP], Integrated Multi-satellite Retrievals for GPM [IMERG]) and the precipitation community should be

invited to comment on the importance of such information for operational merged precipitation products.

Status: Monitor progress and intervene if necessary.

B10.SIDA (D.7). Efforts should be made to supplement the current network of snow-depth observations from selected manual climate-observing stations and global, daily snow-depth analyses with weekly satellite measurements of Snow Water Equivalent (SWE).

Relevant Actions and Plans: The EU EartH2Observe project developed sample SWE products. More recently, new SWE data are being available from the ICESat satellite. The NASA SnowEX field project has provided data that is allowing for calibration and validation, and more reliable intercomparisons.

Recommendation: IGWCO or GEOGloWS should identify an expert on cold seasons process to work with GEOCRI, WCRP (CliC), and GTN Glaciers and Cryosphere representatives to provide an assessment of current activities and to make recommendations on future needs.

Status: Monitor progress and intervene as necessary.

B11.SIDA (D.8). Given the many threats to groundwater quality that arise from salt water intrusion, seepage of contamination, nuclear waste, and fracking, among others, GEO Water should clarify the needs for groundwater quality data and develop a plan for collecting the required observations.

Relevant Actions and Plans: This work appears to be part of the mandate of IGRAC. It should be involved in developing a solution. National agencies such as the U.S. Geological Survey should also be involved. This action is currently addressed by the World Water Quality Alliance (WWQA) under the auspices of WMO and UNEP. IGRAC and the GEMS Water Data Centre for water quality, are both involved in this process.

Recommendation: GEMS/Water and AquaWatch should be invited to work with GEOGloWS and WWQA to review the need for groundwater quality data and to develop a plan to consolidate current (and historical) data in a database. Depending

on the availability of appropriate experts, this issue could be explored as part of discussions on EWVs.

Status: Progress on the Task should be monitored.

B12.RDP (E.3). Methodologies and best practices should be developed for using existing soil moisture in situ data to validate satellite measurements. More upscaling and downscaling studies are needed to validate results against in situ soil moisture measurements. A global-scale project bringing together in situ networks, satellite observations, and appropriate ancillary data should be launched to achieve this goal.

Relevant Actions and Plans: Tools for using in-situ data to validate satellite measurements are being developed for soil moisture at the Vienna University of Technology. Actions to merge satellite with in situ observations of water levels are also being undertaken by International Data Centre on Hydrology of Lakes and Reservoirs (HYDROLARE) and the Global Runoff Data Centre (GRDC).

Recommendation: Progress in these groups should be reviewed to determine if the intent of this recommendation has been met.

Status: Monitor progress in this area of research and application.

B.13. RDP_(E.8). The feasibility of establishing a monitoring system of artificial reservoirs should be developed. The end result of this review could be the use of current and planned data systems to provide a real-time monitoring system of the surface water in storage.

Relevant Actions and Plans:

Radar altimetry has been producing data since 1992 to the present and depending on the satellite series considered should be available until 2030. Through work supported by NASA, CNES and ESA, significant progress has occurred in the development of new radar altimetry products. New developments are now allowing wetland detection down to spatial scales of 10 km and river channel widths as small as 0.5 km wide.

It would be useful to cooperate with ICOLD, HYDROLARE and CNES and work toward a global inventory when SWOT Data become available.

This type of product could become part of the suite of COMPASS products being developed by the City College of New York. The European Commission's Joint Research Centre (JRC) and other groups have also developed tools for mapping reservoirs using Landsat data.

Recommendation: Given the potential for research breakthroughs with new altimeter products it is recommended that the range of products should be reviewed after SWAT is launched.

Status: Continue to monitor the development of new products.

B14.DSS (F.1). Institutions maintaining archives of water cycle variables should apply modern standards of open data stewardship. High-quality products require consistently processed, long-term datasets that are readily available, preferably including one version in the original coordinates (for example, swath-footprint for satellite data). As new quality-control procedures and algorithms are developed, these archives should be reprocessed to ensure that the community has ready access to consistently processed estimates for the entire period of record.

Relevant Actions and Plans: At its recent annual meeting, GTN-H reviewed its procedures to ensure that modern data capabilities are available. GTN-H is launching its plan for a new data discovery service which will introduce new standards for standardization and modernizing data systems to the most recent data service standards.

Recommendation: A meeting or workshop should be organized among GEO, WMO, GTN-H, and other interested organizations on the roles and status of ontologies, standards, and data sharing across all data centres. The terminology and standards used in generating climate data records and climate services have been documented (e.g., Su et al., 2018)[1] and could be a good starting point for future discussions on EWVs.

Status: Monitor progress and GTN-H actions.

B15.DSS (F.2). A set of standards or protocols should be developed for ET

[1] Su, Z., et al. (2018). An overview of European efforts in generating climate data records. *BAMS*. 349-359. doi: https://doi.org/10.1175/BAMS-D-16-0074.1

measurements, databases, and metadata, including FLUXNET and other tower networks. Tower operators providing data for research and operations should ensure they meet these standards and also make available sufficient metadata along with objective evaluations of their datasets. GEO members should provide long-term support to key stations in their countries to maintain a reference network for flux tower measurements.

Relevant Actions and Plans: FLUXNET has been invited to become a GTN-H data centre but it has not happened yet. GEWEX held a workshop on evaporation in October 2019 in Sydney, Australia that identified some measurement issues.

Recommendation: GTN-H leadership has made a commitment to investing more effort into recruiting FLUXNET as a data centre.

Status: Monitor GTN-H's progress.

B16.DSS (F.3). An international cooperation and coordination mechanism should be developed to advance the technical implementation of global sediment databases and data portals. This mechanism should include existing data initiatives and build on the GEOSS Common Infrastructure {now data services} as a framework for bringing together all relevant Earth observation data.

Relevant Actions and Plans: GTN-H together with the GEMS/Water Data Centre has started to contact existing data initiatives, e.g. the UNESCO International Sediment Initiative, in order to intensify the exchange of data and knowledge in this area. User requirements and applications (e.g. sediment flows into the oceans) for a global data set are still under discussion.

Recommendation: GTN-H should take the lead in consulting with AquaWatch and GEMS/Water to discuss strategies on how to coordinate international sediment databases.

Status: Monitor progress and intervene if necessary.

B17.DSS (F.4). A review of the WMO regulations on hydrometeorological data exchange should be undertaken to assess their effectiveness in enabling the exchange of data with the Global Runoff Data Centre (GRDC) and the Global Precipitation Climatology Centre (GPCC) and enabling the exchange of data

between countries. In addition, the practices of countries in disseminating data should be reviewed.

Relevant Actions and Plans: WMO and GTN-H are planning to undertake a review of regulations. This recommendation should be harmonized with their planned effort to ensure they are implemented within a larger policy context.

Recommendation: The GTN-H study plan and terms of reference should be passed to IGWCO so that they can ensure that their concerns about GPCC and GRDC practices are addressed.

Status: Monitor progress and provide inputs as opportunity arises.

B18.DSS (F.8). A priority should be placed on hydrometeorological forecasting capabilities and how to help the forecast community work more closely with agencies responsible for both in situ and space-based monitoring systems. Hydrometeorological forecasts are an essential component of extreme event forecasts such as floods and droughts.

Relevant Action and Plans: The NOAA National Water Center is implementing the U.S. National Water Model supported by development work at the National Center for Atmospheric Research. GEOGloWS has a major global flood prediction capability developed through Brigham Young University. Other centres have regional and national projects related to floods and droughts, including the University of Maryland, Princeton University, and the University of Connecticut. GEO has started to provide more coordination for these flood-related projects. Activities that are redundant to the Copernicus Global Flood Awareness System GloFas and WMO HydroSOS should be avoided and synergies (e.g. through Multi-Model-Ensembles) should be explored and promoted.

Recommendation: GEOGloWS will continue working with ECMWF and GloFas to deliver on this priority.

Status: Monitor progress and intervene as necessary.

B19.ECD (G.1). The use of ET products in international end-user decision-support tools through workshops and pilot projects should be expanded. This could be done

through the careful design of training modules and demonstration projects related to ET within the GEO Water capacity development activities.

Relevant Actions and Plans: An ET workshop was held at the World Bank in Washington, D.C. (circa 2016) and a number of recommendations remain to be acted upon. The importance of ET data is being clarified within the EWV framework. GEOGloWS has articulated deliverables that will help to address demand for ET data.

Recommendation: The needs for ET data services should be considered within the GEOGloWS EWVs activity and its capacity building activities.

Status: Monitor progress and intervene as necessary.

Section C: Recommendations which have been or will be transferred to other agencies to lead.

This section includes those recommendations which have been found to be beyond the scope of the IGWCO CoP mandate or its capabilities in terms of resource requirements for doing a thorough examination or ensuring a comprehensive outcome. When a specific willing implementing agency has been identified, the IGWCO CoP will work with that agency to gain its cooperation and understanding in leading the effort.

C1.EUE3 (A.5). An evaluation should be undertaken of the data holdings of global data centres to determine which centres have and make available data that can be effectively used to assess the magnitude and frequency of extreme events and the ability of global and regional models to simulate water cycle processes.

Relevant Actions and Plans: While GEOGloWS has started an activity related to extremes, it has a different focus than this recommendation. GTN-H could play a significant role through its federated data centres by collecting and highlighting data extremes for different variables. Furthermore, this recommendation could be a valuable service to the WCRP_'s research community dealing with Extremes. The planned GTN-H data network maturity index may be able to help locate data related to extreme events.

Recommendation: Given that actions on this recommendation have not advanced in a substantive way, it is recommended that WCRP, the primary beneficiary of this activity, be invited to take the lead in addressing it. Initially WCRP could be asked to advise on the parts of the activity that should be priorities.

Status: Action needed to engage WCRP in leading these activities.

C2.SDA (C.8). Plans should be developed for a mission optimized to measure cold season processes and variables from space drawing on experience with algorithms for cold season microwave measurements and cold season field projects.

Relevant Actions and Plans: CEOS has reviewed this recommendation and concluded that this problem is not of sufficient priority to merit further study. There was some concern within IGWCO CoP that more work was needed but a counter-argument has not yet been advanced. NASA has taken some steps to develop a cold region initiative with the ICESat and its related field campaign that address these recommendation's intent. ESA is in the process of studying an L-band synthetic aperture radar system on a Copernicus mission with a strong emphasis on cryospheric processes. Also, the ESA Copernicus Imaging Microwave Radiometer (CIMR) or Sentinel 11, is in development and after launch will be focused on polar regions. (More coordination with existing system may be needed.)In addition, the first of 2 Russian Arctic satellites has been launched into a Molniya orbit, providing geostationary-like coverage of the North Polar region.

Recommendation: This recommendation should be referred to WCRP (CliC) and GEOCRI with the suggestion that they form a small team to explore needs and opportunities.

Status: Action needed.

C3. SDA (C.9). Attention should be given to the further development of multi-channel satellite sensors that will be able to provide freeze/thaw patterns under different vegetation conditions.

Relevant Actions and Plans: CEOS has reviewed this recommendation and the status of freeze/thaw measurements from the Soil Moisture Active Passive (SMAP) mission and other missions. CEOS concluded that without a further statement of need, this recommendation does not need any further attention.

Recommendation: The ability to monitor soil moisture, ice content, and depth of the active layer (in freeze/thaw process) is needed at a scale of one kilometre to advance modelling and forecasting of land-atmosphere interactions of energy, water, and gasses and climate change impacts (both for numerical weather prediction and Earth system model applications). Furthermore, there appears to be no assessment of the extent to which ICESAT-2 launched on September 15, 2018 meets the needs of the community for enhanced cold season data products including freeze/thaw conditions and permafrost conditions. This issue should be referred to a task team involving the GEO Cold Regions Initiative (GEOCRI), WCRP, and others to assess the needs in more detail.

Status: Action needed.

C4.SIDA (D.2) A global observational network dedicated to clouds and water vapour should be established. This network should include high-calibre radiosonde stations (some collocated with Baseline Surface Radiation Network stations, others in critical areas lacking such data, particularly equatorial zones), GPS, and lidars. These observations should be freely available to the scientific community.

Relevant Actions and Plans: Some initial plans were developed under the GEO Water Societal Benefit Area (SBA) but these have not been carried forward. As a result of moving to GEO Phase II, the water vapour and cloud topic has received a lower level of attention within the GEO Water initiatives and community activities.

Recommendation: Given current priorities, this recommendation seems most appropriate for the WMO and its World Weather Research (WWR) programme. An invitation should be issued to WMO to take the lead in addressing this issue.

Status: Action required.

C5.RDP (E.1). Research on individual-sensor and multi-sensor algorithms, including precipitation algorithms, should be supported. Operationally useful estimates from individual sensors over complex terrain, icy/snowy surfaces, coast, and land (in general) are priorities that require substantial development work. Improved algorithms for the objective, optimal combination of precipitation observations from widely disparate sources must see continued research and development, potentially including assimilation approaches. Conversely, as an

additional initiative, combinations incorporating both observations and numerical model/reanalysis estimates should be supported. This action should particularly benefit polar and cool-season mid-latitude regions, since the sparseness of the in situ network has led to some investigators relying more on numerical model outputs than on observations.

Relevant Actions and Plans: While important for GEO, this issue would likely be best coordinated by World Weather Research Programme (WWRP) and an institution with the interest and resources to lead the activity.

Recommendation: The interest of space agencies in this activity should be clarified. WWRP should be approached to assess its interest in coordinating this activity.

Status: Transfer to WWRP.

C6.RDP (E.2). Advanced cloud and water vapour parameterizations should be developed for weather and climate models in tandem with new observational capabilities, with the goal of significantly improving their integrity and building confidence in the resulting model predictions.

Relevant Actions and Plans: Model development is needed to support these applications. A number of research labs and forecast agencies support these activities, such as ECMWF, NASA, NOAA, and many international research groups. Internationally, this activity falls within the remit of WCRP and the WWRP.

Recommendation: WCRP should be approached to assess its interest in coordinating activities on this topic.

Status: Action required.

C7.RDP (E.4). Work on radiative transfer models should be expanded. The spectral properties of soil samples should be analysed and reported back to a central body (e.g., the ESA Soil Moisture Climate Change Initiative). Moreover, vegetation information used in retrieval algorithms needs to be verified regularly on site. For this, vegetation observations are required at selected soil moisture stations to provide continuous assessments of the vegetation dynamics, which directly influence the soil moisture retrievals.

Relevant Actions and Plans: No action is planned by the IGWCO CoP and its partners on this issue. This issue would be best coordinated through a research programme like WCRP.

Recommendation: Encourage WCRP to take the lead in developing a strategy for addressing this need.

Status: Action required.

C8.RDP (E.5). High priority should be given to generating improved global soil texture maps in order to improve modelling and retrieval of soil moisture. Furthermore, a more concerted effort is needed to develop an integrated soil moisture product.

Relevant Actions and Plans: FAO is taking action to update their soil texture maps.

Recommendation: Assess FAO progress and ask it to take the lead for this recommendation.

Status: Action required.

C9.RDP (E.7). A dataset including the bathymetry of all surface water bodies around the globe should be developed, possibly under the leadership of UN Water.

Relevant Actions and Plans: There are indications that an initial product could be developed for the Surface Water and Ocean Topography mission (SWOT). GEOGloWS is also a contributor through the Centre National D'Etudes Spatiales (The French National Centre for Space Studies - CNES). Together with CNES, HYDROLARE is working on a bathymetry for selected lakes and reservoirs with the goal of determining seasonal changes and trends in the volume of lakes and reservoirs (for monitoring changes due to climate change and/or human influences)

Recommendation: Follow up with the Head of HYDROLARE, CNES and the Laboratoire d'Études en Géophysique et Océanographie Spatiales (LEGOS) for an update and a discussion on a future course of action. The Bathymetry data could also be used to enrich existing data bases such as those at HHYDROLARE.

Status: Action required.

C10.RDP (E.10). Priority should be given to research on the development of algorithms and new sensors to measure the water equivalent of snow on the ground under a wide range of vegetation conditions. Furthermore, it may be possible to design improved algorithms to more effectively utilize existing data sources.

Relevant Actions and Plans: Field measurements taken in preparation for the ICESat mission could help to address this problem. WMO's Global Cryosphere Programme is preparing a report on aspects of this issue.

Recommendation: This work is best carried out in a research environment. WCRP, GEOCRI, and WMO's Global Cryosphere Programme should be invited to help address this issue and coordinate these activities. It would be appropriate to start the effort with the compilation of existing research on algorithms and new sensors. Given their recent preparation of a report it would be appropriate to transfer this activity to WMO's Global Cryosphere Programme to lead.

Status: Action required to transfer this activity to WMO's Global Cryosphere Programme.

C11.RDP (E.11). An initiative should be launched to develop a research-quality dataset of the climatology of snow properties, initially regionally, and eventually globally, integrating in-situ, microwave, and visible snow measurements. Efficient ways should be found for distributing the data among all interested researchers.

Relevant Actions and Plans: NASA along with the University of Arizona have developed a number of snow products on a climatological time scale for the Continental US (CONUS) including gridded SWE and snow depth from assimilated in-situ and modeled data. These products are available at: Active Archive Center. https://nsidc.org/data/nsidc-0719/versions/1doi: https://urldefense.proofpoint.com/v2/url?u=https-3A__doi.org_10.5067_0GGPB220EX6A&d=DwIGaQ&c=0CCt47_3RbNABITTvFzZbA&r=Hw6cRzHjAtVP3WlldYx9hjiOJZQ4-teTkqKuoSyzhGU&m=iGBbLl0IJmPI-7DD2ZFUv47mNEbYTQYV2THvFrjvzIo&s=XXQ9MgNy7WiTVeyIxgzMTrsqsw2EE_IgaP0MNDsEvPw&e= <https://urldefense.proofpoint.com/v2/url?u=https-3A__doi.org_10.5067_0GGPB220EX6A&d=DwIGaQ&c=0CCt47_3RbNABITTv

FzZbA&r=Hw6cRzHjAtVP3WlldYx9hjiOJZQ4-teTkqKuoSyzhGU&m=iGBbLl0IJmPI-7DD2ZFUv47mNEbYTQYV2THvFrjvzIo&s=XXQ9MgNy7WiTVeyIxgzMTrsqsw2EE_IgaP0MNDsEvPw&e=>

Rutgers University has launched a Global Snow Lab which produces global snow cover maps based on visible wavelength satellite data as a means of monitoring the effects of climate change (See https://climate.rutgers.edu/snowcover/) . Other groups are providing similar suites of products but these products have not been brought together for inter-comparisons and use in applications.

Recommendation: It appears that in addition to NASA efforts other groups are producing similar products for other regions globally. An inventory of these products and example outputs would be helpful for users. A group such as the IPWG with an on-going interest in these products should be identified to steer the response to this recommendation.

Status: Action required.

C12.RDP (E.15). GEO should work with WCRP, GCOS and other relevant organizations to promote water-cycle data and model integration activities that include critical water cycle processes corresponding to current and future water cycle observations, such as terrestrial water storage (i.e., snow pack, soil moisture, dynamic water tables), surface water elevations and discharge, and isotopes/fluorescence.

Relevant Actions and Plans: NASA addresses many of these needs through its contributions to GEWEX and the NASA Energy and Water Study (NEWS). GEWEX and GTN-H are supporting a GCOS assessment of the consistent monitoring of the water cycle and will promote the principles of integrated monitoring and modeling in its upcoming Water cycle monitoring paper.

Recommendation: WCRP should be invited to coordinate this activity. The possibility of synergies with actions under Recommendation A.8 regarding uncertainties should also be considered.

Status: Action required.

C13.RDP (E.16). GEO should promote water cycle data and model integration activities to support future water cycle observing system simulation experiments that can be undertaken in collaboration with the international GEOSS community to quantify the impact of each variable in an integrated water cycle observing system.

Relevant Actions and Plans: GEWEX has a plan to hold a workshop on product integration in March 2020 (delayed by COVID?). This results from this workshop could be good background for the GEOGloWS EWV assessment. Information exchange with GCOS will facilitate this work.

Recommendation: The possibilities should be discussed with GEOGloWS and GEWEX to determine if other groups have an interest in taking a leadership role.

Status: Action should be taken to find a lead for this effort.

C14.ECD (G.2). A web-based clearinghouse should be established for water cycle training materials, primarily intended for professionals and pre-professional students. This inventory would facilitate improved training and allow capacity building activities to have a central site and provide access to training materials appropriate to a variety of audiences that have been independently developed across many organizations.

Relevant Actions and Plans: The GEO Secretariat initially had agreed to provide coordination. However, given the progress of the regional GEO programmes and their ability to deal with a more homogenous language group it would be beneficial to engage them more in this activity. For example, AmeriGEO has developed the InterAmerican Academy of Science and technology, a space with more than 255 on demand courses and other types of training (See: https://academy.amerigeoss.org/)

There would still be a role for global oversight and either the GEO Secretariat or some other high-level group could provide this oversight and maintain links with regional services.

Recommendation: Individual regional GEO programs should be invited to develop and publish inventories of their courses and related training activities.

Status: This recommendation should be transferred to GEO regional programs (e.g., AmeriGEOSS) for action.

C15.ECD (G.3). Periodic GEO Water Strategy capacity-building workshops should be convened, without specific geographical focus, to develop a broad strategy for GEO Water capacity-building. These workshops should focus on developing synergies between the work done in different geographical areas, finding methods for more effectively transferring the results from one region to another, and developing common training materials that can be translated and used in different geographical areas.

Relevant Actions and Plans: NASA, GEOGloWS, and AWCI have been actively carrying out water-related Capacity Building activities. GEOGloWS, with its outreach to each of regional GEO activities (AmeriGEO, AfriGEO, AO GEO and EuroGEO), could address this action. The Committee on Space Research (COSPAR) and ESA (TIGER in Africa; Dragon in China) capacity development activities should also be considered in this decision.

Recommendation: These groups, including GEOGloWS, COSPAR, NASA, ESA, TIGER, and Dragon (and others not listed), should be encouraged to continue these efforts. Discussions should be held with GEO to see how these activities could best be coordinated. This recommendation should be communicated to the GEO Secretariat for its action.

Status: Action required

Summary

Although the list of outstanding actions is longer than the authors would wish for, actions are underway on all but 9 of the actionable recommendations remaining from the GEOSS Water Strategy. There are 14 recommendations that are better suited to other agencies or organizations to undertake and negotiations remain to be completed regarding their transfer. The IGWCO CoP plans to address those recommendations needing to be resolved over the next six months including the 9 recommendations within its area of responsibility for which there is no clear plan of action developed.

The number of completed recommendations is 17 and currently another 18 recommendations are still in progress. During the next review period those individuals who are leading these efforts will be encouraged to map out the steps required to bring them to completion.

Furthermore, to give focus to IGWCO efforts and coordination it will give priority to addressing the following recommendations:

B1, B1.EUE (A.2). GEO Water activities should develop and launch a continuous process to identify, articulate, and further refine user needs in the various water communities from the local scale to the global scale. The process should build upon existing work by GEO such as the Water SBA Needs report; utilize existing draft taxonomies of user types such as the one developed by the GEO User Interface Committee; interact with communities of users in professional organizations such as the International Water Resources Association and with UN agencies such as UNESCO and United Nations Environmental Programme (UNEP); identify needs and water-related information from other relevant GEO connections, networks, projects, and Work Plan activities; publish findings regularly; and prepare a sustainability strategy because user engagement is an ongoing consultative process.

B5.DAS (B.1). An integrated monitoring system should be developed to track consumptive and non-consumptive water use and its changes using satellite and in situ observations along with models that relate water use to land cover and demographic information.

The structure of IGWCO has changed in the past 6 months and there are now two co-chairs so the ability to place more emphasis on this activity should help move this plan forward.

Appendix A:

GWS recommendations which have been addressed, reviewed and closed,

D1.SDA (C.1). The feasibility of developing a "Water-Train" satellite constellation should be assessed. This suite of satellites would be modelled after the A-Train, providing a space segment of an observation system that would capture all fluxes and stores of the water cycle using a diverse suite of platforms and instruments. This system would operate as a Virtual Water Cycle Constellation.

D2.SDA (C.2). Satellite missions such as those in the A-Train and the planned EarthCare and GCOM-W2 missions and field experiments should be closely coordinated to measure cloud properties, with the goal of providing data for the study of precipitation processes and energy budgets. Furthermore, these satellite measurements should be transitioned into operations and sustained in the long term.

D3.SDA (C.3). Advanced satellite technologies, such as hyperspectral infrared and millimetre/sub-millimetre and microwave radiometers, should be promoted to improve horizontal and vertical resolutions of key measurements of clouds, water vapour, and aerosols. As well, multi-frequency radars should be sustained and Doppler capabilities should be introduced to observe the cloud precipitation particle continuum and provide vertical velocities for critical cloud-process studies.

D4.SDA (C.6). The need in the community for thermal band imaging sensors on satellites has been addressed by CEOS and GEO. Routine Land Surface Temperature (LST) observations at high spatial/low temporal (e.g., Landsat), moderate spatial/temporal (e.g., MODIS), and low spatial/high temporal (e.g., GOES, Meteosat, and other geostationary platforms) are essential in order to improve ET estimation from the field to the continental and, ultimately, to the global scale. Responsible agencies need to process and make available LST datasets from GOESS satellites so that these products can be used to map ET in near-real time. The launch of LandSAT 9 in September 2021 will help to provide higher resolution data.

D5.SDA (C.7). GEO and CEOS should facilitate the planned NASA/ Deutsches Zentrum für Luft (DLR) [German Aerospace Centre] joint GRACE II mission that will follow the current GRACE Twin. GRACE II is expected to provide improved accuracy and resolution due to technological advances made during the past decade. It is essential for ensuring continuity of the many GRACE applications that have emerged. The U.S. National Research Council's Decadal Survey Study called for a continuation of GRACE follow-on missions with lower-orbit, drag-free satellites with laser interferometry that yield higher spatial resolution data is also a priority for GEO.

D6.SDA (C.10). A feasibility assessment should be undertaken to determine the benefits and technological difficulties of designing a hyperspectral satellite mission focused on water quality measurements.

D7.SIDA (D.4). Additional support should be given to expanding the in situ collection of ET measurements and providing adequately archived and operational flux data that is networked and accessible through the Internet. This effort would be accelerated by recognition of ET as an ECV.

D8.SIDA (D.5). A strong rationale should be developed in order to encourage increased financial commitments by GEO members and other nations to continuous operation and expansion of soil moisture networks. A strategy reviewing the optimum network size and trade-offs between the number of stations and equipment upgrades and demonstrating the benefits of soil moisture in key applications would be part of this rationale. The strategy should also review the benefits of supersites where the full spectrum of environmental variables would be measured. Support is also needed for follow-on missions such as GCOM-W2, which help to provide long-

term global soil moisture measurements. GTN-H has advised that it believes this resource problem has been solved.

D9.SIDA (D.6). GEO Water activities should include projects that will strengthen advanced monitoring networks, data-sharing, and quality control for groundwater measurements and data.

D10.SIDA (D.9). A workshop should be organized to address the application of in situ measurement techniques and data in water quality assessments. The workshop would explore ways to develop harmonized approaches and best practices for water quality measurements and ways to benefit from technological advances. Workshop contributors should include experts in the fields of sensors, data communication, and management, and practitioners operating sensor networks.

D11.RPD –(E.6). An inventory of all surface water data archives, including both natural and artificial lakes, reservoirs, and wetlands, should be developed. Based on the details of this inventory, a plan for implementing a process to establish protocols for collecting data and metadata on surface water stores should be developed.

D12.RPD (E.9). An initiative should be launched to assess the feasibility of combining in situ measurements and GRACE satellite data to produce an integrated groundwater product on a regional basis.

D13.RPD- (E.13). User support should be developed and maintained at the science and parameter level. Work should also continue toward a more distributed and standards-based information system that will free data producers from having to support format and server issues.

D14.RPD (E.14). GEO members should strengthen support for water cycle data integration activities such as GEWEX LandFlux-EVAL to assure that satellite-based estimates of critical water and energy cycle variables are of the highest quality.

D15.DSS (F.5). Efforts by GEO members to support initiatives leading to interoperability should be accelerated. At the same time, users and dataset developers need flexible, low-burden standards at all levels to enable easy adoption of the interoperability concepts being developed.

D16.DSS (F.6). GEO should develop plans to ensure that vitally needed telecommunications infrastructure be established in order to ensure data availability in the developing world and to support the transmission of high-volume satellite datasets during the coming decades.

D17.DSS (F.7). GEO should serve the climate community by promoting the development and use of Geographic Information Systems (GIS) for the analysis of climate and water data along with records on extremes (droughts and floods) to provide real-time and early warning information to decision makers, and data for research by the hydrologic, climate, and ecological communities. The GIS compatible outputs would be useful for the study of extremes and water management under climate change.

Appendix 2

Acronyms:

ACCP - Aerosols and Clouds, Convection and Precipitation

AfriGEO - The African Group on Earth Observations

AGU – American Geophysical Union

AquaWatch - GEO initiative that develops the global capacity and utility of Earth Observation-derived water quality data, products and information to support water resources management.

Ameriflux - a network of PI-managed sites measuring ecosystem CO_2, water, and energy fluxes in North, Central and South America

AmeriGEO, American Group on Earth Observations

AMSR-3 –Advanced Microwave Scanning Radiometer 3

AO GEO - Asia-Oceania Group on Earth Observations

AQUASTAT - FAO's Global Information System on Water and Agriculture

ATMS- Advanced Technology Microwave Sounding

A-Train – IUS-France constellation of research satellites Calipso and Parasoil

AWCI - Asian Water Cycle Initiative

CEOS - Committee on Earth Observation Satellites

CliC - WCRP Climate and Cryosphere

CMORPH - Climate Prediction Center Morphing technique

CNES - Centre National D'Etudes Spatiales (French Space Agency)

COMPASS - Comprehensive Assessment for Water

CONUS - Continental US

CoP – Community of Practice

COSPAR - Committee on Space Research

COVID – Corona Virus Infectious Disease

DAAC – Data and Information Services Center

DLR - Deutsches Zentrum für Luft (German Aerospace Centre)

eartH2Observe – Earth to Observe (EU project)

ECOSTRESS - ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station

ECV - Essential Climate Variables

EO4WEF A GEO Community Activity on Earth Observations for the Water Energy Food Nexus

ESA - European Space Agency

Esri – a supplier of GIS software, web GIS and geodata applications

ET - evapotranspiration

EU - European Union (EU)

EUMETSAT - European Organisation for the Exploitation of Meteorological Satellites

EuroGEO – The European Group on Earth Observations

EWV - Essential Water Variables

FAO - Food and Agriculture Organization

FLUXNET – Flux Tower Network

GCI - GEOSS Common Infrastructure

GCOM-W2 - Global Change Observation Mission for Water - 2

GCOS – Global Climate Observing System

GEMS/Water – Global Environmental Monitoring Programme for Water

GEO – Group on Earth Observations

GEOCRI - GEO Cold Regions Initiative

GEOGloWS – GEO Global Water Sustainability

GEOSS – Global Earth Observation System of Systems

GEWEX - Global Energy and Water Cycle Exchanges project

GGMN - Global Groundwater Monitoring Network

GIS - Geographic Information Systems (GIS)

GLOFAS – Global Flood Awareness System

GMI/AMSR2 – Advanced Microwave Scanning Radiometer (2)

GOES – Geostationary Operational Environmental Satellites

GOSAT-W - Greenhouse gases Observing Satellite

GPCC - Global Precipitation Climatology Centre

GPM Global Precipitation Measurement mission

GPS – Global Positioning Systems

GRACE – Gravity Recovery and Climate Experiment

GRDC - Global Runoff Data Centre

GSMaP - Global Satellite Mapping of Precipitation

GSFC – Goddard Space Flight Center

GTN Glaciers and Cryosphere - Global Terrestrial Network - Glaciers and Cryosphere

GTN-H - Global Terrestrial Network – Hydrology

GWS - GEOSS Water Strategy

HYDROLARE - International Data Centre on Hydrology of Lakes and Reservoirs

H-Sat –EUMETSAT support for operationally hydrological services that generates, validates, distributes and archives high-quality datasets and products.

HWRP - Hydrological and Water Resources Programme of WMO
HydroSOS - Hydrological Status and Outlook System

ICESat - Ice, Cloud and land Elevation Satellite

ICOS - Integrated Carbon Observations System

ICWRGC - International Centre for Water Resources and Global Change

IGWCO - Integrated Global Water Cycle Observation

IGRAC - International Groundwater Resources Assessment Centre

IHE - Institute for Water Education

IHP - Intergovernmental Hydrological Programme of UNESCO

IMERGE - Integrated Multi-satellite Retrievals for GPM

IPWG – International Precipitation Working Group

JAXA - Japan Aerospace Exploration Agency

JRC - Joint Research Centre of the European Commission's

LandFlux-EVAL – Project for the Evaluation and intercomparison of Land Fluxes

Landsat – Land (Remote Sensing) Satellite

LST - Land Surface Temperature (LST)

Meteosat - - EUMETSAT Meteorological Satellite

MetOp-SG - polar orbiting meteorological satellites which form the space segment component of the overall EUMETSAT Polar System –Second Generation

MODIS - Moderate Resolution Imaging Spectroradiometer

NASA - National Aeronautics and Space Administration

NCAR - National Center for Atmospheric Research

NEON - National *Ecological* Observatory Network (US)

NEWS – NASA Energy and Water Study

NOAA – National Oceanic and Atmospheric Administration

NSIDC - National Snow and Ice Data Center

NWC - National Water Center

NWM - National Water Model

SBA - Societal Benefit Area

SDG – Sustainable Development Goal

SMAP - Soil Moisture Active Passive

SnowEX – Snow Experiment

SWE – Snow Water Equivalent

SWFP - Sustainable Water Future Programme

SWOT - Surface Water and Ocean Topography mission

TIGER – Terrestrial Initiative in Global Environmental Research (ESA)

UNEP United Nations Environmental Programme

UNESCO - United Nations Educational, Scientific and Cultural Organization

UNFCCC - United Nations Framework Convention on Climate Change

UN Water – United Nations Water

USGS - U.S. Geological Survey

WaPOR – *FAO* Water Productivity Open-access portal

WCRP - World Climate Research Programme

W-E-F - Water-Energy-Food (Nexus)

WMO - World Meteorological Organization's

WWRP - World Weather Research Programme