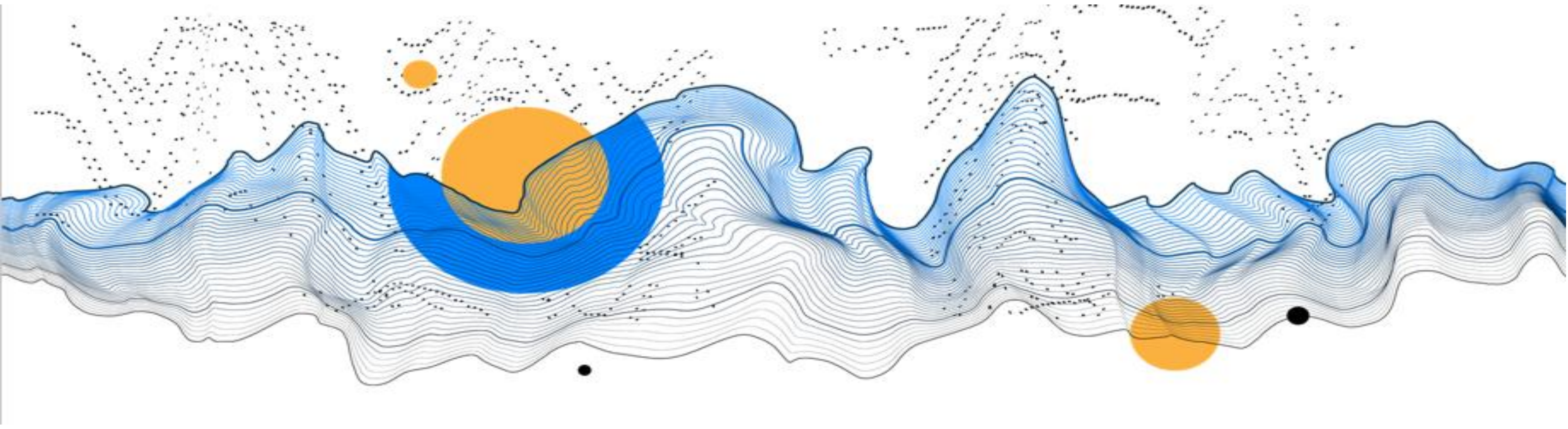

GLOBAL CLIMATE OBSERVATION SYSTEMS

Stocktake Event Summary Report

Author and Contributors: Ned Dwyer (UCC), Frank McGovern (EPA), Petra Manderscheid (JPI Climate), Alberto Francioli (CMCC)

EQUINOX
JPI Climate
MAGICA
Maximizing the synergy of European research Governance and Innovation for Climate Action
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GLOBAL CLIMATE OBSERVATION SYSTEMS

Stocktake Event Summary Report

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ACRONYMS TABLE

Acronym	Full Expansion
AMOC	Atlantic Meridional Overturning Circulation
C3S	Copernicus Climate Change Service
CAMS	Copernicus Atmosphere Monitoring Service
CCI	Climate Change Initiative
CDS	Climate Data Store
CIM	Climate Information Management
CLMS	Copernicus Land Monitoring Service
COP	Conference of the Parties
DG Defis	Directorate-General for Defence Industry and Space
DG RTD	Directorate-General for Research and Innovation
DRC	Democratic Republic of Congo
EC	European Commission
ECVs	Essential Climate Variables
EEI	Earth's Energy Imbalance
EID	Earth Information Day
ERB	Earth's Radiation Budget
ERA5	ECMWF Fifth-Generation Atmospheric Reanalysis
ES	Earth Systems
ESA	European Space Agency
EU	European Union
EUMETNET	European Meteorological Network
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
FTE	Full-Time Equivalent
GEO	Group on Earth Observations
GCOS	Global Climate Observing System
GRACE	Gravity Recovery and Climate Experiment
GRACE-FO	GRACE Follow-On
IODE	International Oceanographic Data and Information Exchange
IPCC	Intergovernmental Panel on Climate Change
IGCC	Indicators of Global Climate Change
JPI	Joint Programming Initiative
LAI	Leaf Area Index
LLM	Large Language Model
LULUCF	Land Use Land Use Change and Forestry
MAGICA	EU funded project on climate action
NBS	Nature-Based Solutions

Acronym	Full Expansion
NDC	Nationally Determined Contribution
NOAA	National Oceanic and Atmospheric Administration
OGC	Open Geospatial Consortium
UNFCCC	United Nations Framework Convention on Climate Change
WCRP	World Climate Research Programme
WIGORC	Working Group on Observations for Research in Climate
WMO	World Meteorological Organization

EXECUTIVE SUMMARY

The Global Climate Observing Systems (GCOS) Stocktake Workshop was convened by the Joint Programming Initiative (JPI) Climate, supported by the Horizon Europe MAGICA project and the Equinox Process. Held in response to ongoing challenges to climate observation systems and critical alerts regarding the sustainability of global observation systems during COP30 in Belém, the workshop aimed to address the escalating threats to the Global Climate Observing System (GCOS) and the Essential Climate Variables (ECVs) it monitors.

The core objectives of the workshop were threefold:

1. Assess the Current State: To evaluate the status, gaps, and vulnerabilities of global observation systems across atmospheric, oceanic, and terrestrial domains.
2. Strengthen Science-Policy Links: To determine how to better connect observation systems with international policy frameworks, specifically the UNFCCC and the Paris Agreement.
3. Enhance Usability: To explore strategies for improving the accessibility, quality, and usability of climate data for decision-makers.

The overarching conclusion of the workshop is that the network of global climate observing systems is fundamental for monitoring and enhancing our understanding of climate variability and climate change, yet it is under unprecedented stress. Despite decades of improvement, the system faces a "tipping point" characterized by declining funding, fragmentation, and critical single points of failure. The GCOS secretariat itself faces potential closure due to financial shortfalls, threatening the continuity of data essential for the Paris Agreement's Global Stocktake and national reporting.

Overview of Key Issues Discussed

The workshop sessions revealed a complex landscape of challenges spanning technical, financial, and communicative domains.

The State of Observation Systems

The analysis of ECVs across the three domains highlighted systemic risks:

- Atmosphere: While many variables have short-term funding stability, the system is fragile. Critical vulnerabilities include reliance on a single satellite for Earth's Radiation

Budget (CERES), aging in-situ ozone instruments, and a dependence on a single US laboratory for greenhouse gas calibration.

- Ocean: Ocean observations are at a critical juncture. There is a widespread decline in in-situ platforms (moorings, gliders), with a 50% loss of tropical moorings in recent years. Deep-ocean and biogeochemical measurements remain severely under-sampled, and the World Ocean Database faces operational risks due to personnel and funding cuts.
- Terrestrial: The terrestrial landscape is fragmented and heterogeneous. Significant gaps exist in mountainous regions, tropical ecosystems, and the Global South. Ice sheet monitoring is particularly vulnerable, and terrestrial water storage relies heavily on the GRACE-FO satellite, creating a single point of failure.

The Science-Policy Interface and Communication

A recurring theme was the disconnect between scientific data and policy action.

- Narrative Gap: The current technical narrative fails to connect with policymakers. The community must move to framing observations in terms of risk, resilience, and economic return on investment (ROI).
- Data Integrity vs. Simplicity: Scientists often emphasize uncertainties to maintain integrity, but policymakers require clear, simple messages about what is known (e.g., "emissions are rising") to drive action.
- Timeliness and Relevance: Data often arrives too late for decision-making, and the link between observation outputs and actionable policy needs (e.g., loss and damage assessment) is insufficiently structured.

Fragmentation and Silos

The global observation landscape is distributed across institutions, programmes, funding mechanisms, and data systems.

- Single Points of Failure: Heavy reliance on a small number of countries (particularly the US) and specific individuals for calibration standards creates systemic fragility.
- Funding Models: A critical structural limitation is the reliance on short-term, project-based research funding rather than sustained operational infrastructure investment. This model is unsuitable for the long-term continuity required for climate monitoring.
- Capacity Disparities: Developing nations in the Global South lack the infrastructure, data-sharing agreements, and technical expertise to utilize advanced data (e.g., Copernicus), hindering their ability to meet Nationally Determined Contributions (NDCs).

The Business Case for GCOS

The workshop emphasized that climate observations are a public good under threat.

- Economic Value: The Copernicus Climate Change Service (C3S) demonstrates a cost-benefit ratio of 10:1 to 100:1. For example, the wind energy sector alone saves more through access to high-resolution data than the entire C3S program costs.
- Future Scenarios: Three funding options for GCOS were presented, ranging from "Minimal Sustenance" (SFr200k–SFr1M/year) to "Hayday Levels" (SFr3.5M–SFr5M/year). The current trajectory risks the collapse of the secretariat and the loss of critical coordination functions.

Conclusions

The workshop concluded that the window for action is closing. The transition to high-resolution modelling, AI applications, and the urgent need to monitor extreme events require immediate upgrades to the observing system. However, funding is stagnating, and the GCOS secretariat is at risk of closure.

Key conclusions include:

1. Observations as Infrastructure: In-situ networks must be recognized as critical national infrastructure, comparable to bridges or roads, rather than mere scientific endeavours.
2. Need for a Unified Front: Fragmentation must be addressed by integrating the distinct but complementary roles of WMO (implementation/standards), GCOS (requirements/risk), GEO (value demonstration) and other organisations and programmes.
3. Shift in Narrative: To secure funding, the community must move beyond technical descriptions to articulate the value of observations in terms of societal resilience, security, and economic benefit.
4. Global Equity: Addressing the capacity gap in the Global South is not just a matter of training but requires establishing entire data governance infrastructures to ensure equitable participation in the Paris Agreement.

Next Steps

To address these challenges and prevent the degradation of the global observing system, a series of actions were proposed:

1. Develop a Targeted Communication Strategy:
   - Know your audience and create an "elevator pitch" tailored to specific audiences (e.g., finance ministers, health officials, defence sectors) that links observations directly to their priorities (security, health, economic stability).
   - Adopt a business-case approach similar to the Copernicus model, quantifying the ROI and the financial losses incurred by data gaps.
   - Move beyond the "Earth Information Day" niche to integrate observation needs across all relevant UNFCCC agenda items.

2. Strengthen Institutional Coordination:
    - Leverage initiatives like the iClimateAction project to clarify and integrate the roles of WMO, GCOS, and GEO, breaking down silos to present a unified front to funders.
    - Establish official, mandated science-policy interfaces at national and regional levels to ensure continuous dialogue rather than sporadic interactions.
3. Enhance the GCOS Status Report and Implementation Plan:
    - Redesign the next Status Report to profile risks of missing data on extreme events and human/ecosystem impacts, rather than just average conditions.
    - Include a clear roadmap for safeguarding investments and a multi-dimensional requirements table that addresses emerging needs (AI, extremes, high-resolution modelling).
    - Reframe the names of Essential Climate Variables (ECVs) to be more policy-relevant and understandable.
4. Expand Global Engagement and Capacity Building:
    - Organize side events in Bonn and other international fora to broaden the participants and audience, beyond the European sphere.
    - Enhance capacity-building programs in the Global South that go beyond training to establish national data systems, governance frameworks, and data-sharing agreements.
    - Secure funding to fill critical in-situ data gaps in underrepresented regions to improve the validation of satellite products.
5. Prepare for COP 31:
    - Use the period leading up to COP 31 to refine the messaging and strategy, ensuring that the "Earth Information Day" at the conference is backed by a robust, pre-agreed narrative that effectively influences the Global Stocktake and future climate finance decisions.

The workshop marked the beginning of an ongoing effort to translate these key messages into action, emphasizing that without sustained investment and coordinated advocacy, the global ability to monitor, understand, and respond to climate change will be severely compromised.

WORKSHOP BACKGROUND

Systematic observations of the Earth's climate system are fundamental to implementation of the United Nations Framework Convention on Climate Change (UNFCCC) and Paris Agreement. Since 1993 the Global Climate Observing System (GCOS) Secretariat, its sponsoring and constituted bodies, have acted to support the work of the UNFCCC and subsequently the Paris Agreement through coordination and support for informing and advancing the development of observations of Essential Climate Variables (ECVs) across the Earth's Climate system.

Since 2016 information from GCOS has been provided to the UNFCCC and the Paris Agreement via Earth Information Day[1]. Parties to the Conference of the Parties (COP) 30 in Belém, Brazil in November 2025, were alerted to new challenges to GCOS operations and threats to sustained observations. These were noted in formal conclusions from that meeting.

To respond to these recent developments, the Joint Programming Initiative (JPI) Climate, through the Equinox Process supported by the Horizon Europe MAGICA project organised a Global Climate Observations Systems Stocktake Workshop to determine the current state of play of climate observation systems and the threats to sustained observations of ECVs. The Stocktake also considered how the information is used by Parties to the UNFCCC and Paris Agreement as well as options to improve its utility to these processes. The Stocktake was part of an ongoing process, with the goal of fostering inclusive, cross-sectoral dialogue to bridge science and policy and support more effective climate action.

STOCKTAKE INTRODUCTION

Purpose and Objectives

The GCOS has a vital role in coordinating observations across the Earth system and in supporting international processes such as the UNFCCC, including through contributions to fora such as Earth Information Day.

The core objectives of the Stocktake were to:

I. Asses the current state, gaps, and vulnerabilities of global observation systems;
II. Determine how best to strengthen the connection between observations and policy frameworks, particularly the Paris Agreement; and
III. Explore how to improve the accessibility and usability of climate data for decision-making.

The global climate observing system is currently under significant stress, nonetheless it is vital to note climate observations are a public good under threat, requiring urgent, coordinated, and sustained international investment.

[1] Earth Information Day (EID) provides a platform for dialogue, enabling the exchange of information on the state of the global climate system and advancements in systematic observation during COPs

Structure, Roles and History of GCOS and European Developments

GCOS has had a key role since 1992 in coordinating global observations across atmospheric, oceanic, and terrestrial domains, which can be considered quite a complex and fragmented landscape. The fifty-five identified ECVs help to define observation requirements and guide their monitoring and reporting. A process to rationalise the set of ECVs is currently underway. As part of its work, in recent years GCOS has changed its focus from that of identifying observation gaps to recognizing systemic risks. Such risks include declining in-situ networks, uncertainty around satellite mission continuity, vulnerabilities in data repositories, and a growing reliance for funding on a small number of countries and institutions—creating critical single points of failure. The threat to the sustainability of climate observations is now the highest since GCOS was established in 1992, and even the GCOS programme itself faces potential closure due to funding shortfalls.

The European Commission's Copernicus programme is Europe´s primary contribution to systematic Earth observations. It has a key role in supporting a wide range of EU policies—from climate and environmental monitoring to security and resilience. Earth observation is increasingly embedded across European policy domains and are used in structured processes by the European Commission, such as the Knowledge Centre on Earth Observation[2], to translate policy needs into observation requirements (Figure 1). It is important to integrate satellite data with in-situ observations, as the latter are essential for calibration, validation, and ensuring the reliability of climate services. Frameworks like GCOS are critical to anchor European efforts within a global system, but ongoing coordination, alignment, and investment are needed to effectively bridge observation systems and policy demands.

EU legislative area	Main Copernicus services/products	Relevant GCOS "ECVs"
LULUCF Regulation (2018/841, 2023/839) — Land use, land-use change & forestry	CLMS: HRL Forest/Tree Cover Density, Land Cover Change, HR-VPP; C3S climate variables; CAMS fire emissions	- Land Cover (Terrestrial ECV) - Above-ground biomass - Soil Moisture - Fire Disturbance - LAI, FAPAR, fCover - Surface Albedo
Effort Sharing Regulation (2023/857) — National emission ceilings	C3S ERA5 climate reanalysis; Heating & Cooling Degree Days; CAMS GHG monitoring	- Surface Air Temperature - Precipitation - Humidity - Surface Wind - Radiation budget
EU Climate Law (2021/1119) — Climate neutrality monitoring	C3S Climate Indicators; CMEMS ocean carbon fluxes; CAMS GHG trends	- CO_2, CH_4, N_2O concentrations - Surface temperature - Ocean heat content - Sea level, ocean colour, carbon flux

Figure 1: Example of how EU legislative areas map onto Copernicus services and relevant GCOS ECVs

Research and innovation funding, is a vital complement to advance and develop observation systems. In Europe this is coordinated mainly through Horizon Europe. Earth observations have a very transversal nature operating across research domains, including climate, environment, and space, and are vital in supporting EU climate policy, the Paris Agreement, and contributions to the Intergovernmental Panel on Climate Change (IPCC). Research priorities in Europe are developed through strategic research agendas and stakeholder consultations, and in relation to Earth observations one such initiative includes the iClimateAction project[3] linking WMO, GCOS and the Group on Earth Observations (GEO). However, a fundamental structural limitation of

[2] https://knowledge4policy.ec.europa.eu/earthobservation_en (last access: 23/03/2026)

research funding is that it is short-term and project-based, making it unsuitable for sustaining long-term observation systems. While research plays a critical role in innovation and system development, it cannot replace operational funding. Therefore, it is critical that observation systems are transitioned away from research-driven funding models to sustained infrastructure investments, supported by coordinated action across EU institutions and Member States.

Key Insights

- The GCOS has a vital role in coordinating observations across the Earth system and in supporting international processes such as the UNFCCC.
- Frameworks like GCOS are critical to anchor European efforts within a global system, but ongoing coordination, alignment, and investment are needed to effectively bridge observation systems and policy demands.
- It is vital that Earth observation systems are transitioned away from research-driven funding models to sustained infrastructure investments.
- The threat to the sustainability of climate observations is now the highest since GCOS was established in 1992, and even the GCOS secretariat itself faces potential closure due to funding shortfalls.

SESSION I: State of Play – Observations Across the Domains

Every five years GCOS has published a status report which is a snapshot of the observing system at a given time. This status report helps towards the development of regular requirements and an implementation plan which propose actions to address gaps and improve the observing system for climate. The 55 Essential Climate Variables currently defined by GCOS cover the atmospheric, oceanic and terrestrial domains. The observations are from a mix of in-situ sensors and remote satellite systems. Despite ongoing improvements, there are still shortcomings in the observations, for some variables having spatial and temporal gaps or difficulty in attaining the required accuracy to meet GCOS requirements. After decades of sustained improvements in observation capabilities, numerous observation systems are under threat. GCOS has carried out a detailed analysis of ECVs, thus highlighting a system under significant and growing strain. Using a structured evaluation framework (Figure 2), they have identified key risks including single points of failure, declining funding stability, and threats to continuity across multiple observation components. The next status report and high-priority action plan will address these risks and sustainability issues comprehensively and will be published in February 2027.

Figure 2: Legend used for GCOS structured evaluation framework.

Atmosphere

Concerning the atmospheric ECVs, the majority have funding stability for the next five years, however the situation is less stable than it was in 2022. Many of the components of the observing systems are under threat and one of the ECVs demonstrates a critical single point of failure (Figure 3). Some critical vulnerabilities include reliance on a limited number of satellite missions (often US-funded), degradation of in-situ networks (e.g. ozone instruments are aging and prone to failure), and dependence on centralized data repositories like some of those housed at the National Oceanic and Atmospheric Administration (NOAA). Specific concerns included uncertainties around long-term measurement of the Earth's radiation budget (ERB), loss of satellite limb-sounding capabilities, and greenhouse gas calibration systems that are reliant on one US based laboratory. ERB observations, represent a single point of failure as they are dependent on one satellite (CERES), which is already in extended lifetime. These weaknesses are not isolated but systemic, thereby reducing the resilience of the global atmospheric observing system. Urgent action is needed to diversify support, strengthen redundancy, and ensure continuity.

ECV	Single Point of Failure	Funding (level) stability compared to 2022	Funding stability for next 5y	Components under threat
Surface pressure				Marine networks
Surface temperature				Marine networks, voluntary networks
Surface humidity				Marine networks, voluntary networks
Surface winds				Marine networks
Precipitation				Volunteer manual rainfall networks
Surface radiation budget	Critical to ensure calibration and comparability		Uncertain regionally	BSRN in the Southern Hemisphere, Arctic
Earth Radiation budget	Single agency and single satellite (CERES) in orbit		Follow-on mission announced	Due to the single point of failure and the risk of space-based observations
Clouds				

Lightning				GEO Ring continuity uncertain (western hemisphere)
UA Temperature				Radiosondes
UA humidity				**Limb sounders** (vertical profile humidity UTLS) Radiosondes
UA winds				Radiosondes
Ozone			Uncertain for some components	**Limb sounders** (vertical profile UTLS) Brewers, Dobsons
Aerosols		In Europe ACTRIS established as an ERIC in 2023		Limb sounders
GHGs	Calibration standards			Calibration
Precursors				Limb sounders

Figure 3: for each atmospheric ECV the table indicates risk of single point of failure, funding stability for the next five years and compared to 2022 and components under threat. (Legend for colours in Figure 2).

Ocean

The ocean has a key role as the primary absorber of excess heat and is a vital component of the carbon cycle. Many ocean observation systems are heavily dependent on short-term research funding and individual initiatives, making them inherently unstable and difficult to sustain. None of the ocean ECVs can be considered as risk free. There has been a widespread decline in in-situ observation platforms—including moorings, research cruises, and gliders—and there are significant gaps in subsurface and biogeochemical measurements, with potential single points of failure apparent (Figure 4). There are critical limitations in the ability to accurately estimate air-sea heat fluxes and at the moment surface currents cannot be sufficiently resolved. Regarding sub-surface observations, the deep ocean is highly under sampled, there has been a loss of 50% of the tropical moorings over recent years and many biogeochemical variables (except for O_2) remain inadequately observed. There is also growing uncertainty over the sustainability of sea-ice observations. Weaknesses are also present in data infrastructure and include the absence of global data centres for several key variables. For example, the World Ocean Database, which is operated as a project of the International Oceanographic Data and Information Exchange (IODE) programme has lost personnel and financial support therefore impacting its operations. A major concern is the heavy reliance on US contributions, which creates a critical vulnerability in global coverage. Ocean observations are at a tipping point, and without a shift toward sustained, operational funding and coordinated global investment, the ability to monitor and predict climate change will be severely compromised.

ECV	Single Point of Failure	Funding (level) stability compared to 2022	Funding stability for next 5y	Components under threat
Subsurface temperature	Very dependent on one country, globality difficult to achieve			Decrease in observations for in situ networks (e.g. research cruises, moorings, gliders)

Subsurface salinity	Very dependent on one country, globality difficult to achieve			Decrease in observations for in situ networks (e.g. research cruises, moorings, gliders)
Surface salinity				Lower resolution in the satellite mission
Surface temperature				Decrease in observations for in situ networks (e.g. research cruises, moorings, gliders)
Subsurface current				Tropical moorings in Western Pacific, Indian Ocean far from their targets
Surface current				New satellite mission providing direct measurements not funded
Sea state				Tropical moorings, drifting buoys
Sea level				Tropical mooring arrays very affected
Ocean surface stress				Decrease in observations for in situ networks (in particular ship observations)
Ocean heat flux				Decrease in observations for in situ networks (moorings, ship-time)
Sea Ice				Cuts in several satellite missions
Biogeochemistry				Research cruises, ship-time decreases. Several BGC ECVs rely exclusively on ship-based observations
Biology/Ecology				There are no global networks per se, they are communities of practice

Figure 4: for each oceanic ECV the table indicates risk of single point of failure, funding stability for the next five years and compared to 2022 and components under threat. (Legend for colours in Figure 2).

Terrestrial

The terrestrial observation system landscape can be characterised as one of complexity, heterogeneity, and fragmentation. While the majority of variables show a positive status in relation to not being subject to a single point of failure and in terms of five-year funding, nonetheless there are significant challenges, including gaps in both satellite and in-situ observations, uncertainties in mission continuity, and limited global data infrastructure (Figure 5). Ice sheets and ice shelf monitoring is particularly vulnerable. Also, terrestrial water storage is reliant on the GRACE_FO satellite mission, and is therefore exposed to a single point of failure. Many terrestrial ECVs are reliant on single funding sources and lack long-term sustainability. Across terrestrial ECVs there are strong geographical disparities, with under-observation in regions such as the Global South, mountainous areas, and tropical ecosystems. In-situ networks are often nationally managed, leading to inconsistencies in data standards, accessibility, and coverage. More than half of the terrestrial ECVs do not have global repositories for in-situ data, and for those that due there is a lack of duplication of these repositories, which is a concern. In general, terrestrial observation systems are constrained by fragmentation, uneven capacity, and limited coordination, which together hinder their effectiveness for global climate monitoring and policy support.

ECV	Single Point of Failure	Funding (level) stability compared to 2022	Funding stability for next 5y	Components under threat
Hydrosphere				

Evaporation from Land				In-situ networks (short-term research funding)
Groundwater			Not secured for several national networks	In-situ networks
Lakes			Not secured for several national networks	In-situ networks (short-term research funding)
Rivers			Not secured for several national networks	In-situ networks
Soil Moisture			Uncertain for many national and regional networks	In-situ networks (short-term research funding)
TWS	Single satellite mission (GRACE-FO)			
		Cryosphere		
Glaciers			Variable among different countries for in-situ networks. Uncertain for some satellite missions.	Continuity for both some satellite missions and national in-situ networks is at risk
Ice Sheets and Ice Shelves	GRACE-FO mission provides the one direct mass change measurement of ice sheet mass (complemented by indirect estimates).		No replacement planned for the ASTER and MODIS sensors	Some satellite missions with gaps in continuity or no secured follow-on plans
Permafrost			Not secured for several in-situ networks relying on single institutions or individuals	In-situ networks (particularly in the Artic)
Snow			Stable funding not always secured for (especially regional) in-situ networks	In-situ networks (short-term funding). Need for new satellite missions.
		Biosphere		
Albedo			Uncertainty for some NASA mission's	Both satellite and in-situ components partially under threat
FAPAR				Some in-situ networks
LAI				Some in-situ networks
Biomass			No stable support for many national in-situ observations	In-situ networks (short-term support). Need for satellite missions continuity.
Fire				
Land Cover			No stable support for many national in-situ observations	In-situ networks (national)
Land Surface Temperature			Funding stability affected by budget cuts expected from US	In-situ networks (regional). Need for satellite missions continuity.
Soil Carbon			Declining funding for national in-situ observations	In-situ networks (national)
		Anthroposphere		
Anthropogenic GHG Fluxes				
Anthropogenic Water Use	No info	No info	No info	No info

Figure 5: for each terrestrial ECV the table indicates risk of single point of failure, funding stability for the next five years and compared to 2022 and components under threat. (Legend for colours in Figure 2).

Key Insights

- After decades of sustained improvements in observation capabilities, numerous observation systems are under threat.
- Weaknesses in atmospheric observation systems are not isolated but systemic, thereby reducing the resilience of the global atmospheric observing system. Urgent action is needed to diversify support, strengthen redundancy, and ensure continuity.
- Ocean observations are at a tipping point, and without a shift toward sustained, operational funding and coordinated global investment, the ability to monitor and predict climate change will be severely compromised.
- Terrestrial observation systems are constrained by fragmentation, uneven capacity, and limited coordination, which together hinder their effectiveness for global climate monitoring and policy support.

SESSION II: Respondents – User Applications & Perspectives

Climate observations are essential for monitoring and reporting climate change at national, regional and international level. They underpin the provision of climate services and support climate action and inform policy development and direction. They are used to identify new, and provide the evidence base to meet existing, challenges, in climate research. ECV information is used across scientific application domains such as modelling, meteorology and the cryosphere as well as for informing climate policy.

Role of Observations in Climate Science

Climate observations are crucial to reduce uncertainty in climate science, particularly in relation to key drivers, feedback, and model evaluation. Knowledge of aerosols and short-lived climate forcers is limited and is a major source of uncertainty in understanding historical and future climate forcing — especially in the context of emerging risks such as geoengineering interventions, and solar radiation modification. Comprehensive observations are vital in such a scenario. Regarding the carbon cycle so far, its natural functioning has accounted for absorption of almost half of the annual CO_2 emissions, but its efficiency is reducing as the climate warms. Moreover, there are uncertainties in the carbon cycle, particularly regarding land sinks and permafrost, as well as the role of cloud processes in determining climate sensitivity and precipitation patterns. The ocean's role as a heat reservoir is also critical for understanding long-term climate dynamics. A major area of uncertainty is the ocean´s interaction with Antarctic sea ice, and possible instability in parts of the ice shelf. Climate models also indicate a slowing down of the Atlantic Meridional Overturning Circulation (AMOC)[4], but observations are critical to detect changes and variability. Climate change hotspots have also emerged, some of these due to sea level rise, therefore coastal monitoring systems are vital to inform appropriate responses. Improved observation systems are essential to constrain uncertainties, validate models, and detect emerging risks, making them indispensable for credible climate projections and policy decisions.

Role of Observations in the Science-Policy Interface

Climate observations underpin operational weather forecasting, seasonal prediction, and climate services. Modern forecasting systems rely on the integration of satellite and in-situ data, and any degradation in observational inputs directly impacts forecast quality and reliability. Continuous, high-quality time series and robust calibration/validation processes are vital to ensure consistency over time. There is growing user demand for actionable climate information, particularly for adaptation planning and risk management. Observation systems are not only scientific assets but critical operational infrastructure; any gaps or discontinuities translate immediately into reduced societal preparedness and resilience.

With regards to policymaking climate observations act as the essential bridge between scientific research and actionable policy. They enable policymakers to make informed, accountable, and timely decisions. The core challenge, however, lies in translating complex climate science into

[4] The AMOC circulates ocean water from north to south and back in a long cycle within the Atlantic Ocean.

clear, compelling messages that policymakers can understand and act upon. Tools like the Keeling Curve[5], WMO State of the Climate reports, and global climate change indicators provide clear, understandable points of information (Figure 6). These visual representations of rising greenhouse gas levels allow policymakers to see exactly where we currently stand and how conditions are accelerating. Policy makers frequently shift attention to other agendas, creating a constant need to bring renewed attention to climate issues. Even when delivering the same core messages, repetition is essential. This persistence emphasizes the urgency for action and ensures climate considerations remain on the policy agenda.

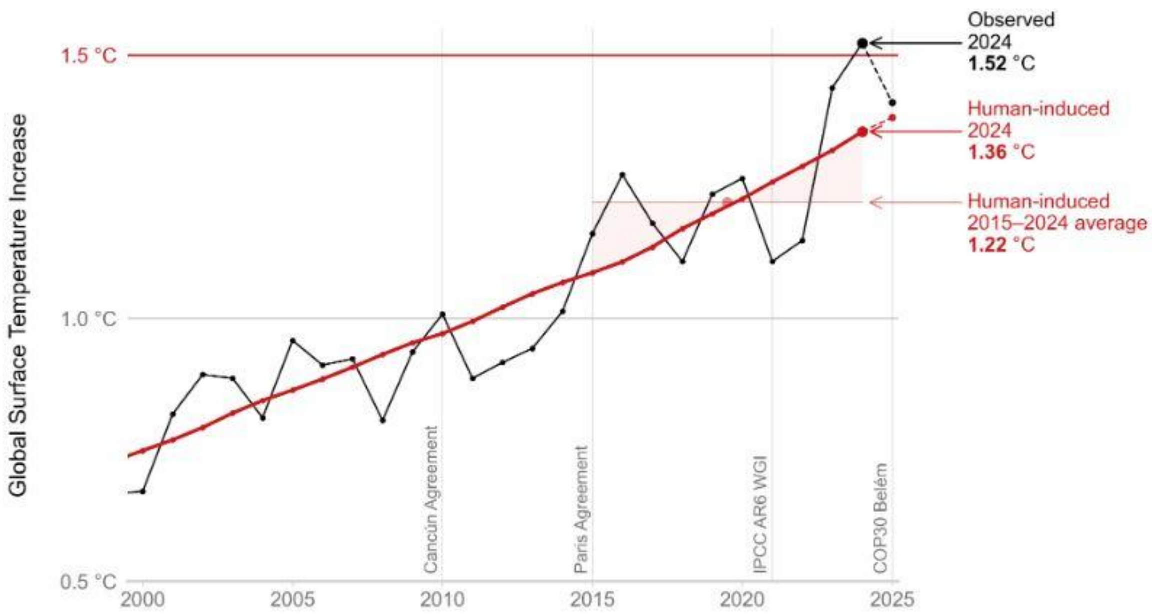

Figure 6: One of the global climate change indicators. Annual global surface temperature increases since 2000 (black line), and the part attributed to human activities (red line) (Foster et al., 2025)

Open access to public meteorological data via a climate data aggregator:

Long-term, consistent datasets are crucial for climate monitoring and the development of climate indicators. Reliable detection of trends and variability depends on homogeneous, uninterrupted data records, which are essential for tracking progress under frameworks such as the Paris Agreement. Breaks in observation continuity or inconsistencies in data processing can compromise the integrity of climate indicators and undermine their policy relevance. Increasing demand for high-resolution, policy-relevant indicators further intensifies the need for stable observation systems. The RODEO initiative, funded by the European Meteorological Network (EUMETNET) and the European Commission is a system, currently run by nine European

[5] The Keeling Curve is a graph that shows the ongoing change in the concentration of carbon dioxide (CO_2) in Earth's atmosphere, based on continuous measurements taken at the Mauna Loa Observatory in Hawaii since 1958.

meteorological services, that allows the seamless sharing of in-situ observations and climatological time series. It is essentially a climate aggregator which provides data in a generic climate format. Users can interact with the system and retrieve data for their chosen geographical area. Some of the data types provided include essential climate variables for the surface atmosphere, in some cases at hourly intervals, and some derived data such as climate indices. The system is underpinned by Open Geospatial Consortium (OGC) standards to allow for easier sharing of data. Next steps focus on clarifying data policy issues with some of the participating meteorological services to allow data sharing through the aggregator.

Data rescue through the METEOSAVER application

Data rescue is critically important for advancing understanding of current and future climate change, as historical datasets provide the foundation for analysing climate system components, calibrating satellite data, constraining reanalysis products, and evaluating climate models. The METEOSAVER project exemplifies this work, highlighting how gaps in historical records—particularly in regions like central Africa where precipitation data shows extensive missing coverage—can be addressed through systematic rescue efforts. For example, a data rescue project carried out in the Democratic Republic of Congo (DRC), involved first digitizing paper records through scanning or photography, then transcribing images into usable spreadsheet formats. A machine learning software for transcription that is now Open Access, enabled quality-controlled extraction of historical temperature, precipitation, and humidity data. Over 9,000 weather sheets were scanned leading to the extraction of over 1 million records of daily and sub-daily climate data, covering a period from 1960 to the early 1990s. These efforts are coordinated by C3S and are particularly vital given the DRC's status as home to the world's second-largest rainforest—a critical ecosystem for global mitigation and adaptation strategies. Such data rescue initiatives transform fragmented historical records into actionable climate intelligence, filling crucial gaps in regions where observational networks have historically been weak, ultimately enabling more accurate predictions and informed policy decisions for climate resilience worldwide.

Monitoring of the Cryosphere

The cryosphere provides vital services in many areas of the world, for example meltwater from Andean glaciers provide drinking water in Chile, more than 60% of hydro energy in Switzerland comes from glacier and snow-fed rivers, Arctic sea ice dampens wave heights thus reducing risk to shipping. Cryosphere observations are therefore critical for operational reasons but also for understanding ice sheet dynamics and projecting sea-level rise. Melting of parts of the Antarctic ice shelf could add 20cm to sea level rise by 2100 regardless of any mitigation. To understand such implications, satellites missions such as GRACE are very important to monitor ice volume and its rate of change. The cryosphere is both a sensitive indicator of climate change and a major contributor to long-term impacts yet remains under-observed due to logistical and environmental challenges. Observations in polar regions depend heavily on satellite missions and sparse in-situ networks, both of which face uncertainties in continuity and coverage. Gaps in cryosphere data directly translate into uncertainties in sea-level projections and risk assessments, which are crucial for coastal planning and adaptation. From an EU policy perspective cryosphere observations are important to inform the EU resilience framework and its Arctic policy, with significant ramifications on Arctic communities, ecosystems and maritime transport among others. Enhanced understanding of mountain glaciers is also important in terms of their impacts through flooding, landslides, and contribution to hydro power among others. The cryosphere represents a high impact but vulnerable component of the observation system, requiring sustained investment and targeted attention.

Mitigating climate risks to critical infrastructure with nature-based solutions

The integrity of critical infrastructure is very much under threat due to climate change; therefore, resilience is key. There is a growing use of climate observations in commercial applications, for risk assessment, and climate services. Allied with this are nature based (NBS) solutions which can help mitigate some of the infrastructure vulnerability. To inform such NBS, climate observations are critical. These observations are integrated with other data, including satellite observations, to generate risk analyses, which can then inform a suite of possible site-specific NBS. Further research is required to improve resilience metrics and prediction models that incorporate NBS with a view towards ensuring more resilient infrastructure. Although large volumes of data are available, users increasingly require processed, accessible, and decision-ready information rather than raw datasets. Underpinning this is a need for stable and reliable observation systems for supporting private sector innovation and investment. Data accessibility, usability, and clear governance frameworks are key enablers.

Expanding data usage

Efforts towards expanding the user base for ECVs would help to underline their importance and would potentially help in putting pressure on funding agencies to continue funding observation systems. Artificial Intelligence (AI) may be harnessed to make data more easily accessible by a wider user-base, not just those already within the climate community, but these areas are still in their infancy. Archives such as those created under the European Space Agency (ESA) Climate Change Initiative (CCI) offer great potential for exploitation and funding is becoming available to promote wider usage.

Communicating climate change issues

Often climate observations are taken for granted by policy and decision makers, and their vital nature is sometimes not appreciated. It may be that new ways of communicating issues related to climate change are required. For example, there is a need to communicate better on climate hotspots, i.e. places with a large exposure, multiple vulnerabilities and multiple climate change drivers which lead to intensification of climate risks. Such information is also required at city level and in business sectors as it is highly related to the resilience of infrastructure and services. Highlighting the multiple uses of climate observations is important and may help towards their maintenance. Communicating impacts on human health due to climate change may also help in awareness raising. For example, melting permafrost is leading to the release of significant quantities of mercury, which is then entering the food chain, impacting not only indigenous people that rely on seal meat, but downstream communities that eat fish as well.

Key Insights

- The messages reaching policymakers must be clear, simple and concisely framed. When observations are properly communicated, they stress the need for enhanced ambition and action on mitigation. This is why sustained investment in climate monitoring infrastructure and effective science communication is not just scientifically valuable—it's politically essential for driving meaningful climate action.

- The investments required to ensure a robust and sustainable observation system, which leads to a reduction in the uncertainty faced for decision making are tiny compared to investments needed for climate adaptation itself.
- Data continuity and consistency are fundamental to climate monitoring and policy evaluation, and disruptions in observation systems have long-term consequences for the ability to assess climate change.
- Data rescue initiatives transform fragmented historical records into actionable climate intelligence, filling crucial gaps in regions where observational networks have historically been weak, ultimately enabling more accurate predictions and informed policy decisions for climate resilience worldwide.
- Cryosphere observations are critical, particularly for understanding ice sheet dynamics and making sea-level rise projections, yet it is a very vulnerable component of the observation system.
- Satellite sensors are evolving from simply climate observation systems to being used to enforce regulations, verify corporate claims and provide hyper-local intelligence. There is a shift towards a science as a service model.
- A nature-based solutions framework, that incorporate climate observations offers a holistic approach to infrastructure resilience rather than relying on reactive interventions.

SESSION III: Future Directions for GCOS - Opportunities and challenges for science, policy, research and innovation

GCOS has evolved from cataloguing information on discrete ECVs towards an integrated observing system that can deliver coupled energy-water-carbon budgets in near real time. Characterising these great cycles is key to ensuring understanding of the evolving climate system and to constrain projections of future changes. Moreover, climate indicators are required for reporting and to inform and underpin decision-making.

The Energy Cycle

The current excess of emissions in the atmosphere means that there is an energy imbalance at the top-of-atmosphere with less energy leaving the Earth system than what is being received by the sun. The Earth's energy imbalance (EEI), which has been persistent since at least 1970, is the most fundamental metric of climate change, hence accurate monitoring of energy flows is essential for understanding. The ocean has a central role in absorbing excess heat (89%), with the land (5%) cryosphere (4%) and atmosphere (1%) representing the other components of excess heat storage (Figure 7: Total Earth system heat gain in ZJ relative to 1960 and from 1960 to 2020. The ocean accounts for the largest amount of heat gain. (Schuckmann et al., 2023)). These estimates are reached by combining observations from satellites, airborne craft, in-situ data, reanalysis and models. Capturing and explaining EEI is useful because it integrates all aspects of climate change and it has the potential to be a helpful indicator to communicate the issues. Nonetheless there are significant gaps in the observation system and with key satellite missions not sustained there is a significant threat to the ability to continuing to make accurate estimates of the energy and heat flux. Indeed, for land there is no international repository for the relevant data, with its maintenance relying on a research project. There are also gaps in the hydrological and cryosphere observing systems. A comprehensive, cross-domain observation system is required to accurately monitor the energy budget of the planet, which underpins all aspects of climate change assessment.

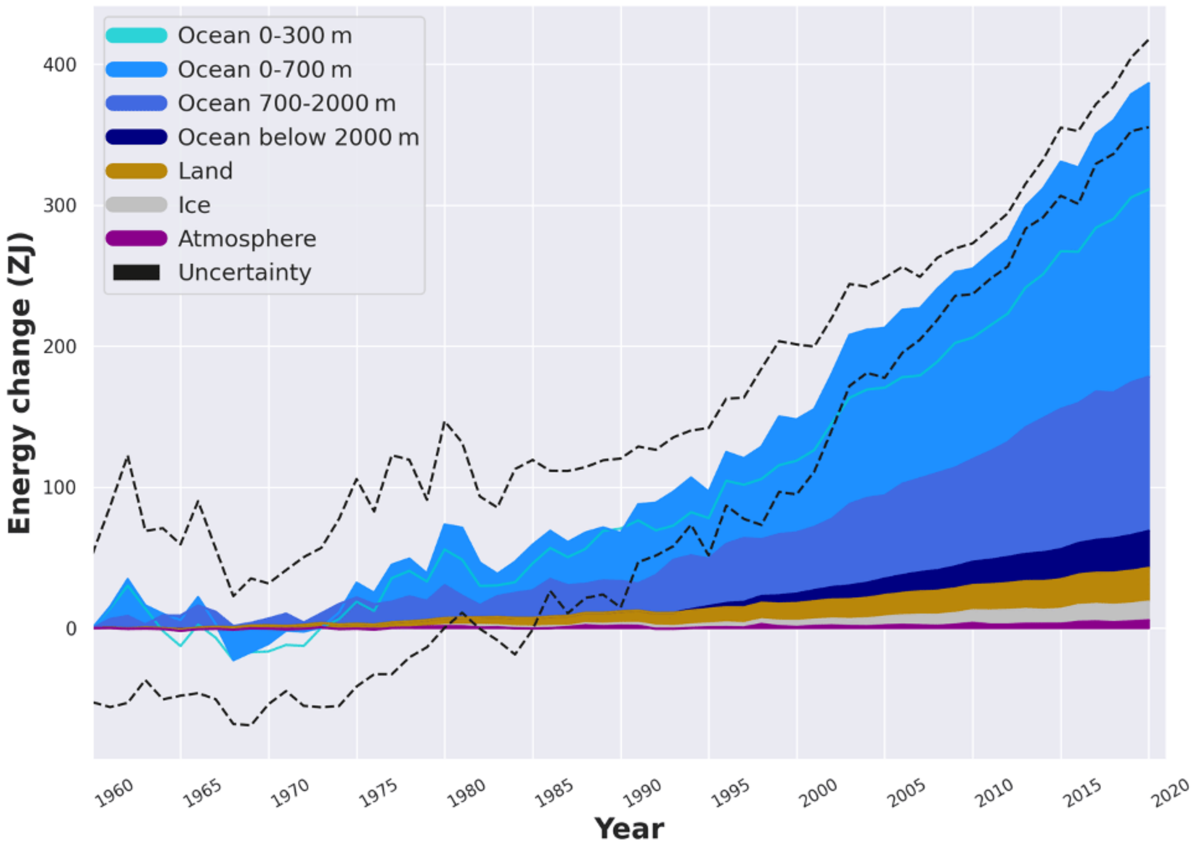

Figure 7: Total Earth system heat gain in ZJ relative to 1960 and from 1960 to 2020. The ocean accounts for the largest amount of heat gain. (Schuckmann et al., 2023)

The Water Cycle

Careful management of freshwater resources is crucial for the survival of life on our planet. Humans use it as drinking water, to produce energy and to grow food and it is also crucial for the maintenance of Earth´s ecosystems. Perturbations to the water cycle led to extremes causing floods and droughts for example. The latest assessment of the water cycle was carried out in 2021 (Dorigo et al., 2021), but it includes many uncertainties (e.g. moisture transport from ocean to land). Monitoring of water processes across atmospheric, terrestrial, and hydrological systems is highly complex, and there are significant data gaps, under-observed regions, and short observational periods for many variables including rainfall, soil moisture and river flows (Figure 8). Moreover, data exchange is challenging with national security concerns sometimes being cited as reasons for not releasing data. Also, there are delays with hydrological data being made available (up to two years), as oftentimes rigorous data checks need to be carried out before releasing data. The 5th edition of the state of global water resources report will be published soon. It has been reassuring to see a growth in the number of countries reporting and the number of variables and observations stations included since the first edition in 2021.

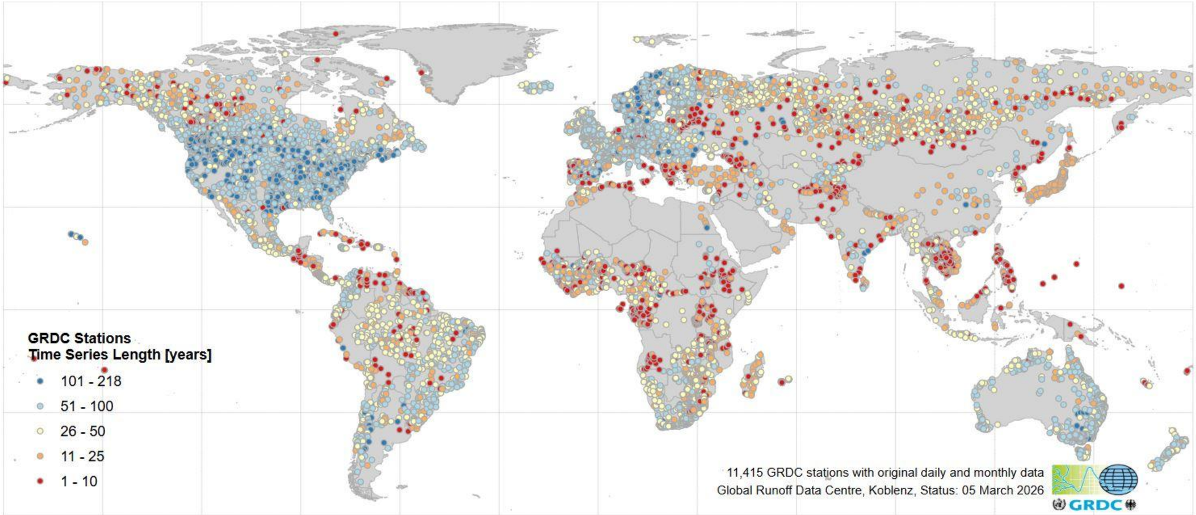

Figure 8: Data record length (years) for hydrological stations whose data are included in the Global Runoff Data Centre. Many stations have records of less than 30 years, which is the minimum period required for robust climate analysis.

The Carbon Cycle

The Global Carbon Budget serves as a critical test of understanding of the climate system by balancing carbon dioxide sources, such as fossil fuel emissions, cement production and land-use change, against sinks in the atmosphere, land, and ocean. While roughly half of anthropogenic emissions accumulate in the atmosphere, the remaining half is absorbed by land and ocean sinks, yet significant uncertainties persist in quantifying these sinks accurately. A major shortcoming highlighted is the reliance on the Keeling Curve, a foundational time series that is surprisingly underfunded and dependent on a single institution, creating resilience risks for the global community. Furthermore, there is a concerning divergence between model-based estimates and observation-based estimates of the ocean carbon sink, a gap that has widened since 2000 and exceeds the annual emissions of the entire EU. This discrepancy stems largely from severe data gaps, particularly in the Southern Ocean and deep ocean interior, where ship-based observations are sparse and declining despite the need for increased coverage. Interior ocean carbon measurements face additional challenges due to a lack of direct satellite capability and reliance on repeat hydrography. Argo floats[6] also have limitations as they do not measure CO_2 directly. In addition, there is a critical dependency on a single US laboratory for reference materials related to dissolved inorganic carbon observations. Similarly, land sink estimates rely heavily on dynamic global vegetation models without sufficient observational constraints from networks like FLUXNET, which suffer from poor spatial coverage in key regions like tropical African forests (Figure 9). While observations are essential for constraining these numbers and reducing the "carbon budget imbalance," current data scarcity and institutional

[6] Argo floats are autonomous devices used in oceanography to collect data on temperature, salinity, and currents in the ocean.

fragility hamper the ability to resolve these differences, necessitating urgent investment in diversified, sustained observation networks to improve climate predictions and policy decisions.

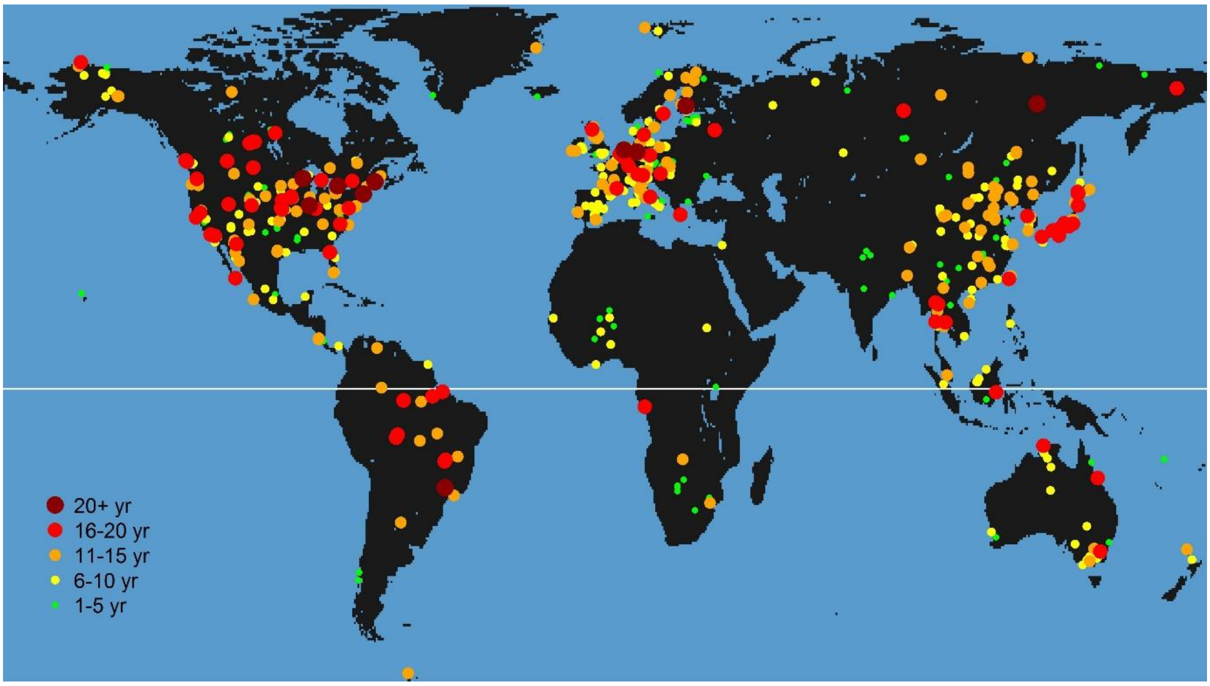

Figure 9: The duration (years) of observations at FLUXNET sites. Note the sparse and uneven data distribution.

Indicators of Global Climate Change

The climate indicators being tracked—including greenhouse gas emissions, atmospheric concentrations, Earth energy imbalance, radiative forcing, temperature attribution, and extreme events—all consistently show changes moving in the wrong direction (Figure 10), with 2024 marking the first year the annual average temperature reached approximately 1.5°C above pre-industrial levels, though the long-term average remains below this threshold. These changes align with scientific projections and demonstrate that climate change is accelerating rapidly. This work, involving 64 authors from 54 institutions across 17 countries, aims to build on IPCC authority by providing robust annual updates that package complex science with uncertainty estimates for policymakers. The relevance for global climate negotiations is critical: these indicators serve as the primary evidence trusted by UNFCCC negotiators, helping them understand the urgency of acting and the human contribution to observed changes. However, the science is becoming increasingly politicized, with countries sometimes exploiting small differences between indicators to justify rejecting updates, while also criticizing the effort for lacking institutionalization and representativeness. The report is deliberately published at conference time to inform COP negotiations, emphasizing that all these high-quality observation datasets produced by the scientific community are essential for credible policy decisions. The team is actively seeking input from negotiators on what information should be prioritized in communications, recognizing that sustained investment in observation networks is fundamental to maintaining the credibility and utility of climate science for international policymaking.

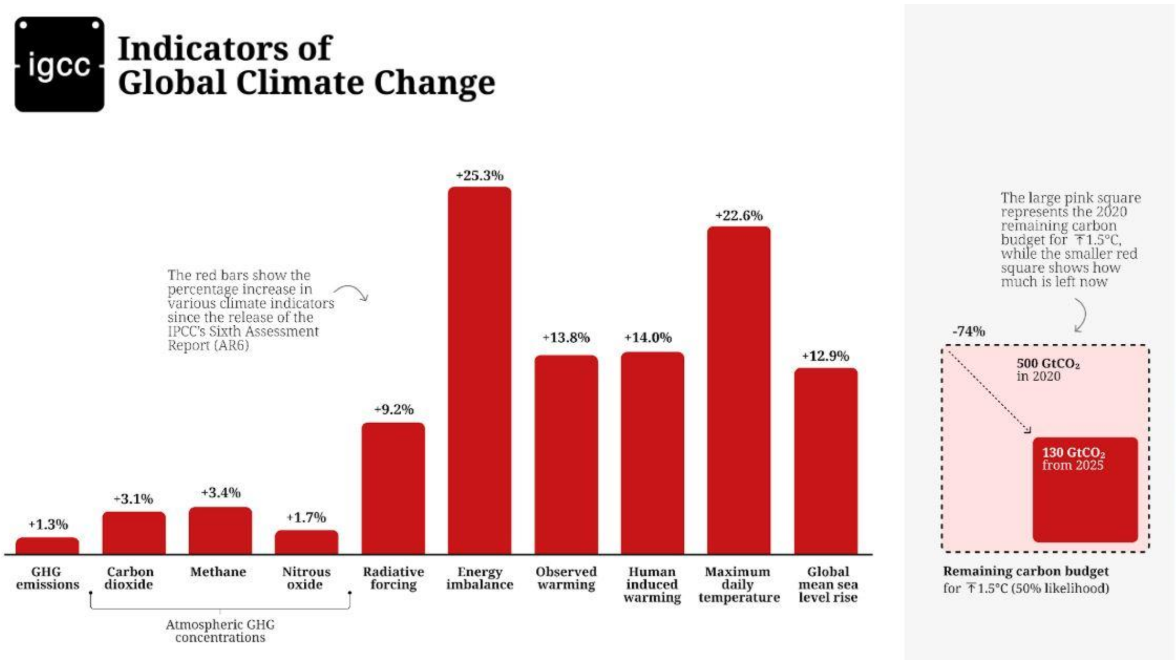

Figure 10: Percentage increase in various climate indicators since the release of the IPCC´s sixth assessment report in 2021. The panel on the right shows changes between 2020 and 2025 in the remaining carbon budget to remain below the 1.5ºC threshold. (Forster et al, 2025)

Key Insights

- A comprehensive, cross-domain observation system is required to accurately monitor the energy budget of the planet, which underpins all aspects of climate change assessment.
- Monitoring of water processes across atmospheric, terrestrial, and hydrological systems is highly complex, and there are significant data gaps, under-observed regions, and short observational periods for many variables.
- Observations are essential to reducing the "carbon budget imbalance," however current data scarcity and institutional fragility hamper the ability to resolve these differences, necessitating urgent investment in diversified, sustained observation networks to improve climate predictions and policy decisions.
- Indicators such as global temperature, energy imbalance, and carbon budgets are critical for tracking progress and communicating climate change to decision-makers and the public. Trusted, consistent and representative information presented to negotiating teams in a clear manner is vital to underpin international policy making.

ROUNDTABLE: Data Archives, Generation, Access and Custodianship

The C3S in-situ programme

Currently climate change impacts are costing the EU approximately €45 billion annually and without robust action the cost could reach a cumulated €5 trillion by 2050. The Copernicus Climate Change Service (C3S) represents a comprehensive climate observation program with demonstrable economic value, delivering a cost-benefit ratio ranging from 10:1 to 100:1, meaning every euro invested returns between 10 and 100 euro to European society. For example, the wind energy sector alone saves more through access to higher-resolution ERA5[7] products than the entire C3S programme costs. ERA5 serves as a foundational dataset that underpins numerous applications, including all AI weather models which are trained on this free and open reanalysis product. The C3S program encompasses extensive in-situ observations covering land surfaces, marine environments, upper air, and ground-based stations, supported by the climate data store developed over the past decade and now housing several world-class datasets. Artificial intelligence plays an increasingly important role, with new methodologies enabling extraction of value from historical observations to improve forecasting capabilities and support data rescue efforts, though in-situ observations remain essential. C3S collaborates closely with ESA and EUMETSAT to transition research into operational services, currently offering 29 essential climate variables and 45 ECV products, with 35 of the 55 GCOS-defined variables observable from space. As data custodians, C3S acts as both curator and archive guardian, rescuing data from archives and decommissioned satellites globally, particularly in the Global South where observational networks are less developed. However, the programme faces challenges including the need for sustainable funding beyond 2028 and ensuring that datasets are current and continuous. Critically, the communication narrative must evolve beyond climate change itself to address energy security, water security, and food security—issues that are more meaningful to policymakers and justify continued investment in observations that enable risk assessment and resilience building.

Ensuring maintenance of in-situ observation networks

In-situ observation networks should be recognized as critical national infrastructure, comparable to bridges or roads, rather than merely scientific endeavours. Despite a demonstrated return on investment ranging from 6:1 to 100:1, funding remains chronically insufficient because policymakers fail to prioritize these routine maintenance tasks over new, flashy projects. This underfunding leads to a decline in data availability as old instruments are not maintained while new capabilities are added without adequate resources. While data rescue and sharing are vital, a crucial preceding step is simply sustaining the physical generation of data. Emerging AI approaches offer promising solutions by being able to assimilate diverse, non-standard data sources (like webcam images) directly into models, potentially revitalizing the value of existing observations. However, significant challenges remain in data sharing; many

[7] ERA5 is the fifth generation ECMWF atmospheric reanalysis dataset, providing hourly estimates of global climate variables from 1940 to present, covering atmospheric, land, and oceanic parameters.

organizations collect valuable data but lack the means to process and share it effectively. Regarding next-generation radiation measurement satellites, Europe may have missed an opportunity to ensure continuity of observations, as the loss of such critical long-term records would be a severe blow to the global research community and our ability to understand the Earth's energy balance

DISCUSSION: messaging, science-policy interface, data integrity

There is a critical gap in communicating climate change: while scientists often emphasize uncertainties and data limitations to maintain integrity, policymakers require clear, simple messages about what is known (e.g., emissions are rising, the climate is warming) to drive action. Communication should shift from abstract metrics like energy imbalance to tangible impacts on water, food, and economic security, and scientists must collaborate with communication professionals to craft effective and coherent narratives rather than trying to master this skill themselves. Although there are still major uncertainties, especially about carbon sinks, these issues should be discussed within the scientific community and not shred with policymakers as it can cause them to disengage. Furthermore, there is a pressing need for structured, officially mandated dialogue between science and policy at national and regional levels, where such interfaces are currently disappearing, to ensure that scientific data directly informs policy questions and that policymakers understand the implications of the data. There is also a necessity of breaking down silos between disciplines (such as meteorology and metrology) and funding streams to establish robust data standards and cross-calibrated instruments. The reliance on single individuals for critical calibration standards and the lack of open metadata threaten the continuity and comparability of long-term datasets, underscoring the need for a unified, multidisciplinary approach to maintain the integrity of the global observation network.

Key insights

- climate observations deliver exceptional economic value with a strong return on investment, yet this critical infrastructure requires sustained funding and better communication to policymakers. To secure continued support, the narrative must shift from abstract climate change concerns to tangible impacts on energy, water, and food security that align directly with decision-makers' priorities.

- there is a pressing need for structured, officially mandated dialogue between science and policy at national and regional levels, where such interfaces are currently disappearing, to ensure that scientific data directly informs policy questions and that policymakers understand the implications of the data.

A Way Forward – A Business Case for GCOS

GCOS, which has existed since 1992, is both indispensable and under-recognised, requiring urgent strategic repositioning. It has played a foundational role in shaping the global observation landscape—defining ECVs, informing international processes such as the UNFCCC, advocating for the retention of in-situ observation systems and underpinning major programmes like Copernicus and the ESA Climate Change Initiative. Despite this, GCOS has remained largely invisible outside expert communities, limiting its ability to attract sustained political and financial support thereby it is at risk of being sidelined or marginalised despite its importance and potential.

There is an urgent need to articulate a clear and compelling economic and societal value proposition for climate observations. This includes demonstrating the return on investment and the costs of inaction, particularly in the context of escalating climate risks and economic losses. GCOS is at a critical juncture in terms of resources and funding. Since 2015 staffing has reduced from eight FTE to just over three FTE, the secretariat itself faces the risk of closure in the near term due to declining and fragmented financial support (Figure 11).

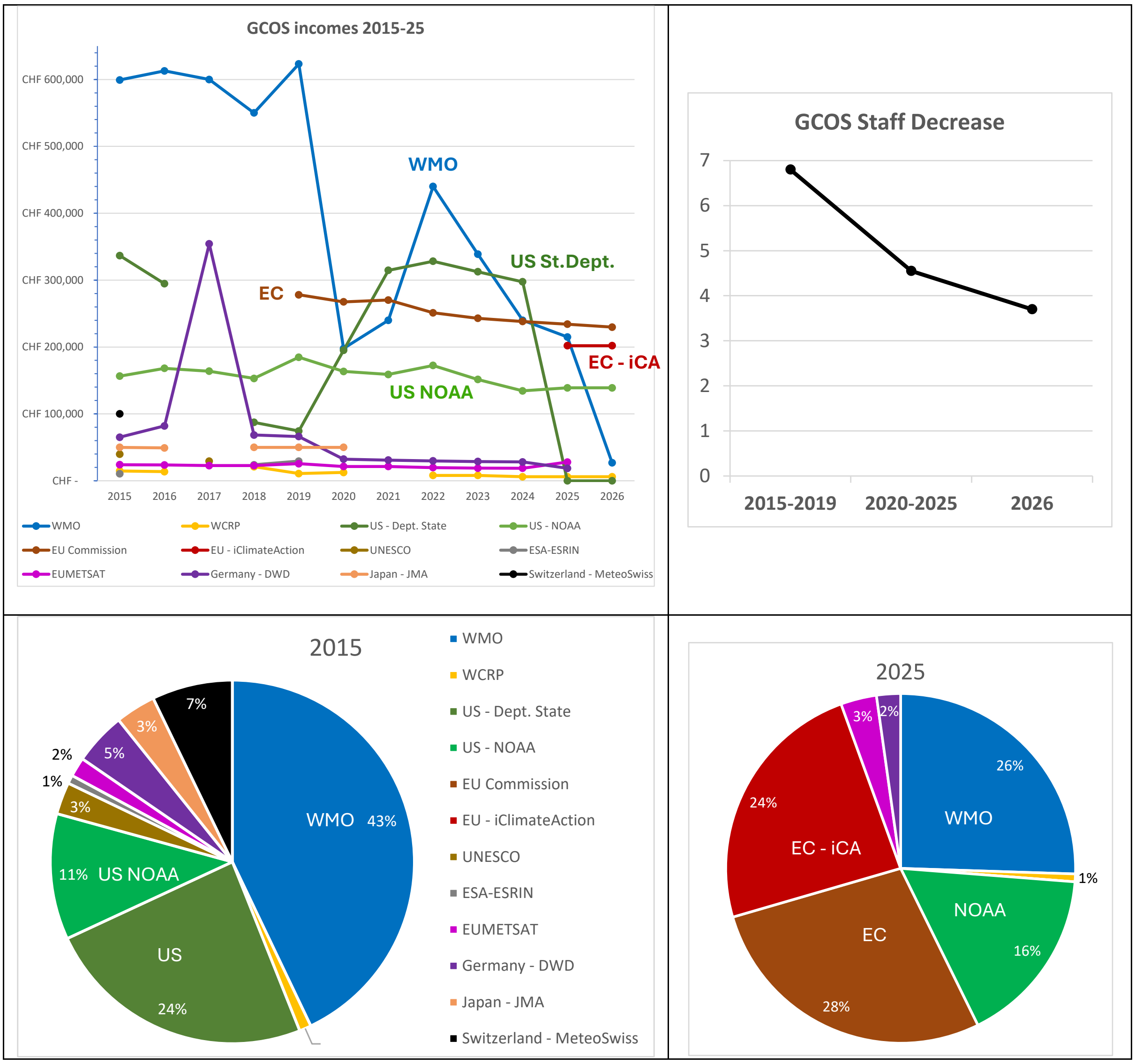

Figure 11: Summary of changes in financial support and staffing at GCOS through time. Top left funder contributions per annum. Top right staffing levels change. Bottom pie charts showing reduction in diversity of support through time (2015 left, 2025 right). Data prior to 20155 is less complete.

To ensure that GCOS remains active and viable there are three possible futures:

- **Option 1: Minimal Sustenance (Basic Support)**
  GCOS maintains a three-person secretariat to handle essential in-house tasks like producing the Status Report, Implementation Plan, and ECV requirements, with limited networking and COP attendance. Its financial requirements would be of the order of a few hundred thousand Swiss Francs per year.

- **Option 2: Restored 2010 Levels (Enhanced Support)**
  The body returns to support levels seen around 2010, with five FTE, enabling periodic reassessments of Earth cycles, meaningful consultations, expanded work with networks (WCRP, UNFCCC), regional/national engagement, and more quantitative, actionable reporting. This should be achievable for less than two million Swiss Francs per year.

- **Option 3: "Hayday" Levels (Maximum Ambition)**
  GCOS recaptures the peak support levels when it was newly established, with eight FTE, allowing for sustained user engagement, conferences, workshops, extensive collaboration with diverse organizations, deep regional/national engagement, and new work on adaptation and AI applications. The financial cost would be between 3.5 and 5 million Swiss Francs per year

Sustained climate observations require strong, dedicated and sustained coordination. Without a stronger business case and coordinated advocacy, both GCOS and the broader observing system could risk losing the support needed to remain viable, effective and relevant.

Key Insight

In a rapidly changing climate, it is not possible to manage what is not observed. GCOS ensures that society has the observations needed to anticipate risks, act early, and build resilience for present and future generations. Its future must be ensured.

SESSION IV: Value of Earth Observation – Stakeholder Responses

Building on the picture of the current state of the climate observations landscape and being aware of the challenges facing both the GCOS secretariat and observation infrastructure in general, several issues were identified that need to be addressed to help reinforce the robustness and usage of observations while also adapting to new realities in terms of communicating the vital need for observations and therefore the appropriate funding requirements for their maintenance and coordination.

Communicating the value of Earth observations to decision-makers

There are persistent difficulties in communicating the value of climate observations in ways that grab the attention of policymakers and funders. The scientific importance of observations is well understood within the scientific community, however their societal, economic, and risk-reduction value is not clearly or consistently expressed. The observations community needs to move beyond technical narratives and frame observations in terms of resilience, security, and economic benefit, particularly in a context where competing priorities (e.g. defence, energy) are gaining political traction. Improving the "narrative" around observations is as important as addressing technical gaps, and clearer articulation of value is essential to unlock sustained investment. For policymakers we need to understand their priorities and very clearly articulate what problems we can help them solve with better observations. In fact, if observation systems can be made more multi-purpose it increases the likelihood of more sustained funding. There is also a need to be aware of the changing geo-political landscape and devise ways of messaging that can address resistance towards understanding the need for sustainable observations. Organisations such as GCOS can act as information brokers, translating the scientific information into understandable terminology and messages for policymakers.

Observation systems can better support policy processes such as the UNFCCC

Climate observations are already deeply embedded in international policy frameworks, particularly through their role in supporting the Global Stocktake[8], national reporting, and transparency mechanisms under the Paris Agreement. However, the link between observation systems and policy processes remains insufficiently structured and visible. Effective communication between the scientists and policy makers requires that key messages are introduced and explained with a view to building consensus before annual COP meetings and ensuring data timeliness for decision-making. Organised and official dialogues, using specific and agreed language can help ensure that information and knowledge transfer is more robust and can help smooth the science-policy interface and support decision making. GCOS can have a role in providing better alignment between observation outputs—such as datasets and indicators—with actionable policy-relevant needs, ensuring they are accessible, timely, and fit for purpose. Ultimately, the goal is to bridge the gap between scientific capabilities and policy needs, ensuring observations translate into meaningful action while maintaining scientific integrity.

Ensure trust, quality, and usability of climate data

The value of climate observations ultimately depends on trust in the data, which requires robust systems for calibration, validation, and traceability. High-quality, consistent, and comparable measurements are essential to build confidence among users, particularly in policy and operational contexts. Data quality is not only a technical issue but also a foundational requirement for credibility and decision-making. At the same time, usability remains a challenge: users increasingly require processed, accessible, and interoperable data products, rather than raw observations. Bridging the gap between data generation and user needs is a key priority.

Enhancing the use of observations in the modelling community

The Working Group on Observations for Researching Climate (WIGORC) is a newly established body under the World Climate Research Programme (WCRP) designed specifically to bridge the critical gap between climate observations and modelling. Its primary mission is to identify observational gaps from a modeller's perspective and advocate for data practices that support evolving needs, such as high-resolution kilometre-scale models, AI applications, and the shifting

[8] The global stocktake is a process for countries and stakeholders to report on progress towards meeting the goals of the Paris Climate Change Agreement

focus from modelling averages to predicting extremes. The group is actively developing task teams to address capacity building, data rescue, and the standardization and improvement of uncertainty metadata, aiming to ensure that observational data effectively translates into actionable risk assessments for society and decision-makers.

Synergies between space-based products and in-situ data

The European Space Agency (ESA) operates the Climate Change Initiative (CCI), a flagship program running for nearly two decades that generates long-term global datasets for many Essential Climate Variables (ECVs) as defined by GCOS. A critical enabler of this work is the existence of GCOS's detailed requirements tables, which among others, specify necessary spatial and temporal resolutions, serving as guiding principles for ESA's satellite mission development and ensuring data robustness for monitoring climate variability. The CCI suite offers significant opportunities by creating consistent, multi-decadal records that allow for rigorous climate analysis, while fostering a vital feedback loop where lessons learned from satellite data processing help refine and evolve GCOS requirements over time. Crucially, ESA emphasizes that these satellite-derived products are not standalone solutions; their accuracy and reduced uncertainty depend heavily on in-situ observations for calibration and validation, particularly in underrepresented regions. Therefore, the CCI program represents a synergistic approach where space-based capabilities are maximized through the integration of ground-truth data, ultimately strengthening the global observing system and the reliability of climate information.

Addressing fragmentation across observation systems

Fragmentation of the global observation landscape, spanning institutions, funding mechanisms, and data systems is a key challenge to be addressed. This fragmentation leads to inefficiencies, duplication, and gaps, and makes it difficult to provide coherent messaging and to present a strong case for investment. To break down silos there is a need to distinguish between structural weaknesses and temporary geopolitical disruptions. It should be noted that organizations like WMO, GCOS, and the Group on Earth Observations (GEO) possess distinct but complementary roles that must be integrated rather than isolated. WMO focuses on implementing observations and setting standards, GCOS acts as the "climate conscience" by rigorously defining requirements and identifying risks, while GEO concentrates on downstream exploitation and demonstrating the value of data. The *iClimateAction* project, funded by the EU, is currently serving as a key mechanism to achieve this integration by analysing these specific roles within the value chain to foster better coordination. By clarifying how each entity contributes—from filling basic data gaps to defining climate needs and showcasing societal benefits—the project aims to build a larger, cohesive partnership that can effectively communicate the full value of observations, thereby strengthening the resilience of the global observing system against single points of failure and persistent data gaps.

To break down silos within the observation communities there is a need to establish more cross-disciplinary meetings and incentivise collaborative frameworks so that different perspectives can be shared. For example, the need to produce special IPCC reports have seen people from the three IPCC working groups working together, which has helped to break down barriers, build a common understanding and lead to enhanced collaboration. In addition, representatives from different organisations and groups need to come together to ensure that there is common and coordinated messaging towards policymakers, which will help in amplifying the message. Furthermore, there are quite a number of sources of information on climate change produced between the IPCC cycles (e.g. WMO State of the Climate, annual Indicators of Global Climate Change (IGCC) updates) however it is crucial that the way the information is presented aligns well with IPCC type reporting, so as to ensure coherence and consistent messaging.

International cooperation and capacity building

There is a critical need for international cooperation and capacity building with the Global South, to address the gaps that threatens effective policymaking. As highlighted by experiences in Kenya, Senegal, and South Africa, many nations lack functional national climate data systems, struggle with inter-ministerial data sharing agreements, and face a fundamental shortage of technical expertise. This deficit is so profound that even national space agencies often lack the ability to utilize advanced resources like Copernicus data, leaving senior government advisors without the evidence base needed to draft Nationally Determined Contributions[9] (NDCs). While organizations like WMO recognize that the current implementation of observation systems relies heavily on a small group of wealthy nations, addressing this disparity requires a massive, coordinated ecosystem of development projects and climate finance. Building local capacity is not merely about training individuals; it is about establishing the entire infrastructure—from data governance to technical skills—necessary for developing countries to transform raw observations into actionable climate resilience strategies.

Potential Priorities for the next GCOS status report.

The next GCOS status report, to be published early in 2027, must move beyond describing average conditions to explicitly profiling the risks of missing observations on extreme events (such as storms, heat stress, and sea-level rise) that directly threaten human life and societal resilience. The report should feature a strong call to action that frames GCOS as essential for safety and well-being, while also including a clear value proposition that quantifies the Return on Investment (ROI) to demonstrate to funders the tangible benefits of supporting the observing system.

Furthermore, it must be geographically inclusive, allowing diverse regions—from small islands to deserts—to see their specific realities reflected, thereby addressing equity and making the data personally relevant. Additionally, the report should explicitly leverage GCOS work to support the UNFCCC and Paris Agreement by focusing on practical applications like assessing losses, attribution science, and greenhouse gas monitoring, rather than just tracking Essential Climate Variables in isolation.

In addition, the status report should analyse the entire observation value chain, identifying specific barriers at every stage from fundamental metrological standards and calibration to data access and communication between communities. The report should also address the need for multi-dimensional requirements tables that evolve beyond current complexities to meet

[9] Nationally Determined Contributions are national climate action plans by each country under the Paris Agreement.

emerging demands for extreme event monitoring, kilometre-scale modelling, and AI applications, which require higher resolution and lower uncertainty tailored to specific use cases.

GCOS should emphasize the need for safeguarding past and future investments in observation infrastructure by providing a clear and plausible roadmap to coordinate global activities. It needs to stress the urgency of maintaining data collection, as the loss of observations is like driving blind through a thunderstorm; risks must be concretely quantified to convince stakeholders of the critical and urgent need for continuous funding.

In the ongoing rationalisation of ECVs it may be helpful to rename them to make them more understandable and policy relevant. Moreover, it is important to explicitly link climate change effects to humans and ecosystems in priority areas to demonstrate clear impacts and this also will help to capture decision-makers' attention.

Key Insights

- The scientific community must move beyond technical descriptions to articulate the value of observations in terms of societal resilience, security, and economic return on investment. To secure sustained funding, observations need to be framed as essential for solving specific policy problems (e.g., disaster risk reduction) rather than just as abstract scientific data, with organizations like GCOS acting as translators between science and policy.
- Fragmentation across institutions (WMO, GCOS, GEO) and funding mechanisms creates inefficiencies and gaps. Collaborative frameworks and enhanced collaboration can lead to a more unified, resilient global observing system.
- There is a severe disparity in the ability of developing nations to utilize climate data, with many lacking functional national systems, data-sharing agreements, and technical expertise. Ther is a need for climate finance, infrastructure development and capacity building.
- The reliability of climate data depends on the entire value chain, from fundamental metrological standards and calibration to data access and interoperability. Data generated for one purpose needs to be effectively repurposed for other purposes including climate modelling, AI applications, and extreme event analysis.
- The next GCOS status report must shift focus from describing average conditions to quantified risks of missing data on extreme events (storms, heatwaves) and human/ecosystem impacts. It should be geographically inclusive, support UNFCCC processes, and provide a clear roadmap for safeguarding investments in observation infrastructure, as well as highlight links between the observations collected and impacts.

OUTCOMES AND NEXT STEPS

From the meeting it was clear that the Global Climate Observing System (GCOS) is in a precarious state, characterized by a lack of visibility outside a small circle of experts and with an urgent need to redefine its narrative. The current technical focus fails to engage policymakers and funders. The GCOS community must change the narrative to one centred on risk, resilience, and economic return on investment (ROI), demonstrating the tangible costs of *not* investing (e.g., inability to predict extreme events). The global observation landscape is quite fragmented across institutions and funding silos. This leads to lack of coordination thereby creates inefficiencies and "single points of failure". Many developing nations lack the infrastructure, data-sharing agreements, and technical expertise to utilize advanced data (like Copernicus), hindering their ability to meet Paris Agreement obligations. The integrity of climate data depends on the entire value chain—from fundamental metrological standards and in-situ calibration to satellite validation and data accessibility. Breakdowns at any stage (e.g., data rescue, metadata standards) compromise the utility of the entire system. The window for action is closing. The transition to higher resolution modelling, AI applications, and the need to monitor extremes require immediate upgrades to the observing system, yet funding is stagnating or declining. The Equinox process, under which this workshop was organised acts as a platform for dialogue and collaboration. This workshop marks the beginning of an ongoing effort to carry forward key messages on climate observations and translate them into action.

Next Steps

To address these challenges, a series of actions were proposed:

1. **Develop a Targeted Communication Strategy:**
   - Know your audience and create an "elevator pitch" tailored to specific audiences (e.g., finance ministers, health officials, defence sectors) that links observations directly to their priorities (security, health, economic stability).
   - Adopt a business-case approach similar to the Copernicus model, quantifying the ROI and the financial losses incurred by data gaps.
   - Move beyond the "Earth Information Day" niche to integrate observation needs across all relevant UNFCCC agenda items.
2. **Strengthen Institutional Coordination:**
   - Leverage initiatives like the iClimateAction project to clarify and integrate the roles of WMO, GCOS, and GEO, breaking down silos to present a unified front to funders.
   - Establish official, mandated science-policy interfaces at national and regional levels to ensure continuous dialogue rather than sporadic interactions.
3. **Enhance the GCOS Status Report and Implementation Plan:**
   - Redesign the next Status Report to profile risks of missing data on extreme events and human/ecosystem impacts, rather than just average conditions.
   - Include a clear roadmap for safeguarding investments and a multi-dimensional requirements table that addresses emerging needs (AI, extremes, high-resolution modelling).
   - Reframe the names of Essential Climate Variables (ECVs) to be more policy-relevant and understandable.
4. **Expand Global Engagement and Capacity Building:**
   - Organize side events in Bonn and other international fora to broaden the participants and audience, beyond the European sphere.

- Enhance capacity-building programs in the Global South that go beyond training to establish national data systems, governance frameworks, and data-sharing agreements.
- Secure funding to fill critical in-situ data gaps in underrepresented regions to improve the validation of satellite products.

5. **Prepare for COP 31:**
   - Use the period leading up to COP 31 to refine the messaging and strategy, ensuring that the "Earth Information Day" at the conference is backed by a robust, pre-agreed narrative that effectively influences the Global Stocktake and future climate finance decisions.

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