UNITED NATIONS
OFFICE FOR OUTER SPACE AFFAIRS

THE SPACE4WATER PROJECT

Building bridges for knowledge exchange

UNITED NATIONS

On the right: Erg Iguidi, West Sahara Desert – This area of wind-shaped sand dunes is relatively humid, with abundant groundwater towards its north-eastern edge. Patches of seasonal vegetation support gazelle, and the area is even used for pasture.
26° 17′ N, 6° 13′ W
Landsat-8
© USGS/ESA

Publishing production: English, Publishing and Library Section, United Nations Office at Vienna.

space4water PORTAL

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UNITED NATIONS
Vienna, 2023

Credit: UNOOSA/Andrew Peebles

FOREWORD

Today, humanity faces a plethora of challenges related to water. As an effect of drought, some regions' populations see their water reserves gradually but surely emptying. Around 40 per cent of the world's population is affected by water scarcity. Elsewhere, people suffer from flash floods, rising sea levels or extreme weather. Rising sea levels affect agriculture, livelihoods, biodiversity and coastal habitats that are home to 900 million people.

We, the international community, have the responsibility to address and mitigate the impacts of these issues. We are alarmingly off track to achieving Sustainable Development Goal 6 and all water-related goals and targets by 2030. We need to strengthen our ambition and put an ever-stronger focus on cooperation, utilizing all available technologies and advancing capacity in their use and development.

Space technologies have gradually become instrumental for water management. By expanding access to information and knowledge, underpinning climate action, stimulating sustainable development and allowing for the monitoring of natural resources, we have become much better equipped to address water-related challenges. The next step in fully tapping the potential of space assets to improve life on Earth is to democratize access to these transformative tools and scale their application to benefit communities worldwide. In a world riddled with inequalities, we cannot let the space sector become yet another field of persistent gaps among and within countries.

To advance access to space solutions for addressing water challenges, the United Nations Office for Outer Space Affairs (UNOOSA) launched a dedicated Space4Water project at the beginning of the Water Action Decade in 2018. The Project, with its three pillars of conference series, web portal and community building, addresses knowledge exchange between scientific communities, policymakers, intergovernmental organizations, the private sector, civil society and the public. Through these efforts, we are strengthening communities, amplifying the voices of Indigenous communities, connecting them with professionals with the technical background to address their issues, and sharing a vast range of learning opportunities at different knowledge levels.

In the delivery of this project, we are grateful to collaborate with the Prince Sultan Bin Abdulaziz International Prize for Water (PSIPW). Together, we are contributing to

international water-related efforts such as the Water Action Decade and the Global Acceleration Framework. The conferences we have organized together since 2008 serve as important platforms to debate the latest issues and trends. With the Space4Water portal we created a catalyst for the use of space technology and data for water, as well as for networking, information and knowledge-sharing, and awareness-raising.

Our joint efforts drive a multitude of activities: we foster the exchange of data, information and knowledge between actors in the space and water sectors. We conduct capacity-building activities on the use of space-based data for more sustainable management of water and aquatic ecosystems. We contribute to innovation and improving water governance by connecting 90 stakeholders from various sectors and research disciplines; and we moderate action-oriented dialogues from the local to the global level.

With the Space4Water stakeholder community, which met for the first time in 2022, we created a new format that takes advantage of the limitless perspective looking at our blue planet from space. We look at water in its interconnected nature by using a "from source to sea" approach. We look at the whole water cycle, breaking silos between organizations, professionals and local communities, and shaping a perspective of collaboration to jointly address water issues and some of the most pressing environmental or humanitarian crisis in an inclusive manner.

UNOOSA will continue to support efforts on water to empower future generations and advance sustainability in space for sustainability on Earth. Tackling global challenges requires a willingness to collaborate and innovate. These cannot be addressed from the perspective of a single actor or stakeholder group. By putting our heads together and driving change based on scientific insights and all relevant viewpoints, we can find new solutions and take bold steps towards sustainable development. I can only applaud the outstanding work in the context of Space4Water and emphasize that the long-standing collaboration between UNOOSA and PSIPW is a great success.

Ms. Aarti Holla-Maini
Director, United Nations Office for Outer Space Affairs

Credit: PSIPW

FOREWORD

Back in 2002, Prince Sultan Bin Abdulaziz Al Saud (1930–2011) was acutely aware of the pending water crisis that we are confronting today. He realized that to avoid a major humanitarian tragedy, innovative solutions were needed. In that year, he established the Prince Sultan Bin Abdulaziz International Prize for Water (PSIPW) to encourage and recognize cutting-edge scientific innovation in water resources management and conservation.

This new international prize was unique among global water science awards in its emphasis on two areas of achievement: innovation and interdisciplinary work. These qualities are both strongly evident in one of the most critical areas of water science and technology: the space and water nexus. Indeed, many of our laureates over the years have been honoured for their space science-related work, as recipients of our specialized prizes for surface water, groundwater and water management, as well as our unique Creativity Prize dedicated to the achievements of interdisciplinary research teams.

This awareness of the pivotal role of space technology for water management, and its inherently innovative and interdisciplinary nature, led to the first collaboration between PSIPW and UNOOSA: the first International Conference on the Use of Space Technology for Water Management, which was held in Riyadh in 2008. The success of the conference led UNOOSA and PSIPW to agree to holding the conference on an ongoing basis in partnership with various national space agencies.

At that first Conference in Riyadh, the seeds for another cornerstone of our cooperation were planted. One of the conference resolutions was on the need to establish an international database of space and water scientists. PSIPW agreed to undertake the

development of this database and in 2009, at the meeting for the Committee for the Peaceful Uses of Outer Space (COPUOS), PSIPW presented its vision of a global community portal for space and water stakeholders, which was approved for further development. PSIPW then contracted a private company in France to develop a prototype of the portal, which was unveiled in February 2012 at the COPUOS Scientific and Technical Subcommittee meeting.

To enable the development of the actual Space4Water portal and facilitate the expansion and diversification of our cooperative activities under the umbrella of the joint Space4Water Project, UNOOSA and PSIPW entered into an ongoing memorandum of understanding in 2016. The Space4Water portal was officially launched in 2018 at the United Nations Headquarters in New York on the occasion of the eighth PSIPW Awards Ceremony.

PSIPW looks forward to our ongoing successful cooperation with UNOOSA in fostering the efforts of all stakeholders in the space and water resources sectors to advance water science through the use of space technology for the benefit of all humanity.

Dr. Abdulmalek A. Al Alshaikh
General Secretary, Prince Sultan Bin Abdulaziz International Prize for Water

The vision of the Space4Water project is to enable all stakeholders involved in the space and water communities to access data and knowledge, to be creative and to realize their full potential in contributing to a world in which the availability and sustainable management of water and sanitation for all has become a reality.

CONTENTS

1.

WHY SPACE4WATER

Space technologies, and satellite remote sensing technology in particular, have demonstrated proven capabilities in meeting the challenges of water resource management, as rapid population growth and development pressures continue to impose additional stresses on valuable resources. Water scarcity is a major global challenge. While parts of the world are becoming dryer, others are becoming much wetter. Hurricanes become stronger and flooded coastlines more frequent. Water-related disasters include floods, storm surges, waves, tsunamis, landslides, droughts, epidemics and contamination, to name just a few.

Climate change also leads to the melting of permafrost and glaciers, the drying up of permanent water bodies or wetlands, and to more extreme wet and dry seasons which can have far-reaching effects such as food crises and migration. Today, 90 per cent of all disasters and consequences of climate change are water-related.

Continuous Earth observations from space are crucial to managing water resources for the benefit of humankind and the environment. They also provide important forecasting services to mitigate the impacts of water-related disasters such as floods and droughts.

Remote sensing satellites provide data on several key water-related variables (for example, rainfall, precipitation, floods, droughts, water storage, soil moisture and evaporation) using spatial and temporal scales that are appropriate for reliable assessments. A satellite-based approach to the assessment and management of water resources is especially important in countries and regions of the world where adequate hydrological networks do not exist. Effective management of water resources includes the monitoring of surface water, soil moisture, snow and total water storage. It also allows for effective management of water-related risks, including floods and drought.

Thematic Mapper image of the Mergui archipelago in the Andaman Sea, Myanmar

Credit: Michael Taylor, NASA

Earth observation applications for water management include mapping land cover and land use, vegetation, surface water extent, flood risk and extent, snow cover, wetlands and monitoring river ice, soil moisture and water quality, as well as changes in surface mass and total water storage, which indicate changes in groundwater levels. Earth observation data supplement respective ground-based/in situ monitoring for many aspects of water management.

Starting with its session in 2004, the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) considers matters connected to the use of space-related technology in water resource management. The Committee noted that in response to the deepening water crisis, space technology could contribute to better water resource management by providing data and information on the availability of water resources and water use. The Committee also noted that once converted into practical information, scientific data on water resources provided by satellites could be used to formulate policy and implement programmes at the national, regional and international levels, including those of the World Bank, the United Nations Development Programme and other entities of the United Nations system. Innovative scientific solutions are needed to help solve the water crisis, and space technology applications provide tools for effective water resources management.

Both the Water Action Decade and the Space4Water project started in 2018, which means the first half of the Water Action Decade has passed. Aimed at raising awareness and defining a road map to advance the global water agenda, the Decade was proclaimed to accelerate efforts towards meeting water-related challenges.

The United Nations 2023 Water Conference that took place at United Nations Headquarters in New York, on 22–24 March 2023, co-hosted by Tajikistan and the Kingdom of the Netherlands gathered Heads of State and Governments to identify challenges and obstacles to implementing the Water Action Decade, and to discuss proposed actions and initiatives to overcome these challenges. This effort is also supported by the SDG 6[1] Global Acceleration Framework, which was launched in 2020. The Framework mobilizes United Nations agencies, Governments, civil society, the private sector and other stakeholders around five cross-cutting and interdependent accelerators. It aims to address bottlenecks, to allow for swift responses to country requests through leveraged expertise mobilization, to align coordinated approaches across sectors, and to strengthen accountability through joint review and learning.

How can we achieve this? By facilitating access to knowledge and the exchange of good practices, by pursuing advocacy, networking and promoting collaboration; and by strengthening communication actions. These are all goals and action areas of the Space4Water project.

[1] SDG 6: Ensure access to water and sanitation for all.

2.

AT A GLANCE

Collaboration between the Prince Sultan Bin Abdulaziz International Prize for Water and the United Nations Office for Outer Space Affairs

Access to and further development of innovative technologies to address water issues need to be encouraged and supported worldwide. The United Nations Office for Outers Space Affairs (UNOOSA) and the Prince Sultan Bin Abdulaziz International Prize for Water (PSIPW) have together been working on this goal for over a decade.

Since 2008, UNOOSA and PSIPW have been co-organizing a series of international conferences on the use of space technologies in water management. The first conference was hosted in Saudi Arabia, the second in Argentina, the third in Morocco, the fourth in Pakistan, and the most recent one was hosted in Ghana in 2022.

UNOOSA and PSIPW signed an agreement on the development of the Space4Water portal in 2016 and the portal was launched in 2018. The Space4Water portal is a platform where practitioners from the water and space sectors can exchange knowledge and pull together resources to improve water management. Owing to the success of the portal, a new agreement was signed in 2020 to allow for long-term sustainability and an expansion of the scope of the project.

Sand seas of the Namib Desert
Credit: ESA

UNOOSA is mandated to deal with space affairs, specifically the peaceful uses of outer space. Among its mandates, it promotes international cooperation in the field, as well as the use of space science and technology for sustainable development, particularly for the benefit of developing countries. The Office is integral to the work of the United Nations in advancing multilateralism on space matters as it serves as secretariat to the Committee on the Peaceful Uses of Outer Space (COPUOS), a body responsible for intergovernmental dialogue on cooperation, advancing space research programmes, studying space-related activities that could be undertaken by the United Nations and analysing legal problems arising from the exploration of outer space.

Learn more at www.unoosa.org

Figure 1.

Former Director of UNOOSA, Simonetta di Pippo, officially announcing the launch of the Space4Water portal

Credit: PSIPW

Figure 2.

Assistant Secretary-General for Economic Development and Chief Economist Elliott Harris at the launch of the Space4Water portal

Credit: PSIPW

Figure 3.

Space4Water project staff and portal developer Nina Kickinger presenting the Space4Water portal

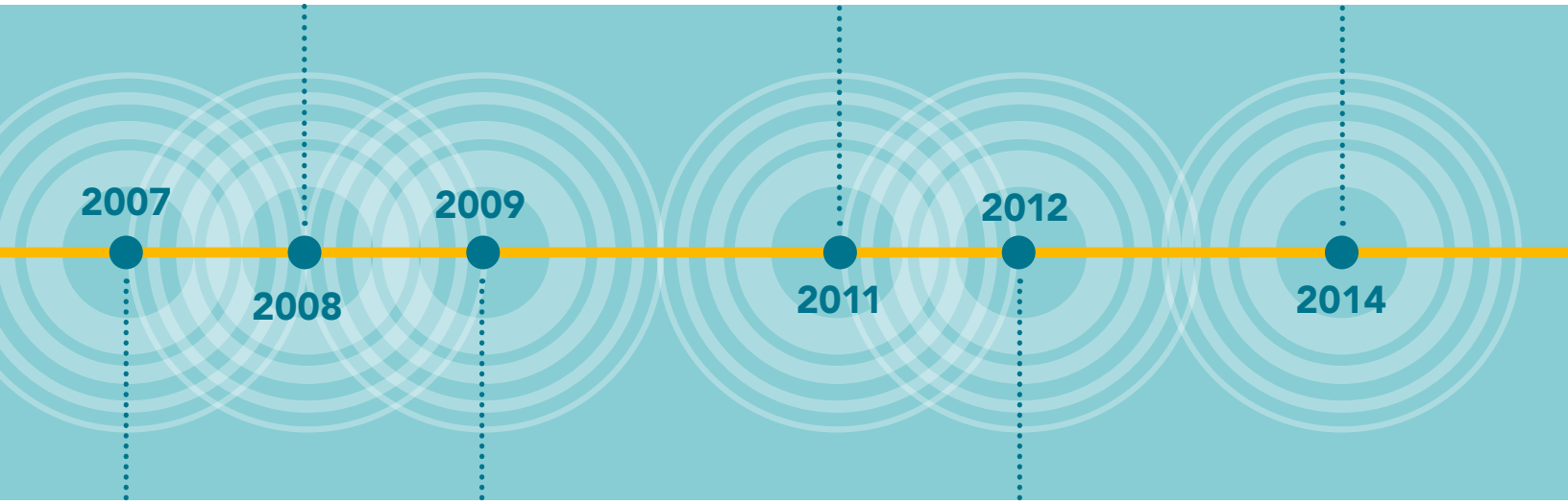
Credit: PSIPW

The Prince Sultan Bin Abdulaziz International Prize for Water (PSIPW) is a scientific prize with a focus on innovation. Established in 2002 by HRH Crown Prince Sultan Bin Abdulaziz, it rewards the efforts made by scientists, inventors and research organizations around the world which contribute to the sustainable availability of drinking water and the alleviation of the escalating global problem of water scarcity. To this end, PSIPW awards a suite of five biennial prizes, covering the entire water research landscape. In this way, PSIPW encourages research to find solutions to the various water-related challenges facing the world today.

Learn more at www.psipw.org

Figure 4.
The eighth Awards Ceremony of the PSIPW at the ECOSOC Chamber at United Nations Headquarters in New York, during which the Space4Water portal was officially launched
Credit: PSIPW

A SPACE4WATER TIMELINE



2007 — First cooperation agreement between UNOOSA and PSIPW established

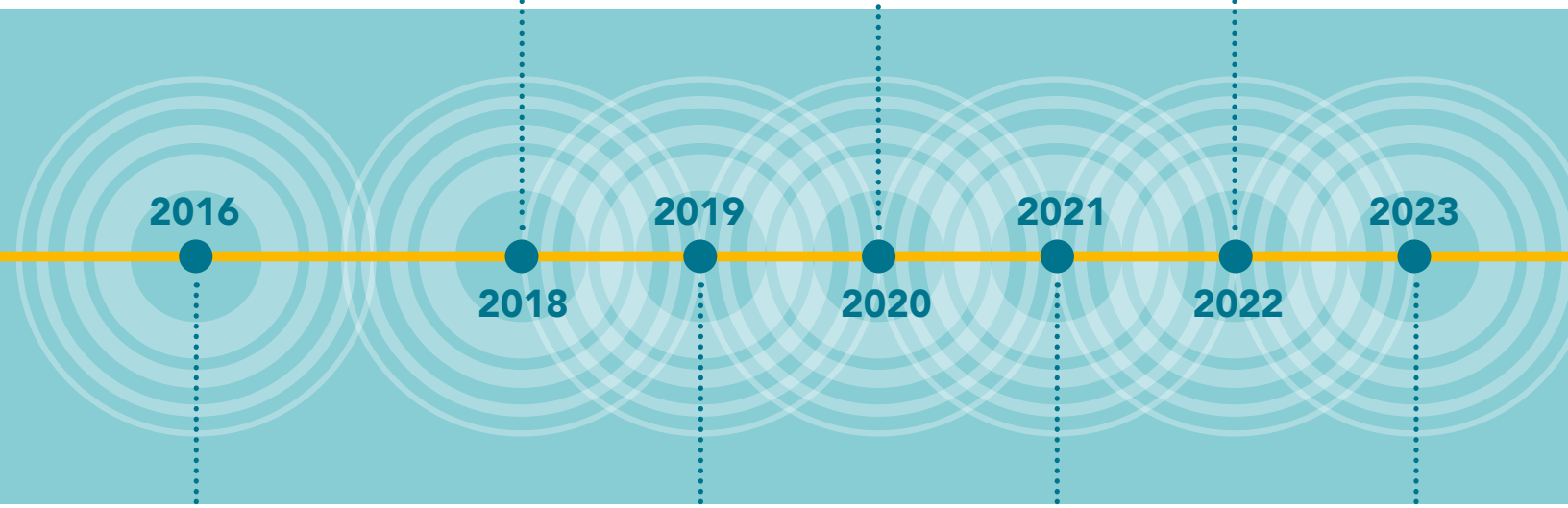
2008 — United Nations/UNESCO/Saudi Arabia International Conference on the Use of Space Technology for Water Management, in Riyadh

2009 — PSIPW presented the project idea to the Committee for the Peaceful Uses of Outer Space (COPUOS)

2011 — United Nations/Argentina second International Conference on the Use of Space Technology for Water Management

2012 — Official presentation of the International Water Portal (first version) at the COPUOS Scientific and Technical Subcommittee

2014 — United Nations/Morocco third International Conference on the Use of Space Technology for Water Management



2016

Signing of the memorandum of understanding and a funding agreement between UNOOSA and PSIPW

2018

Launch of the Space4Water portal

2019

Release of the Meet a Professional feature

2020

Signing of agreements between UNOOSA and PSIPW to sustain and expand the project 2020–2026

Release of the Meet a Young Professional and the data set search features

2021

The Space4Water community welcomes its fiftieth stakeholder

Release of the Local Perspectives and Case Studies features

2022

First Space4Water stakeholder meeting

Participatory workshop for Indigenous women

United Nations/Ghana/PSIPW – fifth International Conference on the Use of Space Technology for Water Resources Management

Release of the Actors Map feature

2023

Second and third Space4Water stakeholder meeting

Release of the Indigenous voices feature

FACTS AND FIGURES

The Space4Water project

Over **600** people

from over **140** countries

participated in person at **5** conferences

A web portal with over **800** knowledge resources
on the use of space technology for water

Articles and success stories as well as interviews with professionals
and young professionals are edited and published **monthly**

~100 stakeholders joined in the first five years

7 Indigenous communities

16 professionals

24 young professionals

Portal statistics

FIGURE 5. Space4Water portal – Number of content items per year (2018–2022)

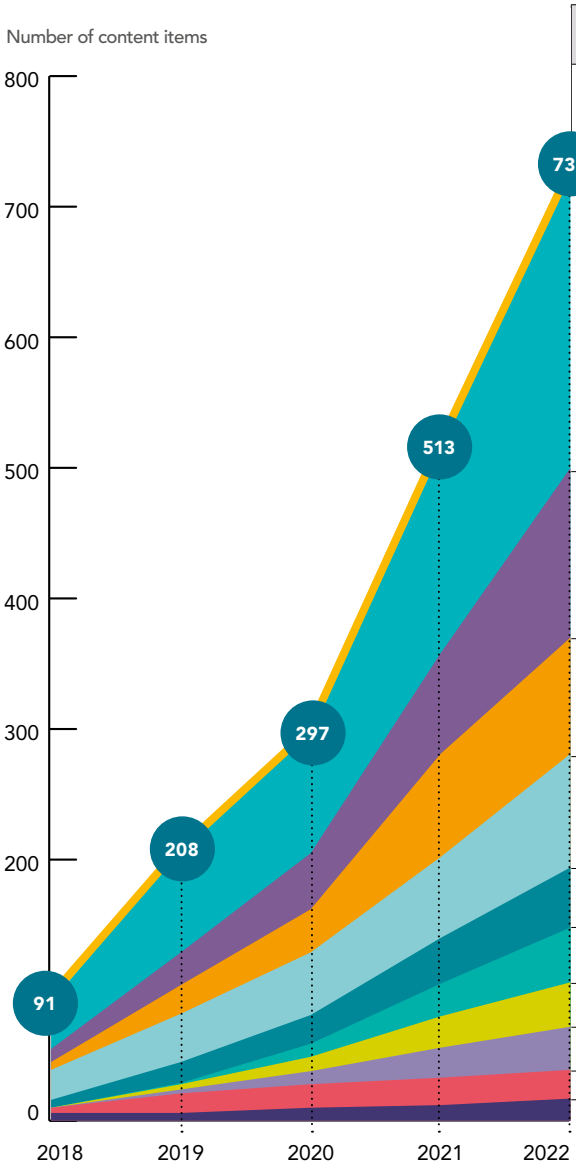


TABLE. Space4Water portal statistics at the end of each year (2018–2022)

Type of content	2018	2019	2020	2021	2022
TOTAL	**91**	**208**	**297**	**513**	**735**
Events	36	79	92	155	235
Publications	10	25	43	77	130
Training material	6	22	33	79	89
Stakeholders	23	37	48	62	87
Articles	6	16	22	35	46
Activities/opportunities	–	1	10	25	42
(Young) professionals	–	4	11	24	34
Interviews	–	3	10	23	33
Software	4	15	18	21	22
Projects	6	6	10	12	17

Note: The Indigenous voices feature was only launched in 2023 and currently features seven Indigenous voices.

Portal access statistics from launch in October 2018 to 30 June 2022:

168,761 users **215,180** sessions **332,199** page views

SPACE TECHNOLOGIES FOR WATER MANAGEMENT, HYDROLOGY AND AQUATIC ECOSYSTEM PRESERVATION

Space technologies cover a range of technologies and are often classified as global navigation satellite systems (GNSS), Earth observation, satellite communication and human spaceflight. The majority of water projects using space technology rely on Earth observation of water bodies via satellites. GNSS has been useful for monitoring water, and GNSS receivers can be used to detect the water content of soil, the depth of snow, snow water equivalent, vegetation water content, and tsunami detection and early warning.

Earth observation contributes to the development of information about the planet's physical, chemical and biological systems. It involves monitoring and assessing the status of and changes to the environment. A combination of remote-sensing satellite data and in situ data collection to monitor the Earth and its water bodies allows for the generation of increasingly reliable information about even the remotest areas.

Finally, spin-off technology from space technology includes innovations made through human space flight, which are later applied to other purposes. In the context of water, spin-off technology today most importantly includes water filtration systems that were originally developed for sustaining sanitation systems for astronauts.

Earth observation instrument types facilitating monitoring of water-related parameters

Satellites can carry various instruments to obtain data on magnetic fields, radiation, the Earth and its atmosphere. Such instruments are equipped with either active or passive sensors. Active sensors use energy to illuminate the objects they observe. They emit radiation in the direction of the target to be investigated and measure the reflectance or backscatter of that signal. Passive sensors, on the contrary, detect natural energy (radiation) that is emitted or reflected by the object or scene being observed. In most cases it is sunlight that is reflected. These passive sensors work like your photo camera, without flash.

The variables described below represent a non-exclusive list of variables or phenomena whose assessment can be supported by space technologies, especially Earth observation.

Examples of observed water-related variables or parameters

PRECIPITATION

Precipitation is an important part of the hydrological cycle. Seasonal changes in the amount and intensity of precipitation can serve as a warning system for a perturbed hydrological cycle. In the same vein, water quality can be compromised through run-off into rivers and lakes, in case of increased rainfall. Rising sea levels caused by increased precipitation can threaten water supply through the intrusion of salt water into upstream coastal waters. Rainfall is monitored from space by radar and microwave radiometers, which generate relevant data.

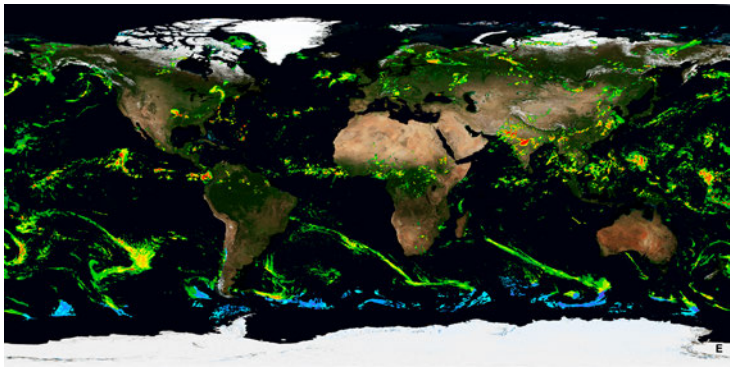


Figure 6.
Global precipitation and snowfall map
Credit: NASA

EVAPOTRANSPIRATION

While precipitation takes water from the atmosphere to the surface of Earth, evapotranspiration can be thought of as the opposite process: it releases water into the atmosphere in the form of vapour. It is an important variable in water resources management which cannot be monitored directly from space and, therefore, it is estimated from other environmental parameters such as surface radiation, soil moisture and plant phenology that can be detected from space.

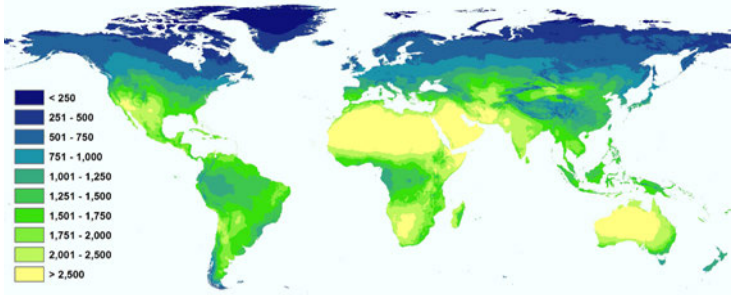


Figure 7.
Global Aridity Index and Potential Evapotranspiration (ET0) Climate Database v3
Credit: Antonio Trabucco, Robert Zomer, CGIAR

SURFACE WATER LEVEL AND EXTENT

The observation of surface water is of importance for mitigating the impacts of hydrological extremes because of the role of surface water bodies and rivers in providing storage during periods of drought, and as the conveyance of flood waters. This applies to human-made reservoirs as well, which can serve multiple purposes such as water storage and flood control. Flooding also manifests itself as temporary surface water that can be observed from space. In all cases, the goal is to measure the level and extent of the surface water and potentially derive volume based on local bathymetric measurements. Identification of surface water can be achieved either from optical or microwave sensors (passive and radar).

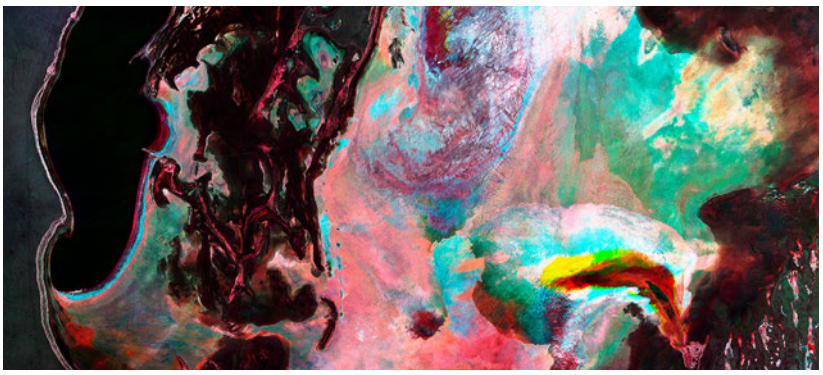


Figure 8.
Aral Sea, this multitemporal Sentinel-1A radar image shows the Aral Sea
Credit: ESA

SNOW COVER

Snow cover is an important variable for climate research. It strongly impacts the energy balance of the continental surface and affects surface humidity and temperature at the lower boundary of the atmosphere. Snow cover is one of 50 essential climate variables (ECVs) that are monitored by satellite remote sensing by the Global Climate Observing System (GCOS). Data products on snow cover are developed from high-resolution Earth observation data generated from synthetic aperture radar and optical sensors.

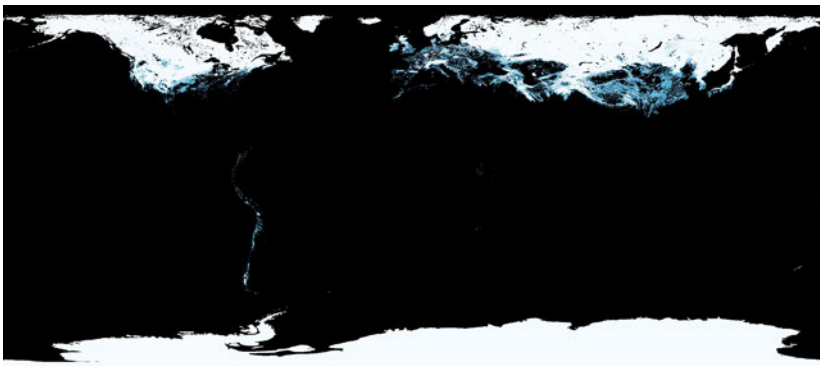


Figure 9.
Global snow cover map
Credit: NASA

GLACIER MONITORING

Glaciers are the largest reservoirs of fresh water on our planet and their melting or growing is one of the best indicators of climate change. Satellite radar data can help monitor changes in glacier mass and, subsequently, their contribution to rising sea levels, but it is a challenging task. Taking satellite images of the ice for a minimum of five years and comparing the results can allow scientists to gain insights into climate change. Monitoring the outside edge of a glacier (the glacier's terminus) will indicate the extent to which the glacier's edge is receding or expanding.

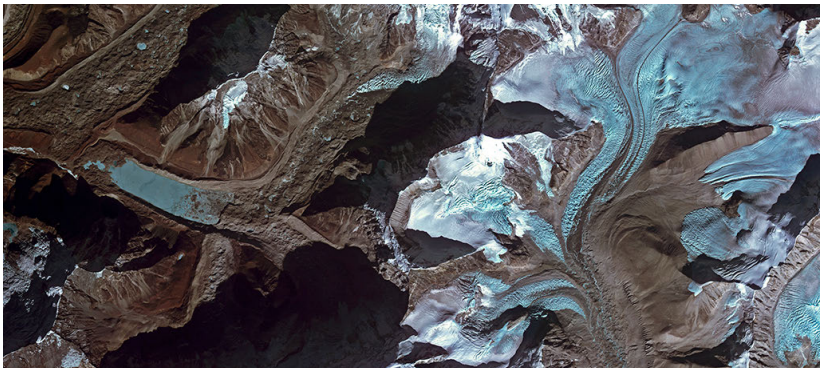


Figure 10
Imja Glacier, Himalayas
Credit: KARI/ESA

ARCTIC LAKES AND PERMAFROST

Permafrost degradation can result in terrain change altering water flow and storage. Water logging and drying up condition the fate of the carbon stored in soils, which is released as either methane or carbon dioxide. Changes in Arctic lakes are studied, and permafrost monitored to keep track of climate change. These changes can be observed from space through optical and radar data.

Lake ice spatial patterns relate not only to the thickness of the ice, but also to movements of the water bodies below. As radar imagery does not depend on sunlight, cracks, openings and ice jams become visible even during the long polar night.

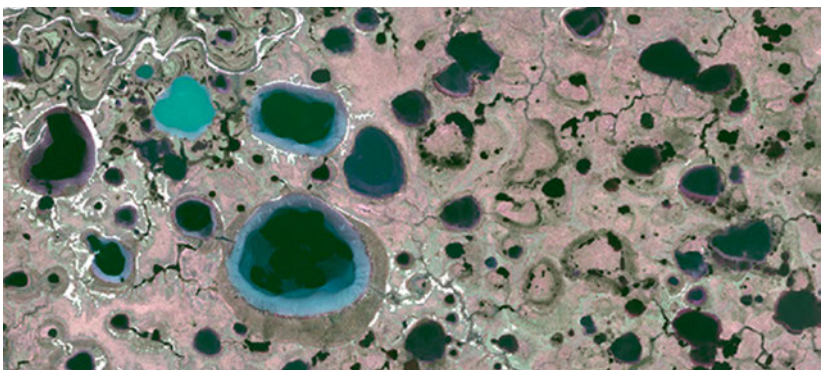


Figure 11.
Arctic lakes from space. Sentinel 2 image of Central Yamal, summer 2017
Credit: ESA

RIVER ICE MONITORING

In addition to surface water extent and height measurements from space, data on river ice can also be extracted from a combination of low and medium and high-resolution satellites. In northern countries, river ice plays a dominant role in the hydrologic regime of rivers and can impact the movement of goods and services where a regular land-based road network does not exist. It may also be used as an indicator of climate change. Thus, collecting up-to-date information on river ice cover can improve our understanding of river ice processes and their societal and environmental impacts.

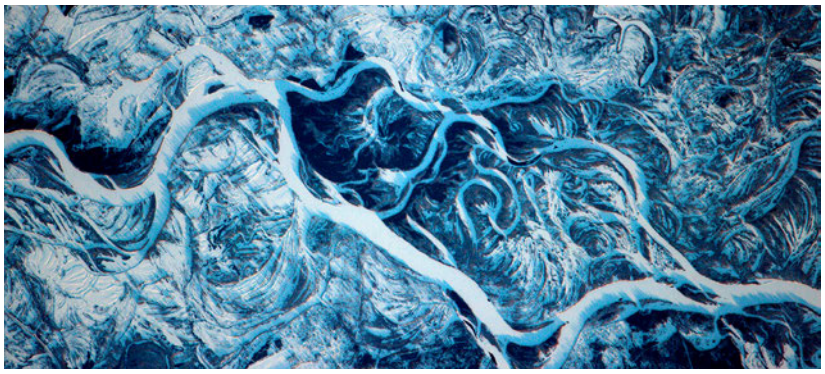


Figure 12.
Ice on the St. Lawrence River, Canada, captured by MODIS
Credit: NASA

SOIL MOISTURE

Another variable of importance is soil moisture. This, like evapotranspiration, is a proxy for monitoring drought, for agricultural and flood management. Soil moisture is estimated by associating its changes with changes in surface emissivity as measured by microwave sensors.

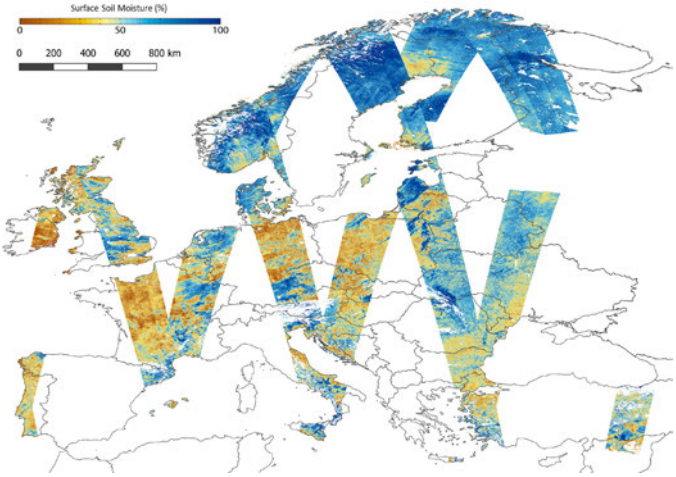


Figure 13.
Copernicus Global Land service, Daily Surface Soil Moisture based on Sentinel 1 over Europe, 24 August 2018
Credit: ESA

WATER QUALITY

Water quality can be monitored from space by means of various indicators. The majority of these are monitored via optical sensors and their assessment is often based on the colour of the pixel. Optical remote sensing can monitor the effects of water quality changes that leave optical traces, hence affecting the colour of a water body. Observable indicators include chlorophyll-a, turbidity and surface water temperature.

Chlorophyll-a/trophic state: Trophic state is the total weight of biomass in a water body. Chlorophyll-a is essential for most photosynthetic organisms to release chemical energy. All oxygenic photosynthetic organisms use chlorophyll-a. So does algae, and the identification thereof in water bodies is possible because of the green appearance of chlorophyll, including on the imagery created by, for example, ocean colour sensors. Increases in chlorophyll-a can amplify the eutrophication of water bodies.

Turbidity indicates how clear water appears as a result of sediments and suspended solids. To be able to convert the optical change in the appearance of the water into an actual quantity, scientists need to know how a change in the suspended matter content by a certain amount affects the spectral properties. For this reason, laboratory analyses and on-site measurements are also necessary when using space technologies to establish the relationship between water quality and optical properties.

Surface water temperature plays an important role in water quality monitoring due to its effects on other water quality parameters such as dissolved oxygen levels or chemical and biological processes as well as on biodiversity. It can be monitored from space by means of microwave radiometers.

Figure 14.
Landsat 8 natural colour image of a swirling green phytoplankton bloom in the Gulf of Finland, Baltic Sea
Credit: NASA

GROUNDWATER

Groundwater constitutes the largest source of water for irrigated agriculture and can serve as a source of drinking water in both developed and developing countries. Globally, it can be monitored and mapped to address water resource issues facing hydrologists, engineers, regulators and resource managers at regional and local levels. When combined with monitoring wells and water quality samples, long-term trends associated with issues such as climate change can be evaluated. The GRACE mission and its follow-up mission are unique as they carry the only sensor dedicated to observing continuous mass changes in water storage. Its resolution of 300–400km is coarse.

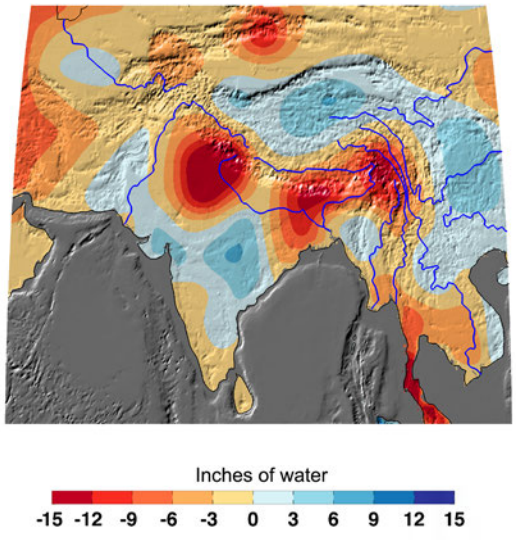


Figure 15.
Cumulative total India fresh water losses as seen by GRACE Mission, 2002–2015
Credit: NASA

VEGETATION

Apart from drought and crop monitoring, vegetation also helps in the control of evapotranspiration in the hydrological cycle. Properties for monitoring, including leaf area index, fractional vegetation coverage or the fraction of sunlight absorbed by canopies, can be estimated from visible/infrared (VIR) sensors or by using spectral reflectance through comparing spectral signatures with surrounding areas. Indices such as the normalized difference infrared index (NDII) that are based on near infrared (NIR) and short-wave infrared (SWIR) of the electro-magnetic spectrum can be estimated to monitor soil/canopy water content. Other proxies such as the moisture stress index (MSI), normalized difference water index (NDWI), normalized multi-band drought index (NMDI) and water band index (WBI) can be used to monitor water content. Vegetation water content (in combination with soil moisture) can be estimated and used to determine the optical depth of vegetation from microwave data. This enables us to monitor the hydrological functioning of plants.

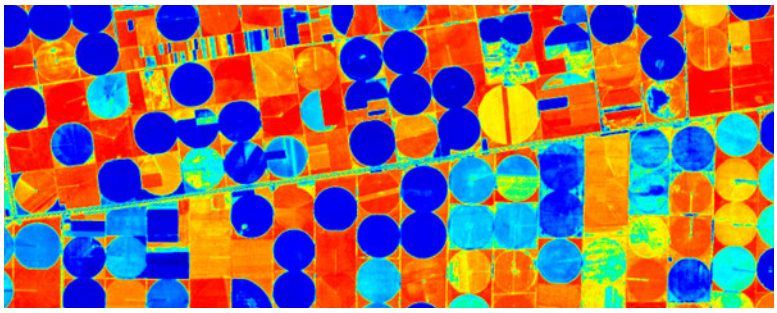


Figure 16.

Normalized multi-band drought index of irrigated fields in the Kherson region, Ukraine

Credit: Wikipedia under Creative Commons licence

Figure 17.

Normalized difference vegetation index image of the Suez Canal, Egypt

Credit: ESA

SPIN-OFF TECHNOLOGY

Spin-offs from space technologies include systems for water testing, for example, with ultraviolet laser scanners, water treatment optimization such as the silver ion biocide delivery system, aquaporins or the Micro-Ecological Life Support System Alternative (MELiSSA) and the assessment of water availability.

Figure 18.

NanoCeram, a filter composed of microscopic alumina fibres to remove all contaminants that has larger pores than traditional filters resulting in higher flow rates and faster filtration processes

Credit: NASA

Interviews, articles and success stories

Monthly, one interview as well as one article on the use of space technology to address any water-related topic is published on the Space4Water portal. If written by a community member, they will be listed both on the landing pages for interviews or articles and success stories, and also on the profile page of the author.

Interviews

Articles and success stories

SPACE4WATER AND THE SUSTAINABLE DEVELOPMENT GOALS

The Sustainable Development Goals (SDGs) can serve as a guiding framework and water is a connecting factor which implicitly contributes to several of the goals. So, improving how we use water globally will also contribute to climate change action, life below water and life on land. It is no surprise that water scarcity affects the Water-Energy Food Nexus, but also our health, poverty and gender equality. To achieve water security, we need collaboration and action. Find an overview of examples of relevant space-based applications to address water issues per SDG.

- Monitoring soil moisture
- Monitoring evapotranspiration and irrigation

- Mapping of waterborne disease
- Mapping and forecasting of mosquito outbreaks

- Monitoring mass changes to changes in groundwater levels
- Water quality monitoring
- Monitoring water parameters via sensor networks facilitated with satellite Internet connection to receive information from remote areas
- Integrating Earth observation data and national surveys e.g., to identify areas at risk of pollution
- Water body extraction/ surface water extent mapping
- Water filtration systems (space technology spin off)
- Identifying best routes for emptying pit latrines and septic tanks
- Identifying locations for well drilling

- Monitoring hydropower dam levels
- Simulating dam breakage and flood modelling

SUSTAINABLE DEVELOPMENT GOALS

- Spin-off technology from space-based innovations

- Meteorological observations
- Precipitation monitoring
- Using GNSS networks to detect the depth of snow, snow water equivalent and vegetation water content
- Flood modelling
- Measuring ice-thickness

- Monitoring water quality e.g. chlorophyll-a, turbidity, chromophoric dissolved organic matter or algae blooms
- Pollution monitoring of plastic or oil spill mapping and recovery (space technology spin off)
- Creating coral habitat maps and heat maps to identify areas of coral reef bleaching
- Decision-making for ecosystem conservation
- Monitoring illegal fishing activities

- Drought and desertification monitoring
- Sediment redeposition
- Sand-storm monitoring
- Wetland classification and monitoring
- Land use land cover
- Soil moisture
- Vegetation health, vegetation indices
- Using GNSS networks to detect water content of soil, snow water equivalent and vegetation water content
- Ecosystem conservation monitoring
- Run-off modelling and environmental flow

3.

THE SPACE4WATER PROJECT

The Space4Water project is a multi-stakeholder platform for interdisciplinary knowledge exchange, making information on space solutions and technologies for water-related topics accessible. It is a capacity-building platform and a portal for expert communities, including those from developing countries.

The Space4Water Project is built on three pillars:

THE SPACE4WATER COMMUNITY

THE SPACE4WATER PORTAL

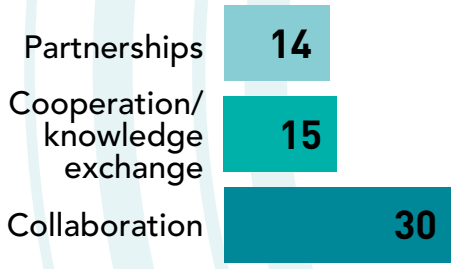
A CONFERENCE SERIES

One of the key strengths of the project is its inclusivity. The project engages actors on a local, national, regional and international level, and has been actively engaging with youth, empowering women and raising the voices of Indigenous communities. The success of the Space4Water project lies in connecting actors and allowing them to learn from each other. The project provides experts, practitioners and affected communities with an opportunity to exchange views on technical matters including challenges and best practices, and to discover potential areas of cooperation. The aim is the creation of a lively community of practice.

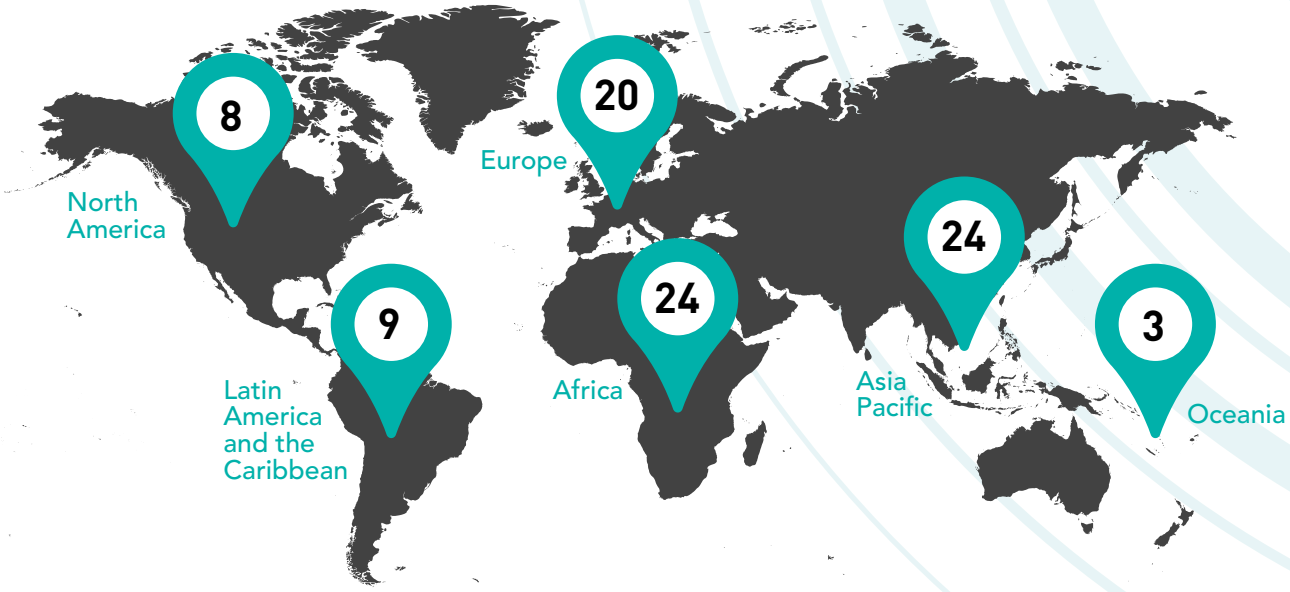
Abu Dhabi
Credit: ESA

STAKEHOLDER GROUPS

STAKEHOLDERS LOOKING FOR:



REGIONAL FOCUS



THE SPACE4WATER COMMUNITY

Space4Water **Stakeholders**

Space4Water stakeholders are professional entities that are active in the field of space technologies and/or water research, management, the processing of space-based data or the development of software applications to that end. They include representatives of academia, international and national organizations and institutes, as well as civil society, non-governmental organizations, research institutes and the private sector, and focus on or use applications of space technologies and data in their work. On the Space4Water portal each stakeholder has a profile page to share knowledge resources on how they are using space-based technology and applications to address water-related issues with the broader Space4Water community and the public, including contact details to reach out and learn more. As of June 2023, the project had 91 stakeholders.

www.space4water.org/stakeholders

THE SPACE4WATER COMMUNITY

Space4Water **Professionals**

Distinguished researchers and other professionals such as chief executive officers or directors of organizations, as well as people in high management positions, pioneers of space technology or water resource management, some of them in developing countries and rural areas, role models and experts will be featured and introduced by means of a photo, a short biography, voluntarily shared contact details and an interview. Researchers are also invited to share their relevant publications. Meet the professionals UNOOSA interviewed and learn from their vast experience by scanning the QR code. Interviewing these inspiring individuals offers a glimpse of what drives some of them, to share in their passion for science and the care these individuals have for our natural resources.

www.space4water.org/meet-professionals

THE SPACE4WATER COMMUNITY

Space4Water **Indigenous voices**

The cultural heritage of Indigenous communities encompasses knowledge of natural resources, including water, and this urgently needs to be considered and protected. This feature invites Indigenous people, especially but not limited to those who play a key role with regard to water in their community to share their knowledge about this valuable resource, their concerns about its state, and the changes in aquatic or water-related environments they observe, among other topics. Every featured individual has a profile page and is featured in an interview. Indigenous voices are invited to join Space4Water stakeholder meetings.

www.space4water.org/indigenous-voices


BE Tech

THE SPACE4WATER COMMUNITY

Space4Water
Young professionals

Younger generations are the ones who will be most drastically affected by climate change and all the decisions humanity takes today. Their voices matter, their knowledge can be on point and their contributions to a sustainable future need to be considered. Space4Water gives young professionals of up to 35 years of age the chance to share their visions and knowledge on the use of space technology for water topics. UNOOSA interviews these young professionals and allows them to share relevant research activities or information on their projects on their Space4Water profile pages. Young professionals are invited to stakeholder meetings. Many of them have written relevant articles published on the Space4Water portal.

www.space4water.org/
meet-young-professionals

Space4Water stakeholder meetings

Space4Water stakeholder meetings are an opportunity for experts to exchange views on technical matters and discover potential areas of cooperation. They aim at creating a community of practice in which mutual learning and exchange of ideas takes place.

THE FIRST SPACE4WATER STAKEHOLDER MEETING

Together with PSIPW, UNOOSA organized the first Space4Water stakeholder meeting convening about 20 individuals representing Space4Water stakeholders, as well as professionals featured on the Portal. They delivered presentations highlighting the complementary skill sets of this community. The meeting further allowed the identification of objectives for the community of practices as well as effective approaches to facilitating the matching of relevant actors. It provided guidance to advance joint efforts for finding space-based solutions to water-related challenges and helped determine future steps. The meeting also addressed how stakeholders assess user needs in water-related sectors.

Figure 19.
Group photo taken at the first Space4Water stakeholder meeting
Credit: UNOOSA

Figure 20.
Panel with Government representatives. Left to right: moderator and representatives from the Zimbabwe National Geospatial and Space Agency, the Kenya Space Agency, the Egyptian Space Agency and the local government of Meghalaya (India)
Credit: UNOOSA

THE SECOND SPACE4WATER STAKEHOLDER MEETING

The second Space4Water stakeholder meeting was hosted online from 11–12 May 2023. Thirty-one participants from 20 countries met to exchange knowledge and collaborate on addressing water-related issues with space-based technology and data, both in theory and practice. Fifteen technical presentations were delivered in four sessions. In the interactive session "Matching water-related problems with space-based solutions", participants collaborated to outline approaches to addressing water-related issues observed and faced by the Indigenous communities represented at Space4Water or other members of the Space4Water stakeholder community.

Quotes from participants

How did you benefit from attending the meeting? What did you learn?

It was a wonderful experience to meet a diverse group.

A common goal. The programme was managed in such a way that every second of it was very significant and interactive.

It has benefited me in various ways: networking, technology updates, looking into water crises in the world and the ideas to handle them, numerous perspectives of looking at water-related issues and their solutions using space technologies; and being part of a community that is progressive and enthusiastic. Finding the way forward gives confidence.

What did you specifically like?

The collective wisdom to identify issues, think of solutions, thinking out of the box for the sake of humanity.

These meetings of experts have a lot of potential for creating partnerships with tangible impact for end users, for communities. The experience of the stakeholder meeting needs to be replicated with incremental improvements.

What was your favourite session and why?

The session "From water-related challenges to space-based solutions". The interaction was active. It breaks the shyness and people shared how they tackle water-related problems using space technology.

The descriptions of water-related challenges, the guidance to get from a challenge to a problem definition, technology and success criteria. It enabled me to consider additional questions, motivated me to refine and improve novelties in investigating compound hydrometeorological extremes, e.g., in India.

Participatory workshop for Indigenous women on their roles and responsibilities related to water

In October 2022, UNOOSA welcomed a group of Indigenous women to participate in a workshop focused on the roles and responsibilities of Indigenous women related to water. Through the insights offered by the six women from different communities and countries participating, we learned about their specific approaches to managing water, obstacles and opportunities linked to space applications, as well as the challenges and environmental changes they observe and face. During the workshop, the Office collected their stories and incorporated them into a new feature on Indigenous voices on the Space4Water portal.

"We have been working hard in building a repository of historical information of our river. Your guidance has been incredibly helpful. We have worked with local experts and historians and have put together a planting event and encouraged our young people to come along and participate. We are undertaking testing on water quality and also working with the local council on wildlife conservation".

Cadence Kaumoana
(nine months after the workshop)

Figure 21.
Participants at the participatory workshop for Indigenous women on their roles and responsibilities related to water
Credit: UNOOSA

Figure 22.
Participants at the participatory workshop for Indigenous women on their roles and responsibilities related to water
Credit: UNOOSA

Figure 23.
A participant at the participatory workshop for Indigenous women on their roles and responsibilities related to water
Credit: UNOOSA

Space4Youth #Youth4Water Competition

In October 2022, UNOOSA and the Space Generation Advisory Council (SGAC) launched the fourth edition of the Space4Youth Competition with a focus on the use of space for water resources management and aquatic ecosystem preservation.

Figure 24.
Space4Youth winners during their Space Camp experience
Credit: UNOOSA

THE SPACE4WATER PORTAL

The Space4Water portal was launched at the beginning of the Water Action Decade in 2018 and serves as a one-stop-shop for activities merging the realms of water and space.

On the Portal, the Space4Water community shares information on projects, initiatives, satellite missions, software, community and data portals, capacity-building and training material, conferences, workshops, water-related challenges, as well as news and publications in the sector.

UNOOSA has been publishing one article and one interview with a Space4Water professional or young professional every month. These serve as an element to foster science communication and raise awareness on the potential of space technology and applications for water.

UNOOSA also regularly researches relevant upcoming conferences, events and training opportunities for the community. Moreover, stakeholders have the possibility to announce opportunities such as their upcoming events, calls or PhD positions that will be communicated with the community.

The Portal provides information on tools and software, or data products that address various levels of technological advancement.

Figure 25.
A screenshot of the Space4Water portal landing page
Credit: UNOOSA

While respecting and valuing innovations and the specialization of technology from the private sector, the Space4Water project refers to projects that are developed in the open domain, and supports the development of open source, open science and knowledge overall.

With its ever-growing repository of resources, the Portal is an invaluable source of information for space and water students and professionals, decision and policy-makers as well as the public. Thanks to the increasing interest in this field as well as proactive outreach activities, the Portal has a continuously growing number of users, bringing the total to around 170.000 individual users within the first five years.

Examples of training material shared on the portal include recommended practices on data sharing for water sector organizations, flood mapping and damage assessment, cloud-based computing solutions, tutorials on Open-Source GIS applications for hydrological applications and Massive Open Online Courses (MOOCs) covering climate change in mountain areas.

The Portal also offers a glossary of over 1,000 definitions of space, water, environmental and data-processing terms, which are continuously updated, to facilitate understanding among related sectors. An interactive visualization to make the Space4Water knowledge body explorable is under development.

Other newly launched Space4Water portal features include the mapping of locations of Space4Water stakeholders and professionals as well as of the local perspectives and case studies shared, and an interactive model of the water cycle.

www.space4water.org

Feature and resource overview

Stakeholders, professionals, young professionals, Indigenous voices – profile pages

Profile pages are there to provide users with an overview of the shared resources that are available to all users of the Portal.

Landing pages for the individual types of actors (stakeholders, Indigenous voices, professionals and young professionals) allow users to filter by name, type of actor, regional and thematic focus of the activities of the actors as well as whether an actor is looking for knowledge exchange, cooperation, collaboration or partnerships and if so, in which thematic areas.

On their profile pages users can share resources, which are also grouped and listed according to type on the resource pages described below.

Projects, initiatives, missions and community portals

This section allows you to explore project descriptions and contact the submitting stakeholders to learn more about their work.

Software, APIs, tools, models, apps

Metadata on software, APIs, tools, models and apps allow users to compare the available software resources by means of their functionality, licences, payment modalities (if any) or target geographic region, and to assess their basic suitability for their own intended use. Authors/publishers of software can be contacted if they have provided contact details. Relevant training material and demo videos for the use of the software can be linked via the portal.

Training material and webinars

This portal section allows you to filter available training materials that were either shared by the Space4Water community or identified by UNOOSA. In the case of the latter, UNOOSA sought the consent of authors/publishers to include metadata on their training materials on the Space4Water portal. In this way, users can search the Portal by type, topic and language, and read brief descriptions of the training materials.

Local perspectives and case studies

The aim of the local perspectives and case studies feature is to learn about gaps in water resource management from affected individuals, communities, civil society, professionals, researchers or organizations in the field to identify needs or potential solutions that space technologies could contribute to.

Because of the remarkably diverse nature of water-related problems, UNOOSA has decided to collect information in different thematic calls, which address one specific target group at a time. The ultimate purpose is to collect and synthesize these needs (in the form of perspectives expressed by civil society, or case studies) and to explore ways of matching needs and solutions to inspire stakeholders of the Space4Water portal to apply existing or develop new solutions to the problems addressed.

Figure 26.
North Darfur water project helps protect women from sexual violence
Credit: UN Photo/ Albert Gonzalez Farran

Local perspectives address a specific water resource management or ecological issue in a certain locality. Local perspectives are collected, screened and categorized by UNOOSA. Depending on the target audience of the call, some of the collected perspectives (detailed and clear descriptions/case studies with technical parameters to be provided) are publicly shared on the Space4Water portal so that solution providers can learn about user needs. Others are collected and published in a curated format, with the possibility of more user interaction than with a traditional case study.

Data set search

To avoid duplication of efforts and foster collaboration with other relevant actors we have integrated, a Group on Earth Observations (GEOSS) data set search widget points users to the existing useful collections of metadata on data sets brokered on a regular basis.

Standards enable interoperability across platforms, APIs, databases, software development, languages and applications. UNOOSA encourages stakeholders to follow standards early in the design phase of their projects

to ease the challenges arising in interoperability endeavours. The utilization of standards and the following exchange of data with other stakeholders and their platforms can unlock the full potential of data and the generation of insights and knowledge.

Publications

Metadata on publications are shared by Space4Water community members to link to relevant research work.

Water-related challenges and space-based solutions

Having collected information on how people are affected on the ground in the local perspectives and case studies features, the water-related challenges and space-based solutions take the Space4Water project to the next stage. The community of practice identifies challenges and co-develops space-based solutions to address them. Water-related challenges and space-based solutions aim at guiding community members to find ways to:

- Describe challenges in a way they can be acted upon
- Identify key space technology and the resources necessary to address them
- Find actors with the skills and experience in addressing these challenges among the stakeholders
- Match willing and able stakeholders with those who posed the challenge – to start collaborating on space-based solutions, ideally by connecting actors who have already worked on parts of possible technological solutions to address the issue

An initial set of water-related challenges was identified together with the participants in the participatory workshop for Indigenous women, who expressed and described the challenges they are concerned about. The Space4Water community started discussing approaches to addressing these challenges and outlined solutions during stakeholder meetings.

The Space4Water portal water-related challenges

The Space4Water portal space-based solutions

Testimonials

The Space4Water portal is an excellent initiative for an academic Institution like IHE Delft, where space technology and Earth observation are considered key for the future of water management. The use of Earth observation data, and related research, has increased tremendously, and we see even further opportunities to do additional research and education on this topic in the future, supporting the achievement of SDG6 and other water-related SDGs.

A portal like Space4Water allows us to identify the community of players in the field, to reach out to them, with the possibility of either leveraging their results, or to think together about future opportunities to develop further innovation, allowing better synergies and avoiding duplication of efforts."

Gaetano Casale, Liaison Officer,
IHE Delft Institute for Water Education

Testimonials

The Space4Water portal is an outstanding opportunity to bring together different stakeholders from science, politics, business and local communities to pool knowledge and exchange ideas. For me, Space4Water is an encouraging example of how people can actively contribute to achieving the SDGs, according to the motto leave no one behind.

Lukas Graf, PhD student in agricultural sciences at ETH Zurich, young professional, user and author of articles on the Space4Water portal

The Space4Water portal is very useful. The portal has valuable information on space-based datasets that can be used to monitor and manage water resources. It also has some recommended software capable for processing water resources data. The portal has training programmes based on water management and webinars that can be accessed freely. Countries can share experiences and learn from others easily. The portal also provides a platform to network with other experts for partnerships purposes. The Space4Water portal contributes to my work positively. There is a lot of information, data and case studies, as well as free training programmes. Space-based technologies such as global navigation satellite systems, Earth observation and satellite communication can be used for research purposes to map, monitor and manage water resources, to focus rainfall and climate change.

Basuti Bolo, Endowed Chair Educational Technologies at Africa University, Zimbabwe, featured professional on the Space4Water portal

CONFERENCES

The purpose of the conference series is to increase the number of entities in developing countries with the capacity to use space science and technology, as well as related applications, for water management and water-related scientific research. The conferences have a scientific and technical focus, involving experts from all regions of the world, but with a focus on regional needs and challenges while rotating locations between Asia, Africa and the Americas. Speakers are experts that present concrete technical actions to improve water management in their area of expertise. In panel discussions, they will debate either technical or policy topics. Beside the main event, practical hands-on sessions, such as demonstrations or workshops, have taken place to complement the more theoretical and scientific presentations and panel discussions. In previous editions, the conferences consisted of three to five days of presentations, with the addition of local visits to facilities relevant to the theme of the conference.

The United Nations/Ghana/PSIPW hosted the fifth International Conference on the Use of Space Technology for Water Resources Management

In May 2022, UNOOSA and PSIPW organized the fifth International Conference on the Use of Space Technology for Water Management, hosted by the Government of Ghana in Accra and online. Over 800 participants from 99 countries registered for the event, attending both in person and virtually. To enhance knowledge exchange and partnership development, as well as to identify user needs, demonstrate actionable solutions and encourage regional contributions, the Conference provided a holistic overview of how space-based Earth observation can improve water resources management.

Figure 27.
Banner of the fifth International Conference on the Use of Space Technology for Water Resources Management
Credit: UENR and UNOOSA

The University of Energy and Natural Resources (UENR) served as 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. The European Space Agency (ESA) and the secretariat of the Inter-Islamic Network on Space Sciences and Technology also supported the conference.

Read about the conference on www.unoosa.org

Figure 28.
The Vice-President of Ghana, HE Mahamudu Bawumia, receives a certificate of participation
Credit: UENR

Figure 29.
The Minister of Education of Ghana, Yaw Osei Adutwum, delivering a speech
Credit: University of Energy and Natural Resources

Figure 30.
High-level representatives at the Conference
Credit: University of Energy and Natural Resources

The United Nations/Pakistan/PSIPW co-organized the fourth International Conference on the Use of Space Technology for Water Management

The conference hosted over 200 participants, with 34 funded by UNOOSA who came from 21 countries. Numerous technical presentations were delivered, gaps identified and participants discussed how space technology could contribute to better management of water resources in general, as well as specific issues such as mountain region-specific water challenges, combating desertification, water storage, floods and drought monitoring, ensuring access to safe drinking water and managing water-related emergencies in developing countries. The event had the following objectives:

- To enhance capabilities of countries in the use of space-related technologies, applications, services and information for identifying, managing and monitoring water resources
- To strengthen international and regional cooperation in this area
- To raise awareness among decision makers, and research and academic communities on space technology applications in addressing water-related issues, primarily in developing countries
- To promote educational and public awareness initiatives in the area of water resources management, as well as to contribute to any capacity-building efforts in this area
- To consider and review new or emerging technologies and approaches in this domain
- To contribute to the Space2030 implementation road maps on health and resilient societies

Previous editions of the conference were hosted in Morocco (2014), Argentina (2011) and Saudi Arabia (2008).

Read about the conference on www.unoosa.org

Figure 31.

The United Nations/Pakistan/PSIPW hosted the fourth International Conference on the Use of Space Technology for Water Management

Credit: Pakistan Space and Upper Atmosphere Research Commission (SUPARCO)

4.

JOIN THE SPACE4WATER COMMUNITY

Researchers

Are you a researcher using space technologies and Earth observation data to assess water issues? Apply here to become a Space4Water professional or a young professional.

Apply as a Space4Water professional or young professional

Indigenous communities

We would like you to raise your voices. Indigenous people, especially if you play a key role with regard to water in your community, are invited to share your knowledge about water, your concerns about its state, and the changes in aquatic or water-related environments you observe. We aim at developing space-based solutions for well-defined water-related challenges within our Space4Water community.

Apply as a Space4Water Indigenous voice

Governmental or intergovernmental organizations, academia, the private sector and civil society

Organizations working with space-based technology of any kind addressing water issues can apply as Space4Water stakeholders.

Apply as a Space4Water stakeholder

Volunteers

If you are interested in writing or translating an article on the use of space-based technologies to address water issues, have a look at the guidelines and send your abstract via email by scanning the QR code below.

Apply to write or translate an article

Do you experience or observe water-related challenges?

We would like to learn about your water-related challenges. Let us know if you experience water-related challenges and submit a description of the problem. We will assess whether the problem can be addressed by using space-based data or technology and look into co-developing potential solutions.

Submit a water-related challenge

Mississippi River Delta
Credit: USGS/ESA

ABBREVIATIONS AND ACRONYMS

COPUOS	Committee on the Peaceful Uses of Outer Space
ECOSOC	Economic and Social Council
ECV	Essential Climate Variables
ESA	European Space Agency
GCOS	Global Climate Observing System
GIS	Geographic Information System
GNSS	Global Navigation Satellite Systems
GRACE	Gravity Recovery and Climate Experiment
MELiSSA	Micro-Ecological Life Support System Alternative
MSI	Moisture stress index
NASA	National Aeronautics and Space Administration
NDII	Normalized difference infrared index
NDWI	Normalized difference water index
NIR	Near infrared
NMDI	Normalized multi-band drought index
PSA	Programme on Space Applications
PSIPW	Prince Sultan Bin Abdulaziz International Prize for Water
SDGs	Sustainable Development Goals
SGAC	Space Generation Advisory Council
STEM	Science, technology, engineering and mathematics
STSC	Scientific and Technical Subcommittee (of COPUOS)
SWIR	Short-wave infrared
UENR	University of Energy and Natural Resources)
UNIS	United Nations Information Service (in Vienna)
UNOOSA	United Nations Office for Outer Space Affairs
VIR	Visible and infrared
WBI	Water band index

Prince Sultan Bin Abdulaziz International Prize for Water

The Prince Sultan Bin Abdulaziz International Prize for Water (PSIPW) is a scientific prize with a focus on innovation. Established in 2002 by HRH Crown Prince Sultan Bin Abdulaziz, it rewards the efforts made by scientists, inventors and research organizations around the world that contribute to the sustainable availability of drinking water and the alleviation of the escalating global problem of water scarcity. To this end, PSIPW awards a suite of five biennial prizes, covering the entire water research landscape. In this way, PSIPW encourages research into finding solutions to the various water-related challenges facing the world today.

Learn more at www.psipw.org

SPACE4SDGS

THE UNITED NATIONS OFFICE FOR OUTER SPACE AFFAIRS (UNOOSA)
IS RESPONSIBLE FOR ADVANCING INTERNATIONAL COOPERATION IN THE PEACEFUL USES OF OUTER SPACE AND HELPS ALL COUNTRIES USE SPACE SCIENCE AND TECHNOLOGY TO ACHIEVE SUSTAINABLE DEVELOPMENT.

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