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Report on the United Nations/Ghana/Prince Sultan bin Abdulaziz International Prize for Water Fifth International Conference on the Use of Space Technology for Water Management

(Accra and online, 10–13 May 2022)

I. Introduction

1. The Fifth International Conference on the Use of Space Technology for Water Management was organized by the Office for Outer Space Affairs under the United Nations Programme on Space Applications. Originally scheduled to take place in 2021, it was held from 10 to 13 May 2022 in Accra and online in a hybrid configuration, owing to the coronavirus disease (COVID-19) pandemic.

2. The Conference was co-hosted with the Government of Ghana and the Prince Sultan bin Abdulaziz International Prize for Water (PSIPW). The University of Energy and Natural Resources was the local organizer, in cooperation with the Ministry of Education, the Ministry of Foreign Affairs and Regional Integration, the Ministry of Environment, Science, Technology and Innovation, and the Ministry of Sanitation and Water Resources. It was supported by the European Space Agency (ESA) and the secretariat of the Inter-Islamic Network on Space Sciences and Technology.

II. Background and objectives

3. The Office for Outer Space Affairs disseminates knowledge about the added value of using space applications in addressing societal issues, notably by holding jointly organized events at the request of Member States under the Programme on Space Applications.

4. The Space4Water project was launched in 2018 to promote the use of space-based technology and space applications in efforts to increase access to water. Space4Water has three pillars: fostering scientific exchange by holding conferences; reaching users worldwide with the Space4Water portal, which informs them and lets them find partners; and building a community by holding meetings of stakeholders in the Space4Water portal.

5. Since 2008, four Conferences on the Use of Space Technology for Water Management had been held every three to four years to showcase the benefits of space

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technology, services and applications for water management. Those conferences took place in Riyadh in April 2008; in Buenos Aires in March 2011; in Rabat in April 2014 and in Islamabad in February-March 2018.

6. The Fifth Conference was held in Accra and online from 10 to 13 May 2022 and had the following objectives:

(a) To expand the use of space technologies and space-based data for better water resource management;

(b) To foster the exchange of knowledge between actors in the space sector and actors in the water management and water research sectors, and the establishment of partnerships between them;

(c) To identify user needs;

(d) To hold sessions to demonstrate possible solutions offered by technology providers.

In addition, the Conference had as its objective to encourage specific regional contributions to its programme by speakers from countries in sub-Saharan Africa.

7. To ensure that the event could be held despite the pandemic, its format was changed from in-person to hybrid. Participants attended in person, in Accra, and online. The organizers applied lessons learned at similar events; all presentations were made available online in advance, so that any time difference and limited Internet bandwidth would not hinder the access to information. Online speakers alternated with speakers attending in person in Accra. The format of the poster sessions was adapted by displaying three-minute video messages (referred to as “lightning talks”) online and in the room. The approach made it possible to fit more speakers into the time available. By carefully selecting the speakers and conferring with them prior to the event, the organizers ensured that the presentations were engaging and contributed to lively exchanges between speakers.

III. Attendance

8. A total of 838 individuals registered to attend the Conference and were granted access to the web-based communication platform. Twenty-nine per cent were women.

9. Members of the diplomatic community were among the participants including representatives of the Permanent Mission of Ghana to the United Nations in Vienna, as were representatives of the Ghana Atomic Energy Commission. Among the space agencies represented were the Bangladesh Space Research and Remote Sensing Organization, the Brazilian Space Agency, the Egyptian Space Agency, the Ethiopian Space Science and Technology Institute, ESA, the Centre national d’études spatiales (National Centre for Space Studies – CNES) of France, the Kenya Space Agency, the National Aeronautics and Space Administration of the United States of America, the National Space Research and Development Agency of Nigeria, the Pakistan Space and Upper Atmosphere Research Commission, the Rwanda Space Agency and the Turkish Space Agency.

10. Representatives of the African Regional Centre for Space Science and Technology Education – English, based in Nigeria, the Joint Research Centre of the European Commission, the Food and Agriculture Organization of the United Nations, the secretariat of the Group on Earth Observation, the Space Generation Advisory Council, the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Human Settlements Programme (UN-Habitat), the United Nations Development Programme, the Economic and Social Commission for Western Asia and the World Meteorological Organization (WMO) were also present.

11. The following 100 countries were represented among the registrations: Afghanistan, Angola, Argentina, Australia, Austria, Bangladesh, Benin, Bhutan, Botswana, Brazil, Bulgaria, Burkina Faso, Burundi, Cameroon, Canada, Chad, Chile,

China, Colombia, Costa Rica, Côte d'Ivoire, Democratic Republic of the Congo, Ecuador, Egypt, Eritrea, Estonia, Ethiopia, France, Gabon, Gambia, Germany, Ghana, Greece, Guatemala, Guinea, Hungary, India, Indonesia, Iran (Islamic Republic of), Ireland, Israel, Italy, Jordan, Kenya, Kyrgyzstan, Lebanon, Liberia, Libya, Luxembourg, Malawi, Mexico, Mongolia, Morocco, Mozambique, Myanmar, Namibia, Nepal, Netherlands, Nicaragua, Niger, Nigeria, Pakistan, Panama, Peru, Philippines, Poland, Romania, Russian Federation, Rwanda, Saint Lucia, Saudi Arabia, Senegal, Serbia, Sierra Leone, Singapore, South Africa, South Sudan, Spain, Sri Lanka, State of Palestine, Sudan, Switzerland, Syrian Arab Republic, Thailand, Togo, Trinidad and Tobago, Tunisia, Türkiye, Uganda, Ukraine, United Arab Emirates, United Kingdom of Great Britain and Northern Ireland, United Republic of Tanzania, United States, Uzbekistan, Venezuela (Bolivarian Republic of), Viet Nam, Yemen, Zambia and Zimbabwe.

12. The number of those who attended online varied throughout the four days and during each day. The highest number of persons connected simultaneously was 93.

IV. Programme, and speaker statistics

13. The programme consisted of four types of events:

(a) Keynote speeches given by senior representatives of the co-organizers;

(b) Presentation sessions led by a Chair with up to six successive speakers, followed by a question-and-answer period;

(c) Panel discussions led by a moderator;

(d) Succinct prerecorded video presentations known as "lightning talks", each lasting three minutes.

14. Twenty-one lightning talks were screened both in Accra and online, spread across four sessions. The format was intended as the online equivalent of a poster session. It helped to increase the number of initiatives that could be presented and enabled less experienced speakers to explain their activities concisely. The videos were screened during the Conference and remained available online.[1]

15. In total, the event resulted in 24 hours of content over four days. There were 68 live speakers: 18 women and 50 men. In addition, there were 16 session Chairs and panel moderators in Accra, 5 of whom were women and 11 men. Twenty-three speakers appeared online: 21 lightning talks and 2 video messages. The lightning talks were presented by 8 women and 13 men; the video messages were delivered during the high-level opening session, both by male speakers. In total, there were 107 speakers: 31 women and 76 men. Their gender ratio corresponded to that among the registrants.

16. Throughout the Conference, attendees were encouraged to submit their questions for the speakers in writing using an online communication platform. The moderator used the same platform to keep online attendees informed about the progress of events in the conference room in Accra. At the end of each talk, whenever time allowed, the moderator read out questions submitted to the speaker through the communication platform, to achieve some level of interaction between those connected online and those attending in person.

17. All talks were made available on the website of the Office for Outer Space Affairs before or during the event to enable attendees with limited bandwidth to download the content.[2]

18. Local organizers in Accra invited a limited number of in-person attendees to participate in a technical visit of a satellite ground station facility.

[1] See www.unoosa.org/oosa/en/ourwork/psa/schedule/2022/un-Ghana-water-schedule.html.
[2] Ibid.

V. Programme content

19. The Conference began with an opening ceremony, during which Ghanaian authorities, co-organizers and sponsors shared their insights into the theme of the Conference. The Vice Chancellor of the University of Energy and Natural Resources welcomed the attendees and explained the rationale for the Conference. The Chief Director of the Ministry of Foreign Affairs and Regional Integration spoke about climate change and how it would require better water management in conjunction with the ambition to leave no country behind on the path towards sustainability. The Director General of the Ghana Atomic Energy Commission stressed the importance of protecting water and noted that water quality in Ghana had continued to decrease owing to, in particular, pollution caused by illegal mining. The Minister of Education emphasized that expanding the use of space technologies and space-based data for better water resource management could be one key to making the economy in Ghana circular. The goal to foster sustainable techniques in water management was in line with Agenda 2063 of the African Union and the global commitments under the 2030 Agenda for Sustainable Development. In pursuit of that goal, Ghana intended to focus on education in science, technology, engineering and mathematics, notably on the development of computer software.

20. After a short video message from the President of Ghana, the Acting Director of the Office for Outer Space Affairs gave a welcome address in which he highlighted the progress made since the launch of the Space4Water project in 2018. He recalled the rationale for Space4Water, a joint initiative of the Office and PSIPW that had made possible both the Conference and the development of the Space4Water portal. In a video message on behalf of the Director General of PSIPW, a representative presented the organization's activities and explained how the laureates of its prize contributed, with their research, to improved water management.

21. During the technical opening session, five speakers presented initiatives to use data generated by Earth observation spacecraft to generate data that can be used in water management. The Director General of the Regional Centre for Mapping of Resources for Development, based in Kenya, explained that obtaining data remained the Centre's main challenge. Some of the data it needed, notably data to prepare for and respond to droughts and flooding, were being provided with the help of satellite technology. The Earth Observation Africa Research and Development Facility is managed by a consortium funded by ESA; it provides content and training programmes online. ESA makes its own data products freely available online; the data originate from spacecraft developed and operated by ESA. The Agency currently works on capturing user requirements for future Earth observation missions. Digital Earth Africa explained how it provided data sets and services and what research it had done specifically for Ghana, in particular the products it had provided to more than 200 of the districts in the country. Now that a large number of data sets were available online, a country's ability to use water resources sustainably depended largely on the ability of water management personnel to understand the data. Training was therefore essential. The Office for Outer Space Affairs gave a presentation about the Space4Water portal in which it showed the content already available and explained how building a community of stakeholders would improve the exchange of best practices.

22. The first session had as its topic space technologies and water-related extremes, and was focused on floods. Ten speakers presented operational projects at the watershed and country level, as well as innovative research results. The frequency of floods was predicted to increase significantly. While satellite-based data contributed to mapping, monitoring and early warning systems, the key challenge was often a lack of local observation data and the difficulty of sharing data between institutions.

23. While the Technical University of Accra had been mapping flood-prone zones in Accra, United Nations initiatives (such as that led by the United Nations Satellite Centre or the World Food Programme) similarly monitored floods, using satellites to identify the flood-prone areas in various regions and checking with geographical

information systems what populations were at risk. Satellite-based precipitation products were now available. Using space-based data in connection with floods was already an established practice in several countries, for example in Rwanda, Malawi or the Islamic Republic of Iran, where space-based observations of soil moisture, precipitations and flood monitoring had been integrated into various forecast models and the validation provided good levels of precision.

24. Access to satellite-based imagery to study floods had increased, making it possible to use global models thanks to the ever higher resolution of the data. The main thread uniting the presentations was that reducing vulnerability required better analysis, forecasting, early warning and planning and, very importantly, global and regional capacity-building programmes.

25. The second session was focused on space technology and water quality. While Africa was home to 25 per cent of the planet's fresh water, its distribution was unequal and stress occurred in some places where rivers and lakes were shared by several countries. Research on the use of satellite data for water management in Africa had grown exponentially, with initiatives such as Group on Earth Observations AquaWatch and plenty of online resources made available by space agencies. In situ observations remained necessary for the calibration and validation of algorithms, for instance to measure the amount of sediment present; that task required the involvement on site of local persons, for instance through "citizen scientist" projects.

26. The four speakers at the second session presented initiatives about lakes in Thailand, about Lake Victoria, and about work done in Uganda and Kenya. Water quality was adversely affected by nutrient loads from industries, agriculture and sewage, leading to algal blooms. Increased urbanization had degraded the quality of lake water significantly; this can be seen, for instance, in the increased concentration of chlorophyll around the shores of Lake Victoria, and in the water turbidity in Lake Naivasha, which gives an indication of the quality of the surface water. The session Chair stressed the need to continue to reduce the production of grey and black water and to use grey water productively, such as for irrigation. She concluded the session by singing a song about the importance of water.

27. Overall, the second session put the spotlight on innovative research projects that demonstrate the value of integrating high-resolution satellite imagery to well-established models, including for lake water quality and chlorophyll estimates. Cloud computing technology was now widely being used to facilitate data processing. Considering the complexity of acquiring long-term in situ data in specific environments, using satellite data instead with modelling and monitoring approaches provided reliable results, at least for preliminary estimates of water quality. Initiatives by various parties to build a global network of validation data were in progress. Open and free access to space-based data of sufficient resolution was now a reality for some water quality parameters, with data sets and data products being globally accessible. The same was true for online training resources.

28. During the third session, five presentations were given in which the speakers addressed the link between space technology, water and health. Several climatic variables, such as temperature and humidity, were important factors in the onset and transmission of diseases. Bacterial meningitis epidemics in the upper eastern region of Ghana had been linked to dust aerosols during very dry and hot weather occurring in the *harmattan* period. Information on dust, obtained from Sentinel satellite data, was analysed to find a correlation. A research project had been conducted in the Lake Chad basin to investigate how pollution had increased while a drought was drying up the lake, thereby threatening the livelihoods of more than 22 million people.

29. About 60 per cent of water bodies in Ghana are polluted, notably by illegal mining activities that cause deforestation and major health hazards, including artisanal gold mining. Because mercury is used in gold extraction and up to 70 per cent of artisanal gold mining in Ghana is illegal, mercury is polluting the immediate atmosphere and the environment around mining sites. It is found in local resources, terrestrial and aquatic systems, and in human bodies. The illegal activities take place

in remote forests and savannahs, which means that they can only be discovered through remote sensing. Limitations remain, such as low satellite revisit rates over a given area, the considerable cost of acquiring private data, and measurement limitations caused by cloud cover. The Ghana Space Science and Technology Institute is seeking to provide real-time information on pollution of water resources to aid law enforcement, and is looking for partners to obtain adequate high-definition satellite data or to launch a suitable satellite instrument.

30. Tele-epidemiology and early-warning systems for mosquito-borne diseases are operational already. One such system is used in European territories, Côte d'Ivoire and Thailand as part of an initiative that also involves Brazil and India. It provides risk and mosquito abundance models; a mobile application is used to notify users and collect crowdfunded feedback, for instance from villagers in Greece. The models are based on Sentinel-2 satellite observation data. The leaders of the initiative are currently developing standards to support decision-making; a tool of this type could be used in other regions of the world. Similarly, a project in Kenya is used to develop maps of areas prone to malaria, combined with reference maps showing population density, to support the work of health practitioners. Socioeconomic factors and natural conditions need to be integrated for hazard mapping, and the Kenya Space Agency is considering the development of similar geographical information system models for other diseases.

31. During the fourth session, on space technology and groundwater, eight presentations were given. While more than 2 billion people depended on groundwater as their water source according to UNESCO,[3] overexploitation prevented groundwater from recharging sufficiently to keep it a sustainable resource. The main challenge was to overcome the lack of direct monitoring information to improve groundwater management. Information obtained from satellite gravimetry (through the Gravity Recovery and Climate Experiment (GRACE) satellite mission) was used to assess groundwater storage, while other types of remote sensing images could be used to map, for instance, the fracture network of low-porosity rock aquifers, in which water moves through fissures. In Morocco, such fractures were being observed to find the hydraulic properties of groundwater reservoirs and infer information on deep reservoirs that were not directly observable, so as to support water prospection in the region. In the Syrian Arab Republic, satellite imagery was being used to assess where to drill wells to find groundwater, while in India, the space agency had been providing similar imagery to replace the highly unscientific traditional methods used by some farmers, with good results. While there was no dedicated satellite data service available yet for groundwater monitoring, projects were under way to prepare such a service.

32. In North Africa, farmers relied on groundwater for their irrigation needs for up to 90 per cent in Libya and up to 86 per cent in Tunisia. In the Arab region overall, farmers relied on groundwater for up to 70 per cent of their demand. In Ghana, agriculture had expanded in areas where precipitation and surface water were limited. Together with the exponential increase of the population in urban areas, this had significantly increased the need for groundwater. The rising demand meant that more energy needed to be expended to extract the water, notably from deeper sources. While renewable energy had made it possible to lower the energy cost of extraction, cheap energy contributed significantly to a further depletion of groundwater, and the water table level receded further. Such a vicious circle could be observed in, for instance, Yemen, where solar energy, had become easier to access since 2016 and was being used to pump up more water.

33. Beside free satellite data sets, developing countries needed training on geospatial techniques and a clearer understanding of how they could use information obtained from geospatial technology in their decision-making processes. Models in which satellite data were used to assess variations in groundwater storage were often

[3] United Nations Educational, Scientific and Cultural Organization (UNESCO), *The United Nations World Water Development Report 2022: Groundwater – Making the Invisible Visible* (2022).

well-suited for the developed world, but did not account for constraints of the developing world: low budgets and limited computing infrastructure required simplified and inexpensive alternate models. In addition, to take the right decision with regard to groundwater shortages, Governments often needed information from a neighbouring country, as their groundwater shortage might be caused by events that they could not address at the national level alone. Supporting resources such as global data sets were required. Remote sensing technology was essential in that regard, but to make improvements, interdisciplinary policy measures would be needed, for instance because the agriculture and energy sectors had a direct influence on the water situation.

34. A presentation was given on a pan-African joint initiative of the European Union and the African Union entitled "GMES and Africa" that involved 122 entities in 47 African countries. It has given rise to a community mostly of public service institutions and academia that continues to grow. A training platform is available with free resources, including training courses. Twelve individual consortiums have been created that focus on specific issues. Some training activities on water-related topics, such as irrigation, wetlands monitoring and river flooding, are organized with specialized partners in specific regions of Africa.

35. The fifth session was held on the third day of the Conference. Given the high level of interest for the topic, it was entirely dedicated to space technology, water scarcity and drought. A first subsession was focused on drought, precipitation and vegetation. In six presentations, participants were explained how satellite data were being used for hydrological assessments. The analysis of water stress hotspots around the world showed that there was currently a discrepancy between global models and regional or local models. For instance, while Lake Chad had dramatically reduced in size since the 1960s, research had shown that rainfall was the main parameter, not anthropogenic causes. Various systems, such as the global Hydrological Status and Outlook System (HydroSOS) of WMO, had been developed to integrate hydrological assessments with data obtained from other capabilities, and to link monitoring and decision-making processes. Such tools provided products at national and local scales that included projections, for instance for rainfall, soil moisture and snow cover.

36. Satellite-based rainfall assessment were used to estimate crop growth where no in situ data of suitable quality were available produce simulations, for example in the Lake Victoria basin in Kenya. However remote sensing data may not yet be sufficiently precise to be fully reliable: in a study conducted in Tamil Nadu, India, to validate high-precision data sources with the help of rain gauge stations, some differences had been found between products based on satellite data and in situ measurements. Satellite data could nevertheless be used for a drought early warning system or as a monitoring tool to support governmental drought insurance schemes for farmers.

37. A second subsession, consisting of six presentations, was focused on water scarcity and drought in basins. The first presentation was given by a representative of the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) programme. In 2018, maps of flood areas of the White Volta River produced by the space community had been made available to Ghana through UN-SPIDER in 2018. In Namibia, a vegetation condition index had been applied to monitor how droughts affected the health of the vegetation. The speaker highlighted the importance of past time series to understand long-term trends in drought indices and their correlation with the impact of the droughts. Similarly, data obtained from the satellites of the European Earth Observation Programme (also known as Copernicus) had been used to develop the Global Surface Water Explorer tool to facilitate the quantification of the extent and dynamics of inland water bodies. The data set of the Global Surface Water Explorer had been endorsed by the United Nations as the official indicator for monitoring progress towards target 6.6 of the Sustainable Development Goals: By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes.

38. In presentations on specific cases, it was shown that satellite-based data could serve to produce reasonable estimates for areas where only few rain gauges were available. Research had been conducted on the major variables affecting water resources in the Zambezi basin to determine how to correct bias in satellite data and optimize model parameters for various sources of data on rainfall. In the Congo River basin, where the local population was highly dependent on the river for its water supply, satellite imagery had been used to understand the link between the major drought in 2005/06 and the dynamics of surface water across the basin. The purpose of the research had been to understand the seasonal and interannual spatio-temporal variability of the Congo freshwater volume and its connection with climate dynamics so as to understand the distribution and characterization of extreme water events. Drought monitoring was being used in support of hydroelectric power generation, such as at the Mtera Hydroelectric Dam in the United Republic of Tanzania, where a specific radiometric index derived from Landsat satellite data was being used to assess water fluctuations. Ultimately, the challenge was to ensure that information reached the officer who managed the water resources, providing him or her with the time series information needed to take the best decision possible from the office. Another project, entitled “Servir”, had resulted in a model to determine the amount of water available for agriculture or to assess the run-off and base flow. The model was available from a free online platform. With the help of the platform, officers were able to plan and regulate resources. In the future, the tool would also quantify the availability of groundwater.

39. At a third subsession, a presentation was given on the use of satellite data to assess the impact of water scarcity and droughts on vegetation and agriculture. Satellite data on water security mostly concerned precipitation measured at short time intervals and on a small scale (e.g. every kilometre once every hour); soil moisture used in agriculture to predict floods and crop failures; groundwater to determine the location of aquifers; and discharge and attrition due to overpumping. Monitoring evapotranspiration was a proxy for water scarcity and was useful in understanding the need for irrigation. Satellites could provide data to measure the vegetation health index and phenomena that affect water quality, such as the bloom of algae, to support health authorities in making decisions. Some pollutants could not be monitored directly by satellites; however, many pollutants not visible optically could still be monitored from space.

40. Drought was one of the extreme hazards in many countries, including Kenya, where the President had declared one drought a national disaster in 2021. Early prediction tools would help to establish better mitigation plans. To ensure water security, data were needed for planning, evaluation, monitoring, managing and enforcement, among other things. All these types of applications required different types of data with specific time frames to meet those needs. Obtaining data directly from satellite observations had many advantages, but obtaining in situ data was still required, notably to calibrate satellite data and allow for interpolation when satellite data were not available. Algorithms for satellite data often needed to be developed for a specific region of the world to ensure their reliability. One of the speakers presented a project on vegetation changes during the monsoon in Pakistan. Changes in vegetation had been assessed over a period of 20 years, which had made it possible to develop models of future trends and predict the severity of future droughts.

41. The last subsession of the fifth session had space technology, water scarcity and drought as its topic and consisted of three presentations. Drought could be related to compound extreme events, which resulted from combinations of hazards, climate drivers and societal drivers. Climate variability, climate change vulnerability and exposure to risk were creating the worst combination of conditions. These extreme events caused economic losses several billions of dollars in magnitude.

42. Droughts were distinct from floods in that they were a slow process, which made it difficult to decide what early action to implement and what impact to focus on: how often was it acceptable to act in vain? The Red Cross explained that it focused on water scarcity because of its primary impact on daily life. In that sense, humanitarian

work was a suitable environment in which to develop meaningful research questions regarding forecast-based early action, as humanitarian work was rooted in the experience of local communities. For instance, a “drought-trigger calendar” could be developed to recommend what variable to observe when, when to take what decision and what action to take locally. To move from policy to action, work was still very much needed on integrated drought management. Monitoring the impact of drought risks required the involvement of many different partners at various levels. While images obtained from satellite agencies could provide historical data and automated networks could collect local data, predictions and projections were also required, as was early warning integration into drought management. In their presentations, all the speakers demonstrated the unique value of high-resolution satellite imagery and its relevance in developing solid models.

43. Various continental and global initiatives were presented or announced, including a meeting of WMO to be held in Abidjan, Côte d’Ivoire in 2023 to support member States in their integrated drought management efforts. To address droughts successfully, the world needed to move from crisis management to risk management.

44. On the last day, during the closing ceremony, the Vice-President of Ghana noted that the use of space applications had progressed significantly in recent years. Nowadays, space was a global commodity that could and should be exploited for socioeconomic development. Developing countries had a strategic and economic interest in investing in space capabilities to compete in the global village. Education in science, technology, engineering and mathematics was essential, and the future of space science depended on what was taught in high schools and elementary schools; space science and technology should not be restricted to universities. The pandemic had shown the importance of water to reduce the spread of COVID-19. Now a growing wave of space enthusiasts in Africa was ready to tackle the new challenges that the time after the pandemic would bring. Ghana was not considered water-stressed, but its water bodies were polluted to a significant degree and it was one of the most flood-prone countries in West Africa. Drought frequency was increasing, which was problematic for the generation of hydropower and for agriculture. The Minister of Education and a speaker for the Ministry of Environment, Science, Technology and Innovation of Ghana expected that the Conference would further national deliberations on the use of space applications. The Government was investing in space technology. Activities in that area were currently being carried out under the Ghana Atomic Energy Commission, but the Government could decide to create a space agency. Several speakers referred to the recent Ghana space policy bill and looked forward to its being signed into law.

45. Presentations on the need for capacity-building were followed by a panel discussion on capacity-building needs in Africa. A speaker for the Ghana Institution of Engineering highlighted the role of space science and technology adoption for developing countries. Several initiatives, such as the work of the African Group on Earth Observations, prioritized regional needs in it programmes; it focused on sustainable development with projects on health care, agriculture and food security. A speaker for the water management authority of Ghana explained that, while each community had specific needs, its priority remained the assessment of resources, for which it needed data and the capability to assess those data in a meaningful way. Ghana needed to develop a long-term capacity-building initiative to transmit data in a format that could be understood by staff of water management entities so that they could benefit from space services without additional training. Integrating new knowledge into what was being taught at universities in Africa took time and required people who had enough passion to seek and use that knowledge in their everyday work. Language barriers could be an issue, as some African countries had more than 50 languages in use. The speakers concurred on the need to find ways to validate satellite data on water quality and to improve synergies, for instance with activities for climate services.

46. Two presenters explained how user needs assessments were carried out for inland water-related services under Copernicus and for the WMO World Water Data

Initiative. Local users needed reliable remote sensing data so that they could combine those data with their local measurements and calibrate their algorithms. Those requirements were in synergy with the needs of the community of remote sensing experts who needed in situ content. Workshops were held to collect input on user needs and test the validity of the proposed service roadmap with stakeholders. The critical step was to understand users by interacting with them, having feedback processes in place to establish what they needed in their decision-making process. Users' information needs were translated into monitoring targets and outputs within an iterative process with feedback mechanisms, using the well-established WMO regional coordination groups on satellite data requirements, as well as experts at the national level.

47. In the ensuing discussion, panellists referred to the example of user needs for water management in Ghana, where water and sanitation agencies were fragmented: numerous stand-alone water systems were in use by small communities, which made it more complex to adopt new practices. Panellists advocated for active "community-shaping" as a way to help in building capacity to use satellite data in operational settings; in Earth observation missions, after engaging with user communities during the design and development process, close contact with those same end users communities would increase during the exploitation phase of the mission. Providers of satellite-based solutions should look at what could be the gain for different types of actors in each community and reach "champion users" who would act as ambassadors of the solution in question. The end users did not need to know whether the data had come from a satellite, the issue was rather that various data providers needed to trust the validity of their sources of information.

48. The panel agreed that defining user needs was not a one-way street but a mutual exchange and knowledge-sharing exercise that included covalidation. Maintaining engagement with different types of users was challenging: the general public, experts and managers each needed suitable new information. In addition, content should be offered on a regular basis in order to obtain feedback not just once but on a continuous basis. Because the needs were so diverse, the key was to identify community members who worked in partnership with organizations that could include different voices and define priorities. Once information was available, it would still be a challenge for users to exploit that information appropriately.

49. The Chairs of sessions on the five themes of the Conference, and of the two panel discussions, gave a summary of the main recommendations. The panellists noted that making research available, in the sense of publishing it online, did not make that information understandable to those who were taking concrete action to protect water. Telling success stories would be a better way to communicate with and convince non-experts. Since the capabilities of space-based tools had not been in educational curricula for very long, it took time to build awareness. The Office for Outer Space Affairs highlighted that the Space4Water portal and its growing community of stakeholders actively contributed to those efforts. The United Nations and other international actors could act as intermediaries between technical experts and top-level politicians; once aware of what was available, politicians could propose incentives for the adoption of technology that would have a positive impact on local entities.

50. The Office for Outer Space Affairs and the local co-organizers of the University of Energy and Natural Resources concluded the Conference by summarizing the presentations and giving an overview of the roles of those involved in preparing the event. Participants were encouraged to provide written feedback using a dedicated online form.

VI. Conclusions and lessons learned

51. The Conference offered a wide-ranging overview of the ways in which Earth observation from space could help to improve water resources management. Speakers

presented tools, discussed the latest research and raised awareness of available resources and successful initiatives.

52. The use of lightning talks (see para. 14) made it possible to have more speakers and gave younger and less experienced speakers an opportunity to contribute to the event.

53. While the hybrid configuration posed the challenge of incorporating the online audience into the live event in Accra and interactions were limited, the use of the online platform enabled more varied participants to contribute. Throughout the Conference, the organizers used a chat channel for live interactions with the online audience, posting links to reference material and answering questions. Some technical issues in Accra, such as low Internet bandwidth and power cuts, affected the online participants' experience for short periods of time. Anticipating that such technical issues might occur, the organizers had ensured that the presentations were available for download in advance of their delivery; this significantly improved access to information for those connected online.

54. The feedback from participants was overwhelmingly positive. They rated the event 4.48 out of a maximum rating of 5. Words of appreciation were received from speakers and from attendees, in particular from those present in Accra.