Distr.: General
10 March 2025

Original: English

Earth Information Day 2024

Informal summary report by the Chair of the Subsidiary Body for Scientific and Technological Advice

I. Background and overview

1. Earth Information Day provides an opportunity for Parties to engage with the systematic observation community to share and understand latest information, trends and projections in Earth observations to inform negotiations and wider decision-making. During the Earth Information Day, messages on enhancing systematic observations, related initiatives and advancing cooperation have been recognized. Further, Earth Information Day provides a platform to identify gaps and challenges in this regard, and opportunities for addressing them.

2. Earth Information Day 2024 was held on Monday, 11 November 2024 in conjunction with the Baku Climate Change Conference. The event comprised of an opening segment as well as launch of the policy brief on innovation and technology[1] co-authored by the TEC and GEO, updates on the state of the climate from relevant organizations, and thematic breakout discussions on:

(a) Observations for climate change mitigation;

(b) Observations for climate change adaptation;

(c) Observations for averting, minimizing, addressing loss and damage, and strengthening resilience to extreme events including heat stress;

(d) Advancing innovation, technology and digital transformation;

(e) Enhancing observation in critical ecosystems and vulnerable regions.

3. The event was held under the overall facilitation/guidance of the SBSTA Chair, Harry Vreuls. The information note on the event, programme, presentations from experts, outcomes of breakout discussions and webcast are available on the event webpage.[2] Guiding questions for the respective thematic breakout session were provided to participants beforehand, to facilitate discussions and respond to the information needs presented by Parties and stakeholders.

4. Parties are encouraged to consider the key messages, outcomes and discussions from Earth Information Day 2024 presented in this report, for relevant upcoming negotiations, decision-making and cooperation, with a view to effectively supporting the implementation of the Convention and the Paris Agreement.

[1] See https://unfccc.int/documents/641185 p.25–26.

[2] See event page https://unfccc.int/event/earth-information-day-2024-mandated-event.

Abbreviations and acronyms

AR	Assessment Report of the Intergovernmental Panel on Climate Change
AI	Artificial Intelligence
CEOS	Committee on Earth Observation Satellites
CGMS	Coordination Group for Meteorological Satellites
CH_4	methane
CO_2	carbon dioxide
COVID-19	coronavirus disease 2019
COP	Conference of the Parties
ECV	essential climate variable
EWS	early warning system
EW4ALL	Early Warnings for All initiative
GAW	Global Atmospheric Watch
GBON	Global Basic Observing Network
GCF	Green Climate Fund
GCOS	Global Climate Observing System
GEO	Group on Earth Observations
GHG	greenhouse gas
GIS	Geographic Information Systems
GNSS	Global Navigation Satellite System
GOOS	Global Ocean Observing System
G3W	Global Greenhouse Gas Watch
IPCC	Intergovernmental Panel on Climate Change
LDC	least developed countries
MHEWS	multi-hazard early warning system(s)
mm	millimeters
NAP	national adaptation plan
NDC	nationally determined contribution
NOAA	National Oceanic and Atmospheric Administration
NCAI	NOAA Centre for Artificial Intelligence
ppb	parts per billion
ppm	parts per million
RBON	Regional Basic Observing Network
SBSTA	Subsidiary Body for Scientific and Technological Advice
SIDS	small island developing State(s)
SOFF	Systematic Observations Financing Facility
TFI	Task Force on National Greenhouse Gas Inventories of the Intergovernmental Panel on Climate Change
TEC	Technology Executive Committee of the United Nations Framework Convention on Climate Change
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
WG	Working Group of the Intergovernmental Panel on Climate Change
WIGOS	World Meteorological Organization Integrated Global Observing System
WMO	World Meteorological Organization

Key messages, Earth Information Day 2024

1. The year 2024 was on track to being the warmest year on record, with global mean surface temperature of 1.54+/-0.13ºC, and the last ten years, 2015-2024 have been the warmest decade on record. However, sustained observations over time indicate that warming has not reached the Paris Agreement long-term temperature goal.

2. Global GHG concentrations, based on the three key GHGs of CO_2, CH_4, and N_2O, reached record observed levels in 2023 at approximately 420 ppm, 1934 ppb and 336.9 ppb respectively.

3. Sea level continues to rise, at 4.77 mm per year, ocean heat content is increasing and glacier mass loss is accelerating, including as reflected by the low Antarctic and Artic Sea ice extent in 2024. Ocean heat content was the highest on record in 2023.

4. EWS coverage remains low in the global south, particularly in SIDS and LDCs, however progress has been made, including under the EW4ALL initiative to bridge the gaps, with over half of the countries having MHEWS.

5. Advancements are being made in innovation and technologies for advancing Earth observations through, for instance, AI, Machine Learning and other novel methods and there is need to enhance the deployment of fit-for-purpose and scalable solutions.

6. Sustained long-term observations and monitoring as well as historical data sharing is key to effectively informing climate policy and action. Countries are encouraged to support efforts to increase monitoring capacity and close observational gaps in under observed regions.

7. Financing, including through innovative financing models, for Earth observations is critical to filling observation gaps as well as ensuring a country's compliance with GBON. The SOFF is providing long-term open-ended support to countries to enhance Earth observation.

II. Summary of proceedings

A. Opening segment and launch of TEC Knowledge product

1. Opening statements

5. SBSTA Chair, Harry Vreuls outlined the organization of work for Earth Information Day 2024 and underlined the importance of Earth observations and particularly, Earth Information Day, for understanding climate change and informing decision-making and negotiations at COP 29.

6. UNFCCC Director for Intergovernmental Support and Collective Progress Division, Cecilia Kinuthia-Njenga, stressed that systematic observation, through the provision of climate data, is the backbone of all climate efforts, including EWS, understanding climate risks and impacts and addressing loss and damage especially in vulnerable regions. She further highlighted the importance of Earth Information Day for transparency in climate action, and reiterated that inclusive engagement and partnerships, as demonstrated by the diverse perspectives shared at the event, strengthens climate action.

7. IPCC Chair, Jim Skea[3], provided an update on AR7 and highlighted the relationship between Earth observations and the work of the IPCC, stressing the relevance of Earth observations in advancing climate science as reflected throughout IPCC's assessments. For instance, with the contribution of Earth observations, the AR6 WG I report[4] reflected the changing state of the climate system, the Earth's energy budget, climate feedback and sensitivities and affirmed that human influence has warmed the Earth. Further, Jim Skea explained that observation systems can support vulnerable regions and communities, especially in coastal regions, while also addressing developments in land use, agriculture, and human settlement, through the work under WG II. Specifically, the upcoming IPCC special report on Climate Change and Cities will include urban observations and modelling tools for monitoring and evaluation of sectors and unaccounted sources when discussing reducing urban risks and emissions. In this instance, local scale studies, in-situ and remotely sensed observations, high resolution model outputs and databases on city-relevant emissions, impacts and hazards will also support the report. The WG II will produce revised and updated technical guidelines on impacts and adaptation, including adaptation indicators, metrics and methodologies, thereby supporting work on the global goal on adaptation and showing where Earth observations can support monitoring of progress in climate change adaptation. The role of Earth observations for EWS which necessitates effective adaptation was also highlighted.

8. Jim Skea outlined the work under the TFI, who will produce a methodology report on short-lived climate forcers[5] by the end of 2027, which will be informed by and rely on recent advancements in observations. Under the taskforce, the IPCC held an expert meeting on the use of atmospheric observation data in emission inventories in September 2022[6], which among other things considered the potential for using atmospheric observations to verify GHG inventories and comparison of national inventories leading to improvements in bottom-up inventories and supplementing IPCC emission factors. In addition, the TFI will produce a methodology report on CO_2 removal technologies and carbon capture, utilization and storage by the end of 2027, with the role of Earth observations in estimating relevant emissions and removals falling within its scope.

9. WMO Secretary-General Celeste Saulo outlined the key findings of the WMO State of the Climate Update 2024[7], and the importance of Earth observations and cooperation for effective climate action. In summarizing its key findings, Celeste Saulo highlighted that 2024

[3] Read the full speech at https://www.ipcc.ch/2024/11/11/ipcc-chair-cop29-earth-information-day/.
[4] See Climate Change 2021: The Physical Science Basis https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/.
[5] See https://www.ipcc.ch/report/methodology-report-on-short-lived-climate-forcers/
[6] Read the report of the IPCC expert meeting 2209_AtmObs_Report.pdf.
[7] WMO. 2024. *State of the Climate 2024: Update for COP29*. Geneva: WMO. Available at https://library.wmo.int/records/item/69075-state-of-the-climate-2024.

was on track to being the hottest year on record, as warming temporarily hit 1.5 °C and that the past 10 years have been the warmest on record. Based on an analysis of at least six datasets, the global mean air temperature from January to September was 1.54 °C above the pre-industrial average. However, she highlighted that this does not translate to failure to meet the Paris Agreement long-term temperature goal. According to the update, GHG concentrations had reached record levels in 2023 and continued to rise in 2024, and that glacial mass loss, sea level rise and ocean heating are accelerating, with extreme events impacting communities and economies across the world. To support policy makers in their climate action efforts, the need to track, monitor and communicate where current warming is, including relative to the long-term temperature goal was highlighted. To facilitate this, the WMO established an international team of experts who will refine tracking and monitoring work in support of the UNFCCC and IPCC.

10. Celeste Saulo recognized the importance of continued investment in Earth observations, research and climate services in creating a safe future for all. Further, the importance of the relevant data provided by observation technologies, such as ground-based and satellite systems, to track emissions, assess impacts and measure progress was recognized. Collectively, accurate and reliable data enables science-based decisions and effective climate action and policies, while also underpinning all efforts to limit global warming, protect biodiversity and ensure climate resilience through EWS and early action. Collaborative efforts across science and technology were highlighted as advancing this data-driven understanding of climate change and these include efforts by WMO, GCOS, G3W, Climate Information Services for Climate Action and the UN EW4All initiative. The Earth Information Day was commended for providing the latest scientific information and advancing a multidisciplinary approach to Earth system observation.

11. Yana Gevorgyan, Director of GEO secretariat, delivered a video message outlining the gaps in access to EWS and ways of bridging these gaps. She highlighted that millions of people, especially those on the frontline of climate disasters, lack access to reliable EWS, and that many countries, particularly SIDS and LDCs, and many nations across Africa, lack the resources to implement effective EWS. She underlined GEO's commitment to bridge these gaps by leveraging Earth intelligence to transform data into actionable insights, and referred to the TEC-GEO policy brief, which outlines innovative data-driven solutions for EWS and provides a roadmap for countries to respond to the climate-related crisis. Yana Gevorgyan reiterated GEO's shared vision with the EW4ALL initiative, for every person to have access to resilient and inclusive EWS.

2. TEC-GEO policy brief

12. Thibyan Ibrahim, Chair of the TEC, delivered a keynote address on the joint TEC-GEO policy brief titled "Realising Early Warnings for All: Innovation and Technology in Support of Risk-Informed Climate Resilience Policy and Action[8]", and presented key technologies and action points from the policy brief. Thibyan Ibrahim highlighted the increasing climate impacts experienced in vulnerable countries, especially SIDS and LDCs, and the importance of good quality MHEWS, to which millions of people still lack access. The policy brief provides a roadmap for harnessing information and technology for climate information and disaster risk knowledge, to inform MHEWS as well as support in understanding climate risks.

13. The TEC Chair presented proven fit-for-purpose technologies reflected in the policy brief which include:

(a) Surface, air, ocean and space-based sensors for gathering Earth information;

(b) Citizen science to ground truth remote sensing Earth observations;

(c) GNSS to capture patterns of human movement, rising sea levels and changing shorelines;

[8] Technology Executive Committee and Group on Earth Observations. 2024. *Realising Early Warnings for All: Innovation and Technology in Support of Risk-Informed Climate Resilience Policy and Action*. Bonn: UNFCCC. Available at https://unfccc.int/ttclear/tec/early_warning_systems.html.

(d) Internet of Things which offers powerful data gathering and integrating capabilities;

(e) Simulation models for risk assessment, risk mapping, impact scenario development, and early warning threshold definitions;

(f) Cloud computing to process, store and facilitate access to big data;

(g) AI and machine learning to efficiently produce and use risk knowledge based on big data;

(h) GIS to link data to maps and to delineate climate information and risk knowledge;

(i) Data cubes and analysis to analyse Earth observation satellite data for individual hazards and context specific needs;

(j) Application Programming Interfaces to link and integrate data applications within a single hazard or multi hazard context for planning early actions and preparedness.

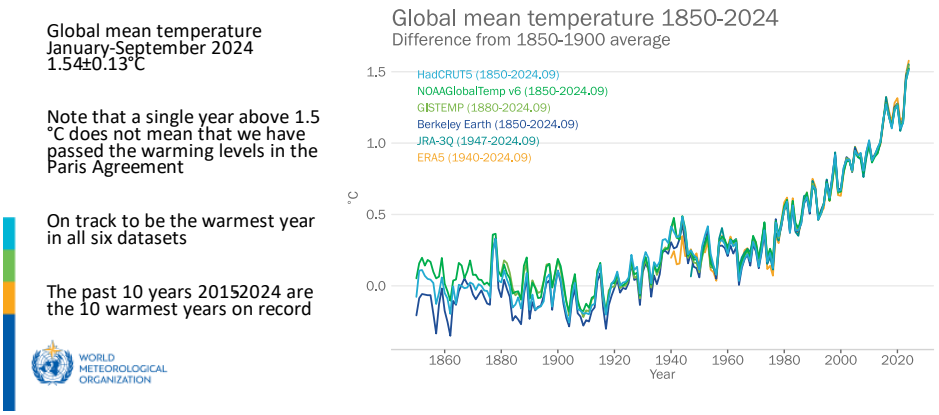
14. Thibyan Ibrahim also emphasized that the combined implementation of the listed technology measures, due to their complementary features, will result in efficiency and superior us of the innovations. In addition to technological measures, the policy brief outlined actions that constitute a high-level strategy for scaling up EWS and coverage for all. These include consideration of the technologies in climate action plans such as NDCs and NAPs, leveraging investments for multi-sectoral solutions, partnerships with the public and private sector and capacity building for stakeholders.

B. Updates on the state of the climate

1. WMO 2024 State of the Climate Update

15. John Kennedy and Trewin Blair presented the preliminary State of the Climate 2024 Update for COP 29. The State of the Climate Update 2024 consists of key climate indicators, assessment of current warming levels in the context of the Paris Agreement, some extreme events and their social economic impacts and summaries of other progress reports on climate action such as on renewable energy, climate services, global water resources and EW4ALL. According to the update and based on six datasets, the global mean temperature for 2024 was 1.54+/- 0,13ºC, above the 1850–1900 average. Further, 2024 was on track to being the warmest year[9] on record, and that the past ten years, 2015–2024 are the warmest ten years on record, as reflected in figure 1.

Figure 1
Global mean temperature, WMO.



Source: Slide 3 of *Dr John Kennedy and Dr Blair Trewin's presentation* at EID 2024.

[9] Across all six datasets of HadCRUT5 (1850–2004.09), NOAAGLOBALTemp v6 (1850–2024.09), GISTEMP (1880–2024.09), Berkeley Earth (1850–2024.09), JRA-3Q (1947–2024.09), ERA5 (1940–2024.09).

16. GHG concentrations, based on the three key GHGs of CO_2, CH_4, and N_2O, reached record observed levels in 2023 at 420 ppm, 1934 ppb and 336.9 ppb respectively. This represents 151, 265 and 125 per cent increases for CO_2, CH_4 and N_2O respectively compared from 1750. Further, records indicate an increase in ocean heat, with the increase being significant in the last two decades, and ocean heat content was the highest on record in 2023. According to the update, sea level rise, caused by ocean heat and melting ice, is accelerating at 4.7 mm per year between 2014 and 2023. The extent of the Arctic and Antarctic Sea ice in 2024 has been well below average (in comparison with records from 1978–2024), where 2024 recorded the seventh and second lowest in the satellite record, respectively, and where 2023 was the lowest for both seas. Additionally, glacier mass loss is accelerating, with 2023 reporting the largest single year loss on record, equivalent of 1.2 m water ice.

17. Trewin Blair illustrated the link between current warming trends and the Paris Agreement, indicating that while the 2024 global mean temperature is likely to exceed 1.5ºC, this does not translate to sustained observed warming of above 1.5 ºC, as warming levels are considered as an average over multiple years, such as for a 10–20-year period. Trewin Blair explained that WMO is currently developing an objective and scientifically robust methodology on assessing current global warming levels, to provide an absolute number and assess the probability of 1.5ºC warming. In estimating current warming, possible approaches will include, in the first instance combining recent observations with short-range projections (e.g. previous 10 years and projected next 10 years, 2014–2033), secondly, applying statistics of fit to recent observations and thirdly, assessing the current human contribution to warming. Trewin Blair acknowledged the uncertainties related to the approaches, with the highest uncertainty related to the third approach.

2. Global Climate Observing System

18. Thelma Krug, Chairperson of GCOS, provided updates on the GCOS in relation to the 55 key climate indicators, ECVs, as well as requests to Parties to enhance global observations. The GCOS five-year implementation plan[10] tracks ECVs, identifying observational gaps and data needs for climate science and services, and monitoring is reported through status reports. GCOS engages with various programmes and initiatives to respond to ECVs requirements such as through the CEOS-CGMS Working Group on Climate which supports coordination of space-based observations, SOFF advisory board, GOOS ocean and biochemical panels. For instance, the GOOS biochemical panel is supporting monitoring of GCOS and G3W mandates related to GHG monitoring and data management in the ocean.

19. In 2023, the GCOS Climate Monitoring Principles[11], which are applicable across all observing domains and technologies were revised and adopted at the 78th session of the WMO Executive Council, as well as included in the new WIGOS Manual[12]. The monitoring principles provide guidance to ensure that observations are suitable and provide a foundation for climate policy, including across mitigation, adaptation and loss and damage. Parties were requested to consider replacing the Climate Monitoring Principles contained in decision 11/CP.9[13] with the new version.

20. Thelma Krug also highlighted gaps in funding to close observational gaps, especially for in-situ observations, across almost all GCOS ECVs, as well as for coordination. She therefore called on Parties to enhance their support in this regard, particularly to WMO and GCOS. Observational gaps that were highlighted include those related to geographical coverage, decreasing monitoring capacity as observed in the upper-air network, long-term data preservation and access to data. Parties were therefore encouraged to share historical archives of data with regional and global repositories, which is also essential for adaptation metrics to support the global goal on adaptation, EW4ALL and work under IPCC AR7. In

[10] WMO. 2022. *The 2022 GCOS Implementation Plan*. Geneva: WMO. Available at https://library.wmo.int/doc_num.php?explnum_id=11317.

[11] GCOS monitoring principles adopted by COP 5, and updated version adopted by COP 9.

[12] WMO. 2024. *Manual on the WMO Integrated Global Observing System: Annex VIII to the WMO Technical Regulations*. Geneva: WMO. Available at https://library.wmo.int/records/item/55063-manual-on-the-wmo-integrated-global-observing-system-wmo-no-1160?offset=42.

[13] Decision 11/CP.9 https://unfccc.int/documents/3606.

recognizing the role and contribution of countries towards a comprehensive global observing system, GCOS emphasized and encouraged collaboration at national level and requested Parties to designate GCOS national coordinators[14].

3. Global Greenhouse Gases Research and Monitoring at WMO

21. Gianpaolo Balsamo, Director at WMO, presented on the latest update on GHG monitoring by WMO through the GAW and its G3W. The GAW aims to understand the long-term changes in GHG levels as well as to address related information gaps. The initiative supports the implementation of GCOS and provides key information to the processes under the Convention, through the GHG bulletin, as well as support implementation of the Paris Agreement. According to the GAW and GHG bulletin[15], GHG levels have increased by 27 per cent over the past 50 years and reached new record in 2023, with a global mean abundance of 420 ppm in CO_2, a 151 per cent growth compared to pre-industrial levels and averaging 2.4 ppm per year over the past ten years. Gianpaolo Balsamo illustrated variations in the growth over the years caused by the El Nino phenomena, occurrence of large fires or droughts which affects the Earth's CO_2 uptake capacity and the COVID-19 pandemic which saw a pause in anthropogenic emissions. Further, CH_4 has increased by 265 per cent since pre-industrial period, averaging 10.7 ppb per year over the past ten years, as reflected in figure 2.

Figure 2
Global greenhouse gas levels, WMO

	CO_2	CH_4	N_2O
2023 global mean abundance	420.0±0.1 ppm	1934±2 ppb	336.9±0.1 ppb
2023 abundance relative to 1750[a]	**151%**	**265%**	125%
2022–23 absolute increase	2.3 ppm	11 ppb	1.1 ppb
2022–23 relative increase	0.55%	0.57%	0.33%
Mean annual absolute increase over the past 10 years	**2.4 ppm yr^{-1}**	**10.7 ppb yr^{-1}**	1.07 ppb yr^{-1}

WORLD METEOROLOGICAL ORGANIZATION

[a] Assuming a pre-industrial mole fraction of 278.3 ppm for CO_2, 729.2 ppb for CH_4 and 270.1 ppb for N_2O.

Source: Slide 4 of *Dr Balsamo's presentation* at EID 2024.

22. Gianpaolo Balsamo indicated that monitoring of GHGs is conducted by research funded observations through a network of 146 stations measuring CO_2 and CH_4, which is comparatively lower to temperature monitoring, with over 3,000 stations, and leading to observation gaps and high uncertainties. The importance of the contribution of information from in-situ and satellite-based monitoring and related models, through the G3W, to deliver timely and policy relevant information was emphasized. Gianpaolo Balsamo outlined satellites that are being launched, which will increase capacity of real-time and accurate reporting. Partnerships such as with the US GHG Measurement, Monitoring, and Information System, Copernicus and the National Institute for Environmental Studies of Japan support the G3W and he urged more countries to support the programme. The programme's funding needs are at USD 1 billion for the next four years, aimed at supporting the installation of in-situ measurements to calibrate satellites and verify models. Using an Earth System approach, the G3W aims to support monitoring of GHGs, including by leveraging 50 years of

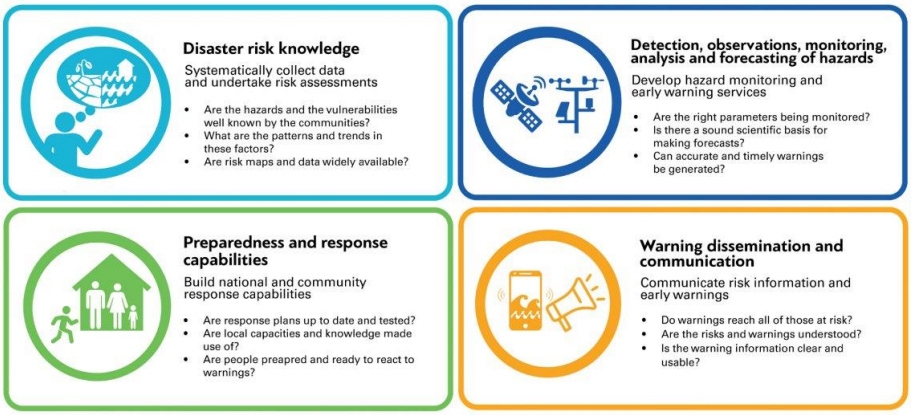
[14] See https://unfccc.int/resource/docs/2009/sbsta/eng/03.pdf.
[15] WMO. 2024. *WMO Greenhouse Gas Bulletin: The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2023*. WMO Greenhouse Gas Bulletin No. 20. Geneva: WMO. Available at https://library.wmo.int/records/item/69057-no-20-28-october-2024.

monitoring by WMO, for the implementation of the Paris Agreement, such as measuring the efficacy of actions to albeit CH_4 emissions[16].

4. Early Warning for All initiative

23. Ko Barrett, WMO Deputy Secretary-General, presented an update on the EW4ALL initiative, which was launched at COP 27 and is aimed at protecting every person on Earth with EWS by 2027. Ko Barrett highlighted the increasing intensity and impacts of extreme events such cyclones, floods, heatwaves, droughts and wildfires on societies and ecosystems, caused by increasing heat in the ocean and atmosphere. The EW4ALL activities are organized around four pillars of early warning which are disaster risk knowledge; detection, observations, monitoring analysis and forecasting; warning dissemination and communication; and preparedness and response capabilities led by various UN agencies, as reflected in figure 3.

Figure 3
EW4ALL pillars



Source: Slide 3 of *Ko Barrett's presentation* at EID 2024.

24. Progress across the pillars is monitored through a robust monitoring and evaluation framework, with results published in the annual update Global Status of MHEWS Report.[17] The 2024 report indicates that there is progress in advancing early warnings, where half of countries have MHEWS in place and that those with comprehensive systems have fewer disaster-affected people per capita. The report also indicated that risk knowledge continues to lag behind other pillars in both coverage and comprehensiveness and that observations and forecasting are improving, however gaps remain particularly for impact-based forecasting. Further anticipatory action is gaining momentum, however only one third of countries reported have plans to act on early warnings. Ko Barrett also highlighted that innovations and new technologies are bringing opportunities to scale up MHEWS, as observed in the improvements of both hardware and software platforms for data sharing and AI.

25. The EW4ALL initiative commenced with a focus on vulnerable countries, 30 LDCs and SIDS, and is expanding to actualize the initiatives' goal for global reach. The approach to scaling up is therefore multifaceted, ensuring a country-led approach, with coordinated technical and financial support from partners, multilateral development banks, and bilateral donors and peer-based partnerships. In its planned scaling up, the initiative will support sustained capacity enhancement efforts, provision of technical tools and training, and embracing other existing actors investing in EWS particularly private sector who are leveraging AI for data assimilation and forecast accuracy. Parties were invited to continue reflecting early warning actions in their climate action plans and called for increased efforts to make EWS a reality for all.

[16] More information on the Global Methane Pledge can be accessed https://www.globalmethanepledge.org/.
[17] See https://www.undrr.org/media/102535.

5. Systematic Observations Financing Facility

(a) Bridging observation gaps: Role of the SOFF and innovative financing models

26. Markus Repnik, Director at WMO, provided an update on the SOFF[18], a UN climate fund created in 2021 to provide open-ended support to countries to advance systematic observation, close observational gaps and enhance compliance with GBON. The SOFF supports 60 countries, with expansion planned for other lower middle-income countries, of which 18 countries have approved investment support. Over USD 110 million has been mobilized from 12 initial partners, and the need for more resources to meet country demands, including through innovative financing models was emphasized.

27. In advancing innovative financing models, the SOFF recognizes that weather and climate data represents a global public good and therefore the facility provides long-term open-ended grant-based finance to countries. Further, the SOFF in partnership with the GCF is planning a joint accelerator programme for fragile and conflict-affected states and plans to set up the first SOFF impact bond. Markus Repnik stressed that innovative finance, both in terms of mobilization and means of provision to countries is required to close the data gaps and advance systematic observation. The SOFF has also adopted innovative models in its support to countries using a systemic and long-term approach to ensure sustainability, peer to peer technical support and through a community of practice, where over 70 partners are part of the SOFF community. In its new form of partnerships, the SOFF calls for increased investments in countries with the largest data gaps and through long-term grants.

(b) Experiences on the SOFF application and implementation: Malawi update

28. Lucy Mtilatila, the Director of the Department of Climate Change and Meteorological Services in Malawi, highlighted the country's experience under the SOFF. She cited recurring extreme events experienced in Malawi including floods in 2015, 2019 and 2023 and droughts in 2024, affecting the population's recovery from these events. While the country has weather and climate stations that monitor climate extremes, challenges remain in maintaining the stations and for them to meet GBON requirements. In sharing the country's experience under the SOFF readiness phase, Malawi highlighted support from its peer advisors, Iceland and Norway, who supported the country in conducting a national assessment of the observation network, identifying gaps, commitments and priority actions, including for surface and upper air stations. Malawi produced a hydromet diagnostic report[19] that sets a baseline on observations, and discusses, among other things, governance, modelling and dissemination, contributing to adaptation and EW4ALL efforts.

29. Lucy Mtilatila expressed that the readiness phase helped the country to identify gaps in observations, which is attracting co-financing as well as helping the country to prioritize needs, as reflected in its implementation plan. The country is also developing maintenance and capacity-building plans, quality assurance strategies, coordination plans and receiving peer to peer long-term support as a means for ensuring sustainability of the EW4ALL efforts. Following the readiness phase, Malawi transitioned to the implementation phase, where the SOFF steering committee conditionally approved USD 3.4 million funding for four years. The funding will focus on compliance of the GBON stations during this period. The urgent need for support, including in the form of finance and human and institutional capacity, to support gaps in observation and provision of meteorological services was stressed.

6. The role of AI and Machine Learning in Earth Observation, Modelling and Predictability

30. Rob Redmon, Director for NCAI, shared experiences in leveraging AI and machine learning to advance understanding of the changing environment, manage and conserve coastal and marine resources and advance weather forecasting and prediction. Responsible AI was acknowledged as a rapidly evolving and emerging technology which is leading positive disruption, including by increasing efficiency, accuracy, and analysis of large datasets. For instance, NOAA is utilizing AI to support USA's economy and protect lives

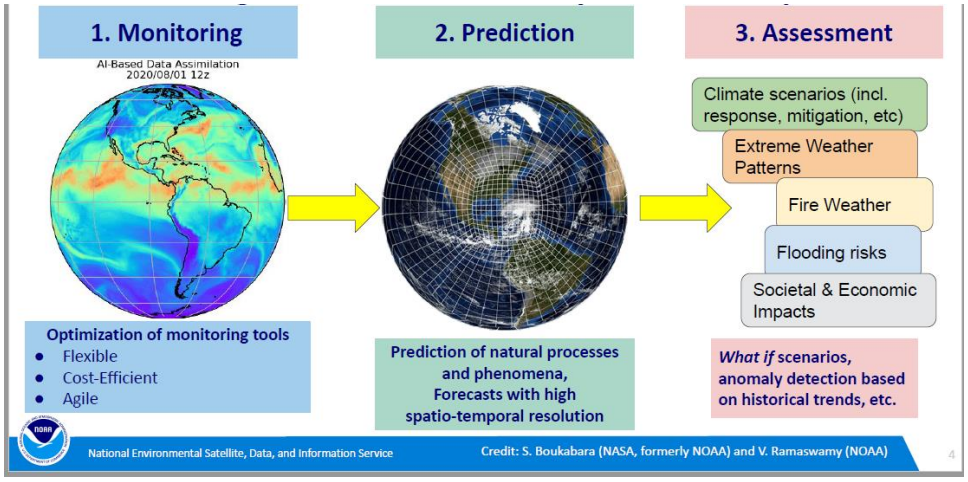
[18] See https://www.un-soff.org/.
[19] See https://www.un-soff.org/document/malawi-country-hydromet-diagnostics/ .

and property. The USA has growing environmental intelligence data, currently exceeding 60 petabytes, and it is positioned for AI-analysis readiness, to serve relevant communities and enhance investments in Earth and ecosystem observations and modelling.

31. In describing the application of the AI-related innovations, NOAA is developing many AI-enabled applications including for providing more accurate weather forecasts, predicting space weather, studying protected species, reviewing aerial and underwater surveys and for bathymetric and geographic surveys. Examples of such efforts include the tropical cyclone research training data set[20] and the lighting cast product widely used for wildlife and fire management, aviation and forecasting. NOAA also holds public workshops to build communities of practice around harnessing AI to solve various challenges and the latest workshop focused on AI and heat resilience.

32. Another application, the digital twins for Earth system[21], reflected in figure 4, was recognized as a globally emerging new technology. NOAA is pursuing the innovation to solve challenges related to Earth system predictability, diverse data integration and modelling, uncertainty quantification and hazard communication. NOAA is integrating AI as a technological service throughout the observation value chain: monitoring, prediction and assessment and related services.

Figure 4
Digital twin for Earth system concept, NOAA



Source: Slide 4 of *Dr Rob Redmon presentation* at EID 2024.

33. Specifically, NOAA's goal is to advance its monitoring and prediction capabilities at local and community scales, integrate weather and climate infrastructure with socio economics to support communities, advance resilience planning and enhance emergency management as well as post-event analysis. According to NOAA, key features for the innovation includes supporting diverse user interaction and exploration of scenarios and models from societal and economic impacts. NOAA's current partnerships includes the AI for Public Good US-European Union partnership, which leverages innovation to examine extreme weather events such as tropical cyclones and urban heat stress.

C. Thematic breakout discussions

34. Five thematic breakout sessions were held in parallel, providing a platform for scientists, the observation community and policymakers to engage on the various topics by sharing information, experiences, good practices, lessons learned and gaps, and opportunities. Each breakout session included a moderator, sharing of information and experiences by expert presenters from relevant institutions and countries, and an open

[20] See https://rammb-data.cira.colostate.edu/tcprimed/.
[21] See https://esto.nasa.gov/earth-system-digital-twin/.

exchange of views informed by the guiding questions[22], followed by a reporting back session facilitated by Patricia Nyinguro and Frank McGovern.

1. Breakout discussion one: Observations for climate change mitigation[23]

35. During the session, participants discussed progress made in GHG monitoring, significance of sustained and integrated long-term observations to inform climate policy, advancements in technologies, investment needs, and the role of partnerships and collaborations. Participants considered:

(a) The need to maintain long-term climate observations through stable and sustained investments, robust partnerships, and integration of consistent standards across in-situ and satellite networks. The progress made in GHG monitoring, including through the work of the G3W and satellite community such as CEOS-CGMS, who considered the outcomes of the first global stocktake was recognized;

(b) Advancements in technologies, satellite infrastructure and expansion of observation networks which enhance the capabilities in monitoring GHGs and short-lived climate forcers, as well as improve global transparency (through independent verification of emissions and supporting national inventories). Participants also recognized advancements in ocean monitoring which contribute to improved climate models and mitigation strategies;

(c) Transition from research-driven to operational GHG monitoring systems to provide near real-time and high quality data to support the implementation of the Paris Agreement and the Convention;

(d) Integration of satellite and in situ-based systems across all domains as well as advancing the Earth system approach;

(e) Collaboration among international, regional and national institutions to ensure interoperability and consistency of observational data to maximize its utility for monitoring mitigation and other climate actions. The capacity building requirements and needs for both in-situ and satellite-based networks and across sectors for their effective application were discussed.

2. Breakout discussion two: Observations for climate change adaptation[24]

36. During the breakout session, participants explored the opportunities and challenges of using Earth observation systems to support climate adaptation and resilience including EWS. Further, participants reflected on the various data sources and recognized challenges associated with access and data sharing. Participants also considered:

(a) Sustained systematic and consistent Earth observations, from various sources such as space observations and in-situ observations which support tracking and measuring the impact of adaptation actions as well a global adaptation indicators. Participants highlighted the ongoing challenges related to defining actionable indicators to effectively monitor progress on adaptation efforts;

(b) Integration of diverse data sets and sources to support decision making, including real-time information from satellites, in-situ measurements, drones, aircraft, and buoys, to provide a comprehensive picture of climate risks and impacts. Participants reflected on gaps in data systems, which are fragmented and challenges in access and data-sharing frameworks. Further the integration of socio-economic factors to physical climate data was considered as essential in providing inclusive vulnerability and risk assessments; understanding how communities, economies, and ecosystems are affected and how they can adapt to those impacts and changes;

(c) Advancing innovations such as high-resolution satellite data, EWS and real-time hazard monitoring tools to understand climate risks and support long-term resilience.

[22] The agenda for EID 2024 with a full list of moderators, rapporteurs and expert presenters can be accessed here https://unfccc.int/sites/default/files/resource/Draft%20Agenda_EID_11112024.pdf.

[23] Guiding questions and relevant resources are available at https://unfccc.int/documents/642875.

[24] Guiding questions and relevant resources are available at https://unfccc.int/documents/642876.

For example, observation systems can help improve the sustainability of fisheries and coastal agricultural systems by enabling communities to monitor gradual changes, assess risks, and translate these insights into timely and effective interventions.

3. Breakout discussion three: Observations for averting, minimizing, and addressing loss and damage, and strengthening resilience to extreme events including heat stress[25]

37. The breakout session highlighted the critical role of Earth observation systems in addressing loss and damage from extreme events, including those related to heat stress and collaboration among countries to advance observations. Gaps related to the monitoring of other climate parameters and geographical spaces such as data from the open ocean were also discussed. Participants also considered:

(a) The need for integrated Earth monitoring from satellite and in-situ observations for informed decision-making in minimizing risks and advancing resilience to extreme events. For instance, in urban planning, heat maps can be transformed into human discomfort indices to guide in designing buildings and infrastructure that mitigate heat impacts, while in agriculture, vegetation indices can optimize irrigation strategies and improve crop yields, addressing the dual challenges of water management and heat stress;

(b) Significance of monitoring climate parameters such as urban heat stress, wildfires and marine heatwaves. Discussions also emphasized the role of global ocean observing systems in improving forecasting and tracking marine heatwaves, which pose significant threats to biodiversity and livelihoods. Despite its importance, critical data gaps persist, such as bathymetry[26] and open-ocean monitoring beyond sea level rise;

(c) Enhancing EWS, through the provision of real-time data as well as ensuring that observational data is accessible to users and linked with both short and long-term actions-such as tailored heat wave bulletins;

(d) Incorporating socioeconomic factors with observational data;

(e) Funding gaps and needs to sustain Earth observations, particularly in ocean monitoring, beyond sea-level rise, and in vulnerable regions.

4. Breakout discussion four: Advanced technologies, innovation and digital transformation[27]

38. The breakout session explored how advanced technologies and digital innovations can transform Earth observation for climate risk monitoring and climate action. Participants highlighted the need for scalable, fit-for-purpose solutions and emphasized collaboration, capacity building, and leveraging trusted data to enhance decision-making. Participants also considered:

(a) Current advancements in innovations and technologies such as AI, machine learning and big-data; which are transformative tools in monitoring the Earth systems, climate risks, vulnerabilities and hazards. Further, access to open, transparent, reproducible and reliable big data is vital for solutions that can be trusted by policy-makers and end users;

(b) Synergies across technologies, such as the role of big-data in AI data-centric models. Further, leveraging both low and high-tech solutions for sustainable systems, such as the integration of Earth observation sensors, modelling tools, AI and mobile technologies that enable citizen science;

(c) Targeted investments in infrastructure and capacity building support for the effective uptake and use of existing scalable solutions;

(d) Enhancing international cooperation including through regional, South-South cooperation and engagement with the private sector which can enable technology transfer and resource mobilization.

[25] Guiding questions and relevant resources are available at https://unfccc.int/documents/642877.
[26] Study and measurements related to undersea surface and ocean floor.
[27] Guiding questions and relevant resources are available at https://unfccc.int/documents/642878.

5. Breakout discussion 5: Enhancing observation in critical ecosystems and vulnerable regions[28]

39. During the breakout discussion, participants explored global and regional observation systems, data needs, historical data sharing, capacity building, and future challenges. Participants considered:

(a) The interactions of regional (RBON) and global (GBON) observation systems which provide unique and differentiated data, and together (focus on certain areas and global systemic observation view) provide complementary data supporting environmental monitoring across diverse ecosystems, from ocean to deserts;

(b) Capacity needs for systematic observation and the contribution of the SOFF in closing observation gaps. Further, participants reflected on innovative financing including the future of the facility, which requires USD 1 billion over the next ten years to support its work;

(c) Increased focus and need for ocean and vulnerable ecosystems' systematic observations;

(d) High-resolution data particularly for extreme events and EWS. Participants also highlighted gaps in maintaining in-situ monitoring;

(e) The risk of frequency bandwidth encroachment by telecom satellites which threatens high-resolution Earth observation capabilities. Participants discussed collective advocacy by the Earth observation community to safeguard the frequency bandwidth and ensure continued functionality of satellite data systems.

[28] Guiding questions and relevant resources are available at https://unfccc.int/documents/642879 .

Annex 1

List of moderators and expert contributors for breakout sessions

Moderator and rapporteur	*Expert contributors*
***Group 1**. Earth observations for climate change mitigation*	
Wenying Su (CEOS-CGMS), Antonia Bombelli (GCOS)	Yugo Kanaya and Akihito Ito (Japan), Gianpaolo Balsamo and Greg Carmichael (G3W)
***Group 2.** Earth observations for climate change adaptation*	
Binyam Yacob Gebreyes (IIED, LDCs), Clement Albergel (ESA)	Thelma Krug (GCOS), Cromwell Lukorito (IPCC) and Daniela Cuellar Vargas (WMO)
***Group 3**. Observations for averting, minimizing, and addressing loss and damage, and strengthening resilience to extreme events including heat stress*	
Cheryl Jeffers (AOSIS), Paul Fisher (ESA)	Hajja Naseem (SOFF), Beth Greenaway (UK) and Suzan Elghrabawy (GOOS)
***Group 4**. Advanced technologies, innovation and digital transformation*	
Rui Kotani, Sara Venturini (GEO)	Vanessa Gray (ITU), Laurence Rouil (Copernicus Programme) and Abdullah Alkhedhair (Saudi Arabia)
***Group 5.** Enhancing observation in critical ecosystems and vulnerable regions*	
Andrew Ferrone (EU), Patrick Gibson (UKSA)	Lorant Czaran (UN-SPIDER), Peter Thorne (GCOS), Yongxiang Zhang (China) and Ueneta Toorua (Kiribati)