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UN-SPIDER Bonn International Conference

Space-based Solutions for Disaster Management: Early Warnings for All

12-14 March 2024, Bonn, Germany
organized by UN-SPIDER and ZFL
in cooperation with DLR

hosted by the UN-SPIDER Bonn Office

Report

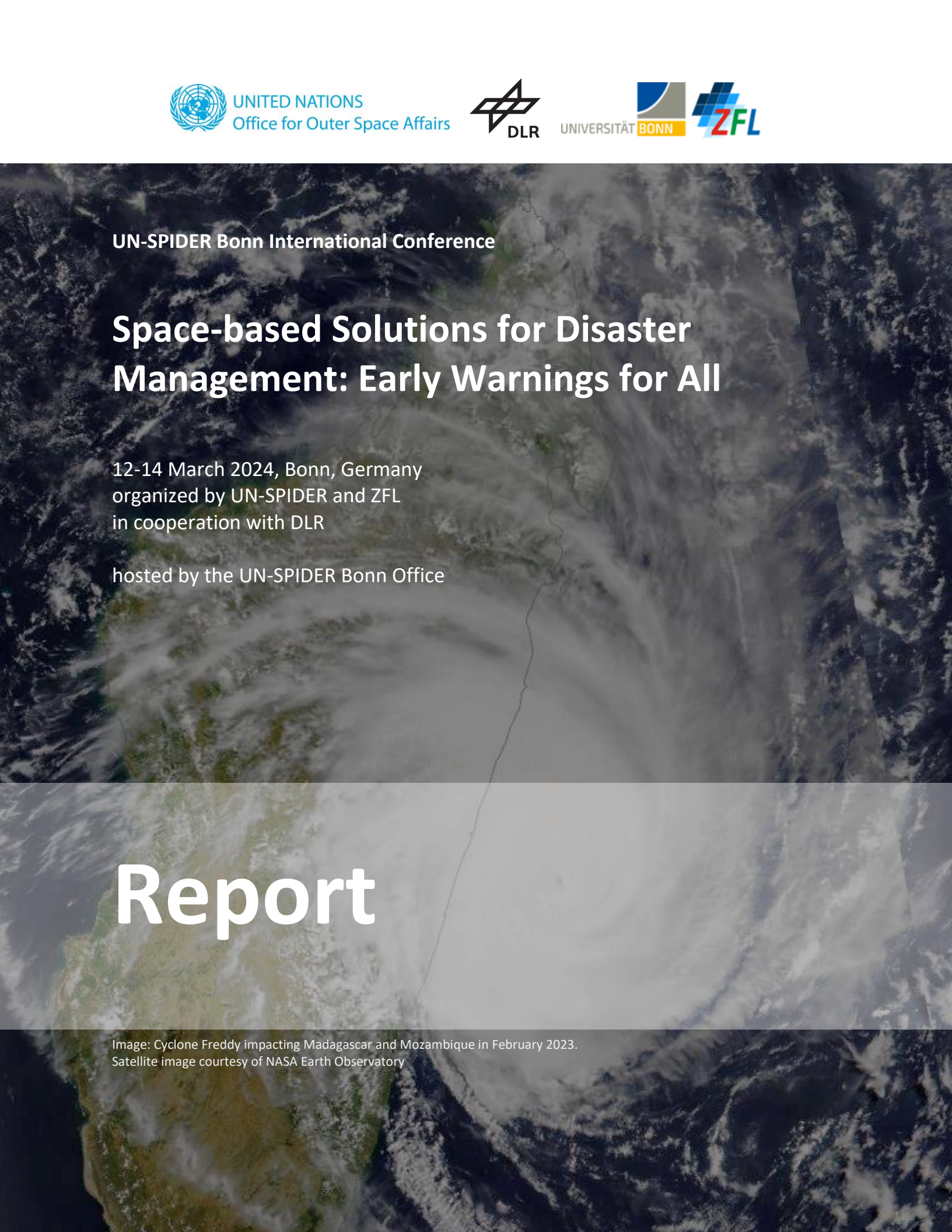

Image: Cyclone Freddy impacting Madagascar and Mozambique in February 2023.
Satellite image courtesy of NASA Earth Observatory

This document has not been formally edited

In its resolution 61/110 of 14 December 2006 the United Nations General Assembly agreed to establish the "United Nations Platform for Space-based Information for Disaster Management and Emergency Response - UN-SPIDER" as a new United Nations programme, with the following mission statement: "Ensure that all countries and international and regional organizations have access to and develop the capacity to use all types of space-based information to support the full disaster management cycle".

UN-SPIDER aims at providing universal access to all types of space-based information and services relevant to disaster management by being a gateway to space information for disaster management support; serving as a bridge to connect the disaster management and space communities; and being a facilitator of capacity-building and institutional strengthening.

Whereas there have been a number of initiatives in recent years that have contributed to making space technologies available for humanitarian and emergency response, UN-SPIDER is the first to focus on the need to ensure access to and use of such solutions during all phases of the disaster management cycle, including the risk reduction phase, which will significantly contribute to reducing the loss of lives and property.

UN-SPIDER Bonn International Conference on Space-based Solutions for Disaster Management: Early Warnings for All

Organized by the

United Nations Office for Outer Space Affairs (UNOOSA) / UN-SPIDER

and the

Center for Remote Sensing of Land Surfaces (ZFL), University of Bonn

In cooperation with the

German Aerospace Center (DLR)

Bonn, Germany
12th-14th March 2024

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Acknowledgements

The organizers of the conference would like to acknowledge the financial support of the Federal Ministry of Economic Affairs and Climate Action (BMWK) of the Government of Germany, the German Aerospace Centre (DLR), and the Centre for Remote Sensing of Land Surfaces (ZFL) through its SPEAR project (Space-based Earth observation Applications for Emergency Response and Disaster Risk Reduction) of the University of Bonn which was essential to organize the conference. Additionally, the organizers would like to express their sincere gratitude to all the participants of the conference who gave inspiring presentations, contributed to the poster exhibition, served as moderators, panellists, and rapporteurs during the panels and participated actively during discussions.

Background

Natural and man-made disasters cause tremendous damage to societies around the world. They lead to loss of lives and property, displace people from their homes and destroy livelihoods, and disrupt sustainable development efforts worldwide. In recent years, climate change, extreme weather, population growth, and urbanization have led to an increasing number of people being threatened by natural hazards, and it has become a global challenge to mitigate disaster risks and reduce the loss of people's lives, property and livelihoods. Developing countries are particularly susceptible to the impact of hazards as societies are more vulnerable and exposed, and less resilient to recover.

Convinced that space technologies can play a vital role in supporting disaster management, the United Nations General Assembly (UNGA) established the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) in 2006 as a programme to be implemented by the United Nations Office for Outer Space Affairs (UNOOSA). The General Assembly mandated UN-SPIDER to provide universal access to all countries and all relevant international and regional organizations to all types of space-based information and services relevant to disaster management to support the full disaster management cycle.

In 2019, The UNOOSA, through its UN-SPIDER programme, and the Center for Remote Sensing of Land Surfaces of the University of Bonn (ZFL) launched the “Spaceborne Earth Observation Applications for Emergency Response and Disaster Risk Reduction” (SPEAR) project to understand needs, develop solutions and strengthen national capacities in using space-based information for disaster monitoring and prevention in Africa in line with international and regional frameworks. The UN-SPIDER Bonn International Conference marked the end of the first phase of the SPEAR project (2019-2024) and allowed for a recap, summaries of activities and achievements, and exchange of experience and lessons learned. Furthermore, the conference offered room for discussions, to collect feedback and suggestions on the way forward for the next project phase, which is planned to be started in 2024.

Thematically, the conference focused on space technologies for early warning systems, which are a key asset to address the challenges of coping with natural and man-made hazards. The topic has received

widespread attention worldwide. For example, Goal 3 "Ensure healthy lives and promote well-being for all at all ages" and Goal 13 "Take urgent action to combat climate change and its impacts" of the 2030 Agenda for Sustainable Development encourage countries to develop early warning systems; Article 7 "Enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change" and Article 8 "Loss and Damage associated with Climate Change Impacts" of the Paris Agreement also place a high priority on strengthening early warning systems; the Sendai Framework for Disaster Risk Reduction 2015-2030 explicitly calls for the development of multi-hazard early warning systems to improve their availability. At the same time, in recent years, the international community has launched extensive discussions on topics such as "early warning, early response" and "early warnings for all", hoping to improve society's ability to respond to disaster risks by developing a sound mechanism for early warning and emergency response to natural disasters led by the government, participated by the society and coordinated by various parties. In March 2022, the UN Secretary-General launched the “Early Warnings for All” initiative which calls for every person on Earth to be protected by early warning systems by 2027.

Advances in science and technology have brought new development opportunities to improve the accuracy and effectiveness of early warning. As an all-weather, all-day, full-coverage technology for Earth observation, space-based technologies play an irreplaceable role in disaster risk management, especially in disaster risk identification, assessment, monitoring, and early warning. Additionally, the quality of satellite sensors, availability, and access to and use of satellite imagery and Earth observation services have significantly improved in recent years, with more and more space agencies embracing open data policies that facilitate access to archived and up-to-date imagery.

Strengthening technical skills and setting up institutional and inter-institutional structures is important to ensure that the benefits of space-based information reach civil protection agencies and other actors involved in disaster management activities. Partnerships can facilitate access to data, for instance through emergency mechanisms such as the International Charter Space and Major Disasters and the Copernicus Emergency Management Services.

This International Conference thematized the issues raised above and helped with identifying challenges, highlighted solutions, and encouraged partnerships for using space technologies in early warning systems. Furthermore, the conference contributed to an increased understanding and use of space-based technology approaches and satellite-based applications in developing countries to respond to challenges posed by natural hazards with a thematic focus on early warning activities.

More specifically, the event contributed to:

- Showcase recent advances and identify challenges to the use of space-based information and technologies in disaster management in developing countries.
- Present and provide hands-on experiences on technical solutions ranging from standalone desktop packages to cloud computing environments that facilitate the access to and use of space-based data and information products for early warning and disaster management.

- Understand and enhance the effectiveness of space-based technology in multi-hazard early warning applications, especially in the identification, analysis, monitoring, and risk assessment.
- Share and exchange practices and experiences in the operationalization of impact-based multi-hazard early warning systems, promote integration and convergence within the systems and enhance the effectiveness and efficiency of multi-hazard early warning decision support.
- Build on the outcomes of UNOOSA international conferences and symposia to identify capacity-building needs and opportunities regarding the full use of the increasing amount of space-based information and new techniques to access, combine, process, analyse and present the data.
- Provide a forum to discuss partnerships to facilitate access to data and applications tailored to the needs of disaster management stakeholders.

The Conference was structured in terms of 10 different sessions. It started with an opening segment and an introduction to set the scene (session 1). Five sessions focused on early warning systems targeting hydrometeorological hazards (session 2), geological hazards (session 3), environmental hazards (session 4), extraterrestrial hazards (session 5), and health and biological hazards (session 7). Session 9 on novel technologies and future outlook (session 9) gave an overview of future developments. The sessions on space community perspective (session 6), academic and capacity-building perspective (session 8) and disaster management perspective (session 10) were structured in terms of High-Level Panels at which distinguished panellists addressed specific issues and provided key messages to keep in mind during and after the conference.

The sessions allowed experts taking part in the conference to express their views, comments, and suggestions regarding how to promote the use of Earth observation in the context of Early Warnings for All.

Participants

The conference brought together 113 participants representing the following institutions:

United Nations Organizations:
Food and Agriculture Organization (FAO)
United Nations Convention to Combat Desertification (UNCCD)
United Nations Framework Convention on Climate Change (UNFCCC)
United Nations Office for Disaster Risk Reduction (UNDRR)
United Nations University - Institute for Environment and Human Security (UNU-EHS)
United Nations Office for Outer Space Affairs (UNOOSA)
World Meteorological Organization (WMO)

International Organizations:
Committee on Earth Observation Satellites (CEOS, Working Group on Disasters and EOTEC DevNet)
European Centre for Medium-Range Weather Forecasts (ECMWF)
European Space Agency (ESA)
European Union Agency for the Space Programme (EUSPA)
Global Drought Observatory (GDO Copernicus)

Global Flood Awareness System (GLOFAS Copernicus)
International Water Management Institute (IWMI, UN-SPIDER Regional Support Office)

National and Governmental Agencies:
Algerian Space Agency (ASAL, UN-SPIDER Regional Support Office)
BEYOND Centre of Excellence, National Observatory of Athens, Greece (BEYOND CE, NOA, UN-SPIDER Regional Support Office)
Federal Ministry for Economic Affairs and Climate Action of Germany (BMWK)
National Office for Risk and Disaster Management of Madagascar (Bureau National De Gestion Des Risques Et Des Catastrophes, BNGRC)
National Centre for Space Studies of France (Centre National D'Etudes Spatiales, CNES)
National Research Council of Italy, Institute for Electromagnetic Sensing of the Environment (CNR IREA)
Royal Center for Remote Sensing of Morocco (Centre Royal de Télédétection Spatiale, CRTS)
National Disaster Management Centre of South Africa (NDMC)
German Aerospace Center (DLR)
Egyptian Space Agency (EGSA)
German Federal Office for Civil Protection and Disaster Assistance (BBK)
Geographic Institute Agustín Codazzi, Colombia (IGAC, UN-SPIDER Regional Support Office)
Iranian Space Agency (ISA, UN-SPIDER Regional Support Office)
Mexican Space Agency (AEM, UN-SPIDER Regional Support Office)
Ministry of Housing and Land Use Planning of Mauritius
National Disaster Management Organization of Ghana (NADMO)
National Early Warning and Response Mechanism Coordinating Centre of the Gambia (NCCRM)
National Geographic Institute of Belgium (NGI)
National Institute for Meteorology and Geophysics of Cabo Verde (INMG)
National Space Research and Development Agency of Nigeria (NASRDA, UN-SPIDER Regional Support Office)
Research and Innovation Agency, Indonesia (BRIN, UN-SPIDER Regional Support Office)
South African National Space Agency (SANSA, UN-SPIDER Regional Support Office)
Pakistan Space & Upper Atmosphere Research Commission (SUPARCO, UN-SPIDER Regional Support Office)
Bezirksamt Lichtenberg von Berlin, District Emergency Management Agency of Berlin

Non-Governmental Organizations:
@fire - International Disaster Response Germany
German Committee on Disaster Prevention (DKKV)
IMPACT Initiatives
Norwegian Refugee Council (NRC)
Trans-African Hydro-Meteorological Observatory (TAHMO)

Academia and Research Centres:
Asian Institute of Technology, Thailand (AIT, UN-SPIDER Regional Support Office)
Ben-Gurion University of the Negev, Israel (UN-SPIDER Regional Support Office)
Central European University, Hungary

Federal University of Santa Maria, Brazil (UN-SPIDER Regional Support Office)
Fraunhofer Institute for Technological Trend Analysis
German Institute of Development and Sustainability (IDOS)
German Research Center for Geosciences (GFZ Potsdam)
Institute of Geodesy and Geoinformatics Science, Technical University of Berlin
Ruhr-University Bochum (RUB)
Cologne University of Applied Sciences (TH Cologne)
Universitat de Lleida
University of Jena
Center for Remote Sensing of Land Surfaces, University of Bonn (ZFL, UN-SPIDER Regional Support Office)
University of Botswana

Private Companies:
Airbus
DEIMOS
Google
HCP international
Iridium
LEOBLUE
Maydai.ai
MSCI

Member States

The conference in Bonn was attended by in total 113 experts and participants from 34 Member States from Africa, Asia, Europe, North America, and South America, from the following countries:

Algeria, Austria, Belgium, Botswana, Brazil, Cabo Verde, China, Colombia, Czechia, Egypt, France, Gambia (Republic of the), Germany, Ghana, Greece, Indonesia, Iran (Islamic Republic of), Israel, Italy, Madagascar, Mauritius, Mexico, Morocco, Mozambique, Netherlands (Kingdom of the), Nigeria, Pakistan, South Africa, Spain, Sri Lanka, Switzerland, Thailand, United Kingdom of Great Britain and Northern Ireland, United States of America.

Opening Segment

The conference was opened by the Director of the United Nations Office for Outer Space Affairs (UNOOSA), the Director of Applications and Science at the German Aerospace Center (DLR) and the former speaker of the Center for Remote Sensing of Land Surfaces (ZFL) of the University of Bonn.

In her welcome remarks, the **Director of UNOOSA** welcomed participants to the International Conference, noting the importance and timely focus on leveraging space-based solutions for disaster management, particularly emphasizing early warnings for all**.** Furthermore, she acknowledged the exacerbation of disaster impacts due to climate change, inadequate development frameworks, urban migrations, and conflicts, and highlighted examples like the COVID pandemic, locust plague, and the 2004 Indian Ocean tsunami. The Director continued by outlining that since 1990, the UN has led initiatives to engage stakeholders globally in proactive disaster risk reduction, notably through frameworks like the Sendai Framework for Disaster Risk Reduction 2015-2030. Furthermore, she pointed out that UNOOSA recognizes space technologies as vital tools for sustainable development, enabling comprehensive monitoring of Earth's environment, climate change manifestations, and disaster dynamics. In this context, she noted that the UN General Assembly launched UN-SPIDER in 2006 and since then this programme has assisted over 50 developing countries in utilizing space-based information for disaster management and acts as a liaison between the space and disaster management communities. The director stressed that the focus on early warning comes timely, as the UN Secretary-General launched the “Early Warnings for All” initiative to ensure global early warning system coverage by 2027. To support activities in this direction, she launched the UNOOSA / UN-SPIDER publication: "Space Technologies for Early Warning Systems"[1], showcasing space community contributions to enhancing early warning systems across various hazard domains. The director closed her opening remarks by emphasizing the conference's purpose to share examples of how space technologies can enhance routine early warning operations and by expressing hope for a successful conference, anticipating fruitful discussions and motivation to advance space-based solutions for disaster management.

The Director of Applications and Science at DLR thanked UNOOSA and UN-SPIDER for the organization of the conference and ensured a continued commitment of DLR to support the UN-SPIDER Bonn Office. Germany has been a strong supporter of space-based technologies for disaster management, even before the creation of the UN-SPIDER platform, and decided to support UNOOSA and UN-SPIDER with the opening and continuous operation of the Bonn Office. DLR established the SPEAR project together with the University of Bonn and the ZFL, combining scientific contributions with international cooperative work. The Director highlighted that this successful cooperation via the SPEAR project will be renewed, as the current agreement is expiring. A second phase for another five years has been agreed upon and will start this year (2024), aligning well with the new space strategy of Germany, which includes international

[1] United Nations (2024): Space Technologies for Early Warning Systems. Available at: https://www.un-spider.org/sites/default/files/un-spider_spacetechnologiesforearlywarningsystems2024.pdf

cooperation as one of its key pillars. Furthermore, he informed the audience that later this year, DLR will organize the World Space Forum in Bonn, focusing on space sustainability.

In his opening remarks, **the former speaker of the ZFL** thanked UNOOSA, the UN-SPIDER Bonn office and DLR for the joint organization of the conference and the long-lasting cooperation within the UN-SPIDER framework. In its role as UN-SPIDER Regional Support Office and through joint projects with UN-SPIDER, ZFL has worked very closely especially with the Bonn office of UN-SPIDER, since 2016. This cooperation will be continued via the second phase of the SPEAR project already mentioned by DLR. The former speaker of ZFL highlighted the important role of academia, new approaches and possibilities for teaching, e-learning, and the increased availability of learning resources for young people in developing countries. Developments that can help with strengthening capabilities and capacities for the use of space technology for disaster management and risk reduction. He pointed out that collaboration and knowledge sharing are key for strengthening risk management and early warning efforts around the globe.

Session 1: Introduction and Setting the Scene

In her keynote speech, the **Head of Earth Observation at DLR** highlighted the Centre's innovative efforts in the areas of space administration and showcased the trends of recent space technologies and how they are contributing to early warning and disaster management as well as to environmental protection and other applications. She made participants aware that DLR is collaborating with the European Space Agency (ESA), UNOOSA and other organizations in disaster management efforts worldwide. She highlighted the support of DLR to global services by Copernicus addressing wildfire, drought, flooding, landslide, and other hazards. She also commented on the engagement of DLR as a member of the International Charter Space and Major Disasters and the Committee on Earth Observation Satellites (CEOS) and reiterated that DLR will continue to collaborate with UNOOSA in disaster management efforts.

The coordinator of the ZFL showcased the work of ZFL in the context of droughts, floods, and capacity building. He discussed research efforts carried out at ZFL to enhance the use of Earth observation in applications related to disaster management, including the use of Copernicus services such as the Global Flood Awareness System (GloFAS) and to map risks and impacts related to various types of hazards such as floods, droughts, and wildfires. Further, he explained the role of ZFL as UN-SPIDER Regional Support Office and the SPEAR project, which is a collaborative effort between ZFL and UNOOSA funded by the German Ministry for Economic Affairs and Climate Action (BMWK) that aims to understand needs, develop solutions, and strengthen national capacities regarding the use of space-based information for disaster monitoring and prevention in Africa in line with international and regional frameworks. The speaker confirmed that the SPEAR project will be continued in a second phase from 2024 to 2029.

The Head of the UN-SPIDER Bonn Office highlighted how UN-SPIDER has been promoting the use of space technologies to confront the challenges of natural hazards since 2006. Since 2014, the programme began to implement efforts with several partners including some of its Regional Support Offices to contribute to strengthen early warning systems related to droughts and floods; and in recent years, geological and

environmental hazards. The presentation included an overview of early warning systems, the applications of different space technologies in contributing to such systems, and information on the Early Warnings for All initiative. Specific examples regarding how space-based technologies can contribute to early warning were introduced, covering applications from telecommunication, navigation, and Earth observation. He also referred to the new publication from UNOOSA and UN-SPIDER on "**Space Technologies for Early Warning Systems**", which was launched in the opening segment of this conference. He commented that it is one of UN-SPIDER´s contributions to the International Network on Multi-Hazards Early Warning Systems (IN-MHEWS), the Sendai Framework for Disaster Risk Reduction, and the Paris Climate Agreement. It includes theoretical background and over 80 case studies on examples of space technologies for EWS for different categories of hazards, such as hydrometeorological, geological, health, environmental, coastal, and extraterrestrial hazards. He concluded his presentation noting that many experts who contributed to this publication are featured as presenters at the conference.

After the three keynote presentations, an expert from **the World Meteorological Organization (WMO)**, made a presentation on "WMO Space Programme's Overview and the Role of Space-based Earth Observations to Support WMO Major Strategic Priorities, Including EW4All". She provided an overview of the WMO Space Programme and the important role of space-based Earth observations in supporting WMO's major strategic priorities, including the Early Warnings for All initiative. The speaker covered key activities such as the space-based component of the WMO Integrated Global Observing System (WIGOS), satellite data access, space weather coordination, and user engagement. The presenter highlighted the importance of Pillar 2 of the Early Warnings for All initiative (Observations and Forecasting) in delivering outcomes such as increased availability of quality observation data, enhanced data exchange, and improved forecasting capabilities for priority hydrometeorological hazards. Ultimately, she demonstrated how space-based Earth observations are essential for societies to better understand and respond to the challenges of our changing climate. The speaker also noted that the WMO's contribution to the implementation of the Early Warnings For All Initiative shall be accorded the highest priority in the WMO Strategic Plan 2024–2027. During the following Q&A session, the presenter clarified that hazards occur across various borders and jurisdictions, to which the WMO representative responded that WMO can help with cooperation, but it is often best to cooperate with local authorities.

The representative from **Iridium Communications** gave a presentation on "Iridium Satellite Data Delivery for Emergency Warning Systems". Iridium has various communications services for voice and data, which have been enhanced with the launch of its new satellite constellation. The presenter spoke of the options available and provided some practical examples of existing solutions. He showed options ranging from short burst data connection devices, which help with tracking and monitoring in remote areas, to larger scale packages like their Iridium Certus line, which enables the transfer of real-time data to mobile units. Examples included case studies where they helped predict floods in coastal areas of Africa and using UAVs in tropical cyclones. The Q&A session included a question regarding the cost of the service, which the representative assured is cost-effective, and a comment by the UNOOSA director that the use cases in Iridium should be expanded upon for the global community.

The expert from **Airbus Defence and Space** gave a presentation on the "Use of Space-based Products in Early Warning Systems (Digital Elevation Models, Land-use/Land-cover Layers, Urban Footprints)". Space products are highly useful for early warning systems targeting a variety of hazards. Digital elevation models (DEMs), such as the high-resolution WorldDEM, are, for instance, used in inundation modelling for sea-level rise and coastal EWS, flood hazard mapping and to identify the areas exposed to hydrological risks, and landslide hazard mapping and monitoring landslides on a local, regional and global scale. The presenter provided an overview of the use of space-based products including land-use/land-cover layers, and urban footprints. The representative discussed the WorldDEM Neo, which offers a combination of global coverage, highly accurate WorldDEM data, up-to-date and fresh data acquisition (from 2017-2021) and a unique resolution.

Session 2: Hydrometeorological Hazards

In recent decades, the contribution of space technologies to EWS for hydrometeorological hazards has been significant. Hydrometeorological hazards result from the state and behaviour of the Earth's atmosphere, its interaction with the land and oceans, the weather and climate produced and the resulting distribution of water resources. The most frequent and impactful hydrometeorological hazards are winter and typically storms, floods, droughts and more recently heat waves. These types of hazards can emerge, develop, and cause impacts quickly (rapid-onset) or gradually build over time before effects are realized (slow-onset). The required capability from space technologies for early warning systems depends on the type and characteristics of the hazard. Through continuously evolving satellite capabilities and the continual development of space technologies, Earth observation data is helping to increase the accuracy of EWS for these types of hazards.

The session on hydrometeorological hazards was commenced by a presenter from the **European Center for Medium-Range Weather Forecast (ECMWF)** with the presentation "Space Technologies to Monitor Severe Weather". He addressed the topic of forecasting and monitoring of intense cyclones using newly developed tools, such as the ENSEMBLES project. Tropical cyclones are among the most devastating natural hazards on Earth. Therefore, monitoring and forecasting are crucial. With large forecast datasets covering the past 20 years, ECMWF contributes to predicting tropical cyclones, often with a high degree of confidence. Satellite imagery from various sensors supports the monitoring of cyclone development from the early stages onward, and with better monitoring and forecasting comes improved early warning. The presenter brought up the example of Cyclone Dorian, which was able to provide early warning four days before a direct impact on Windward Islands.

An expert from the **Joint Research Centre (JRC), representing the Global Flood Awareness System (GloFAS)** continued with the presentation on "The Copernicus Emergency Service Operational Global Flood Awareness System and Global Flood Monitoring Product". She discussed how the Copernicus Emergency Management Service (CEMS) provides operational river flow and inundation forecast, as well as monitoring data using modelling and satellite observations through its GloFAS and the Global Flood Monitoring (GFM) product. The representative illustrated the procedures and processes for the provision of river flow forecast, forecast-based rapid flood mapping and impact assessment products, as well as the

satellite-based monitoring of flood extent. GloFAS provides daily updates on forecasts at a 5km resolution, highlighting expected flooding over the next 30 days, and provides a seasonal hydrological outlook. GFM offers complete global monitoring of floods at a high 20m resolution, with less than 8 hours between sensing and product delivery, and integration into current emergency systems through application programming interfaces (APIs) and user interfaces (UIs).

An expert from **the Trans-African Hydro-Meteorological Observatory (TAHMO)** presented on the topic of "Modular Flood Early Warning Systems for Small Communities in Africa". He brought up the fact that two-thirds of Africa's urban population live in cities with less than 700,000 people. For smaller settlements like these, it will usually not be financially feasible to develop flood early warning systems (FEWS). Therefore, they have built a system of simple building blocks, enabling a range of very simple to sophisticated operations. The modular approach allows people to simply click systems together without long and expensive design studies. The total cost of ownership is intended to be relatively low, helping to ensure accessibility. The representative introduced some examples from Kenya and Ghana through the EU-funded TEMBO Africa project (Transformative Environmental Monitoring to Boost Observations in Africa). The speaker also brought up the importance of data sharing across countries to better facilitate the widespread access and application of EWS tools like that which they presented. During the following discussion, many voiced concerns regarding the resource demand, data availability, and next steps for the project. The expert answered by discussing the importance of data collection through pilot projects, and substitutions for certain local data that is currently not available, while still recognizing the need for future resources and in-situ settlement monitoring.

An expert from **DLR** presented "Automatic Monitoring of Warnings and Early Triggering of Satellites During Flood Events". She discussed the recent opportunity to automate the triggering of rapid mapping processes in the event of potential crises provided by the large availability of web-based and remotely sensed data. Their research aims to improve the early tasking of high-resolution satellites by monitoring and aggregating data sources, such as warnings, to derive potentially affected areas of interest. The intention is that this approach will support experts in determining whether the acquisition and analysis of new satellite imagery can support local disaster response, with a focus on making data provision as automated as possible. Such automated systems would be index-based, where programmed thresholds, if reached, would trigger emails to be sent out to responsible authorities, thus alerting them that they may need satellite data.

A representative from the **Food and Agriculture Organization (FAO)** presented "FAO's Agricultural Stress Index System (ASIS) for Agricultural Drought Monitoring and Early Warning". He talked about the next generation of the system which offers full capabilities to support parametric crop insurance, social protection schemes, early action, national drought management plans and to guide public investments. Once calibrated to a particular region ASIS can help identify the percentage of a particular agricultural crop affected by drought, aggregate that information to particular regions, and provide information as to the categories of drought throughout a region of interest. The system proposed different vegetation indices to assess the impact of drought in agriculture; including an agricultural drought forecast that

provides more time to the decision-makers for implementing anticipatory actions to mitigate the drought in agriculture. In the following Q&A segment, the speaker stressed that ASIS is designed primarily with drought and other rainfall-driven disasters in mind, and no other factors that could impact agricultural outputs such as insect populations in the region.

An expert from the **Joint Research Centre (JRC), representing the Global Drought Observatory (GDO)** followed with a presentation on the GDO. The GDO provides drought-relevant information for early warning and emergency response globally. Based on a combination of satellite-based Earth observation, hydro-meteorological models and in-situ data, key drought indicators are monitored and forecasted. One particular indicator of drought included in the GDO is the Soil Moisture Anomaly (SMA) indicator, which determines the onset and duration of agricultural droughts, which arise when soil moisture availability to plants drops to such a level that it adversely affects crop yield, and hence, agricultural production. Maps that display soil moisture distribution can serve as direct indicators for assessing the state of (potential) agricultural droughts which can be used to inform early warnings and pre-emptive decision-making.

An expert from the **International Water Management Institute (IWMI)**, presented the "South Asia Drought Monitoring System (SADMS)". The IWMI and the Indian Council of Agricultural Research (ICAR) launched SADMS to monitor droughts in South Asia. The goal of the program is to enhance drought preparedness, reduce vulnerability, and build resilience to the devastating impacts of droughts in the region. The system covers the countries Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka, and employs an integrated severity index. SADMS offers open-access satellite data and provides various stakeholders with additional information for drought management. The data provided by SADMS can be used in not only drought monitoring and early warning but also in drought vulnerability and rapid needs assessment. The overall impact of the program thus far can be seen in its inclusion in data-informed decision-making through early warning, its impact on reducing losses and protecting livelihoods, its effect on strengthening resilience and climate adaptation, and its facilitation in regional collaboration.

Session 3: Geological Hazards

Collectively, geohazards make up a relatively small proportion of the total disasters that occur around the world (15 per cent from 2000-2019). However, the potential impacts, leading to significant loss of life and financial cost, make the potential to warn of geohazards a key ambition for disaster management organizations worldwide. A geological hazard is an extreme natural event in the crust of the Earth that poses a threat to life and property. Natural geohazards such as earthquakes, tsunamis, volcanic eruptions, landslides, and sinkholes can occur without warning and cause damage to persons, infrastructure, and livelihoods. The Earth's surface is constantly shifting and moving, sometimes slowly, but sometimes swiftly and violently with catastrophic and immediate results. While considerable progress has been made in recent decades in the field of early warning, early warning systems are generally less developed for geohazards and significant challenges remain in advancing the development of these systems for specific hazards, particularly for sudden-onset hazards such as earthquakes.

A representative from the **Institute for Electromagnetic Sensing of the Environment of the National Research Council of Italy (CNR-IREA)** presented "Spaceborne and Airborne DInSAR Products Generation and Analysis to Support Civil Protection Activities in Volcanic and Seismic Regions". CNR-IREA is an Italian service provider of European Plate Observing Systems (EPOS) with a portfolio of satellite Earth Observation services aimed at generating value-added products for Solid Earth applications and natural disaster analysis, prevention and mitigation. In the last decades, Differential Synthetic Aperture Radar Interferometry (DInSAR) has been demonstrated to be an effective tool to detect and follow earth surface deformations with a centimetre to millimetre accuracy in different hazard scenarios. In particular, the DInSAR techniques are nowadays playing an important role in studying ground deformation phenomena, such as volcanic eruptions and seismic events, thanks to their capability to provide dense measurements over wide areas and at relatively low cost. The presenter spoke of the DInSAR-related activities that are carried out by CNR-IREA which support the Italian Department of Civil Protection (DPC) for volcanoes and seismic areas studying and monitoring. EPOS scientists benefit from the on-demand EPOSAR service that implements an advanced Differential Synthetic Aperture Radar (SAR) technique, referred to as the Parallel Small Baseline Subset (P-SBAS) approach, to detect Earth surface displacements with sub-centimetre accuracy. EPOSAR outputs are extremely effective in investigating natural and/or man-made hazards.

A representative from **DLR and ZFL** presented "Multimodal Earth Vision for Natural Hazard Multi-Risk Assessment and Early Warning". Early Warning systems frequently require detailed knowledge of the corresponding hazard-prone areas, elements at risk and corresponding vulnerability. In this presentation, the speaker discussed the suite of new geospatial data sources and novel methods, mainly related to the field of Artificial Intelligence to extract thematic information, with a focus on natural hazard risk-related exposure useful for EW. One such application includes anticipating future risks. The presenter discussed the use of such tools in estimating future populations in earthquake-prone areas, as well as future populations in tsunami-prone areas using modelling.

An expert from **DLR** presented on "Landslide Risk Assessment and Mitigation in Cities”. The number of vulnerable citizens in areas of landslide risk is rising globally due to climate change and urban growth. Landslide Early Warning Systems (LEWS) can decrease vulnerability. However, knowledge of landslide-prone areas, exposed assets and population is a precondition for the installation of LEWS. The presenter discussed the experiences of developing a LEWS prototype in the landslide-prone neighbourhood of Bello Oriente in Medellín, Colombia. These experiences have been implemented in a data-driven approach using knowledge from remote sensing, geo-engineering and landscape architecture to localize landslide-prone areas suitable for low-cost and easy-to-use LEWS instrumentation in the entire city. The workflow enables decision-makers to balance financial costs and the potential to protect exposed populations. This particular prototype LEWS uses social integration and is able to provide suggestions to decision-makers as to which communities are the most affected and should be given special attention. During the following Q&A session, some questions focused on community building and social trust regarding these LEWS, to which the DLR representative responded that the first step in implementing such systems is discussion, to build trust and illustrate the potential of mapping possible disasters.

A representative from **Airbus Defence and Space** presented on "InSAR for Landslide Mapping and Surface Motion". Spaceborne X-band SAR data are an extremely valuable tool to monitor subsidence in every point on earth with a resolution of up to 1mm/year vertical displacement. The applications are multiple, from landslide to generic geohazard mapping. It can be developed using free and open Copernicus data, as well as very high-resolution data. The presenter provided an overview of such applications, with practical indications on how to access the data. He provided use-case examples of how multi-temporal InSAR analysis contributes to the estimation of potential risk assessment including estimation of slope movement and estimation of the land subsidence in the city to find out which districts suffer from the severe land subsidence by using ascending and descending orbits to convert to the vertical subsidence.

Session 4: Environmental Hazards

Satellite technologies contribute to monitoring actual and potential degradation over time, allowing disaster management practitioners to monitor how the risk of environmental hazards is changing, which in turn can be used to inform the risk picture for early warning services for a range of hazards. Environmental hazards can cause widespread harm to humans and the physical environment and arise through the degradation of natural systems, such as the deterioration of air and water quality, land and soil degradation, and loss of biodiversity. Degradation can be a very gradual process, and hard to discern on a day-to-day basis, or it can be very rapid, with sudden contamination and destruction of the environment from hazards such as wildfire.

An expert from **the BEYOND Center of Excellence (BEYOND) of the National Observatory of Athens (NOA)**, presented "Experience from Greece / FireHUB". FireHub is a tool developed by BEYOND, intended to help facilitate early warning and decision-making during an emergency, and covers territories around the Mediterranean, North Africa, the Balkans, the Middle East, and the Black Sea. This tool is able to utilize real-time satellite data to detect fires, and then issue a fire alert with corresponding visuals that are updated every five minutes, offering consistent updates and quicker response times than traditional fire monitoring systems. FireHUB offers a 500m resolution daily prediction of fire ignition utilizing machine learning techniques, in addition to a 20km resolution dispersion in model estimation.

The representative from **Geographic Institute Agustín Codazzi (IGAC)**, presented the "Susceptibility of Vegetation to Forest Fires". The presenter discussed an innovative method to assess the susceptibility of vegetation to forest fires using Sentinel-2 imagery, meteorological data, and complementary geospatial information. He addressed how the use of this method can contribute to early warning efforts, and how a new fuel model provides more accurate estimations for potential fires. Compared to other fire indices, the Susceptibility Vegetation Fire Index (SVF) can be estimated at a high resolution but will require further development and local in-situ settlement for accuracy and calibration.

The representative from the **Fraunhofer Institute for Technological Trend Analysis (INT)** presented "Innovation in European Wildfire Risk Management Research: An Overview over research and development activities / Firelogue". The subject of the presentation included Earth Observation and early-warning-related research and development activities in wildfire risk management under the European

Green Deal. The presenter discussed different risk management phases including prevention, preparedness and response, and gave an overview of space-based approaches for wildfire risk assessment, the development of fire danger indices, and the use of new technologies for early detection. In terms of early warning, the session also included aspects of wildfire spread and modelling that may be applied during a wildfire event.

Session 5: Extraterrestrial Hazards

Extraterrestrial hazards originate in outer space and can impact the planet. Hazards of this type include near-Earth objects, such as meteors, comets and asteroids, and space weather. Space weather represents the influence of solar activity in terms of substantial electromagnetic waves and highly energetic solar particles that can impact satellite constellations and electric power lines on Earth.

An expert from **ESA**, presented on the topic of the "International Asteroid Warning Network and Space Mission Planning Advisory Group". The International Asteroid Warning Network (IAWN) and the Space Mission Planning Advisory Group (SMPAG) are two organizations focused on addressing concerns regarding near-Earth objects (NEO). The IAWN deals with the detection, monitoring, and characterization of NEO threats. The SMPAG offers a platform for international cooperation through its recommendations for procedures and communication plans in case of impacts. To further prepare for the possible threat of NEOs, the SMPAG offers options, and implementation plans for space missions for NEO deflection, as well as the proposal of a work plan for planetary defense at a global level.

A representative from the **German Research Centre for Geosciences (GFZ)** presented "Space Weather Early Warning, KP Index". Geomagnetic storms impact both space technology and life on Earth, constituting space weather hazards. Notable incidents like the Quebec blackout of 1989 underscore the vulnerability of power grids. With over 1,000 active satellites and a €125 billion industry, space weather's effects are critical. The presenter showcased space weather forecasts developed in their team's recent Horizon 2020 project, "Prediction of Adverse Effects of Geomagnetic Storms and Energetic Radiation" (PAGER). The PAGER Project addresses stakeholders' needs by providing predictions with lead times of 1-2 days for solar events and up to 4 days for radiation belt fluxes. These predictions utilize various data sources and offer confidence levels, aiding stakeholders in risk assessment. PAGER's forecasts are user-friendly, offering clear variables for practical use. Notably, they provide ensemble predictions, 3-day forecasts for key indices, and real-time forecasting for electron fluxes. The project emphasizes transparency, offering access to codes and data products, fostering collaboration and adaptation to engineering designs.

An expert from the **District Emergency Management Agency of Berlin-Lichtenberg** presented "Disaster Management in the District of Berlin Lichtenberg for Events from Outer Space". Whether it is a crashing satellite or an asteroid, disaster management agencies face a particular challenge due to the inaccuracy of the flight trajectory and the unknown impact point. The worst-case scenario would be the need for large-scale evacuation under time pressure. The lecture showed the sticking points and ideas for possible approaches to dealing with such situations, with a general conclusion that mass evacuation in such a short

time before a collision is very difficult and that asteroids can affect critical infrastructure so badly that people cannot be assisted.

Session 6: Space Community Perspective

The panel on "Space Community Perspective – How space agencies support national disaster management activities" included representatives from space agencies and other space-focused organizations who discussed the promotion and utilization of space technologies for disaster management activities, with a special emphasis on early warning systems. The panel was moderated by the Director of UNOOSA and included representatives from the following institutions as panellists: Algerian Space Agency (ASAL), Indonesian National Research and Innovation Agency (BRIN), Mexican Space Agency (AEM), Egyptian Space Agency (EgSA), Nigerian National Space Research and Development Agency (NASRDA), South African National Space Agency (SANSA), Pakistan Space & Upper Atmosphere Research Commission (SUPARCO), Iranian Space Agency (ISA).

The panel members noted a greater need for more accessible high-resolution data, more training of end users and stakeholders, and furthering current efforts in cooperation at the national, regional, and international levels. Concerns with data accessibility were brought up, including issues with high-resolution data costs and lack of prioritization of such data in national budgets. Additionally, the issue of overspending and duplicate requests of costly data amongst national organizations, rather than sharing and dissemination of a singular data purchase through a primary entity was brought up. Panellists highlighted the importance of training in and awareness of the use of this sort of data amongst end-users, decision-makers, and the public, and to bring attention to the multi-purpose role that such data provides in different industries. The primary sentiment of the discussion amongst all representatives, and reiterated several times by the UNOOSA director, was the importance of collaboration and communication at the national, regional and international scale. During the discussion, panellists introduced activities working with either national disaster management authorities or collaborations with other nations and international organizations both regionally and internationally. One of the highlights of the discussion was the UNOOSA director's comment on the importance of such collaboration, especially in the sharing of data and knowledge with neighbours. The director ended the panel by endorsing the UN-SPIDER knowledge portal as one of these capacity-building and knowledge-sharing endeavours.

Session 7: Health and Biological Hazards

Biological health hazards are of organic origin and include bacteria, viruses, or parasites, as well as mosquitoes carrying disease-causing agents. The consequences of a biological health hazardous event may include severe economic and environmental losses. The management of risks due to biological health hazards is a major priority recognized under the Sendai Framework and the International Health Regulations. Satellite technology provides mechanisms for monitoring environmental conditions that are favourable for the presence of biological health hazards, such as pathogenic microorganisms and mosquitoes. Proxy data can be used to detect the presence of biological health hazards. This information is proving valuable to health early warning systems.

A member from the **BEYOND Centre of Excellence** presented "Early Warning System for Mosquito-Borne Diseases (EYWA)". Beyond has developed an early warning system that is helpful in the forecasting and risk mapping of West Nile virus outbreaks. This system is able to help inform decisions aimed at controlling the threat of mosquito-borne diseases through its predictions on mosquito abundance, habitats, breeding sites, and pathogen transmission risk. EYWA assessments provide information on the expected population of different species of mosquito and can provide early enough information as to the risk these populations may pose with transmitting diseases.

A representative from **ZFL** presented "Space Technologies for Locust Outbreaks Monitoring". Desert locust outbreaks can cause significant danger to food security and livelihoods, as swarms feed on any vegetation in their path. In 2020, the most severe locust outbreak in decades in the Horn of Africa demonstrated the need for better early warning, monitoring, and mitigation. The representative showed how earth observation can play an important role before, during, and after an outbreak of locust. The presentation included an overview of the lifecycle of locusts, and how habitat analysis regarding surface temperature, soil moisture, and elevation, can be performed with Earth observation techniques since locust swarms themselves cannot be directly observed. The presentation also included some of the current limitations of current locust-centric Earth observation efforts.

Session 8: Academic and Capacity-Building Perspective

To bring an academic perspective to the conference, the panel on “Academic and Capacity-Building Perspective – How can academic institutions and capacity-building initiatives and networks bridge the gap between technology provider and user?” included representatives from various academic institutions and capacity-building initiatives. The panel was co-moderated by the speaker of the ZFL and the Director of UNOOSA. The panellists represented the following institutions: United Nations University Institute for Environment and Human Security (UNU-EHS), EOTEC DevNet Network, University of Botswana, Ben-Gurion University of the Negev (Israel), Federal University of Santa Maria (Brazil), Asian Institute of Technology (AIT, Thailand).

The panel noted that several topics were important in bridging the gap between technology provider and user, many of which were shared with the prior panel, including the importance of cooperation at different scales, knowledge exchange, and accessibility. It was conveyed by several panellists that there is not a general lack of capacity, but a need to interconnect and take advantage of existing capacities in affected regions. This also includes strengthened links between agencies and other stakeholders as well as collaboration through global networks. It was further stated that early warning and early action are not purely academic fields but require engagement with traditional authorities, indigenous communities, and local stakeholders and can benefit strongly from building on existing knowledge systems. Knowledge sharing, new education opportunities, e.g. via e-learning, and the work with communities of practice were emphasized. Compatibility between the educational abilities of users/recipients and early warning systems was highlighted as a key requirement for successful early warning and early action.

Session 9: Novel Technologies, Future Outlook

The space community continues to develop missions to enhance the capacity of space technologies to improve early warning systems. Several satellites have been launched into orbit recently and are undergoing initial tests before becoming operational. In addition, several experiments have been carried out in recent years that may become an operational reality once resources are found for their implementation.

A representative from **Mayday.ai Guardian Space**, presented "Multi-hazard Early Warning: Maydai.ai (Guardian Space)". Mayday.ai is a company whose risk and disaster intelligence platform covers multiple disasters in various regions across the globe. Its solutions are timely and highly accurate and are the product of Mayday's proprietary AI fusion engine. Mayday's goal is to contribute to a culture shift towards risk reduction in line with the Sendai goals with its democratization of pertinent fused data and risk reduction through the inclusive engagement of stakeholders. Mayday contributes to Sendai efforts through multi-hazard early warning by dynamic risk modelling, and early detection, but also a live common operating picture (COP), rich visualizations (including 3D) and dashboard reporting.

An expert from the **European Union Agency for the Space Programme (EUSPA)** presented "The EU Space Programme as an Enabler for Multi-Hazard Analysis". They discussed the EU Space Programme's pivotal role in multi-hazard analysis and early warning systems for disaster management. The presenter highlighted how components like Galileo, Copernicus, and the upcoming IRIS² (Infrastructure for Resilience, Interconnection & Security by Satellites) projects contribute to this, emphasizing EUSPA's efforts in ensuring these services are effectively utilized by end-users. The presentation focused on the broad capabilities of these systems rather than specific projects, with real-world examples to demonstrate practical applications in early warning and disaster response.

A representative from **Deimos Space** presented "EdgeAI for Earth: Pioneering Disaster Detection and Response using On-board Machine Learning with Insight4EO". Deploying state-of-the-art machine learning onboard satellites has the potential to detect natural disasters and emergencies from space with unparalleled speed and accuracy. The presenter delved into how Deimos' Insight4EO EdgeAI technology can be used to transform disaster management, enabling quicker and more informed decisions directly from orbit. Artificial intelligence is uniquely capable of processing the large, disparate data sources produced before, during and after a disaster, and can provide a COP. Additionally, Deimos is actively collaborating with ESA and European Civil Services in the ongoing development of Insight4EO.

A representative from **Google** presented "Google AI Flood Forecasting". Researchers at Google have developed a flood forecasting early warning tool that will be integrated into their current search and mapping services to help with early warning around the world. The Flood Forecasting Global Model is a hydrological inundation model that uses global input data (baseline, DEM, weather, and precipitation forecast) to predict where flooding is likely to occur along rivers and drainage networks. These outputs can then be used to create early warning notifications for their users and present the locational data along various points in a river network.

Session 10: Disaster Management Perspective

The final panel on "Disaster Management Community Perspective – How can disaster management agencies utilize the presented tools and what are their needs" addressed how tools and services, like those discussed during the Conference, can be utilized in specific disaster management contexts. Additionally, the panel discussed how the use of space technologies in early warning systems can be further enhanced and integrated in their particular countries. The panel was moderated by the Director of UNOOSA and had the following institutions being represented: National Office for Risk and Disaster Management of Madagascar (BNGRC), Ministry of Housing and Land Use Planning of Mauritius, National Disaster Management Organization of Ghana (NADMO), National Early Warning and Response Mechanism Coordinating Centre of the Gambia (NCCRM) and National Disaster Management Centre of South Africa (NDMC).

During the panel discussion, all participants underscored the pivotal role of UN-SPIDER within the framework of UN agencies and programs. For all panellists, geospatial information emerged as a cornerstone, crucial for enhancing capacity building in disaster management efforts, such as risk modelling for early warning and emergency response. The initiatives of UN-SPIDER, including technical assistance, mapping initiatives, educational opportunities, and funding, were highlighted in this context. Beyond UN-SPIDER efforts, all parties see improvements in their disaster management efforts after tools based on space technologies efforts have been implemented. For future efforts, several panellists pointed out the need for more support in collaboration efforts between stakeholders such as policymakers and experts. More community engagement was highlighted as equally important, along with the inclusion of traditional knowledge. There was an expression of the need for more simulation exercises with various stakeholders involved.

Poster Exhibition and Session

To provide more participants with the opportunity to share their experiences and showcase their work, the organizing committee organized a poster exhibition and a dedicated poster session as an addition to the conference. The posters were prominently displayed for all three days of the conference in an open space adjacent to the conference room. On the second day (13 March 2024), as a way to facilitate one-to-one discussions, participants were invited to explore the exhibition during the dedicated poster session, offering an opportunity for dialogue and engagement as poster creators were present to address inquiries and participate in discussions. Participants had the opportunity to approach these representatives in the more informal setting of a coffee break.

The poster exhibition showcased tools and solutions developed or utilized by the participant or the represented institution. Additionally, case studies presenting the practical application of space-based information or technologies within the realm of disaster management, with a focus on early warning systems were included.

The following table gives an overview of the poster contributions on-site:

Title of Poster	Organization
Enhancing Capacity Building for Better Early Warning and DRR	EOTEC DevNet
Satellite Data-Based Solutions: Parametric Insurance to Protect Vulnerable Communities from Natural Hazards	UNU/EHS MCII
Spatiotemporal Analysis of Sitatunga Population's Response to Flood Variability in Northern Botswana: Implications for Disaster Risk Mitigation	University of Botswana
REACH Initiative: Integrating satellite-based technology and primary data for enhanced hazard assessment throughout the disaster management cycle	REACH - Informing more effective humanitarian action
Towards actionable impact-based early warning: integrating exposure and vulnerability into early warning systems in the IGAD region	UNU-EHS
The Potential of Copernicus for Disaster Management in Africa	ZFL, University of Bonn
Learning with Communities on Aseismic Tsunami from the Gunung Anak Krakatau 2018	BRIN, IDOS, University of Bonn, Universitas Lampung

Closing Remarks

The conference ended with closing remarks by the speaker of ZFL and by the Head of the UN-SPIDER Bonn Office, thanking the presenters, panellists and participants for their active contribution. Follow-up activities are planned and will be conducted in the context of the mutual endeavours of the SPEAR project and the upcoming second project phase, taking advantage of the momentum and the network that the conference has created, to support disaster management agencies and other institutions in the application of space-based technologies for early warning and the entire risk management cycle.

Key Results and Outcomes

The UN-SPIDER Bonn International Conference on Space-based Solutions for Disaster Management: Early Warnings for All led to several outcomes, building upon past activities and providing a roadmap to achieve future objectives.

Outcomes from the point of view of participants

Participants took note of examples of space-based data, products, services, and applications which can contribute to the four pillars of effective early warning systems. Many presentations provided information on how space technologies contribute to improving the monitoring of hydrometeorological, geological, environmental, health, biological, and extraterrestrial hazards. Other presentations addressed the use of products such as digital elevation models to contribute to hazard assessment in case of floods, storm surges, tsunamis, and mass movements such as landslides. Others addressed the use of novel products such as the World Urban Footprint of the German Aerospace Centre, while others addressed novel developments including the use of artificial intelligence, and advances in on-board computing in satellites to expedite the processing of satellite imagery. Furthermore, participants took note of examples of the use of global navigation satellite systems to transmit warnings as in the case of the Galileo constellation of Europe. In addition, the conference allowed participants to take note of other advances through a dedicated poster session. Finally, discussions as part of the sessions, three expert panels and manyfold opportunities for exchange during coffee- and lunch breaks allowed participants to exchange their views and experiences, ask questions and connect.

Outcomes from the point of view of ZFL and UN-SPIDER

The conference allowed UN-SPIDER and ZFL to continue implementing the SPEAR project. The conference itself is part of the annual plan of work for the SPEAR project. In addition, the conference allowed participants and a greater audience worldwide to take note of the launch of the publication on Space Technologies for Early Warning Systems, which is also a task included in the plan of work of the SPEAR project. Furthermore, it allowed UN-SPIDER and ZFL to strengthen the links with partners in Africa, and to establish contact with representatives of government agencies of Egypt, Gambia, Madagascar, Mauritius, and Morocco. These new links have opened opportunities for UN-SPIDER to provide advisory support to these countries in the near future. Additionally, the focus on early warning and mitigation of disaster risk addressed a need raised by many participants in former UN-SPIDER events. The conference clearly showed the importance of these topics and the demand for improved systems, services, methods, education and capacity building in those fields. Building on the results of this event will help to shape the research and implementation activities of the next phase of the SPEAR project.

In summary, the conference allowed UN-SPIDER to continue:

- Bridging the gap between the space and the disaster management communities;
- Raising awareness regarding solutions developed by the space community that contribute to disaster risk reduction efforts;

- Strengthening its networking efforts with institutions in Germany, Europe, Africa, Asia and Latin America.

General outcomes

The conference contributed to the implementation of the Overarching Objective 2 of the ***Space 2030 Agenda: space as a driver of sustainable development***, which includes the need to strengthen the use of integrated space applications to improve early warning systems. In addition, it contributed to the implementation of Overarching objective 3 of this agenda, specifically Increasing awareness of the risks of adverse space weather and efforts implemented to develop and operate early warning systems targeting space weather, such as those carried out by the German Research Centre for Geosciences (GFZ) in Potsdam, Germany.

The conference also contributed to the implementation of the ***Early Warnings for All*** initiative launched two years ago by the Secretary General of the United Nations.

Furthermore, it allowed representatives of national, regional and international organizations; academia, the private sector, and non-government organizations to share information and experiences on the efforts to develop space-based solutions to contribute to early warning systems, and others to inform about their efforts to implement such solutions.

More generally, the conference can be seen as a contribution by UN-SPIDER and ZFL, supported by DLR, to the implementation of the Sendai Framework for Disaster Risk Reduction and the Paris Climate Agreement, both launched in 2015; and which call for the implementation of efforts to contribute to improve early warning systems worldwide.

And finally, the conference is a contribution to the overall aim of UNOOSA to bring the benefits of space to humankind.

Recommendations and Next Steps

The outcomes of the UN-SPIDER Bonn International Conference on Space-based Solutions for Disaster Management: Early Warnings for All have underscored the pivotal role of space-based technologies in enhancing early warning systems across various hazard domains. Building upon these outcomes, it is crucial to prioritize collaborative efforts aimed at leveraging space-based data, products, and services to strengthen early warning systems globally.

To this end, it is recommended to foster increased collaboration among stakeholders, including governments, international organizations, academia, and the private sector. This collaboration should focus on sharing best practices, expertise, and resources to enhance the accessibility and effectiveness of space-based solutions for disaster management. Additionally, there is a need to invest in capacity-building initiatives to empower countries, particularly in regions vulnerable to disasters, with the knowledge and tools necessary to harness space-based technologies for early warning purposes. This includes providing training activities, technical assistance, and access to relevant data and tools to facilitate the adoption and

integration of space-based solutions into existing disaster management frameworks. These recommendations can further create partnerships, advancing efforts to build more resilient and accessible early warning systems.

UN-SPIDER, in collaboration with its partners, is committed to proactively addressing the recommendations outlined in this chapter. The insights from the conference's results and outcomes, alongside the recommendations presented herein, will serve as guidance for shaping the future initiatives of UN-SPIDER and its partners. This strategic approach is particularly crucial in informing the planning of the upcoming next phase of the SPEAR project. By aligning with these recommendations, UN-SPIDER aims to bolster its efforts in bridging the gap between space and disaster management communities, raising awareness about space-based solutions, and strengthening networking endeavours across regions.

Annex – Programme of Activities

Day 1 – 12 March 2024

08:00 – 09:00	Registration	
Opening Segment		
09:00 – 09:30	Opening Ceremony - Welcome remarks by UNOOSA / UN-SPIDER - Welcome remarks by DLR - Welcome remarks by ZFL - Group photo	 UNOOSA DLR ZFL

SESSION 1: Introduction and Setting the Scene		
This session will be used to set the scene regarding early warning systems		
09:30 – 10:00	Keynote presentation by DLR Space Agency	DLR
10:00 – 10:30	Keynote presentation by ZFL	ZFL
10:30 – 11:00	Keynote presentation by UN-SPIDER on space technologies for early warning systems	UN-SPIDER
11:00 – 11:30	**Coffee Break**	
11:30 – 11:50	WMO Space Programme's Overview and the Role of Space-based Earth Observations to Support WMO Major Strategic Priorities, Including EW4All	WMO
11:50 – 12:10	Iridium Satellite Data Delivery for Emergency Warning Systems	Iridium Sat. Comms.
12:10 – 12:30	Use of Space-based Products in Early Warning Systems (Digital Elevation Models, Land-use/Land-cover Layers, Urban Footprints)	AIRBUS Defence & Space
12:30 – 12:50	Questions & Answers	UN-SPIDER/ZFL
12:30 – 14:00	**Lunch**	
SESSION 2: Hydrometeorological Hazards		
This session will focus on space technologies for hydrometeorological hazards		
14:00 – 14:20	Space Technologies to Monitor Severe Weather	ECMWF
14:20 – 14:40	The Copernicus Emergency Service Operational Global Flood Awareness System and Global Flood Monitoring Product	GloFAS
14:40 – 15:00	Modular Flood Early Warning Systems for Small Communities in Africa	TAHMO
15:00 – 15:20	Automatic Monitoring of Warnings and Early Triggering of Satellites During Flood Events	DLR
15:20 – 16:00	**Coffee Break**	

16:00 – 16:20	FAO's Agricultural Stress Index System (ASIS) for Agricultural Drought Monitoring and Early Warning	FAO
16:20 – 16:40	Global Drought Observatory (GDO)	GDO
16:40 – 17:00	South Asia Drought Monitoring System (SADMS)	IWMI
17:00 – 17:30	Questions & Answers	UN-SPIDER/ZFL
17:30	**End of the First Day**	

Day 2 – 13 March 2024

SESSION 3: Geological Hazards		
This session will focus on space technologies for geological hazards		
09:00 – 09:20	Spaceborne and Airborne DInSAR Products Generation and Analysis to Support Civil Protection Activities in Volcanic and Seismic Regions	CNR IREA
09:20 – 09:40	Multimodal Earth Vision for Natural Hazard Multi-Risk Assessment and Early Warning	DLR/ZFL
09:40 – 10:00	Landslide Risk Assessment and Mitigation in Cities	DLR
10:00 – 10:20	Spaceborne InSAR for Landslides and Geohazard Monitoring	Airbus Defence & Space
10:20 – 10:40	Questions & Answers	UN-SPIDER/ZFL
10:40 – 11:00	**Coffee Break**	
SESSION 4: Environmental Hazards		
This session will focus on space technologies for environmental hazards		
11:00 – 11:20	Experiences from Greece / FireHUB	BEYOND Centre of Excellence, NOA
11:20 – 11:40	Susceptibility of Vegetation to Forest Fires	IGAC
11:40 – 12:00	Innovation in European Wildfire Risk Management Research: an overview over research and development activities / Firelogue	Fraunhofer Institute
12:00 – 12:30	Questions & Answers	UN-SPIDER/ZFL
12:30 – 14:00	**Lunch**	
SESSION 5: Extraterrestrial Hazards		
This session will focus on space technologies for extraterrestrial hazards		
14:00 – 14:20	International Asteroid Warning Network and Space Mission Planning Advisory Group	ESA
14:20 – 14:40	Space Weather Early Warning, KP Index	GFZ Potsdam
14:40 – 15:00	Disaster Management in the District of Berlin Lichtenberg for Events from Outer Space	Disaster Management Berlin
15:00 – 15:15	Questions & Answers	UN-SPIDER/ZFL

SESSION 6: Space Community Perspective		
How do space agencies and other representatives of the space community push the use of space technologies in their country/region		
15:15 – 16:30	**Panel**: Space Community Perspective – How space agencies support national disaster management activities	AEM ASAL BRIN EgSA NASRDA SANSA SUPARCO
16:30 – 17:30	**Extended Coffee Break and Poster Session**	
17:30	**End of the Second Day**	

Day 3 – 14 March 2024

SESSION 7: Health and Biologic Hazards		
This session will focus on space technologies for health and biologic hazards		
09:00 – 09:20	Early Warning System for Mosquito Borne Diseases (EYWA)	BEYOND Centre of Excellence, NOA
09:20 – 09:40	Earth observation for desert locust outbreaks	ZFL
Session 8: Academic and Capacity-Building Perspective		
Academic institutions and capacity-building initiatives discuss how to bridge the gap between technology provider and user.		
09:40 – 10:40	**Panel**: Academic and Capacity-Building Perspective – How can academic institutions and capacity-building initiatives and networks bridge the gap between technology provider and user?	UNU-EHS EOTEC DevNet University of Botswana Ben Gurion University, Israel Federal University of Santa Maria, Brazil Asian Institute of Technology, Thailand
10:40 – 11:00	**Coffee Break**	
SESSION 9: Novel Technologies, Future Outlook		
This session will focus on novel technologies		
11:00 – 11:20	Multi-hazard Early Warning: Maydai.ai (Guardian Space)	Maydai.ai, Guardian Space
11:20 – 11:40	The EU Space Programme as an Enabler for Multi-Hazard Analysis	EUSPA
11:40 – 12-00	EdgeAI for Earth: Pioneering Disaster Detection and Response using On-board Machine Learning with Insight4EO	Deimos Space
12:00 – 12:20	Google's Flood Forecasting Product	Google
12:20 – 12:30	Moderated Discussion	UN-SPIDER
12:30 – 14:00	**Lunch**	

Session 10: Disaster Management Perspective		
Disaster management community representatives to discuss how the presented tools can be used and what are the needs of disaster management agencies		
14:00 – 15:00	**Panel**: Disaster Management Community Perspective – How can disaster management agencies utilize the presented tools / what are their needs	BNGRC (Madagascar) MHLUP (Mauritius) NADMO (Ghana) NCCRM (Gambia) NDMC (South Africa)
15:00 – 15:30	**Coffee Break**	
15:30 – 16:00	**Closing remarks**	UN-SPIDER ZFL DLR
16:00	**End of Conference**	

Annex II– Acronyms

AEM - Mexican Space Agency

AIT - Asian Institute of Technology, Thailand

API - Application Programming Interface

ASAL - Algerian Space Agency

ASIS - Agricultural Stress Index System

BBK - German Federal Office for Civil Protection and Disaster Assistance

BEYOND CE, NOA - BEYOND Centre of Excellence, National Observatory of Athens, Greece

BMWK - Federal Ministry for Economic Affairs and Climate Action of Germany

BNGRC - National Office for Risk and Disaster Management of Madagascar

BRIN - Research and Innovation Agency, Indonesia

CEOS - Committee on Earth Observation Satellites

CNES - National Centre for Space Studies of France

CNR - National Research Council of Italy

CNR-IREA - Institute of Electromagnetic Sensing of Environment of National Research Council of Italy

COP - Common Operating Picture

CRTS - Royal Center for Remote Sensing of Morocco

DEM - Digital Elevation Model

DInSAR - Differential Synthetic Aperture Radar Interferometry

DKKV - German Committee on Disaster Prevention

DLR - German Aerospace Center

DPC - Italian Department of Civil Protection

ECMWF - European Centre for Medium-Range Weather Forecasts

EGSA - Egyptian Space Agency

EO - Earth Observation

EPOS - European Plate Observing Systems

ESA - European Space Agency

EUSPA - European Union Agency for the Space Programme

EWS - Early Warning System

EYWA - Early Warning System for Mosquito-Borne Diseases

FAO - Food and Agriculture Organization

FEWS - Flood Early Warning Systems

GDO - Global Drought Observatory

GFM - Global Flood Monitoring

GFZ - German Research Center for Geosciences

GloFAS - Global Flood Awareness System

IAWN - International Asteroid Warning Network

ICAR - Indian Council of Agricultural Research

IDOS - German Institute of Development and Sustainability

IGAC - Geographic Institute Agustín Codazzi, Colombia

INMG - National Institute for Meteorology and Geophysics of Cabo Verde

ISA - Iranian Space Agency

IWMI - International Water Management Institute

LEWS - Landslide Early Warning Systems

NADMO - National Disaster Management Organization of Ghana

NASRDA - National Space Research and Development Agency of Nigeria

NCCRM - National Early Warning and Response Mechanism Coordinating Centre of the Gambia

NDMC - National Disaster Management Centre of South Africa

NEO - Near Earth Object

NGI - National Geographic Institute of Belgium

NRC - Norwegian Refugee Council

P-SBAS - Parallel Small Baseline Subset

PAGER - Prediction of Adverse effects of Geomagnetic storms and Energetic Radiation

RUB - Ruhr-University Bochum

SADMS - South Asia Drought Monitoring System

SANSA - South African National Space Agency

SAR - Synthetic Aperture Radar

SMA - Soil Moisture Anomaly

SMPAG - Space Mission Planning Advisory Group

SPEAR - Space-based Earth Observation Applications for Emergency Response and Disaster Risk Reduction

SUPARCO - Pakistan Space & Upper Atmosphere Research Commission

TAHMO - Trans-African Hydro-Meteorological Observatory

Technical University of Berlin - Institute of Geodesy and Geoinformatics Science

TEMBO - Transformative Environmental Monitoring to Boost Observations in Africa

TH Cologne - Cologne University of Applied Sciences

UI - User Interface

UNCCD - United Nations Convention to Combat Desertification

UNFCCC - United Nations Framework Convention on Climate Change

UNOOSA - United Nations Office for Outer Space Affairs

UNU-EHS - United Nations University - Institute for Environment and Human Security

WIGOS - WMO Integrated Global Observing System

WMO - World Meteorological Organization

ZFL - Center for Remote Sensing of Land Surfaces, University of Bonn