Earth Observation and the Global Goal on Adaptation: ESA-JRC Workshop Report

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Key findings and recommendations

The European Space Agency (ESA) and the European Commission Joint Research Centre (JRC) hosted a workshop on the role of Earth Observation and the UNFCCC Global Goal on Adaptation (GGA) indicators held at ESA's European Centre for Space Applications and Telecommunications (ECSAT) in Harwell, United Kingdom, from 23 to 25 June 2026. The workshop brought together more than thirty participants representing space agencies, European and United Nations organisations, intergovernmental bodies, academia, operational service providers, the private sector, and adaptation practitioners to address the scientific and operational requirements arising from the adoption of the UNFCCC's Global Goal on Adaptation (GGA) list of adaptation indicators at COP30 in 2025.

These 59 GGA indicators fit within eleven thematic Targets that comprise a framework for monitoring progress on climate adaptation action. These targets include seven thematic targets covering water and sanitation; food and agriculture; health; ecosystems and biodiversity; infrastructure and human settlements; poverty eradication and livelihoods; and cultural heritage; and four targets addressing the policy cycle; impact, vulnerability and risk assessment, planning, implementation, and monitoring, evaluation and learning.

The workshop aimed to identify where Earth Observation (EO) could support the monitoring and reporting of the 59 GGA indicators, while also examining its wider role in adaptation planning and practice. Its format combined invited presentations with interactive discussions and a collaborative mapping exercise, enabling participants to share perspectives and assess EO's potential contribution to each indicator.

Drawing on the workshop presentations and discussions, each indicator was assigned one of the following classifications according to the level of support that EO can provide:

- **Direct component:** EO can measure a physical quantity forming part of the indicator, such as land condition, ecosystem extent or selected water-quality characteristics. This label refers to the observable component within the complete reporting construct. Additional information may be required to identify management boundaries, document adaptation actions or establish the relevant population or denominator. *Example:* Satellite observations can directly measure surface-water characteristics. These measurements contribute directly to assessing whether water bodies have good ambient water quality. However, in situ sampling is still needed for pollutants that satellites cannot detect, such as heavy metals, and national thresholds are needed to determine whether the water qualifies as "good".
- **Indirect contribution:** EO provides inputs or proxies that are combined with other evidence to estimate the quantity described by the indicator. For example, observations of environmental conditions may inform assessments of climate-sensitive health risks, while disease incidence and health outcomes require epidemiological records. The relationship between the EO variable and the reporting quantity requires an appropriate method and validation. *Example:* EO-derived rainfall, temperature and surface-water data help model the climatic suitability for infectious disease, but health records are still needed to measure actual incidence.
- **Contextual information:** EO characterises hazards, exposure or environmental conditions relevant to interpreting the indicator, without directly measuring the institutional, administrative or social quantity being reported. Hazard maps, for example, can inform assessments of service resilience, while service records establish whether operations were maintained during and after an event. *Example:* Flood maps show which health facilities are exposed, but operational records determine whether services remained at full capacity.
- **Not established:** An indicator-specific EO contribution was not established in the assessment.

The distinction between indirect contribution and contextual information concerns how observations enter the assessment. An indirect contribution supplies an input to estimating the indicator or one of its components; contextual information supports interpretation of the conditions surrounding it. The appropriate role depends on the methodology, assessment scale and reporting context. Methods may be developed and applied by scientific communities, international organisations, operational services and public institutions across local, regional, national and global scales.

The categories describe the role of EO within the evidence chain rather than the maturity of an operational product. A directly observable component may still require integration with programme records, socioeconomic data, in situ measurements or other information to produce the complete indicator. Where the adopted wording refers to outcomes of adaptation actions, interpreting observed changes also requires evidence linking those changes to the interventions concerned.

Table 1 summarises the number and percentage of the 59 GGA indicators assigned to each EO contribution category. Of the 59 indicators, 11 contain physical components that EO can measure directly, 16 can receive an indirect contribution through model inputs or proxies, and 21 can use EO as contextual information on hazards, exposure or environmental conditions. For 11 indicators, no indicator-specific EO contribution was established. None of the indicators can be measured completely through EO alone: reporting also requires combinations of in situ observations, administrative and socioeconomic data, surveys, local and Indigenous knowledge, programme records and evidence linking observed change to adaptation action. **Table 2** provides the detailed indicator-level synthesis, listing each GGA indicator, its assigned classification and a short explanation of the relevant EO contribution and the additional evidence required. These notes draw from the workshop presentations, discussions, and the pre-COP30 UAE–Belém work programme on indicators, and metadata therein which the Decision defines as a knowledge product. The assessment confirms that EO is an important but partial component of the evidence needed for adaptation monitoring. The degree to which EO will form a fundamental component of any of the identified indicators will be dependent on the chosen methods for indicator development. This will depend on the discussions and decisions that arise from the Belém–Addis Vision on Adaptation, which comprises a two-year policy alignment process that will progress alongside further technical work on metadata and methodologies for the indicators, undertaken by the Subsidiary Bodies.

Table 1: Summary statistics of the resulting indicator classifications.

EO contribution classification	Count	Percentage
Direct – Partial	11	18.6%
Indirect contribution	16	27.1%
Contextual information	21	35.6%
Not established	11	18.6%

The 11 indicators identified as having a direct, but partial EO component are listed below. The strongest near-term opportunities concern water stress and water quality, agricultural management and land degradation, and ecosystem condition, resilience and threat status. Those listed below marked with a **[P]** were identified in the workshop as priority, or ‘low-hanging fruit’, indicators for initial attention because they have connections to other indicator frameworks (e.g., the SDGs). The remaining indicators classified as Direct – Partial, Indirect or Contextual should be explored further through dedicated research and development.

- **9(a)-a** — Level of water stress, including as an outcome of adaptation actions where applicable, accounting for relevant climate hazard intensity and/or frequency.
- **9(a)-b** — Level of water-use efficiency, including as an outcome of adaptation actions where applicable.
- **9(a)-h** — Proportion of bodies of water with good ambient water quality for drinking water supply, including as an outcome of adaptation actions where applicable. **[P]**
- **9(b)-a** — Proportion of area under management for food and agricultural production utilizing practices and technologies relevant to climate change adaptation.
- **9(b)-c** — Level of degraded areas that are under management for food and agricultural production, including as an outcome of adaptation actions where applicable. **[P]**
- **9(b)-d** — Level of food and agricultural yield in areas that are under management for food and agricultural production, including as an outcome of adaptation actions where applicable.
- **9(c)-b** — Level of incidence of climate-sensitive infectious diseases, including as an outcome of adaptation actions where applicable.
- **9(d)-a** — Proportion of climate-resilient ecosystems that are providing services to populations that depend on them.
- **9(d)-b** — Proportion of ecosystem areas with adaptation actions implemented towards enhanced resilience and services. **[P]**
- **9(d)-c** — Level of resilience of ecosystems, including as an outcome of adaptation actions where applicable.
- **9(d)-d** — Level of threat status of ecosystems, including as an outcome of adaptation actions where applicable. **[P]**

Beyond the GGA indicators, the workshop emphasised that EO is most useful when it is designed around a clearly defined adaptation decision rather than the availability of a particular dataset. Satellite observations can provide consistent baselines, monitor hazards and environmental change, support early warning and risk assessment, and help track the physical effects of adaptation measures. However, they must be combined with in situ observations, socioeconomic and administrative data, local and Indigenous knowledge, and evidence on implementation to understand vulnerability, equity, institutional capacity and whether an intervention has genuinely improved resilience.

Participants also stressed that technical capability alone does not ensure operational use. Priorities include co-design with users; transparent methods, uncertainty and traceability; interoperable and service-based delivery; stronger links to national and local planning and reporting systems; and sustained capacity development, particularly in lower-capacity countries and municipalities. Long-term continuity of satellite and in situ observing systems, reanalysis and historical records is equally important, as is moving successful pilots into durable operational services supported by institutional ownership, reliable infrastructure and continuing finance.

Finally, some participants noted that some of the 110 proposed GGA indicators not selected for the final list could also have been directly supported by EO (Direct – Partial categorisation). Examples are listed below, where their indicator ID refers to the former numbering as suggested by the technical experts from the UAE–Belém work programme on indicators.

- **9d09 — Extent of natural ecosystems relevant for climate adaptation:** EO can directly map ecosystem extent and monitor changes over time.
- **9d05 — Extent of climate-resilient ecosystems covered by protected areas and other effective area-based conservation measures:** EO-derived ecosystem maps can be combined with protected-area boundaries to calculate coverage.

- **9b10 — Direct agricultural losses associated with climate-related drivers and events:** EO can map affected agricultural areas and estimate crop damage and biophysical production losses.
- **9b02 — Adoption of adaptation practices and technologies by food and agricultural actors:** EO can detect selected spatially observable practices, including irrigation, cover crops, altered cropping patterns and agroforestry.
- **10c03 — People experiencing direct social and economic impacts associated with climate-related hazards:** EO can map hazard footprints, damaged buildings, affected cropland and disrupted settlements.

In each case, EO could directly measure at least part of the indicator, although administrative, survey, socioeconomic or economic data would still be required to complete the assessment.

Table 2: Workshop synthesis of the extent to which EO can support the 59 selected GGA Indicators. Indicators are classified by the extent to which EO can support their development. Categories are: Direct – Partial, Indirect component, Contextual information, Not established. No indicators can be fully mapped to EO measurable quantities.

GGA Indicator ID	GGA Indicator text	EO contribution	Notes
9(a) - Water	**Significantly reducing climate induced water scarcity and enhancing climate resilience to water-related hazards towards a climate-resilient water supply, climate-resilient sanitation and access to safe and affordable potable water for all.**		
9(a)-a	Level of water stress, including as an outcome of adaptation actions where applicable, accounting for relevant climate hazard intensity and/or frequency;	Direct - Partial	EO is directly useful for basin-scale water-stress assessment by estimating renewable supply, evapotranspiration, surface-water storage and drought intensity, then combining these with sectoral withdrawal statistics and environmental-flow requirements. GRACE-FO, SMAP/AMSR2, Sentinel, MODIS/ECOSTRESS and river runoff/discharge products support the analysis, but sectoral withdrawals—especially beyond agriculture—and attribution to adaptation actions require non-EO data and substantial modelling. Framework references: SDG 6.4.2 (Level of water stress).
9(a)-b	Level of water-use efficiency, including as an outcome of adaptation actions where applicable;	Direct - Partial	EO can partially estimate water-use efficiency, most credibly in agriculture, by combining ET with crop area, biomass or yield estimates and irrigation mapping. Thermal, multispectral, Synthetic Aperture Radar (SAR) and precipitation data support this approach, but the official indicator is monetary value added per unit of water across all sectors, so economic and administrative statistics remain essential. Framework references: SDG 6.4.1 (Change in water-use efficiency over time).
9(a)-c	Proportion of critical water and sanitation infrastructure systems that are resilient to climate-related hazards under different warming scenarios, as appropriate for regions and contexts, including as	Contextual information	EO can map climate hazards and exposure around critical water and sanitation assets using flooding, drought, landslides, cyclones, erosion and ground deformation products. However, determining whether systems are designed, built or retrofitted to be resilient

	an outcome of adaptation actions where applicable;		requires asset registries, engineering standards and administrative evidence; EO therefore provides partial and contextual risk-screening support rather than the full indicator.
9(a)-d	Proportion of the total area of basins and cryosphere for which a climate adaptation plan has been developed and implemented on the basis of different warming scenarios, as appropriate for regions and contexts where applicable;	Indirect contribution	EO can delineate basin and cryosphere areas and characterize glacier, snow, permafrost, water-storage and scenario exposure, helping define the indicator denominator. The indicator itself concerns whether adaptation plans exist and are implemented, so document and governance data—not EO—must establish plan coverage.
9(a)-e	Proportion of the population using safe and affordable potable water services that are climate-resilient, including as an outcome of adaptation actions where applicable;	Contextual information	EO can identify hazard-exposed settlements, informal communities and service areas to target climate-resilient drinking-water investments, using settlement, flood, drought and heat layers. It cannot establish household access, affordability, service reliability, or compliance with faecal and chemical water-quality standards, which require surveys and administrative or in situ data. Framework references: SDG 6.1.1 (Safely managed drinking water services) and the WHO/UNICEF Joint Monitoring Programme (JMP) framework under development for climate-resilient WASH.
9(a)-f	Proportion of the population using sanitation services that are safely managed and climate-resilient, including as an outcome of adaptation actions where applicable;	Contextual information	EO can map informal settlements and climate-hazard exposure to help target sanitation upgrades, but it cannot determine whether household sanitation is safely managed or climate-resilient. The core indicator depends on standardized definitions, household surveys and service-provider records. Framework reference: SDG 6.2.1a on safely managed sanitation services.
9(a)-g	Extent of measures taken to improve and extend water, sanitation and hygiene services to populations disproportionately affected by climate change and to vulnerable groups relative to needs;	Contextual information	EO can identify informal settlements and populations exposed to flood, drought, heat, land erosion etc., helping prioritize WASH measures for vulnerable groups. The extent of measures implemented, sustained engagement and adequacy relative to need remain process- and survey-based and cannot be measured directly from EO. Framework reference: UN-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS).
9(a)-h	Proportion of bodies of water with good ambient water quality for drinking water supply, including as an outcome of adaptation actions where applicable;	Direct - Partial	EO can directly support surface-water quality assessment by retrieving turbidity, suspended matter, chlorophyll-a, Colour dissolved organic matter/CDOM, temperature and bloom indicators from Sentinel, Landsat and ocean-colour data, calibrated with in situ samples. It cannot assess groundwater or all pollutants such as

			heavy metals and dissolved minerals, and national thresholds determine 'good' status, so EO cannot provide the complete indicator alone. Framework references: SDG 6.3.2 (Proportion of bodies of water with good ambient water quality) and the EU Water Framework Directive.
9(a)-i	Number of people per 100,000 supported in planned relocation processes in response to water-related hazards, where adaptation measures were taken to ensure safety of populations.	Indirect contribution	EO can verify planned relocation outcomes by detecting abandonment in hazard zones and new settlement growth in safer areas, using optical, SAR and night-light change detection plus hazard maps. Administrative records are still needed for the number to be relocated and to confirm that movement was planned, voluntary, safe and dignified.
9(b) - Food	**Attaining climate-resilient food and agricultural production and supply and distribution of food, as well as increasing sustainable and regenerative production and equitable access to adequate food and nutrition for all**		
9(b)-a	Proportion of area under management for food and agricultural production utilizing practices and technologies relevant to climate change adaptation;	Direct - Partial	EO can map agricultural area and detect selected adaptation practices—such as irrigation, cover crops, residue cover and agroforestry—from multispectral, SAR and thermal time series. GEOGLAM-like workflows can provide direct information on what land is under agricultural production and for some sustainable/resilient agricultural practices. Coverage is partial because many practices are not remotely observable and robust reporting requires an agreed practice taxonomy, ground truth and survey evidence. Framework reference: SDG 2.4.1 on productive and sustainable agriculture.
9(b)-b	Extent of implementation of institutional frameworks for knowledge transfer, research and development, and extension services supporting climate change adaptation in the areas of food and agriculture relative to needs;	Contextual information	The indicator is primarily institutional and survey-based: EO can provide contextual evidence on cropland extent, drought exposure and where extension or research support may be needed, but it cannot measure the implementation or adequacy of knowledge-transfer, R&D and extension frameworks.
9(b)-c	Level of degraded areas that are under management for food and agricultural production, including as an outcome of adaptation actions where applicable;	Direct - Partial	EO is directly suited to mapping degraded agricultural areas through land-cover change, Normalized Difference Vegetation Index (NDVI) or Net Primary Production (NPP) trends, bare soil, erosion risk and soil-carbon proxies, following an SDG 15.3.1-style framework. Optical, SAR and soil-moisture data can quantify area and trends, with ancillary soil data and validation needed for a complete assessment. Framework reference: SDG 15.3.1 land-degradation methodology (land cover, land productivity and soil organic carbon).
9(b)-d	Level of food and agricultural yield in areas that are under management for food and	Direct - Partial	EO can estimate crop yields and climate-related yield change using vegetation indices, Leaf Area index (LAI), Solar-induced

	agricultural production, including as an outcome of adaptation actions where applicable;		fluorescence (SIF), evapotranspiration, rainfall, temperature and crop models, and can stratify results by hazard year. Because the indicator emphasizes actual yields across crops, livestock and fisheries, official production records and calibration data remain necessary; EO is strongest for climate-driver characterization and crop-yield estimation. Framework reference: FAOSTAT crop and livestock production statistics provide the official-record basis for actual yields.
9(b)-e	Proportion of the population with equitable access to adequate food and nutrition, including as an outcome of adaptation actions where applicable.	Not established	EO can supply drought, heatwave and crop-condition information to identify hazard-prone food-security hotspots and contextualize adaptation outcomes. Equitable access to adequate food and nutrition is nevertheless measured through surveys and models such as SDG 2.1.1/2.1.2, so EO is an indirect supporting input rather than a primary measure. Framework references: SDG 2.1.1 (Prevalence of undernourishment), SDG 2.1.2 (Food Insecurity Experience Scale) and the FAO FIES framework.
9(c) - Health	**Attaining resilience against climate change related health impacts, promoting climate-resilient health services and significantly reducing climate-related morbidity and mortality, particularly in the most vulnerable communities.**		
9(c)-a	Rate of mortality associated with climate impacts compared with counterfactual rates, including as an outcome of adaptation actions or coverage of early warning systems where applicable;	Indirect contribution	EO can define exposure to temperature extremes, flooding, smoke, drought and cyclones etc. using thermal, SAR, aerosol, precipitation and reanalysis products, supporting counterfactual mortality analysis and evaluation of early-warning coverage. Mortality and attribution still require vital statistics, epidemiological response functions and sufficiently fine spatial data to isolate adaptation effects. Framework reference: Lancet Countdown Indicator 1.1.5 on heat-related mortality.
9(c)-b	Level of incidence of climate-sensitive infectious diseases, including as an outcome of adaptation actions where applicable;	Direct - Partial	EO can model climatic suitability for infectious diseases from rainfall, temperature, surface water, vegetation, humidity and elevation, improving spatial coverage and helping interpret adaptation effectiveness. For example, an incidence-decrease, but a climatic suitability increase (due to climate change), is an indication that the adaptation intervention works. Disease incidence must also come from health-surveillance systems, so EO supports the environmental-risk component rather than the full indicator. Framework reference: Lancet Countdown Indicator 1.3.1 on the climatic suitability for dengue, chikungunya and Zika transmission.
9(c)-c	Rate of morbidity associated with climate impacts compared with	Indirect contribution	EO can quantify exposure to temperature extremes, flooding, smoke, drought and

	counterfactual rates, including as an outcome of adaptation actions where applicable;		cyclones etc. and link it to health records for counterfactual morbidity analysis, including labour-capacity impacts from heat. Morbidity outcomes and attribution require health or occupational statistics and epidemiological models; EO supplies the hazard and exposure evidence. Framework references: Lancet Countdown Indicator 1.1.3 on change in labour capacity.
9(c)-d	Proportion of the population vulnerable to climate change with access to mental health and psychosocial support;	Contextual information	EO can characterize climate events and exposed vulnerable populations to inform and contextualise mental-health surveys and response planning, but it cannot measure access to mental-health and psychosocial support. The indicator relies on health-system capacity, service-access and survey data.
9(c)-e	Extent to which climate health services have remained at full capacity during and following climate-related events relative to pre-event service capacity;	Contextual information	EO can document the location, extent and intensity of climate events affecting health facilities and support post-event situational awareness. Whether services remained at full capacity relative to baseline requires facility-level operational and administrative records, so EO has only a contextual role. Framework reference: Sendai Framework Indicator D-2 on health facilities destroyed or damaged by disasters.
9(c)-f	Percentage of health facilities that are resilient to climate-related hazards under different warming scenarios, as appropriate for regions and contexts, including as an outcome of adaptation actions where applicable;	Indirect contribution	EO can combine geolocated health facilities to quantify exposure and screen resilience under warming scenarios. A definitive resilience score still requires engineering standards, facility assessments and administrative data; EO provides partial hazard and exposure evidence. Framework reference: WHO Climate Change and Health Survey.
9(c)-g	Coverage of essential health services that are supported by adaptation measures to ensure continuity during and following climate-related events;	Contextual information	EO can support situational awareness and assess hazard-related accessibility, such as road passability to hospitals, but it cannot measure continuity or coverage of essential health services supported by adaptation measures. Health-system and service-delivery records are the primary source. Framework reference: SDG 3.8.1 on coverage of essential health services within the Universal Health Coverage framework.
9(c)-h	Proportion of health practitioners who have received capacity-building support pertaining to climate change adaptation and health.	Not established	This is a capacity-building indicator based on health-system reporting, such as the WHO Climate Change and Health Survey. EO cannot determine how many practitioners received relevant support. Framework reference: WHO Climate Change and Health Survey.
9(d) – Ecosystems & Biodiversity	**Reducing climate impacts on ecosystems and biodiversity, and accelerating the use of ecosystem-based adaptation and nature-based solutions, including through their management, enhancement, restoration and conservation and the protection of terrestrial, inland water, mountain, marine and coastal ecosystems.**		

9(d)-a	Proportion of climate-resilient ecosystems that are providing services to populations that depend on them;	Direct - Partial	EO can map ecosystem extent, condition and resilience proxies—including productivity, biomass, fragmentation, canopy structure, water availability and coastal condition—and feed ecosystem-service models such as ARIES or InVEST. EO component is limited to the ecosystem-condition component. Linking resilient services to dependent populations requires population, use and socioeconomic data, while the long-term resilience of service flows remains partly model-based. Framework references: GBF Indicator B.1 on services provided by ecosystems and the SEEA Ecosystem Accounting framework; ARIES for SEEA is a relevant implementation platform.
9(d)-b	Proportion of ecosystem areas with adaptation actions implemented towards enhanced resilience and services;	Direct - Partial	EO is well suited to mapping and monitoring ecosystem restoration or other spatial adaptation actions, establishing baselines and tracking changes in condition, biomass, fragmentation and services. Administrative designation and evidence that actions were implemented specifically for climate resilience are still needed. Framework references: Kunming–Montreal GBF Indicator 2.2 on area under restoration and the SEEA Ecosystem Accounting framework.
9(d)-c	Level of resilience of ecosystems, including as an outcome of adaptation actions where applicable;	Direct - Partial	EO can support ecosystem-resilience indices such as BERI and derive condition, stability and recovery metrics from NDVI/LAI or Enhanced vegetation Index (EVI) anomalies, evapotranspiration, soil moisture, biomass and disturbance time series. Interpretation requires an agreed resilience framework and ancillary ecological and climate-scenario information. Framework reference: BERI.
9(d)-d	Level of threat status of ecosystems, including as an outcome of adaptation actions where applicable;	Direct - Partial	EO can directly assess several ecosystem-threat criteria by mapping range reduction, range redistribution/shifts, restricted distribution, degradation, fragmentation, land conversion, fire recurrence and coastal change, supporting the International Union for Conservation of Nature (IUCN) Red List of Ecosystems assessments. Biotic-process disruption and collapse probability require ecological models, field evidence and climate projections beyond EO alone. Framework reference: IUCN Red List of Ecosystems criteria A–E.
9(d)-e	Level of threat status of species, including as an outcome of adaptation actions where applicable;	Contextual information	EO can directly assess several species-threat criteria by mapping range reduction, range re-distribution/shifts, restricted distribution, degradation, fragmentation, land conversion, fire recurrence and coastal change, supporting IUCN Red List of Ecosystems assessments. Biotic-process

			disruption and collapse probability require ecological models, field evidence and climate projections beyond EO alone. Framework reference: IUCN Red List of Threatened Species.
9(d)-f	Level of adaptive capacity, resilience and vulnerability to climate impacts resulting from the implementation of ecosystem-based adaptation actions and nature-based solutions according to information reported by Parties, as appropriate.	Contextual information	EO can provide contextual evidence of changing hazards and impacts from climate change but cannot fully assess adaptive capacity, resilience and vulnerability.
9(e) – Human Settlements	**Increasing the resilience of infrastructure and human settlements to climate change impacts to ensure basic and continuous essential services for all, and minimizing climate-related impacts on infrastructure and human settlements.**		
9(e)-a	Proportion of settlement-upgrading programmes implemented that include climate change adaptation measures and maintain sustained engagement at the local level;	Indirect contribution	EO can help identify settlement upgrading through changes in roof materials, street layout, drainage, impervious cover and flood exposure, and can monitor whether physical adaptation measures appear implemented. Programme coverage, climate criteria and sustained local engagement require administrative and participatory evidence, so EO provides partial verification.
9(e)-b	Proportion of infrastructure and human settlements vulnerable to climate-related hazards and other extreme events relocated to a safer location.	Indirect contribution	EO can detect relocation by comparing built-up footprint and night-light decline in vulnerable areas with growth in safer locations, supported by flood, coastal and landslide risk layers. Administrative records are needed to confirm the affected population, timing and planned nature of relocation.
9(f) – Poverty Eradication	**Substantially reducing the adverse effects of climate change on poverty eradication and livelihoods, in particular by promoting the use of adaptive social protection measures for all.**		
9(f)-a	Level of population living in poverty, including as an outcome of adaptation actions where applicable;	Indirect contribution	EO can provide poverty proxies such as night-time lights, building and roof characteristics, accessibility and vegetation-productivity shocks. These estimates require calibration with household surveys and do not by themselves capture multidimensional poverty or prove adaptation outcomes.
9(f)-b	Proportion of the population in climate-vulnerable areas with access to social protection services;	Contextual information	EO may help delineate climate-vulnerable areas and population exposure, but access to social-protection services must be measured from programme, administrative or survey data.
9(f)-c	Level of social protection systems that consider climate risk management aspects and can respond to climate change impacts.	Contextual information	EO may inform the climate risk context, but whether social-protection systems integrate risk management and can respond to impacts requires institutional and operational evidence.
9(g) – Cultural Heritage	**Protecting cultural heritage from the impacts of climate-related risks by developing adaptive strategies for preserving cultural practices and heritage sites and by designing climate-resilient infrastructure, guided by traditional knowledge, Indigenous Peoples' knowledge and local knowledge systems.**		

9(g)-a	Percentage of at-risk cultural and natural heritage sites and elements with adaptation measures implemented to enhance resilience to climate-related hazards under different warming scenarios, as appropriate for regions and contexts, guided by traditional, local or Indigenous Peoples' knowledge and practices, disaggregated, as appropriate, by tangible and intangible cultural elements;	Indirect contribution	EO can combine heritage inventories with flood, erosion, landslide, wildfire, subsidence and temperature layers, and monitor physical impacts using SAR/InSAR, optical, Digital Elevation Models, fire and thermal products. However, EO cannot inform about future scenarios so modelled projects are also needed. EO can be used for model evaluation and validation purposes. Whether adaptation measures are implemented and guided by traditional, local or Indigenous knowledge requires site-management and stakeholder-engagement data.
9(g)-b	Proportion of cultural heritage protected from climate impacts through digitization measures for preservation and recovery and by storing movable heritage in climate-resilient facilities;	Contextual information	Mostly measured through administrative data. EO does not establish whether heritage has been digitized or movable assets are stored in climate-resilient facilities.
9(g)-c	Percentage of cultural heritage and sites with adaptation measures and emergency preparedness plans in place for climate change related hazards under different warming scenarios, as appropriate for regions and contexts;	Contextual information	Products such as the Copernicus Emergency Management Service products can support hazard and recovery planning for heritage sites, but EO cannot confirm that adaptation measures and emergency-preparedness plans exist or are implemented. Related operational framework: Copernicus Emergency Management Service Risk and Recovery Mapping for cultural-heritage preparedness.
9(g)-d	Level of establishment of institutional arrangements for the provision of regular training on climate change adaptation that incorporates guidance from traditional, local and Indigenous Peoples' knowledge where applicable;	Not established	EO cannot determine whether institutional training arrangements exist or whether traditional, local and Indigenous knowledge is incorporated.
9(g)-e	Percentage of climate adaptation measures focused on cultural heritage that maintain sustained engagement with Indigenous Peoples and/or local communities.	Not established	EO cannot measure whether cultural-heritage adaptation measures maintain sustained engagement with Indigenous Peoples or local communities.
10(a) - Impact, vulnerability and risk assessment	**Towards achieving the outcome specified thereunder – by 2030 all Parties have conducted up-to-date assessments of climate hazards, climate change impacts and exposure to risks and vulnerabilities and have used the outcomes of these assessments to inform their formulation of national adaptation plans, policy instruments, and planning processes and/or strategies, and by 2027 all Parties have established multi-hazard early warning systems, climate information services for risk reduction and systematic observation to support improved climate-related data, information and services.**		
10(a)-a	Level of establishment of multi-hazard early warning systems;	Indirect contribution	Establishment of a multi-hazard early-warning system is primarily an institutional and governance measure spanning risk knowledge, monitoring and forecasting, dissemination, and preparedness. However, EO supplies fundamental information which forms a backbone of EWS. Framework reference: WMO Early Warnings for All.

10(a)-b	Level of conduct of assessments of climate hazards, climate change impacts, and exposure to risks and vulnerabilities based on different global warming scenarios, as appropriate for regions and contexts;	Indirect contribution	EO can generate multi-hazard and exposure layers for flood, drought, heat, wildfire and coastal risk, provide historical event footprints and support scenario-based assessments. The indicator remains partly process-based because it asks whether comprehensive assessments are conducted and used, which requires documentary and institutional evidence. Related frameworks: WMO Early Warnings for All dashboard and UNFCCC Adaptation Committee guidance on impact, vulnerability and risk assessment.
10(a)-c	Level of establishment of multi-hazard monitoring and impact-based forecasting systems, including monitoring stations;	Indirect contribution	EO directly supports the *monitoring* component through, for example, near-real-time flood, drought, fire, temperature, cyclone, precipitation and soil-moisture streams from satellite and meteorological sensors. Establishment of an integrated, impact-based forecasting system—including station networks and operations—must still be evidenced institutionally. Framework reference: Sendai Framework Indicator G-2 on countries with multi-hazard monitoring and forecasting systems.
10(a)-d	Number of people per 100,000 that are covered by early warning information through local governments or through national dissemination mechanisms;	Contextual information	EO provides hazard-monitoring inputs and is a core component of many early warning systems but cannot measure whether people receive early-warning information through recognized national or local dissemination channels. Population coverage must be established from government, telecom and communications-system data. Framework reference: Sendai Framework Monitor Technical Guidance on population coverage by multi-hazard early-warning systems.
10(a)-e	Percentage of the population in a country exposed to or at risk from climate-related disasters protected through pre-emptive evacuation measures following early warning;	Contextual information	EO can delineate event footprints and at-risk populations to support the denominator and evaluate whether evacuations moved people away from danger. Actual pre-emptive evacuation following a warning is an operational outcome requiring event-specific administrative or mobility evidence. Framework reference: Sendai Framework Monitor Target G, Indicator G-6 on populations protected through pre-emptive evacuation following early warning.
10(a)-f	Level of establishment of climate information services for risk reduction and systematic observation to support improved climate-related data, information and services;	Indirect contribution	EO and reanalysis can supply systematic observations of essential climate variables—including precipitation, temperature, soil moisture, sea level, ice and vegetation—and support climate services for risk reduction. Whether services are established, maintained, accessible and tailored to users requires institutional reporting.
10(a)-g	Extent of usage of climate risk information and comprehensive risk assessment based on different	Indirect contribution	EO can provide the multi-hazard, exposure and vulnerability evidence used in scenario-based risk assessments and adaptation

	global warming scenarios, as appropriate for regions and contexts, to inform formulation of national adaptation plans, policy instruments, and planning processes and/or strategies.		planning. The indicator measures whether such information is actually used in NAPs, policies and strategies, so documentary review and institutional reporting remain essential. Related policy frameworks: national adaptation plan processes and disaster-risk-reduction strategies.
10(b) - Planning	**Towards achieving the outcome thereunder – by 2030 all Parties have in place country-driven, gender responsive, participatory and fully transparent national adaptation plans, policy instruments, and planning processes and/or strategies, covering, as appropriate, ecosystems, sectors, people and vulnerable communities, and have mainstreamed adaptation in all relevant strategies and plans.**		
10(b)-a	Status of having national adaptation plans, policy instruments, and planning processes and/or strategies in place;	Not established	This is a policy-status indicator. EO can inform the evidence base of national adaptation plans and strategies but cannot determine whether those instruments exist or their formal status.
10(b)-b	Status of having gender-responsive adaptation plans, policy instruments, and planning processes and/or strategies in place;	Not established	This is a policy and inclusivity indicator. EO may inform adaptation planning but cannot establish whether plans and strategies are gender-responsive; document review and governance evidence are required.
10(b)-c	Existence of national adaptation plans, policy instruments, planning processes and strategies that have been informed by traditional knowledge, knowledge of Indigenous Peoples and local knowledge systems.	Not established	This is a policy and knowledge-inclusion indicator. EO can inform plan content but cannot determine whether traditional, Indigenous Peoples' and local knowledge systems shaped national adaptation instruments.
10(c) - Implementation	**Towards achieving the outcome thereunder – by 2030 all Parties have progressed in implementing their national adaptation plans, policies and strategies and, as a result, have reduced the social and economic impacts of the key climate hazards identified in the assessments referred to under target 10(a).**		
10(c)-a	Extent of implementation of national adaptation plans, policies and strategies relative to planned implementation thereof.	Not established	Implementation of adaptation plans relative to planned milestones is an institutional reporting measure. EO is not a primary source for reporting through policy and transparency systems, though it may provide evidence of implementation or outcomes for selected funded activities.
10(c)-b	Number of deaths and missing persons associated with climate-related hazards, per 100,000 people, including as an outcome of adaptation actions where applicable.	Indirect contribution	EO can map hazard-event footprints and exposed populations, improving attribution of deaths and missing persons to floods, temperature extremes, and other climate hazards. Counts must come from civil registries and disaster databases; heat mortality often relies on statistical estimation, which limits comparability. Framework references: Lancet Countdown Indicator 1.1.5 for heat-related mortality and the European Environment Agency indicator on economic losses and fatalities from weather- and climate-related extremes.
10(c)-c	Net savings as a percentage of gross domestic product from avoided losses, including as an	Indirect contribution	EO can map flood damage, burnt area, crop loss, affected buildings, assets and event intensity to support counterfactual avoided-loss models. Converting these impacts into

	outcome of adaptation actions where applicable.		net savings as a share of GDP requires economic, insurance and national-accounting data, so EO provides indirect support.
10(c)-d	Amount of finance for climate adaptation reported in line with chapters IV, V and VI, as relevant and as appropriate, of the annex to decision 18/CMA.1, disaggregated by the parameters listed in paragraphs 123, 125, 133 and 134, as applicable, of the same decision, which includes the amount of international public finance for climate adaptation provided by developed countries and received by developing countries for the implementation of national adaptation plans, policy instruments, and planning processes and/or strategies;	Not established	This finance indicator is reported through UNFCCC transparency systems. EO is not a primary source for amounts of adaptation finance, though it may provide evidence of implementation or outcomes for selected funded activities. Reporting framework: UNFCCC enhanced transparency framework under decision 18/CMA.1.
10(c)-e	Technology development and transfer for climate adaptation reported in line with chapters IV, V and VI, as relevant and as appropriate, of the annex to decision 18/CMA.1, disaggregated by the parameters listed in paragraphs 127, 136 and 138, as applicable, of the same decision, which includes technology development and transfer support for climate adaptation provided by developed countries and needed and received by developing countries for the implementation of national adaptation plans, policy instruments, and planning processes and/or strategies;	Not established	This technology-development and transfer indicator is reported through UNFCCC transparency systems. The available notes identify no substantive role for EO in measuring support provided, needed or received. Reporting framework: UNFCCC enhanced transparency framework under decision 18/CMA.1 for technology development and transfer support.
10(c)-f	Capacity-building for climate adaptation reported in line with chapters IV, V and VI, as relevant and as appropriate, of the annex to decision 18/CMA.1, disaggregated by the parameters listed in paragraphs 129, 140 and 142, as applicable, of the same decision, which includes capacity-building support for climate adaptation provided by developed countries and needed and received by developing countries for the implementation of national adaptation plans, policy instruments, and planning processes and/or strategies.	Not established	This capacity-building indicator is reported through UNFCCC transparency systems. The available notes identify no substantive role for EO in measuring support provided, needed or received. Reporting framework: UNFCCC enhanced transparency framework under decision 18/CMA.1 for capacity-building support.

10(d) – Monitoring, Evaluation & Learning (MEL)	**Towards achieving the outcome thereunder – by 2030 all Parties have designed, established and operationalized a system for monitoring, evaluation and learning for their national adaptation efforts and have built the required institutional capacity to fully implement the system.**		
10(d)-a	Extent of design of a system for monitoring, evaluation and learning for national adaptation efforts relative to needs;	Contextual information	Design of a monitoring, evaluation and learning system is institutional. EO can supply evidence streams on hazards, impacts and ecosystems, but cannot determine whether the MEL architecture meets national needs.
10(d)-b	Level of operationalization of a system for monitoring, evaluation and learning for national adaptation efforts;	Contextual information	Operationalization of a monitoring, evaluation and learning system is institutional. EO can feed operational monitoring evidence, but system functionality, governance and use require administrative assessment.
10(d)-c	Level of periodic publication of monitoring, evaluation and learning findings regarding the implementation of national adaptation efforts;	Contextual information	Periodic publication of MEL findings is an institutional and communications measure. EO can contribute underlying evidence but cannot establish publication frequency or completeness.
10(d)-d	Level of integration of monitoring, evaluation and learning system findings into national adaptation efforts;	Contextual information	Integration of MEL findings into national adaptation efforts is a policy and decision-making measure. EO can provide findings and evidence to integrate but cannot determine whether they influenced plans or implementation.
10(d)-e	Level of institutional capacity to fully operate systems for monitoring, evaluation and learning for national adaptation efforts.	Contextual information	Institutional capacity to operate MEL systems must be assessed through staffing, governance, resources and procedures. EO can provide monitoring inputs but cannot measure institutional capacity itself.

Introduction

The European Space Agency (ESA) and the European Commission Joint Research Centre (JRC) hosted a workshop on the role of Earth Observation and the UNFCCC Global Goal on Adaptation (GGA) indicators held at ESA's European Centre for Space Applications and Telecommunications (ECSAT) in Harwell, United Kingdom, from 23 to 25 June 2026. The workshop brought together more than thirty participants representing space agencies, European and United Nations organisations, intergovernmental bodies, academia, operational service providers, the private sector, and adaptation practitioners to address the scientific and operational requirements arising from the adoption of the UNFCCC's Global Goal on Adaptation (GGA) list of adaptation indicators at COP30 in 2025.

These 59 indicators fit within eleven thematic Targets which act as a framework for monitoring progress on climate adaptation action. These targets comprise seven thematic targets covering water and sanitation; food and agriculture; health; ecosystems and biodiversity; infrastructure and human settlements; poverty eradication and livelihoods; and cultural heritage; and four targets addressing the policy cycle: impact, vulnerability and risk assessment, planning, implementation, and monitoring, evaluation and learning.

The primary objective was to identify indicators for which satellite-based Earth Observation (EO) could provide direct inputs to country-level monitoring and reporting. A complementary objective was to examine how EO could support adaptation decisions and practices beyond the formal GGA indicator definitions. Through invited presentations and interactive discussions across eight themed sessions, the participants mapped EO potential against the selected 59 GGA indicators.

- Session 1 provided institutional welcomes and introduced the workshop objectives.
- Session 2 introduced the GGA and provided global and European policy context.
- Session 3 discussed the GGA Targets, Indicators and current EO capabilities.
- Session 4 compiled lessons learned from similar, previous initiatives such as European Environment Agency (EEA) indicator practice, the ESA StatEO conference and United Nations Convention to Combat Desertification (UNCCD) land-degradation and drought reporting. This session concluded with an interactive mapping exercise of EO capabilities to the GGA indicators.
- Session 5 expanded the focus of the workshop to adaptation more widely and addressed National Adaptation Plans and experience from country-support programmes.
- Session 6 explored adaptation-community requirements and how EO could be made more useful to support adaptation. Topics included adaptation EO downscaling, risk assessment, future satellite missions, and ongoing developments at Global Climate Observing System (GCOS) and the Copernicus Climate Change Service (C3S).
- Session 7 focused on regional and local applications, including the EU Mission on Adaptation, the Committee on Earth Observation Satellites (CEOS) adaptation handbook, disaster risk reduction, resilience monitoring and urban adaptation.
- Session 8 consolidated the findings through a reflections panel and discussion of next steps.

A detailed agenda of the workshop can be found in **Annex 1**.

The report is structured around the eight workshop sessions. For each session, it summarises the speakers' presentations, includes a key graphic and lists relevant references and web resources.

Session 1: Welcome

Chairs: Susanne Mecklenburg (ESA) and Mark Dowell (EC-JRC)

As co-hosts, Susanne Mecklenburg, Head of the Climate and Long-Term Action Division at ESA, and Mark Dowell, Project Leader for Scientific and Technical Support to Copernicus at the JRC, opened the workshop by outlining the three-day programme and its objectives. They emphasised the workshop's timeliness in relation to the GGA and the anticipated update of the European Union's climate adaptation strategy (the European Climate Resilience and Risk Management Integrated Framework). They also acknowledged that translating adaptation needs into coordinated Earth observation activities has not always been straightforward. The GGA indicators provide a structured framework through which space agencies and CEOS can organise their programmes and coordinate their contributions, drawing on experience with frameworks such as the Essential Climate Variables (ECVs).

Simonetta Cheli (ESA) welcomed participants on behalf of the ESA and highlighted the increasing importance of climate adaptation within the international climate agenda. She emphasised the role of Earth Observation as a strategic asset for supporting climate resilience, adaptation planning and evidence-based decision-making. The opening remarks underlined ESA's commitment to working with international organisations, scientific institutions and policy communities to maximise the societal value of satellite observations.

Alessandra Zampieri (EC-JRC) welcomed participants on behalf of the JRC and emphasised the need for robust scientific evidence to support climate adaptation policies. The presentation highlighted the JRC's role in bridging science and policy through the development of methodologies, indicators and operational tools capable of supporting adaptation decision-making. Emphasis was placed on the importance of collaboration between policy institutions, scientific organisations and operational service providers.

Hugo Zunker (EC DG DEFIS), representing the European Commission's Directorate-General for Defence Industry and Space (DG DEFIS), provided an operational perspective on the role of Copernicus in supporting climate policy and adaptation. As the Directorate-General responsible for implementing the Copernicus programme, DG DEFIS regards it as Europe's contribution to understanding and monitoring the Earth, with support for managing the impacts of climate change now constituting one of its most important areas of application. The intervention also emphasised the role of the Knowledge Centre on Earth Observation (KCEO), a joint initiative of DG DEFIS and the JRC, in connecting EO capabilities with European policy needs. Through cooperation with DG CLIMA, DG ENV, DG AGRI and other Commission services, the KCEO supports the integration of Earth observation into legislation, policy implementation and monitoring. He emphasised that the forthcoming European climate resilience and risk-management framework will introduce increasingly specific requirements for the data and knowledge underpinning adaptation policy. Earth observation can make a substantial contribution, but it must be integrated with information on infrastructure, population, local conditions and other socioeconomic and administrative factors.

Alex Held (CEOS Chair, CSIRO) introduced the Committee on Earth Observation Satellites (CEOS) as the principal international coordination mechanism for civil space-based Earth observation, bringing together more than 60 member and associate agencies operating over 100 satellites. CEOS supports the complementarity, interoperability and sustained availability of observations through coordinated missions, analysis-ready and harmonised datasets, open-data policies, common standards, guidance and information products. His presentation then examined the potential contribution of EO to the 59 Belém Adaptation Indicators, focusing on indicators related to water, agriculture, ecosystems, settlements and multi-hazard

monitoring. Figure 1 (below) linked these indicators to relevant ECVs and EO-derived variables, including precipitation, evapotranspiration, soil moisture, land cover, vegetation productivity, surface water, fire occurrence, land-surface temperature, terrestrial water storage and ocean colour. The presentation argued that EO capabilities are already mature for monitoring agricultural productivity, water availability and environmental change, while ecosystem assessment requires consistent time series to quantify disturbance, resistance and recovery. Settlement relocation was identified as an emerging application in which repeated high-resolution imagery can detect spatial movement relative to hazard zones. However, the presentation also stressed that adaptation applications depend on the integration of multiple datasets at different spatial scales and that socioeconomic and other place-based information remains essential, particularly at the local level where adaptation action occurs. The 2026 CEOS Chair will advance this agenda through two products: an ESA-led edition of the Earth Observation Handbook focused on adaptation and resilience, supported by global case studies; and an inward-facing white paper examining where satellite EO can have the greatest impact, the principal bottlenecks to operational uptake, and how CEOS can better support adaptation decision-making from global to local scales. The second product will draw on the experience of CEOS entities and a survey of member agencies to formulate recommendations for discussion by CEOS Principals.

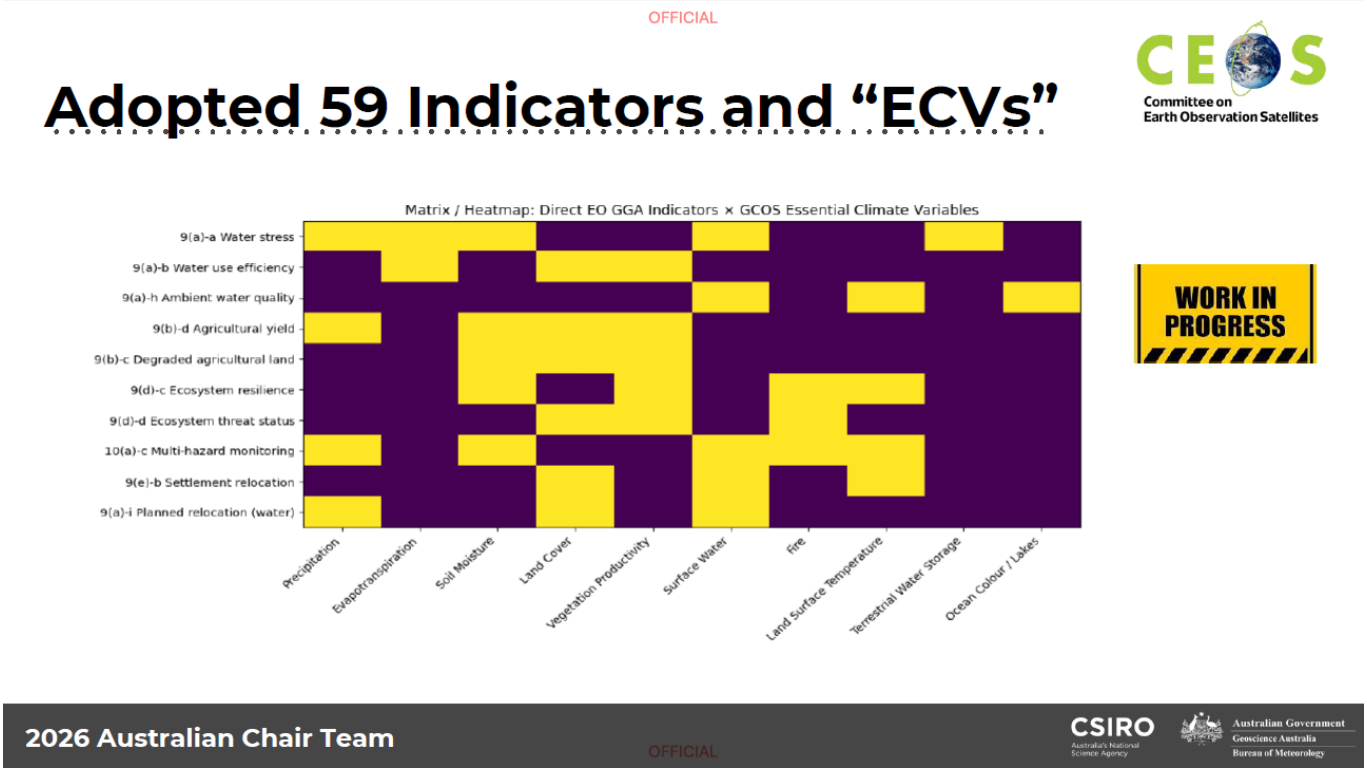


Figure 1. Preliminary matrix linking selected adopted Belém Adaptation Indicators to relevant GCOS Essential Climate Variables (ECVs). Yellow cells identify the ECVs considered potentially relevant to the derivation or assessment of each indicator.

Presentation references and related links

- Connors, S., Schneider, R., Nalau, J., et al. (2025). Earth observations for climate adaptation: tracking progress towards the Global Goal on Adaptation through satellite-derived indicators. npj Climate and Atmospheric Science, 8, 359. https://doi.org/10.1038/s41612-025-01251-1
- UNFCCC (2026). Global Goal on Adaptation. Decision 12/CMA.7, including the Belém Adaptation Indicators. FCCC/PA/CMA/2025/19/Add.2. https://unfccc.int/sites/default/files/resource/cma2025_19_a02.pdf
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- European Commission (2021). EU Adaptation Strategy. https://climate.ec.europa.eu/areas-action/adaptation-and-resilience-climate-change/eu-adaptation-strategy_en
- CEOS. CEOS and the UNFCCC Global Stocktake. https://ceos.org/gst/

- GCOS. Essential Climate Variables: ECV catalogue. https://gcos.wmo.int/site/global-climate-observing-system-gcos/essential-climate-variables
- CEOS and CGMS. Essential Climate Variables Inventory. https://climatemonitoring.info/ecvinventory/
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Session 2: Introduction to Climate Adaptation and the UNFCCC's Global Goal on Adaptation – Policy Context

Chair: Susanne Mecklenburg (ESA)

Maryam Navi (UNFCCC): Global Goal on Adaptation - From the Paris Agreement to Belém

Maryam Navi, Team Lead for the Global Goal on Adaptation within the UNFCCC Adaptation Division, traced the institutional and negotiating evolution of the GGA, from its establishment under Article 7.1 of the Paris Agreement in 2015 to the adoption of the 59 Belém Adaptation Indicators at the Conference of the Parties serving as the meeting of the parties to the Paris Agreement (the "CMA") in 2025 (CMA 7). She explained that the UAE Framework for Global Climate Resilience, adopted at CMA 5 in 2023, provides the structure for assessing collective progress towards the GGA through seven thematic targets—water and sanitation; food and agriculture; health; ecosystems and biodiversity; infrastructure and human settlements; poverty eradication and livelihoods; and cultural heritage—and four targets corresponding to the iterative adaptation cycle: impact, vulnerability and risk assessment; planning; implementation; and monitoring, evaluation and learning. These targets are forward-looking, with achievement envisaged by 2030 and progressively beyond.

As illustrated in Figure 2, the two-year UAE–Belém work programme combined formal mandates, technical workshops and expert meetings, moving from 67 Party and observer submissions and an initial mapping of approximately 9,000 existing indicators in 2024 to a consolidated list of 490 options in May 2025, a final expert list of 100 potential indicators in September 2025 and, ultimately, the politically agreed set of 59 indicators in November 2025. The adopted framework comprises 36 thematic indicators and 23 indicators relating to the four dimensions of the adaptation cycle.

Navi stressed that adoption of the indicator list does not complete the technical process. The indicators remain voluntary, country-driven and sensitive to national circumstances, while their metadata, methodologies, disaggregation, aggregation and reporting guidance still require further development. This work will proceed under the Belém–Addis Vision on Adaptation, including technical work requested for consideration at CMA 9 in November 2027 and the establishment of a technical task force to contribute to this process.

She then situated the indicators within the Baku Adaptation Road Map (BAR), launched at CMA 6 to advance progress towards GGA, improve coherence across the UNFCCC adaptation architecture, aligning adaptation action with adequate adaptation responses in the context of the temperature goal of the Paris Agreement, enhance knowledge-sharing and ensure access to finance, technology transfer and capacity-building. The first phase of the BAR, covering 2026–2028, provides for two workshops per year, a technical paper prepared by the secretariat and Party submissions concerning the focus of the Road Map’s workshops.

The presentation concluded by outlining issues under discussion at the Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation meeting (SB 64), including the follow up to the tripling of adaptation finance by 2035 in the context of NCQG, the technical work required to operationalise the indicators, the Baku Adaptation Road Map, and the development, during 2026–2027, of terms of reference for reviewing the UAE Framework. The overall message was that the indicator framework has been politically agreed, but its consistent application across Parties will partly depend on the development of methodological guidance, technical support and testing, as well as its alignment with national planning and reporting systems.

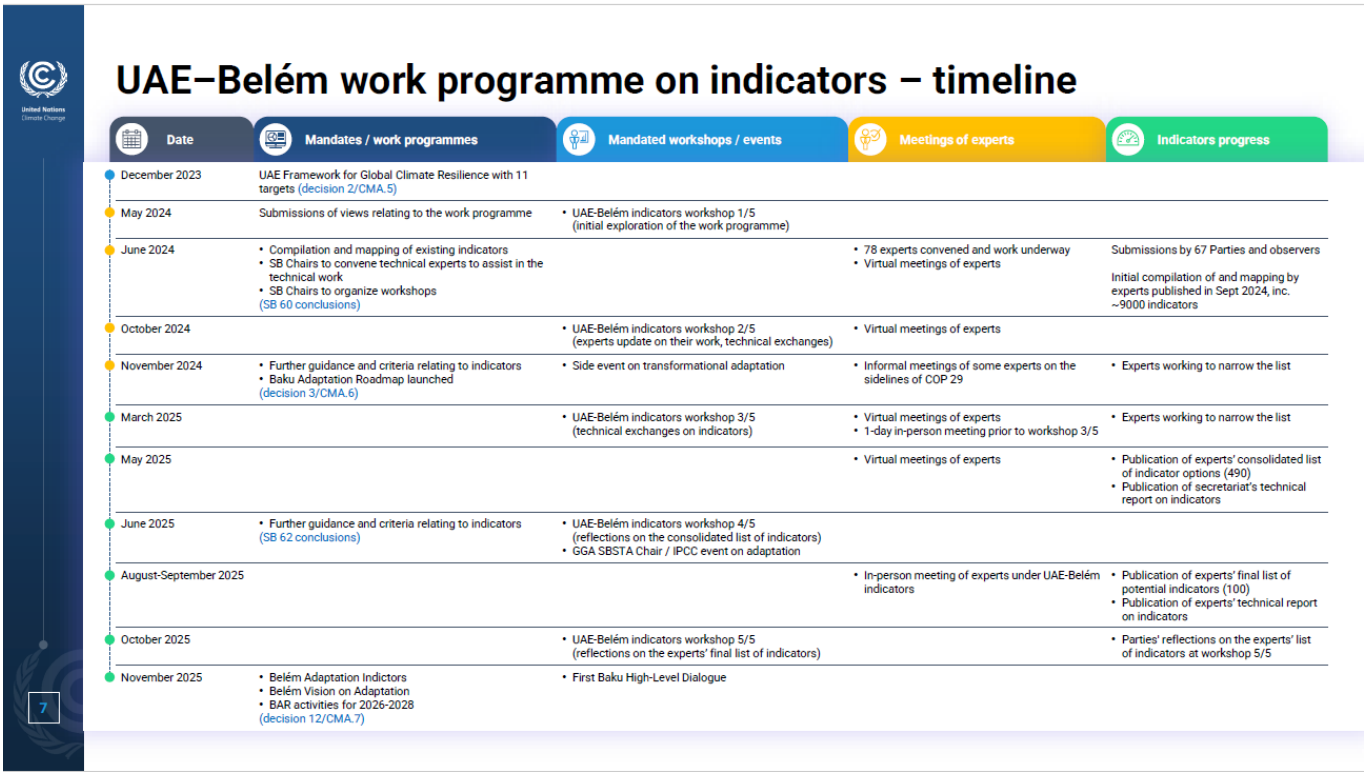


Figure 2. Timeline of the UAE–Belém work programme on indicators, showing the principal mandates, technical workshops, expert meetings and milestones leading to the adoption of the Belém Adaptation Indicators in November 2025.

Presentation references and related links

- UNFCCC (2026). Global Goal on Adaptation. Decision 12/CMA.7, including the Belém Adaptation Indicators. FCCC/PA/CMA/2025/19/Add.2. https://unfccc.int/sites/default/files/resource/cma2025_19_a02.pdf
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- UNFCCC (2023). Global Goal on Adaptation. Decision 2/CMA.5: UAE Framework for Global Climate Resilience. https://unfccc.int/sites/default/files/resource/cma2023_16a01E.pdf
- UNFCCC (2024). Global Goal on Adaptation. Decision 3/CMA.6: UAE–Belém work programme and Baku Adaptation Road Map. https://unfccc.int/sites/default/files/resource/cma2024_17a01E.pdf
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- UNFCCC Expert Group (2025). Technical report on indicators for measuring progress achieved towards the targets referred to in paragraphs 9–10 of decision 2/CMA.5. 8 September 2025. https://unfccc.int/documents/649630
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Elena Saggioro (EC DG CLIMA): European Integrated Framework for Climate Resilience: Role of Climate Risk and Adaptation Monitoring and Earth Observation

Elena Saggioro, Policy Officer in the Adaptation Unit of the European Commission's Directorate-General for Climate Action (DG CLIMA), described how climate adaptation is becoming increasingly integrated into European policy through the forthcoming European Integrated Framework for Climate Resilience, expected by the end of 2026. Announced as the 'European Climate Adaptation Plan' in the Commission's Political Guidelines for 2024-2029, the initiative was being developed as an all-of-Commission policy package intended to strengthen climate resilience across the European Union, its Member States and economic sectors. The package under consideration comprised a Commission communication and a legislative proposal, accompanied by an impact assessment and a Digital European Climate Viewer. At the time of the workshop, these elements remained under development and should therefore not be interpreted as adopted legislation.

Saggioro situated the initiative within the evolution of EU adaptation policy, from the 2013 EU Adaptation Strategy and the launch of Climate-ADAPT to the reporting requirements introduced by the 2018 Governance Regulation, the renewed 2021 EU Adaptation Strategy, the European Climate Law and the EU Mission on Adaptation to Climate Change. This policy evolution has increasingly shifted attention from improving knowledge of climate change towards establishing responsibility for managing climate risks and systematically assessing whether adaptation action is producing measurable resilience gains.

The envisaged framework would connect a common temperature reference trajectory with European, national and sectoral risk assessments, clearer identification of risk owners and the integration of 'climate resilience by design' into decision-making. As illustrated in Figure 3, these elements are intended to support the transition from common climate-risk information to enhanced readiness and adaptation action, followed by the systematic tracking of progress. The framework would also address several cross-cutting dimensions, including digital tools, support for local action, finance and insurance, competitiveness and security, just resilience, and transnational and sectoral considerations. A central objective would be to move from risk information to enhanced readiness and action and, ultimately, to systematic tracking of progress.

Monitoring, reporting, evaluation and learning were presented as potential components of the legislative proposal. Saggioro distinguished three complementary objects of measurement: risk indicators, covering climate hazards, exposure, vulnerability and impacts; output indicators, covering governance arrangements, implemented actions, investments and enabling conditions; and outcome indicators, intended to assess the effects of adaptation measures and the resilience gains achieved. This distinction is important because a reduction in observed impacts cannot automatically be attributed to an adaptation measure, while the completion of an activity or investment does not necessarily demonstrate improved resilience.

The presentation also identified questions of scale and harmonisation. EU-level indicators are needed to track collective adaptation progress, but Member States operate different national climate-resilience monitoring systems. Further work is therefore required to determine whether and how national systems should be harmonised while respecting differences in risks, sectors, capacities and data availability. Indicators must also support a cross-sectoral understanding of resilience rather than treating individual sectors and hazards in isolation.

Earth observation, particularly through the Copernicus services, was presented as an important component of this monitoring architecture. EO already supports the prevention, preparedness, response and recovery

phases of the disaster-management cycle. Yet, EO cannot provide a complete adaptation-monitoring system on its own. Governance quality, investments, enabling conditions, social vulnerability and the attribution of resilience gains generally require administrative, financial, socioeconomic and in situ information. Priorities therefore include filling gaps in observational coverage, especially in situ coverage; integrating EO more effectively with national systems; improving the assessment of adaptation outcomes; exploiting AI-enhanced analytics; and embedding EO-derived information directly into the planning tools used by local authorities, insurers and infrastructure operators.

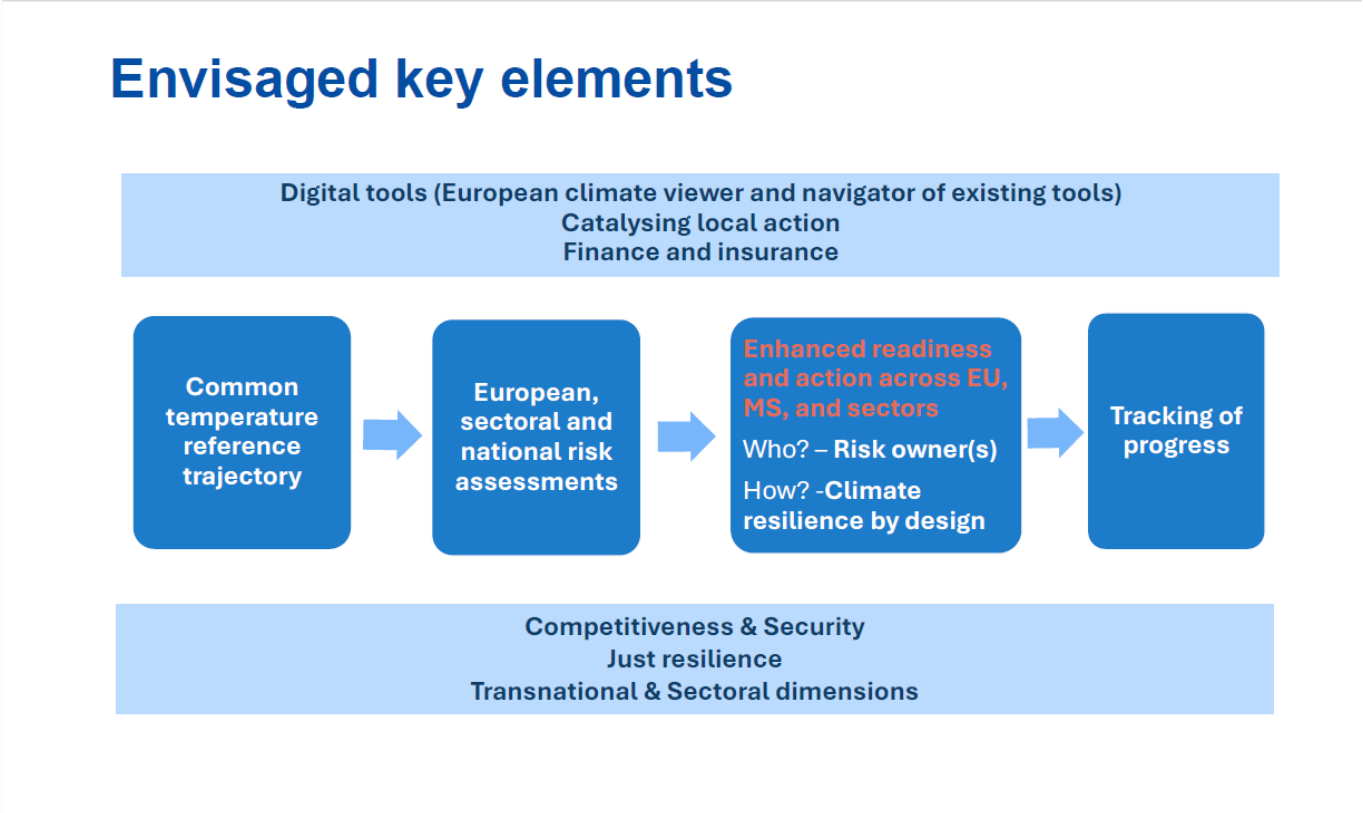


Figure 3. Envisaged key elements of the forthcoming European Integrated Framework for Climate Resilience, linking common climate-risk information and risk assessments to enhanced readiness, adaptation action and the tracking of progress.

Presentation references and related links

- European Commission (2021). EU Adaptation Strategy. https://climate.ec.europa.eu/areas-action/adaptation-and-resilience-climate-change/eu-adaptation-strategy_en
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Karina von Schuckmann (Mercator Ocean International): Unpacking the 59 GGA indicators

Karina von Schuckmann, Senior Advisor for Ocean Science for Policy at Mercator Ocean International and one of the technical experts convened under the UAE-Belém work programme, delivered the workshop's most detailed indicator-level examination of the Belém Adaptation Indicators. Drawing on FCCC/PA/CMA/2025/L.25, von Schuckmann emphasised that the indicators are voluntary, non-prescriptive knowledge products intended to inform nationally determined approaches to adaptation tracking and to constitute a source of input to future Global Stocktakes. They do not create new obligations, universal benchmarks, standardised methodologies, mandatory data-collection processes or compliance mechanisms. Parties are encouraged to test them at their discretion, while the Belém-Addis vision on adaptation provides a two-year policy-alignment and technical process for developing operational guidance, metadata, methods and data standards. The indicators are scheduled for review after the second Global Stocktake in 2029.

Von Schuckmann also stressed the importance of contextualisation. The framework permits indicators to be disaggregated according to social categories; climate-related hazards; geographical characteristics; ecosystem types; administrative and settlement levels; types of adaptation measures; thematic sectors; and subcomponents of the thematic targets. This flexibility is fundamental because similar indicator values can represent different adaptation realities depending on exposure, vulnerability, institutional capacity and national priorities.

EO can contribute at several different levels. In some cases, it can provide a relatively direct biophysical measurement, such as surface-water extent, land condition, crop condition, ecosystem extent, disturbance or inundation. In others it contributes an essential input to a model-derived quantity, such as water stress, yield, exposure, risk or ecosystem resilience. For many indicators - particularly those concerning service access, equity, governance, finance, knowledge, participation, institutional capacity and causal attribution - EO contribution is indirect or contextual. This distinction reinforced the discussion's broader message that no single source of information can support adaptation monitoring comprehensively.

The presentation examined indicator 9(d)(c), 'Level of resilience of ecosystems', as a concrete example of the gap between political wording and technical operationalisation. The experts' spreadsheet had proposed the Bioclimatic Ecosystem Resilience Index (BERI) as one possible methodology and supplied rationale, possible links to other GGA targets and disaggregation by ecosystem type and geography. However, the adopted indicator retained broad wording and did not adopt the proposed metadata. This example showed both the value of the experts' technical work and the methodological choices that remain open.

Von Schuckmann concluded that the adopted list creates a substantial opportunity for the EO community, but only within a multi- and transdisciplinary evidence system. As illustrated in Figure 4, EO can support different stages of the adaptation process, from the assessment of hazards, exposure and vulnerability to the planning and implementation of adaptation responses and the monitoring and evaluation of their effects. Existing EO products, indicators and operational services can be demonstrated against specific GGA

needs; research can reduce uncertainties and address cross-sectoral questions; and new products can be designed around the information requirements of adaptation practitioners. Drawing on Connors et al. (2025), she argued for standardised, operational EO-based adaptation indicators while cautioning against overstating what satellite observations alone can establish, especially for social outcomes, implementation quality and adaptation effectiveness.

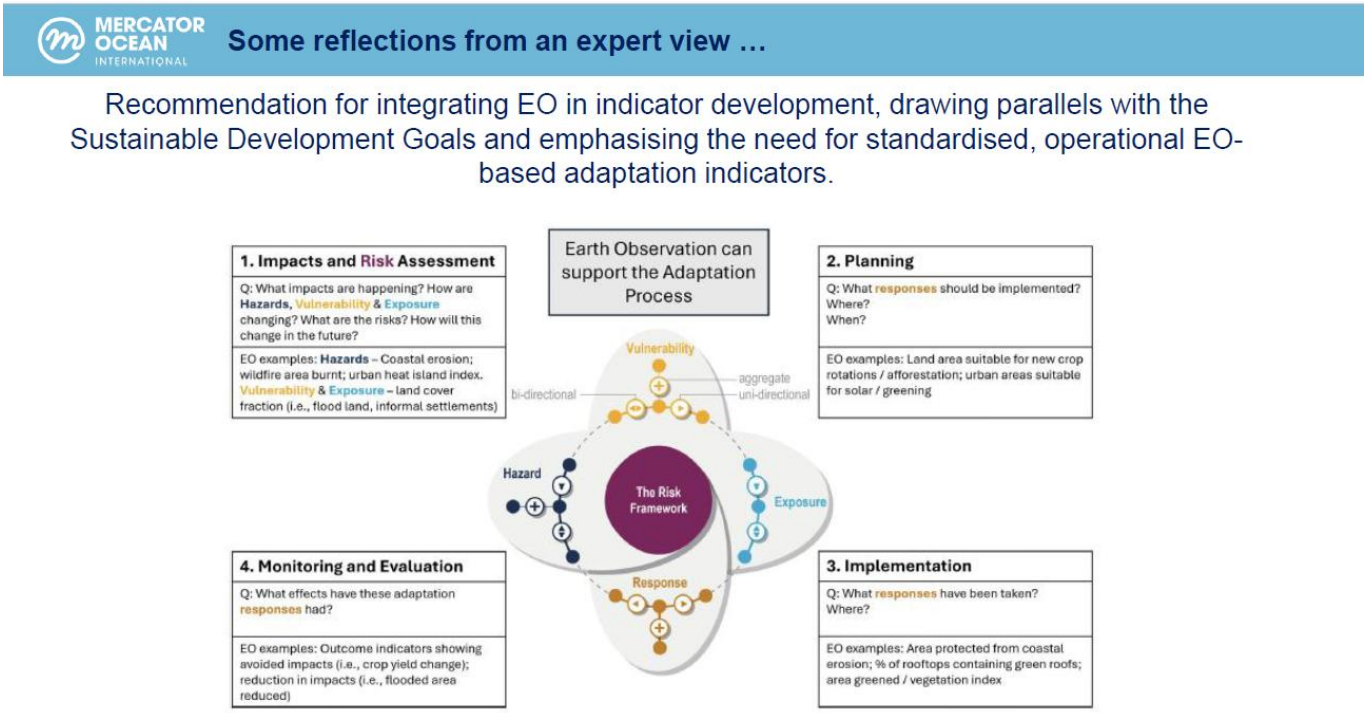


Figure 4: Example contributions of Earth observation across the adaptation cycle, including climate-risk assessment, planning, implementation, and monitoring and evaluation.

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- Mercator Ocean International. Karina von Schuckmann: Petersen Excellence Professorship for research on ocean warming. https://www.mercator-ocean.eu/news-en/dr-karina-von-schuckmann-receives-petersen-excellence-professorship-for-pioneering-research-on-ocean-warming/

Sarah Connors (ESA): Framing EO Science capabilities

Sarah Connors, Climate Applications Scientist at the European Space Agency (ESA), presented some of the scientific foundation underpinning the aims of the workshop and framed the capabilities of satellite Earth observation (EO) for climate-adaptation monitoring.

Connors first outlined the distinctive strengths of satellite EO. These include objective and quality-controlled measurements, repeatability across time and place, coverage from local to near-global scales, continuity and archives extending over several decades, open availability for major missions such as the Copernicus Sentinels, and the capacity to observe a wide range of physical, biological and chemical characteristics of the Earth system. These properties can help standardise climate-impact and adaptation statistics and address important spatial or temporal data gaps, although product fitness for a specific adaptation decision still depends on resolution, accuracy, continuity and accessibility.

As illustrated in Figure 5 and previously mentioned by other speakers, Sarah stressed that climate risk emerges through interactions among hazards, exposure and vulnerability. Adaptation responses can alter these components and the resulting risk. The framework makes clear that EO is particularly well suited to observing many environmental hazards, locations and physical changes, but that demographic conditions, economic circumstances, governance and other dimensions of vulnerability often require non-EO evidence.

The final part of the presentation linked specific EO quantities to GGA-relevant applications. Vegetation variables such as Fraction of absorbed photosynthetically active radiation (FAPAR), LAI and NDVI can support crop-yield estimation, drought monitoring, biomass assessment and the observation of agricultural practices or nature-based solutions. Thermal and atmospheric products can contribute to heat- and air-quality assessment; ocean-colour products can support water-quality and marine-ecosystem applications; river discharge and terrestrial water-storage anomalies can inform flood, drought and groundwater assessments; interferometric observations can detect ground subsidence; and land-cover products provide a cross-cutting basis for mapping change over time. The central message was therefore not that EO provides complete adaptation indicators on its own, but that it supplies consistent and often uniquely scalable evidence for selected components of climate risk and adaptation.

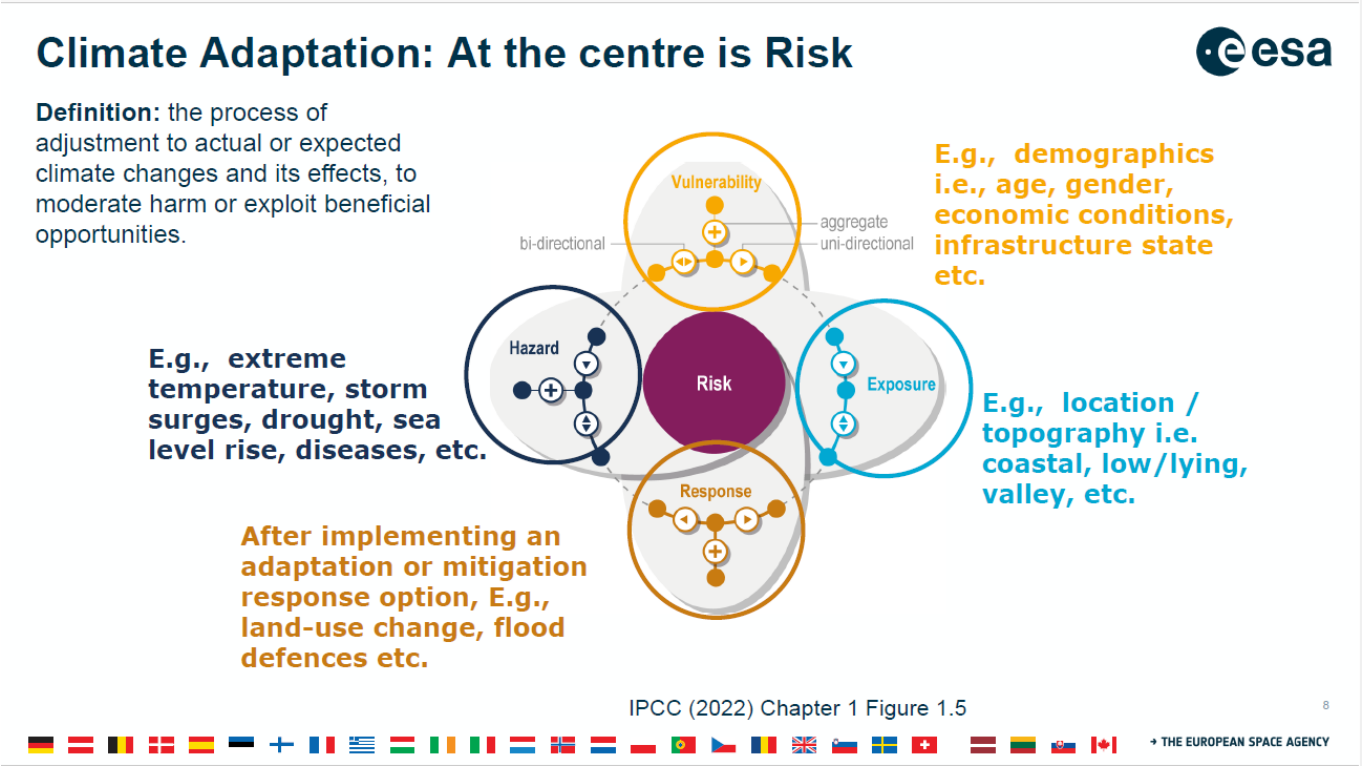


Figure 5: Risk-centred framing of climate adaptation, showing the interactions among hazard, exposure and vulnerability and the role of response options in modifying climate risk.

Presentation references and related links

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Session 3: GGA Targets, Indicators & EO Capabilities

Chair: Sarah Connors (ESA)

Mark Dowell (EC-JRC): Mapping of EO to the indicators – overview of some initial mapping

Mark Dowell, Project Leader for Scientific and Technical Support to the Copernicus Programme at the European Commission's Joint Research Centre, presented an initial structured assessment of the Earth

observation (EO) amenability of the 59 Belém Adaptation Indicators. The work was undertaken with Orestis Speyer of the National Observatory of Athens and the KCEO Team.

The assessment followed a top-down, policy-led value chain in which EO products were assessed for fitness for purpose against policy needs, rather than selected simply because data were available. The initial analysis was technology-agnostic and focused on globally available products that could provide a common basis for comparison, while recognising that they might not be valid in every national or local context. Very few GGA indicators were predominantly EO-based. More often, EO is one input among several, providing direct or partial measurements, proxies or contextual information.

The initial screening found 32 of the 59 indicators to have no *strong* EO amenability. These were mainly process-based or governance indicators, indicators of a clearly administrative or socioeconomic nature, and indicators whose definitions or methodologies were not yet sufficiently mature. Examples included climate-resilient sanitation services, mental-health support and the uptake of agricultural practices assessed through surveys. EO could still provide contextual evidence - such as hazard conditions, the location of informal settlements or environmental change - but not the principal quantity measured by those indicators.

Twenty-seven indicators were judged amenable to EO in some form. Eighteen were selected for detailed workshop discussion: four under water, two under food and agriculture, four under health, four under ecosystems, two under infrastructure and human settlements, one under poverty and livelihoods and one under cultural heritage. For the remaining nine, existing climate services and evidence systems, including C3S products, reanalysis, projections, state-of-climate assessments and the European Climate Risk Assessment, were considered capable of providing a supporting or contextual role. The results of this analysis have fed into the summary Table 1 at the beginning of this workshop report.

The shortlisted indicators illustrate the range of possible EO contributions. EO can contribute relatively directly to physical quantities such as surface-water extent, land condition, ecosystem extent, settlement footprints and hazard intensity. In other cases it supports modelling or supplies proxies, as for crop yield, ecosystem resilience, health risks and poverty. For indicators concerning relocation, adaptation programmes, health outcomes or cultural heritage, satellite information must be integrated with censuses, surveys, administrative records, inventories, in situ measurements and evidence about adaptation intent and effectiveness.

Dowell concluded by positioning the assessment as the beginning of an operational pathway rather than a definitive classification. Follow-up work would require indicator-specific roadmaps developed with Parties, awareness-building, co-design, champion users and integration into operational workflows. The workshop's interactive activity was intended to refine the reasoning, add relevant EO datasets and existing EO indicators, and identify priority candidates that could be prototyped over the following 18 months.

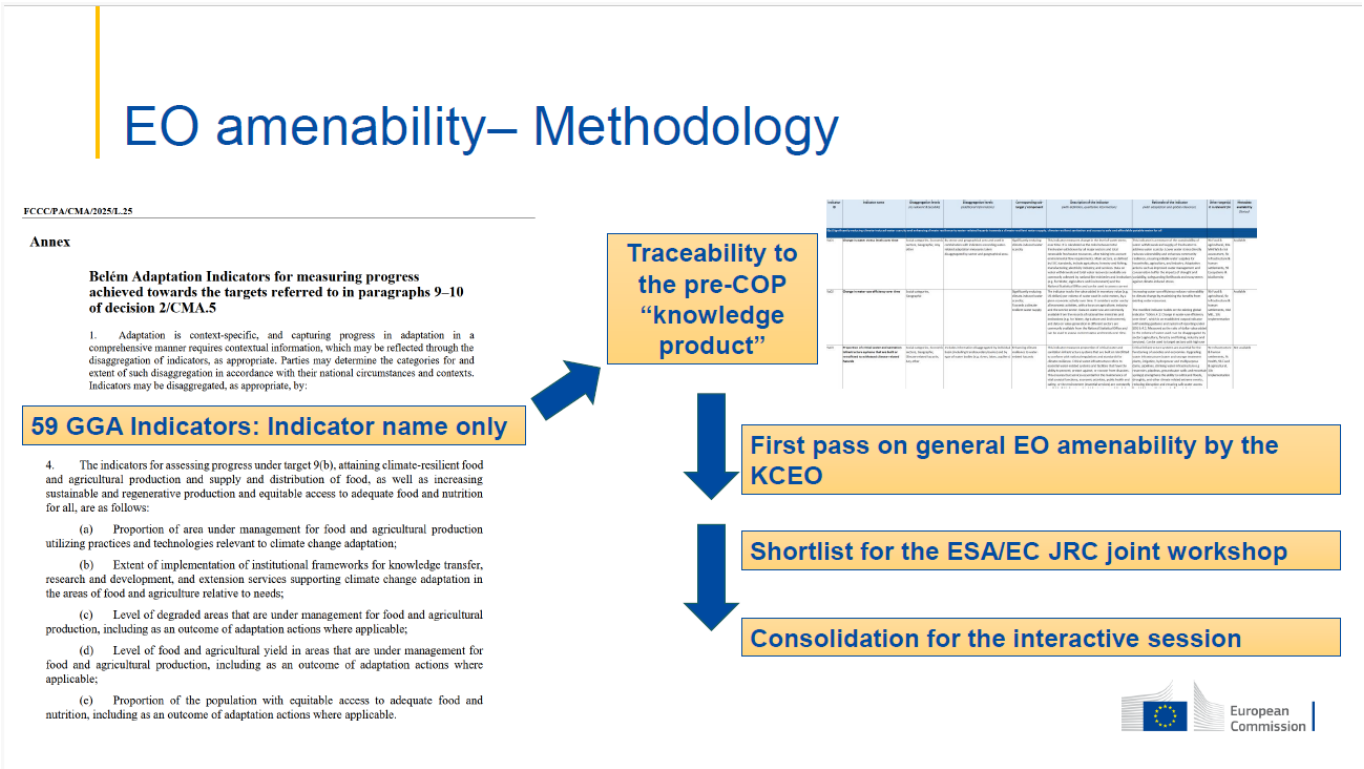


Figure 6: Top-down methodology from the KCEO team used for the initial assessment of EO amenability to the 59 adopted GGA indicators.

Presentation references and related links

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Chiara Corbari (Politecnico di Milano, ESA MICAM Project): MICAM - Monitoring the Impact of Climate Adaptation Measures in Agriculture, Forests and Cities

Justin Sheffield, Professor at the University of Southampton, presented on behalf of Chiara Corbari, the MICAM project, a research initiative designed to monitor the effects and effectiveness of climate-adaptation measures in agriculture, forests and cities. As illustrated in Figure 7, MICAM organises its adaptation indicators around three application domains—agricultural water management, sustainable forest management, and cities and urban heat islands—and maps them indicatively against the thematic and adaptation-cycle targets of the Global Goal on Adaptation (GGA). The identified indicators are intended to be quantified primarily using satellite observations, complemented by a more limited contribution from ground-based information and different modelling approaches.

The presentation began from a persistent evidence gap. Adaptation measures such as mixed-species forestry, fuel reduction, irrigation modernisation, crop diversification, new water sources, urban greening and reflective infrastructure are increasingly implemented, but their effects are difficult to evaluate consistently at scale because intervention records and long-term ground observations are sparse. EO offers objective, repeatable and spatially distributed measurements across the water, carbon and energy cycles. Nevertheless, it has more often supported risk identification and planning than the ex-post assessment of implemented adaptation. Existing climate records can also be too coarse for local interventions and cannot directly measure quantities such as groundwater extraction, governance or human health.

MICAM therefore asks whether adaptation actions implemented over roughly the past two decades have reduced climate-change impacts and whether these changes can be detected using EO. The methodological design is based on a before-and-after comparison against an EO-informed pre-adaptation baseline. Sheffield emphasised that these are project indicators under development, not adopted replacements for the Belém Adaptation Indicators. Their usefulness depends on establishing the timing and location of adaptation actions, using credible baselines and counterfactuals, validating EO-derived changes with inventories, flux towers, fire perimeters, irrigation records and socioeconomic data, and propagating uncertainty through every derived metric. MICAM therefore provides an operational research pathway for testing when observed environmental change can offer evidence of adaptation effects, while retaining the distinction between physical change, implementation and causal effectiveness.

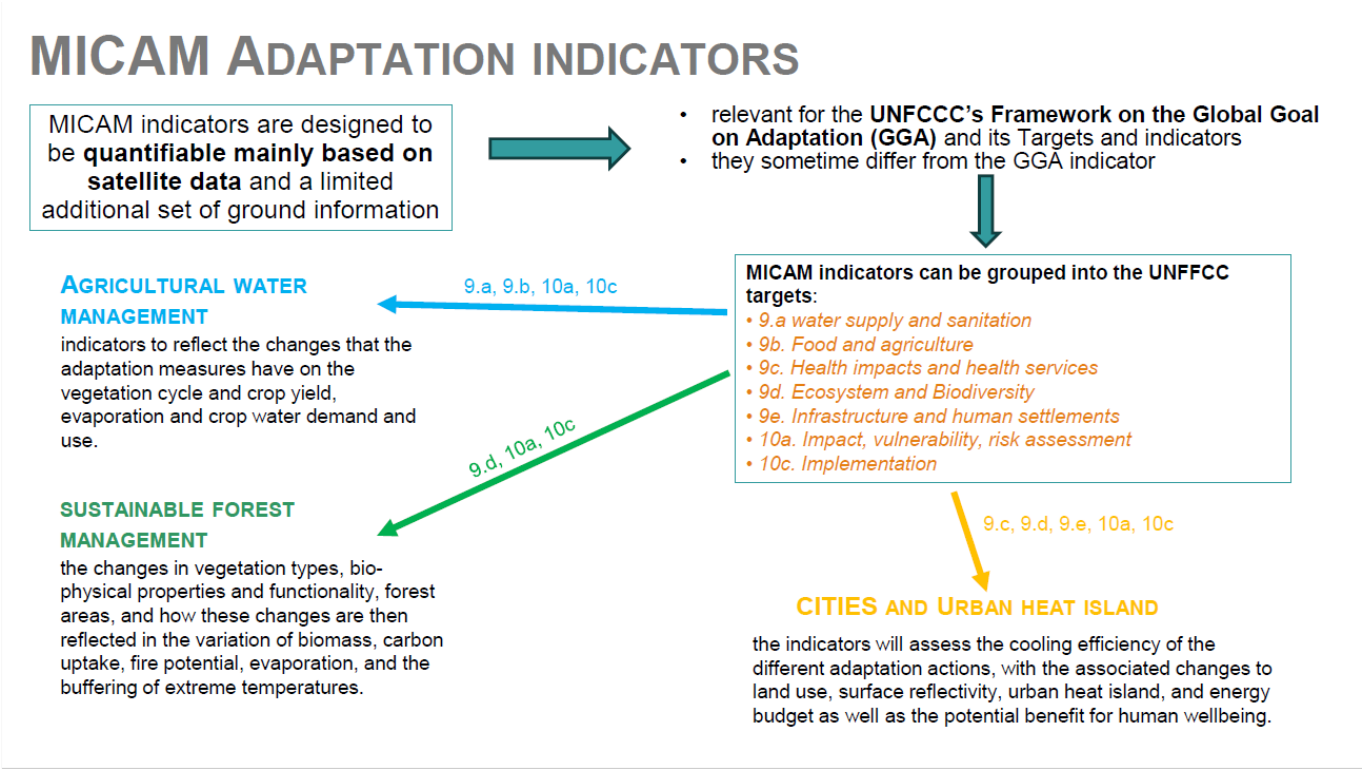


Figure 7: Overview of the MICAM adaptation-indicator framework, covering agricultural water management, sustainable forest management, and cities and urban heat islands.

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Orestis Speyer (NOA / EIFFEL Project): Water, soil and urban EO amenability and insights

Orestis Speyer, exploring the Earth Observation-Policy Interface at the National Observatory of Athens (NOA) and the Greek GEO Office, examined the practical EO amenability of selected Belém Adaptation Indicators in the water, agriculture and soil, infrastructure and human-settlement, livelihoods and cultural-heritage domains. Rather than repeating the complete 59-indicator screening, he used operational services and project applications to demonstrate how EO could contribute to actual indicator implementation while bringing out three aspects of general applicability to the workshop: the same observation should be reused/prioritised wherever it answers multiple policy needs, while adaptation evidence must remain sensitive to sectoral, national and local context, in line with the GGA axiom of adaptation being context-specific.

For water indicator 9(a)-h, on the proportion of water bodies with good ambient quality for drinking-water supply, Speyer noted the explicit connection with the Sustainable Development Goal (SDG) indicator 6.3.2 and showed that operational EO tools already exist. JRC's Global Surface Water Explorer supplies long-term information on surface-water occurrence and change; the Copernicus Land Monitoring Service provides 100 m lake-water-quality products; and the Freshwater Ecosystems Explorer, combining these two, operationalises EO-supported reporting for SDG indicator 6.6.1 on change in the extent of water-related ecosystems. These systems can delineate water bodies and retrieve selected optically observable properties, but country-defined thresholds, groundwater and pollutants that satellites cannot detect still require in situ sampling and national data.

The water example also illustrated the presentation's 'measure once, use many' principle. As shown in Figure 8, the products and sub-indicators assembled within the Freshwater Ecosystems Explorer can inform not only water quality but also parts of GGA indicator 9(a)-a on water stress (regarding the "total renewable freshwater resources“ denominator), 9(b)-c on degraded areas used for food and agricultural production (inland and marine-based aquaculture), 9(d)-a on climate-resilient ecosystems providing services and 9(d)-d on ecosystem threat status. The contribution is strongest for surface-water extent, seasonality and selected degradation signals; renewable-resource accounting, management status, ecosystem services and attribution to adaptation require hydrological, administrative, socioeconomic and in situ evidence.

For agriculture indicator 9(b)-c, Speyer highlighted the post-COP30 methodological caveat stemming from the “including as an outcome of adaptation actions where applicable” phrasing introduced in many of the GGA indicators: soil organic carbon (SOC) loss is only one of the biophysical elements proposed for assessing decline or loss of productive capacity. FAO's Global Soil Information System and ESA WORLDSOILS demonstrate pathways towards harmonised SOC information, while EIFFEL applications in Lithuania combine remote sensing, national Land Parcel Identification System data and engagement with the paying authority. One application maps bare soil, SOC, clay content and SOC stocks; another uses causal machine learning to estimate how practices such as organic farming and crop diversification affect SOC relative to conventional practices. EO can therefore support parcel-level condition and land-suitability analysis, but it does not by itself establish that land is under adaptation management or that an observed SOC difference was caused by the intervention. Still, depending on the interpretation of the “outcome” phrasing, both global and parcel-level approaches may be called for.

The urban example concerned indicator 9(e)-a, on the proportion of settlement-upgrading programmes that include adaptation measures and maintain sustained local engagement. The EIFFEL Urban Sustainability

Pilot integrates EO with building census, cadastral and statistical microdata to estimate building energy efficiency, rooftop photovoltaic potential and air-quality co-benefits from building-block to municipal scale. Speyer used this case to expose an important prerequisite on local engagement: while such outputs are primarily GHG mitigation-related, they should always be part of integrated urban policy which increasingly recognises the nexus between adaptation, mitigation and energy. Building renovation and energy performance are an exemplar of such integration where measures in one domain often lead to co-benefits in the other. Sustained engagement also requires the integration of EO workflows in existing practices such as Sustainable Energy and Climate Action Plans, Climate City Contracts, the EU Nature Restoration Regulation and relevant monitoring and evaluation obligations, ideally at the granularity level necessary. Again, the “measure once, use many” applies as the EIFFEL pilot is also relevant to the energy poverty aspect of 9(f)-a.

For cultural-heritage indicator 9(g)-a, Speyer referred to the UNESCO report “Climate Change in Mediterranean World Heritage Cities”, co-developed with the Greek GEO Office for 114 historic cities and settlements. Current hazards were compiled from site-manager and national-focal-point reporting, i.e. “guided by traditional, local or Indigenous Peoples’ knowledge”, while CMIP5/EURO-CORDEX projections under RCP8.5 were used to examine changes in multi-hazard exposure. The presentation reported that 59% of the cities already experience at least one climate hazard and that most are projected to move from one hazard to two or more, with compound effects and intensity remaining important. This tangible example of EO and the cultural heritage domain already working together, refers only to the identification of risk and support in prioritising sites, capturing the “at-risk” part of the indicator. The Belém indicator ultimately measures whether adaptation measures have been implemented and whether they enhance resilience under relevant warming scenarios; inventories, plans, local knowledge and implementation records are therefore indispensable.

Speyer's overall message was that EO amenability is not binary. Satellite observations can directly measure selected physical components, supply model inputs or spatial proxies, and provide contextual information or part of some GGA indicators. They cannot substitute for nationally determined thresholds, groundwater and pollutant sampling, realisation/documentation of certain adaptation measures or participation evidence, while the “outcome” phrasing may add even more caveats. Existing EO workflows of GGA relevance do exist, operational or at the R&D phase, and should be leveraged bearing in mind the “measure once, use many” principle and the local/national context as well as synergies with other policy activities.

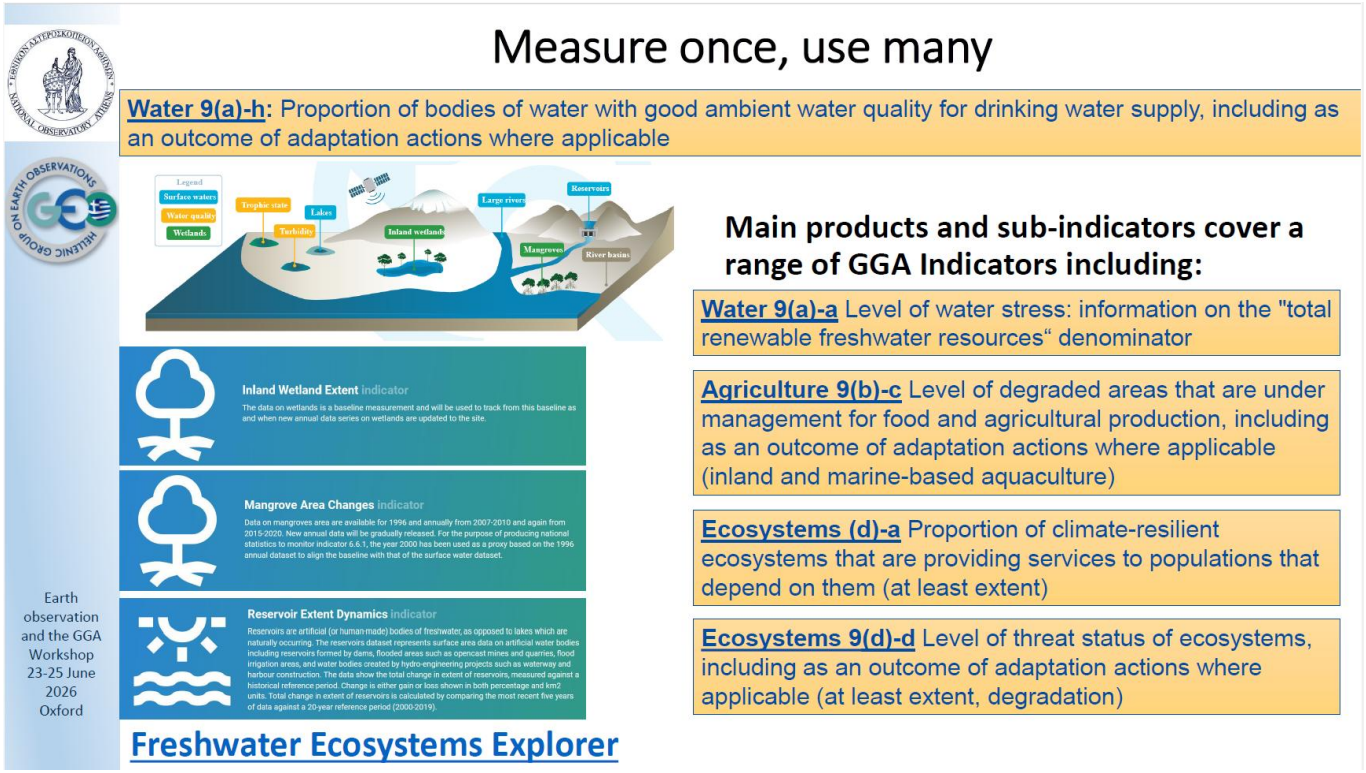


Figure 8: Illustration of the 'measure once, use many' principle.

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- GEO Knowledge Hub. EIFFEL Carbon Monitoring System for Lithuanian Soils. https://gkhub.earthobservations.org/packages/xymq1-ds129
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- GEO Knowledge Hub. Buildings: energy efficiency and renewables. https://gkhub.earthobservations.org/packages/y97kv-4w541
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- European Environment Agency and European Commission. Climate-ADAPT Step 6: Monitoring and evaluation. https://climate-adapt.eea.europa.eu/en/knowledge/tools/adaptation-support-tool/step-6-0

Thomas Kemper (EC-JRC): Using EO for specific GGA Targets: Infrastructure

Thomas Kemper, Scientific Officer in the European Commission's Disaster Risk Management Unit and Global Human Settlement Layer (GHSL) team, examined how EO can support the Belém Adaptation Indicators relating to infrastructure, human settlements, poverty and planned relocation. He presented the GHSL as a globally consistent, free and operational baseline for monitoring where people and built assets are located and how settlements change over time. The presentation tested which observable components of four adopted indicators—9(e)-a, 9(e)-b, 9(f)-a and 9(a)-i—can already be supported by EO and where national or local information remains indispensable. It also noted that indicator 9(f)-i was removed when the proposed list was reduced from 100 to 59 indicators.

As summarised in Figure 9, the mapping considered four Belém indicators in turn. For 9(e)-b, EO can monitor changes in built-up areas and transport infrastructure, delineate climate- and water-related hazards, identify potentially safer locations and detect physical abandonment or construction; however, official records are needed to verify relocation, identify the assets or populations relocated and document safety decisions. For 9(e)-a, EO can reveal physical upgrading and environmental change, but programme implementation, adaptation content and sustained local engagement require administrative and participatory evidence. For 9(f)-a, settlement morphology, population grids and deprivation proxies can support spatial analysis, while poverty must be established using socioeconomic data. For 9(a)-i, EO can map populations and water-related hazards and may corroborate physical movement, but programme records and population denominators are needed to determine how many people received support through planned relocation.

The presentation therefore framed EO amenability as component-specific rather than binary. GHSL and complementary settlement datasets can provide harmonised physical baselines, repeated change measurements and exposure denominators. They are particularly strong for built-up extent, building attributes, settlement morphology and population distribution. They cannot establish adaptation intent, sustained engagement, poverty status, receipt of relocation support or causal effectiveness on their own. Operational reporting will require EO to be integrated with hazard models, cadastral and infrastructure inventories, programme documentation, household and poverty statistics, and locally validated information. The need for national and local integration is also the principal obstacle to fully harmonised global reporting for these indicators.

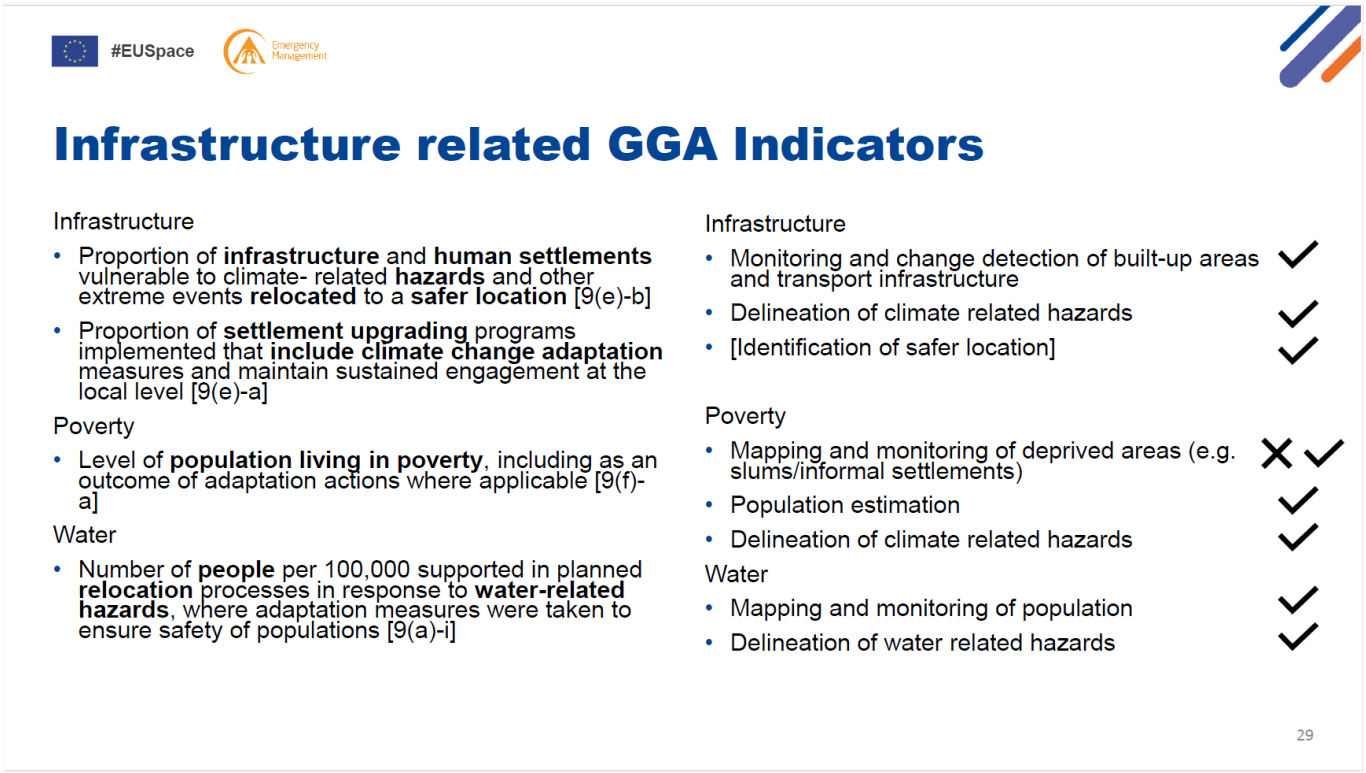


Figure 9: Indicative mapping of Earth Observation capabilities to selected Belém Adaptation Indicators related to infrastructure and human settlements, poverty and planned relocation in response to water-related hazards.

Presentation references and related links

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- European Commission Joint Research Centre. GHSL download wizard. https://human-settlement.emergency.copernicus.eu/downloadWizard.php
- European Commission Joint Research Centre. GHS-OBAT dataset record. https://data.europa.eu/89h/f41a22f1-5741-4c41-86eb-6384654f6927
- Technical University of Munich. GlobalBuildingAtlas. https://mediatum.ub.tum.de/1782307
- DLR. World Settlement Footprint suite. https://geoservice.dlr.de/web/datasets/wsf
- DLR. WSF Tracker / AI4SmartCities. https://www.dlr.de/en/eoc/research-transfer/projects-missions/ai4smartcities-ccn3

Nicolas Monzali (MEWS PARTNERS): Presentation of the Climate Adaptation Insights DestinE Demonstrator

Nicolas Monzali, Business Director at Mews Labs, on behalf ESA's Destination Earth team, presented Climate Adaptation Insights (CAI), a Destination Earth demonstrator intended to help users move from a

policy or adaptation question to relevant climate risks, indicators, datasets and visual outputs. Destination Earth Initiative (DestinE) is a flagship initiative of the European Commission that is building a highly accurate digital replica of the Earth by combining EO data, advanced climate and weather modelling, artificial intelligence, and Europe's world-class supercomputing capabilities. This demonstrator was described as an AI agentic system rather than a new observing mission or an alternative indicator framework. Its purpose is to make the path from adaptation needs to usable EO data and model information more transparent and operational.

The workflow has four steps. CAI first analyses a selected policy document to establish the geographic, temporal and thematic adaptation context. It then extracts climate risks and proposes related adaptation indicators. Next, it explores the Destination Earth data portfolio and services to identify variables and source datasets that could feed those indicators. Finally, where an indicator method and suitable data are available, it calculates and visualises the result. The interface examples showed policy-document review, hazard and indicator selection, dataset discovery, metadata inspection and map-based visualisation within one guided sequence.

For the GGA, the 18 indicators previously shortlisted by the JRC were assessed to determine whether they could be calculated using the DestinE platform. At the time of the workshop, none yet could be calculated in full; however, the demonstrator was still in the development phase. The workshop feedback will be used to improve the demonstrator's planned upgrades.

As summarised in Figure 10, several could be partially informed by data on the DestinE platform, for example, drinking-water bodies, degraded agricultural areas, agricultural yield, climate-sensitive infectious-disease incidence, ecosystem resilience, relocation of vulnerable infrastructure and settlements, and adaptation of at-risk cultural and natural heritage.

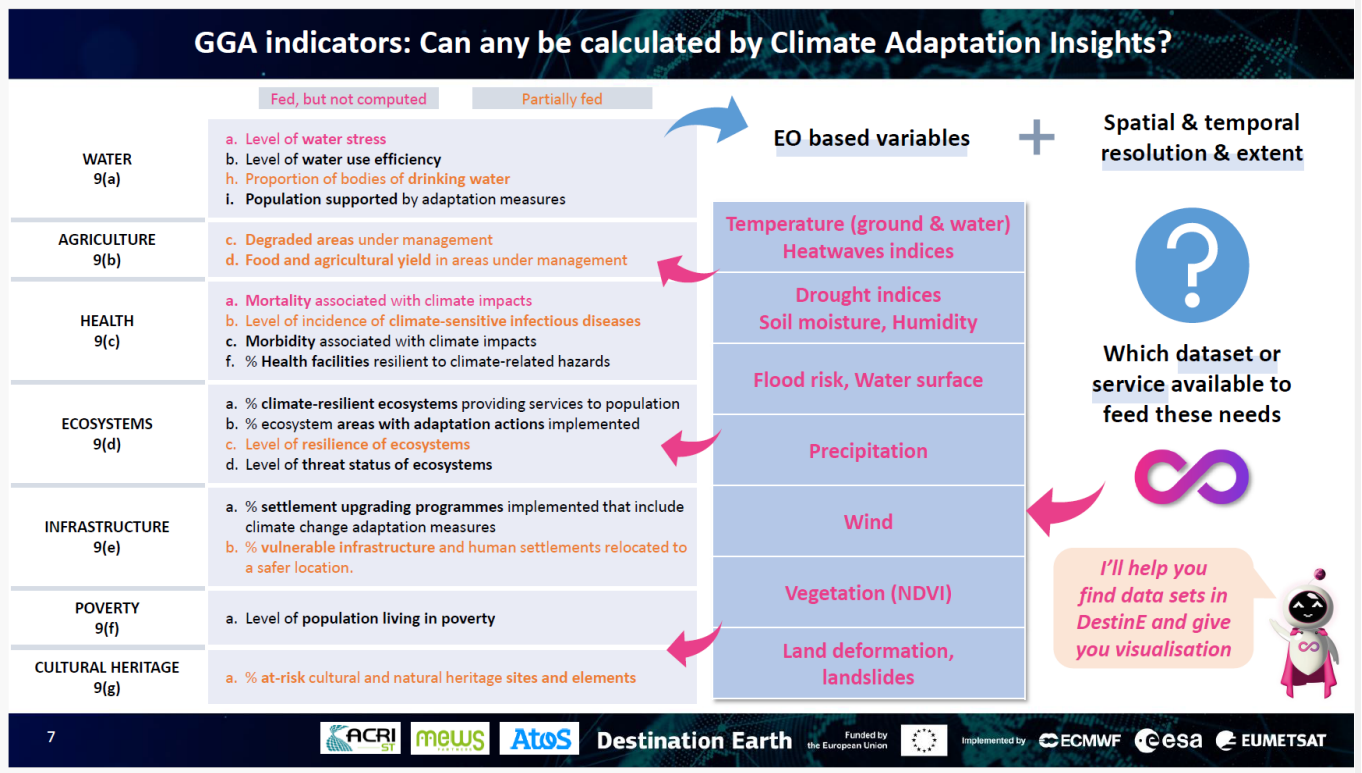


Figure 10: Indicative mapping implemented in the Climate Adaptation Insights demonstrator between the 18 Belém Adaptation Indicators shortlisted for workshop discussion and candidate EO- and model-based variables.

Presentation references and related links

- UNFCCC (2026). Global Goal on Adaptation. Decision 12/CMA.7, including the Belém Adaptation Indicators. FCCC/PA/CMA/2025/19/Add.2. https://unfccc.int/sites/default/files/resource/cma2025_19_a02.pdf
- European Commission. Destination Earth: initiative overview. https://destination-earth.eu/destination-earth/
- Destination Earth. Machine-learning demonstrators. https://destination-earth.eu/procurement/destination-earth-machine-learning-demonstrators/
- Destination Earth. DestinE Platform. https://platform.destine.eu/
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- Destination Earth. Destination Earth Data Lake. https://data.destination-earth.eu/
- Destination Earth. DestinE Data Portfolio. https://data.destination-earth.eu/data-portfolio
- Destination Earth. Destination Earth Data Lake documentation. https://destine-data-lake-docs.data.destination-earth.eu/en/latest/index.html
- Destination Earth. DestinE Data Portfolio documentation. https://destine-data-lake-docs.data.destination-earth.eu/en/latest/dedl-discovery-and-data-access/DestinE-Data-Portfolio/DestinE-Data-Portfolio.html

Session 4: Compiling Indicators – lessons learned from past practice & indicator mapping on the national level

Chair: Mark Dowell (EC-JRC)

Julie Berckmans (EEA): From data to decisions: lessons learned from EEA indicator practice

Julie Berckmans, Climate Risk and Resilience Expert at the European Environment Agency (EEA), presented practical lessons from the European Environment Agency's work at the science-policy interface, focusing on how data are converted into indicators, assessments and decision-support tools for climate adaptation. As shown in Figure 11, the activities of the EEA Climate Risk and Resilience Unit span five interconnected areas: assessing climate risks, documenting impacts, supporting resilience, informing adaptation policy and maintaining European knowledge portals. These areas include the European Climate Risk Assessment and Climate Data Explorer, economic-loss and climate-and-health work, sectoral and just-resilience activities, adaptation-policy reporting and platforms.

A first cross-cutting issue was access to observational data, particularly in situ data. The EEA supports a EuroGEO initiative intended to accelerate implementation of GEO data-sharing and data-management principles for adaptation-relevant observations and to improve the accessibility and integration of in situ and socioeconomic data for the EU Adaptation Strategy, the Mission on Adaptation and Destination Earth. Expected benefits include a clearer understanding of observing-system gaps, improved data-access and licensing arrangements, better local-scale information on adaptation measures and indicators, and stronger national and global datasets on losses and fatalities. Berckmans stressed that large amounts of project-generated information remain fragmented or unavailable, limiting indicator comparability and operational reuse. She then presented selected examples of where satellite-based EO does and does not contribute to indicators compiled by the agency.

The longest-running example was EEA's indicator on economic losses from weather- and climate-related extremes, first used in an EEA climate-risk and vulnerability report in 2012 and now updated annually with an accompanying dashboard. For the EU-27 over 1980-2024, the presentation reported approximately EUR 822 billion in losses and 441,000 fatalities, with exceptionally high annual losses associated with

floods, fires, droughts and heatwaves during 2021-2024. The indicator is policy-relevant for EU Sustainable Development Goal and Eighth Environment Action Programme monitoring, but it is not a direct EO product: monetary losses and fatalities originate in event and impact databases, while hazard observations, Copernicus products and socioeconomic statistics can improve event characterisation, completeness and comparability. An Eionet survey of national loss inventories also revealed variation in hazard classifications, institutional maturity, data sources and reporting practices, supporting the case for harmonised standards and greater integration with Copernicus and the Disaster Risk Management Knowledge Centre.

The European Climate Data Explorer illustrates a different form of operational practice. It provides spatially consistent climate indicators based on bias-adjusted EURO-CORDEX simulations and ERA5 reanalysis, with common reference periods, future periods and emissions scenarios. The presentation highlighted river discharge, runoff, aridity, drought magnitude and drought duration, with access at European, national and sub-national scales. These are derived climate and hydrological indicators rather than solely via direct satellite measurements; their value lies in standardised processing, documented assumptions, regular updates and a common interface that makes climate information usable across adaptation contexts.

For urban and regional adaptation, EEA is testing how artificial intelligence can extract structured and quantifiable information from textual reporting. Mission on Adaptation case studies are collected through a scraper and input adapter, processed through large-language-model extraction and then validated before being consolidated into an EU-wide database and dashboard of implemented measures. The intended outputs could include the type of measure, cost and implementation time. This workflow addresses an important evidence gap because physical change alone cannot reveal what cities implemented, why they acted or how an intervention was governed. It also shows why automated extraction must remain subject to validation and why future collaboration with EO-based evaluation of adaptation effectiveness should preserve the distinction between implementation evidence and outcome attribution.

Berckmans concluded with the Climate-ADAPT dashboard on measuring progress towards climate resilience. Its database brings together more than 1,000 indicators already used across adaptation frameworks and organises them through a risk-response-result classification to help public authorities select indicators suited to their objectives.

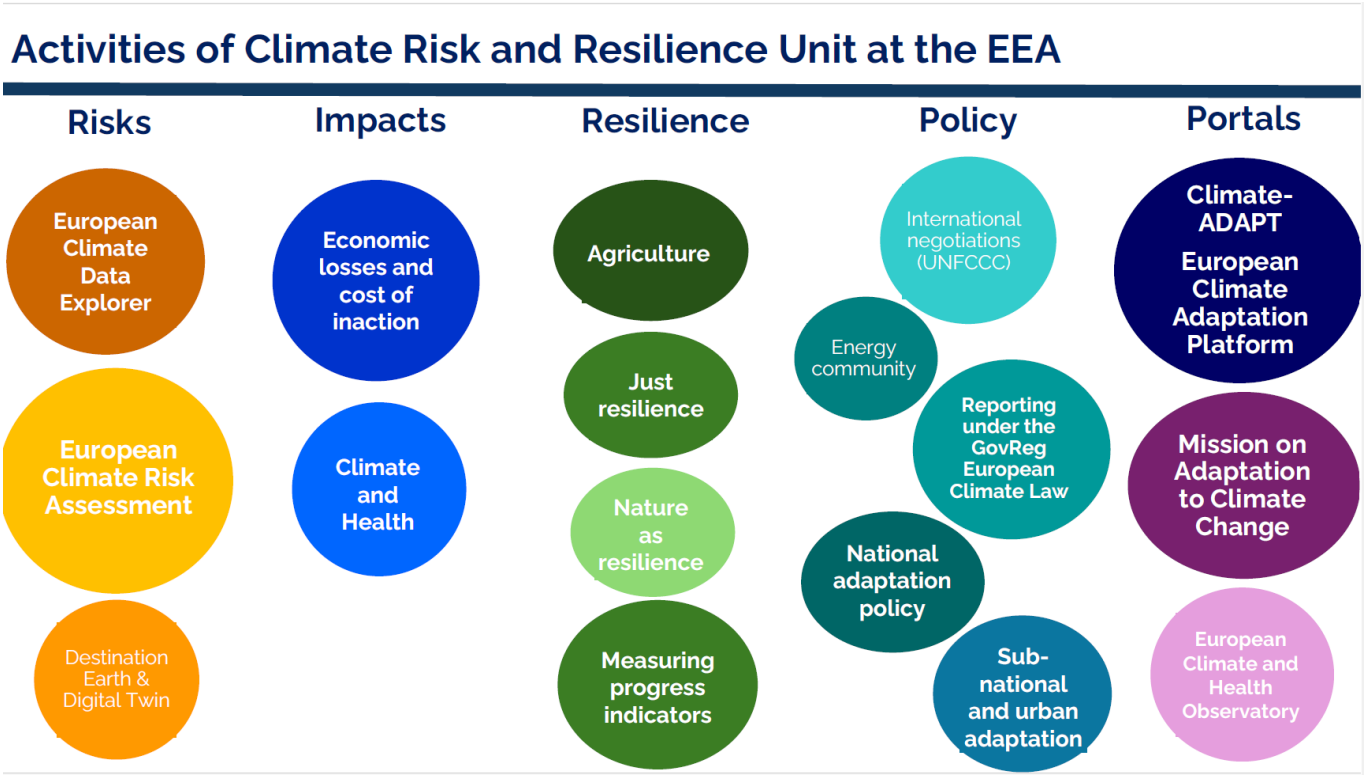


Figure 11: Overview of the activities of the European Environment Agency Climate Risk and Resilience Unit organised across five interconnected areas: climate risks, impacts, resilience, adaptation policy and European knowledge portals.

Presentation references and related links

- European Environment Agency. Economic losses from weather- and climate-related extremes in Europe. https://www.eea.europa.eu/en/analysis/indicators/economic-losses-from-climate-related
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- European Environment Agency (2024). Measuring progress towards climate resilience. https://climate-adapt.eea.europa.eu/en/knowledge/tools/measuring-progress-towards-climate-resilience
- European Environment Agency (2024). Urban adaptation in Europe: what works? https://www.eea.europa.eu/en/analysis/publications/urban-adaptation-in-europe-what-works
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- European Environment Agency and European Commission. EU Mission on Adaptation portal. https://climate-adapt.eea.europa.eu/en/eu-policy/eu-adaptation-policy/eu-mission-on-adaptation
- European Environment Agency. School heatwaves dashboard. https://tableau-public.discomap.eea.europa.eu/views/SchoolHeatWavesEurogeo_V2_1/ProbabilityMap/44519e74-4a61-433b-85bd-5ef02dcf1856/e88e31d7-9e6a-482f-8f3e-2c8ddb0a580c

Giuseppe Ottavianelli (ESA): StatEO: Report from the ESA StatEO conference

Giuseppe Ottavianelli, Head of the Applications Section in ESA's Earth Observation Programmes (EOP) Directorate, presented lessons emerging from ESA's Earth Observation for Official Statistics (StatEO) initiative, focusing on the conditions required for the successful adoption of Earth Observation within institutional and policy workflows.

The presentation placed end-user consultation and co-development at the start of this alignment process. Policy owners, regulators, statistical and environmental authorities, implementers, certifiers, funding bodies, expert networks and civil society may require different forms of evidence and operate under different constraints. StatEO26 was presented as a forum for connecting these communities. The event aimed to identify gaps in the adoption of EO for official statistics and translate them into actionable recommendations for ESA and its partners. The key takeaways were:

- A coordination framework is urgently needed between institutions working on official statistics and EO, moving from ad-hoc collaboration to a structured approach based on long-term planning and political commitment.
- EO quality metrics must be aligned with statistical standards to ensure transparency and compliance with official-statistics principles throughout the data value chain.
- Workflows from EO data to statistics-ready outputs remain fragmented and should be harmonised end-to-end. Adhering to FAIR principles is key to lowering barriers for statistical offices.
- Invest in training with lasting impact to close skills gaps and align EO solutions with operational needs.
- Maintain the event's momentum and direct future investment towards last-mile applications, turning pilots into certified operational production lines supported by reliable long-term infrastructure.

Ottavianelli identified recurring barriers to uptake: fragmented collaboration and workflows, insufficient long-term coordination, skills gaps, misalignment between EO quality metrics and official-statistics standards, limited interoperability and difficulty moving from pilots to certified operational production. The recommended response combines institutional coordination and political commitment with harmonised end-to-end workflows, FAIR data practice, transparent quality and uncertainty information, durable capacity development and investment in last-mile applications and reliable infrastructure.

As illustrated in Figure 12, the proposed path to data adoption and usability is cumulative. It starts with end-user consultation and requirements consolidation, advances through prototypes and large-scale demonstrations in which EO is integrated with other information, and then depends on EO-industry best practice, communities of practice and capacity development. Sustained technical support and direct user stewardship are needed before solutions reach full operational uptake, commercial service provision and direct stakeholder investment. The sequence makes clear that a successful prototype is an intermediate milestone rather than evidence of institutional adoption.

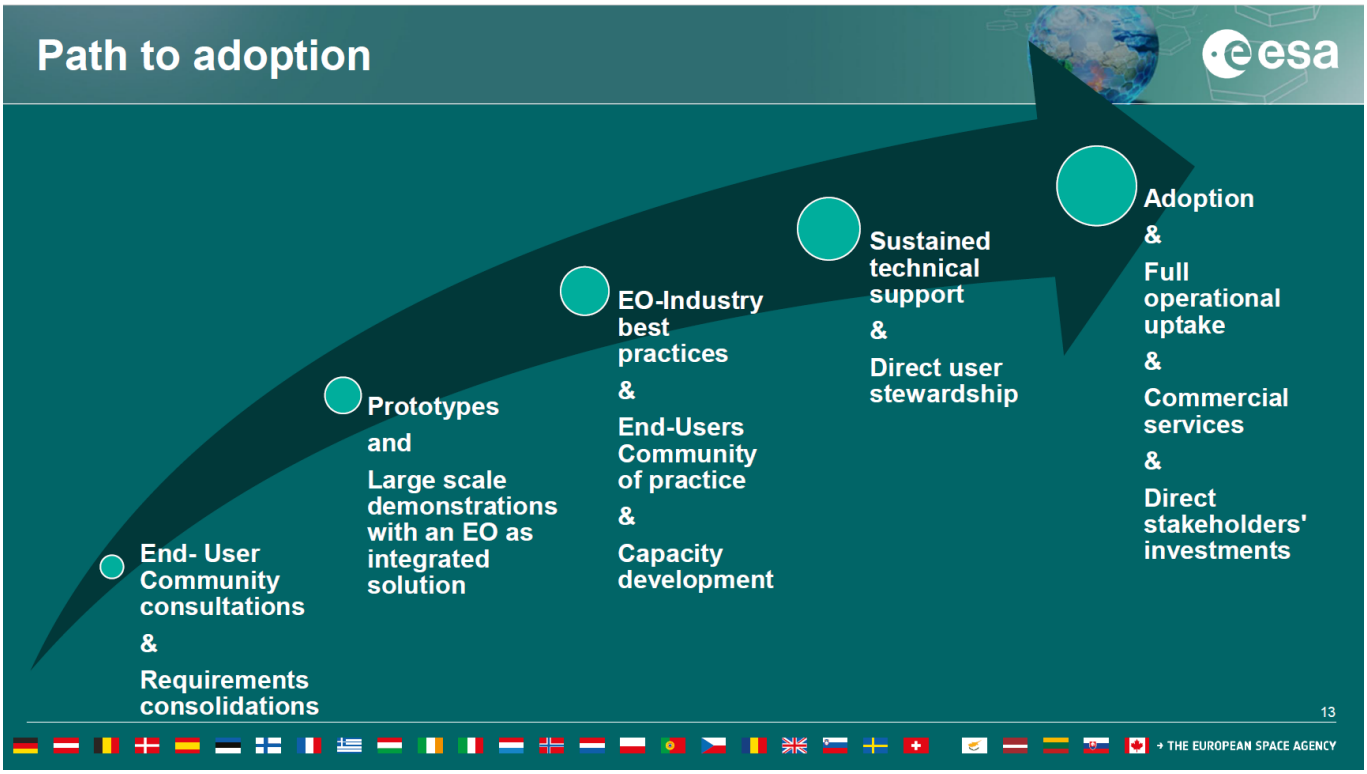


Figure 12: ESA pathway from end-user consultation and EO-integrated demonstrations to communities of practice, sustained support and full operational uptake.

Presentation references and related links

- European Space Agency (2026). StatEO26: Earth Observation for Official Statistics. Event overview. https://eo4society.esa.int/event/stateo26/
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- European Space Agency. Stakeholder Engagement Facility: Official Statistics. https://sef.apex.esa.int/en/key-themes/official-statistics
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- European Space Agency. URBIS24. https://eo4society.esa.int/event/urbis24/
- European Space Agency. EO4Agri. http://eo4agri.esa.int/

Brian O'Connor (UNCCD): Earth Observation for SDG Indicator 15.3.1 and Drought: The UNCCD Perspective

Brian O'Connor, Spatial Data Officer in the Science, Technology and Innovation Unit of the United Nations Convention to Combat Desertification (UNCCD), presented lessons from the ESA-funded EO4SDG assessment of which SDG indicators can be supported by EO.

EO4SDG addressed all 232 SDG indicators through a traffic-light assessment and a collection of national applications. A definite EO contribution was assigned where mature technology, adequate temporal and spatial availability, operational capacity and acceptable compliance and reliability already existed (shown in green in Figure 13). A potential contribution indicated that one or more of these conditions remained incomplete (shown in orange in Figure 13); no contribution meant that EO did not enter the indicator methodology. O'Connor highlighted a subset of water, cities and land indicators, noting that several also appeared in the 2024 synthesis of submissions to the UAE-Belém work programme. The comparison illustrated the value of reusing established SDG evidence while recognising that technical amenability does not automatically create an adopted GGA methodology. Importantly, many of the SDG13 indicators related to climate could not be supported by EO, which could be interpreted as a missed opportunity given the widespread uptake of satellite-based ECVs.

O'Connor then described components of the UNCCD drought indicator (looking at hazard, exposure and vulnerability) and its relation to climate risk. Hazard is calculated from the 12-month Standardized Precipitation Index (SPI-12), with each grid cell assigned to mild, moderate, severe or extreme drought according to its annual precipitation deficit. Exposure is derived by overlaying the yearly SPI classes with gridded population and calculating the number and proportion of people in each class, including sex-disaggregated reporting. These two indicators are spatially explicit, but only the hazard layer is fundamentally climatic; the exposure metric is already a mixed product that depends on demographic estimates.

Drought vulnerability is less directly observable from space. The minimum Tier 1 assessment combines selected social, economic and infrastructural factors, while more comprehensive tiers add context-specific dimensions and validation. The Drought Vulnerability Index shown for South Africa demonstrates that vulnerability is a composite property shaped by living conditions, economic structure, infrastructure and institutional capacity. EO may contribute environmental context or help spatialise some proxies, but household, service, economic and governance data remain indispensable. The three indicators therefore make visible a key GGA distinction: EO can observe hazards and biophysical conditions directly or through derived products, whereas exposure, vulnerability and resilience require integration with non-EO evidence.

Summary

SDG indicators that are in bold also appear in the UAE – Belém work programme on indicators in the 2024 synthesis of submissions.

	SDG6 (Water)	SDG11 (Cities)	SDG15 (life on land)
	❖ **6.3.2 Ambient water quality** ❖ **6.4.1 Water use efficiency** ❖ **6.4.2 Water stress** ❖ **6.6.1 Water-related ecosystems**	❖ **11.1.1 Informal settlements** ❖ 11.3.1 Land consumption ❖ 11.6.2 Urban air quality	❖ **15.1.1 Forest areas** ❖ 15.2.1 Sustainable forest management ❖ **15.3.1 Land degradation** ❖ 15.4.2 Mountain green cover
	❖ **6.1.1 Safe drinking water** ❖ **6.3.1 Safe wastewater treatment**	❖ 11.2.1 Access to public transport ❖ **11.5.2/1.5.2 Damage to infrastructure** ❖ 11.7.1 Public access to green space	❖ 15.1.2 Terrestrial biodiversity ❖ 15.4.1 Mountain biodiversity

Source: Connors et al., 2025, npj Climate and Atmospheric Science

Figure 13: EO4SDG traffic-light framework for assessing the contribution of Earth Observation to SDG indicators. Indicators in bold also appeared in the 2024 UAE–Belém work programme indicator list.

Presentation references and related links

- Connors, S., Schneider, R., Nalau, J., et al. (2025). Earth observations for climate adaptation: tracking progress towards the Global Goal on Adaptation through satellite-derived indicators. npj Climate and Atmospheric Science, 8, 359. https://doi.org/10.1038/s41612-025-01251-1
- UNCCD. Good Practice Guidance for SDG Indicator 15.3.1: Proportion of land that is degraded over total land area. https://www.unccd.int/resources/manuals-and-guides/good-practice-guidance-sdg-indicator-1531-proportion-land-degraded
- UNCCD. PRAIS 4 Reporting Manual - Strategic Objective 1. https://prais4-reporting-manual.unccd.int/en/latest/SO1.html
- UNCCD (2021). Good Practice Guidance for National Reporting on Strategic Objective 3. https://www.unccd.int/sites/default/files/documents/2021-09/UNCCD_GPG_Strategic-Objective-3_2021.pdf
- UNCCD. PRAIS 4 Reporting Manual - Strategic Objective 3. https://prais4-reporting-manual.unccd.int/en/latest/SO3.html
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Session 5: Adaptation planning and implementation at the national level

Chair: Sarah Connors (ESA)

Paul V. Desanker (UNFCCC): The NAP under the UNFCCC Updated NAP technical guidelines building on the IPCC WGII AR6 and GGA framework: EO entry points

Paul V. Desanker, Manager in the Adaptation Division of the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat, explained how the updated National Adaptation Plan (NAP) technical guidelines create practical entry points for Earth Observation within national adaptation

processes. NAPs are a continuous national cycle through which a country assesses climate risks, selects and finances responses, implements them and monitors whether they work, rather than as a one-off planning document. For an EO community, the central implication is that this recurring and evidence-intensive process needs spatially explicit, repeatable information at several stages, while readiness and access to finance remain cross-cutting enablers.

The updated 2025 guidelines organise the NAP process into five modules covering assessment, planning, implementation, monitoring, evaluation and learning, and support. They incorporate the best available science, including IPCC Working Group II AR6, and connect national planning to the seven thematic GGA targets in paragraph 9 and the four adaptation-cycle targets in paragraph 10 of decision 2/CMA.5. Desanker stressed that the GGA defines what adaptation should achieve, whereas NAPs provide the country-owned process through which those goals are translated into priorities, investments and monitoring arrangements.

Desanker highlighted the potential for EO to support the full NAP cycle, from assessing risks to designing and implementing adaptation solutions, while noting that uptake for monitoring and evaluation may remain limited in developing countries. Access to data and the technical capacity to process large volumes remain key barriers, although applications such as CHIRPS, ERA5, land-cover data, disaster-response radar and nightlights in CLIMADA demonstrate early progress. He stated the biggest opportunity lies in using EO to inform national spatial and land-use planning under climate change and enable more precisely targeted adaptation at the system level, with further untapped potential in developing indicators.

Desanker also presented the NAPX Systems Library, which is a data model and schema that turns NAP documents into machine-readable, queryable data. Preliminary classification of the 82 systems in the NAPX Systems Library placed 18 in the high-EO category, 21 in medium, 8 in low and 35 in none. Croplands, forests, ecosystems, settlements and observation systems can often support repeatable EO baselines; water services, fisheries, livestock, ecosystem function and livelihoods generally require EO proxies combined with ground data; and governance, finance, social protection, planning, monitoring frameworks, cooperation and intangible heritage require conventional records and surveys. EO can describe the context in which those institutional systems operate but cannot measure the systems themselves.

Desanker concluded that EO has potential across the full NAP cycle, especially for option analysis, spatial planning and system-level 'precision adaptation', but that access and technical capacity remain binding constraints. Early applications cited included CHIRPS, ERA5, land-cover products, radar for disaster assessment and night lights within CLIMADA. The methodological lesson for GGA monitoring is to begin with the adaptation system and decision, not with the available sensor: EO is strongest when it supplies a transparent and repeatable physical component within a broader national evidence system, while claims about implementation, institutional change or causal effectiveness must remain grounded in administrative, socioeconomic and participatory information. An example of how EO data, together with other data sources, can feed into the GGA theme 9(d) on ecosystems and land cover change is shown in Figure 14.

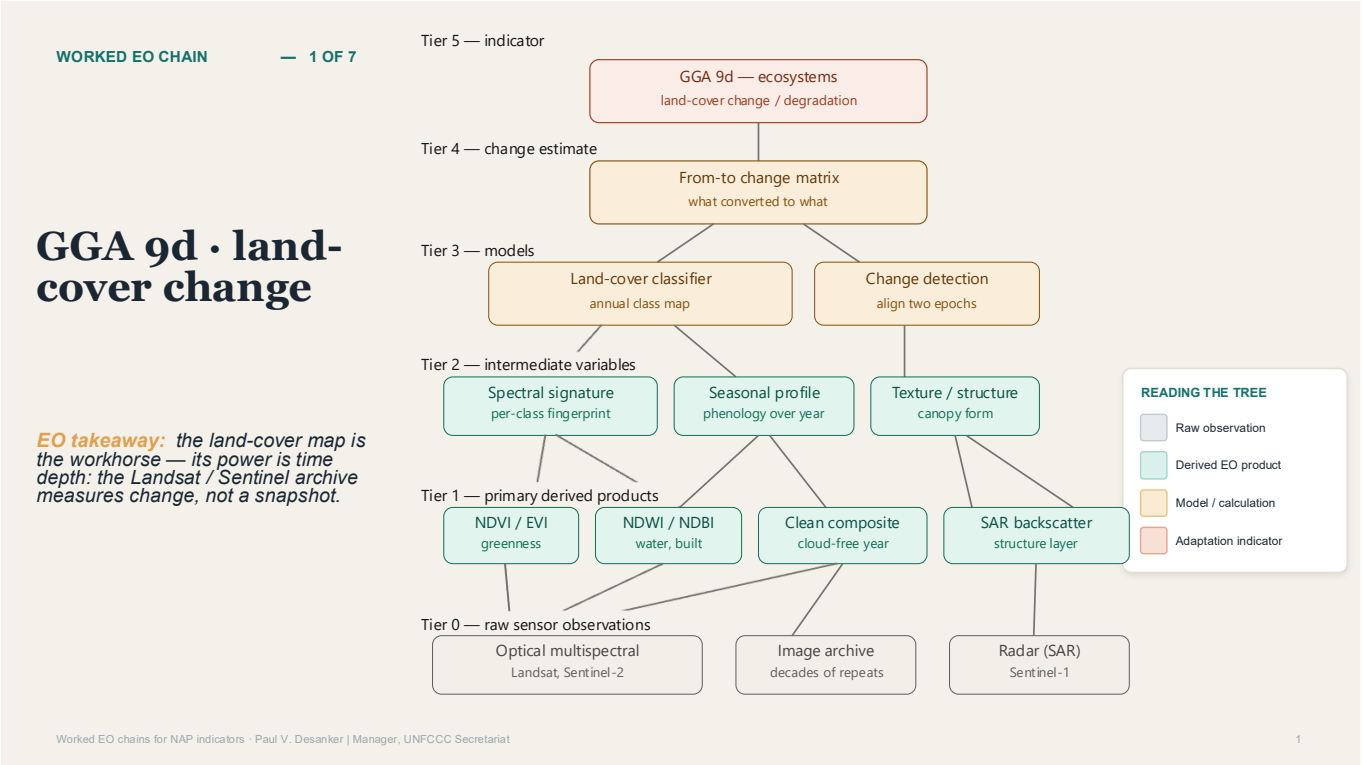


Figure 14. Example of different types of data that can be aggregated to inform GGA theme 9(d) on ecosystems and land-cover change.

Presentation references and related links

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- UNFCCC. National Adaptation Plans. https://unfccc.int/national-adaptation-plans
- UNFCCC. NAPX: NAP Exchange. https://napx.napcentral.org/
- UNFCCC. NAP Central. https://napcentral.org/
- UNFCCC. Least Developed Countries Expert Group (LEG). https://unfccc.int/LEG
- Climate Hazards Center. CHIRPS. https://www.chc.ucsb.edu/data/chirps
- ECMWF. ERA5. https://www.ecmwf.int/en/forecasts/datasets/browse-reanalysis-datasets
- NASA. GPM IMERG. https://gpm.nasa.gov/data/imerg
- NASA. Landsat. https://landsat.gsfc.nasa.gov/
- Copernicus Data Space Ecosystem. Copernicus Data Space - Sentinel. https://dataspace.copernicus.eu/
- NASA Earthdata. GRACE/GRACE-FO. https://www.earthdata.nasa.gov/data/platforms/space-based-platforms/grace-grace-fo
- NASA Earthdata. Black Marble / VIIRS Day–Night Band data. https://www.earthdata.nasa.gov/data/projects/black-marble
- ETH Zurich. CLIMADA. https://climada.ethz.ch/

Panel: Rohini Kohli (UNDP), Theresa Wong (IPCC WGII TSU), Sven Gilliams (GEOGLAM), Rory Scarrott (GEO Blue Planet)

The panel discussion focused on practical experiences of integrating Earth Observation into adaptation planning and implementation processes. Drawing on examples from countries supported through National Adaptation Plans (NAPs), participants highlighted how EO is already contributing to baseline assessments,

climate risk analysis, agricultural monitoring and adaptation implementation. Rohini Kohli presented examples from Moldova, Zambia and Bhutan, where satellite data were used to support climate risk assessments, land-use planning, agricultural monitoring and the development of evidence bases for NAPs. A recurring message was that EO can effectively support planning and monitoring processes, but does not determine adaptation priorities on its own, which must also consider local needs, community perspectives and sector-specific knowledge.

Several speakers emphasised that capacity constraints remain one of the main barriers to operational uptake. Sven Gilliams highlighted the importance of building national ownership and institutional capacity, noting that externally produced EO datasets are often not sustained once projects end. Effective implementation requires long-term engagement, co-development with national institutions and continued support beyond project lifetimes. Similar concerns were raised for Small Island Developing States (SIDS) and Least Developed Countries (LDCs), where data accessibility, technical expertise and organisational capacity often limit the ability to use EO products in practice. Rory Scarrott stressed the need for stronger links between data producers and end users, arguing that adaptation planning should start from user needs rather than available datasets. Common issues raised by Green Bond Principle-linked national adaptation managers include access, use barriers and resolution suitability, with the volume of data available also obscuring the information they could use.

The discussion also highlighted the importance of co-design and integrated evidence systems. Theresa Wong noted that decision-makers frequently prioritise usable and actionable information over methodological sophistication, reinforcing the need for EO communities to work closely with practitioners and implementing agencies. Participants repeatedly emphasised that adaptation decisions require the integration of EO products with local knowledge, socioeconomic information and stakeholder participation/engagement. The panel concluded that Earth Observation has significant potential to strengthen adaptation planning, implementation and monitoring, but that real impact will depend on sustained partnerships, institutional uptake, capacity development and the embedding of EO products within existing national planning and reporting frameworks.

Interactive Indicator Mapping

Following the panel session, participants completed an interactive mapping exercise that synthesised the preceding presentations and updated the assessment of where EO can support the 59 selected GGA indicators. Indicator wording was taken from the UNFCCC Decision CMA.7 on the Global Goal on Adaptation. The results of the exercise were incorporated into the final mapping table presented in the Summary.

Session 6: Adaptation Action – How to make EO more useful for adaptation?

Chair: Susanne Mecklenburg (ESA)

Johanna Nalau (Griffith University): Adaptation from Above – User requirements from the adaptation community for scientific assessment

Johanna Nalau, Associate Professor at Griffith University and an IPCC AR7 Working Group II Coordinating Lead Author, presented the information needs of the adaptation community and their implications for Earth

Observation (EO). Her central argument was that satellite observations provide one line of evidence within a broader assessment of adaptation. Their value depends on the questions being asked: identifying where risks are concentrated, understanding why people and systems are vulnerable, assessing whether responses are working, and determining which future options are feasible and effective.

Nalau first outlined examples of established EO applications, including coastal risk mapping, habitat loss and gain, urban heat, drought, crop management, flooding and wildfire monitoring. She then extended the discussion towards tracking adaptation progress, identifying priorities and hotspots, and examining the presence or absence of enabling conditions. This progression shifts attention from observing hazards alone towards understanding exposure, vulnerability and the capacity to respond. The presentation also emphasised that adaptation takes place across interacting levels, from local and sub-regional settings to state, regional, national and global processes. Information suitable for one level does not necessarily answer the questions asked at another.

As illustrated in Figure 15, Nalau organised the discussion around the questions adaptation professionals need evidence to answer: whether adaptation is progressing; whether decisions are reducing risk and increasing adaptive capacity; which places and groups are most vulnerable, and why; which cross-border risks require attention; and which adaptation options work, where and under what conditions. These questions connect monitoring past and present outcomes with prioritising future action according to its potential effectiveness and feasibility. Their implications for EO extend beyond identifying observable environmental variables: the purpose of the assessment, the decision being supported and the relevant spatial and temporal scales must guide data selection.

Nalau then introduced GGA-TrackEO, an ESA-supported project investigating the usability of EO data for adaptation and risk indicators across climate timescales extending over decades. The presentation described work addressing six of the eleven GGA targets across three representative case-study locations: Valencia, Brisbane and Cape Town, covering combinations of drought, urban heat and coastal flooding.

The presentation concluded with questions about how EO could improve understanding of future change, how satellite and other datasets could be analysed together to assess past and prospective adaptation, and whether adaptive capacity can be observed from space. The user requirements that should guide indicator development and scientific assessment. EO becomes useful when its observable quantities are matched to a defined decision, an appropriate scale and a clear adaptation objective, and integrated with the evidence needed to interpret vulnerability, implementation and outcomes.

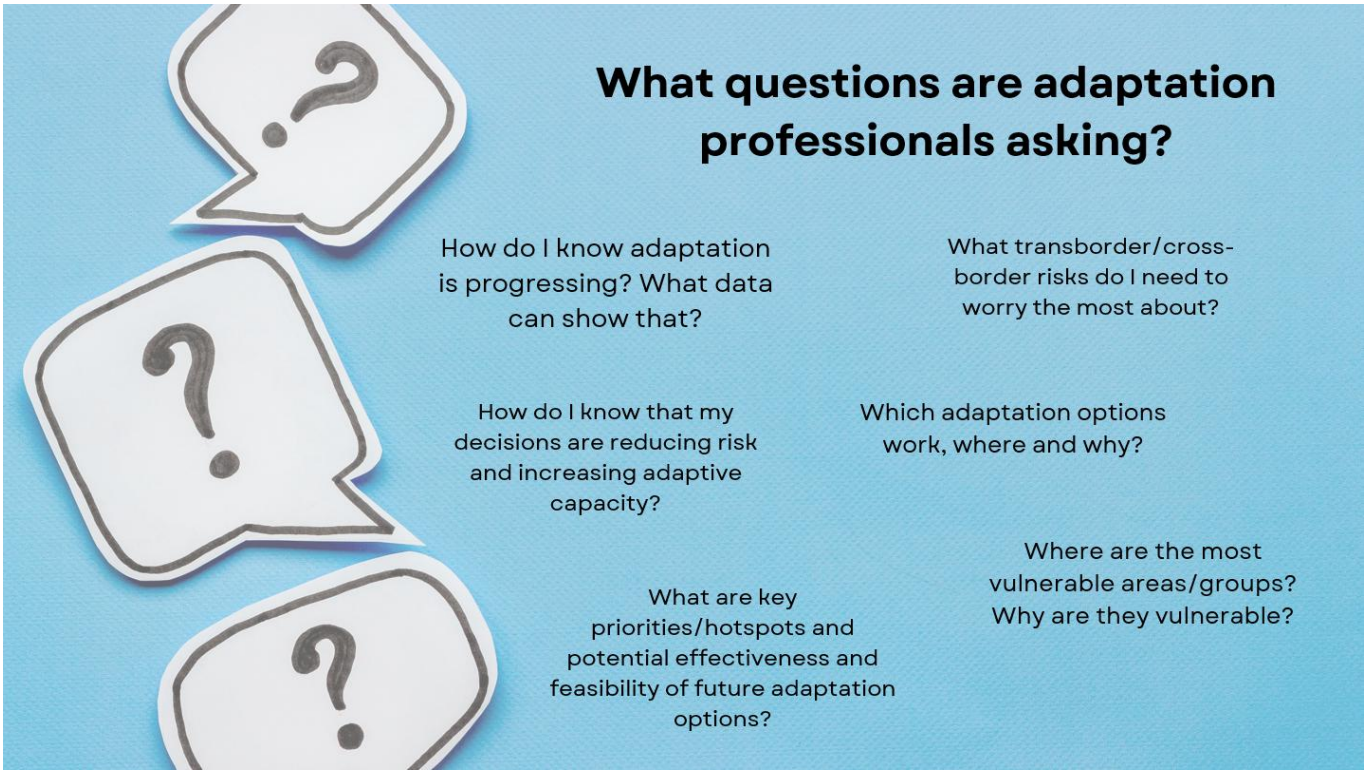


Figure 15. Key questions guiding the information needs of adaptation professionals, covering adaptation progress, risk reduction and adaptive capacity, vulnerable places and groups, cross-border risks, and the effectiveness and feasibility of adaptation options. The questions frame the evidence needed to evaluate existing responses and prioritise future action.

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Mike Perry (National Centre for Earth Observation): Downscaling EO Capabilities and risks, strengths and weaknesses

Mike Perry, Simulation Scientist in the University of Leicester's Earth Observation Science group and researcher within the National Centre for Earth Observation (NCEO), examined the opportunities and risks of super-resolution and downscaling for thermal Earth Observation. The presentation focused on land surface temperature (LST), where users often need both frequent observations and fine spatial detail not currently observable by satellites. Perry framed downscaling as a way to reduce this information gap for urban heat analysis and climate adaptation, while stressing that the resulting product is an estimate rather than a new high-resolution thermal observation.

The thermal case arises from a sensor trade-off. Sentinel-3 SLSTR supplies frequent LST at approximately one-kilometre resolution, whereas Landsat 8 provides much finer thermal detail but with a nominal 16-day revisit and additional losses from cloud. Revisit and cloud-interference therefore create a spatial-temporal knowledge gap that limits the estimation of urban thermal trends, variations and the effectiveness of heat-mitigation measures. Perry argued that long, internally consistent, high-resolution time series could support more targeted urban planning, but only if their uncertainty and provenance remain visible.

The first limitation is physical and temporal. A downscaled field inherits the dynamics of the high-resolution surface representation used by the algorithm. Localised heating or short-lived events that do not alter that representation cannot appear in the output unless they are already resolved in the coarse thermal observation, described in the presentation as events larger than approximately one kilometre. Consequently, fine-looking maps should not be interpreted as proof that the sensor observed every small-scale temperature event.

The presentation also highlighted a methodological imbalance in the literature. Perry reported more than 120 LST-downscaling papers in the preceding year, with roughly three quarters using AI or machine learning and one quarter using physical or statistical methods. Yet validation and uncertainty estimation remain uncommon, and many studies validate primarily through intercomparison with a nominally high-resolution sensor. This is particularly problematic for machine-learning approaches because agreement between products does not establish truth, errors may be shared, and apparent spatial detail can conceal model dependence.

The proposed workflow being developed by Perry addresses these issues through a physics-based iterative optimal-estimation scheme. As shown in Figure 16, the chain combines Sentinel-3 LST at one-kilometre resolution, a Sentinel-2-derived surface representation at 100 metres and ERA5 information for LST gap filling. It jointly estimates fine-resolution LST and land surface emissivity (LSE) while propagating uncertainty through the retrieval. The intended strengths are physics-based inference, end-to-end traceability and an uncertainty value accompanying each output rather than being added as an afterthought.

The UK case study provides the first larger-scale test that still needs robust evaluation like careful spatio-temporal matching, independent in situ evidence where available, stratification by surface type and season, and validation of the uncertainty estimates themselves.

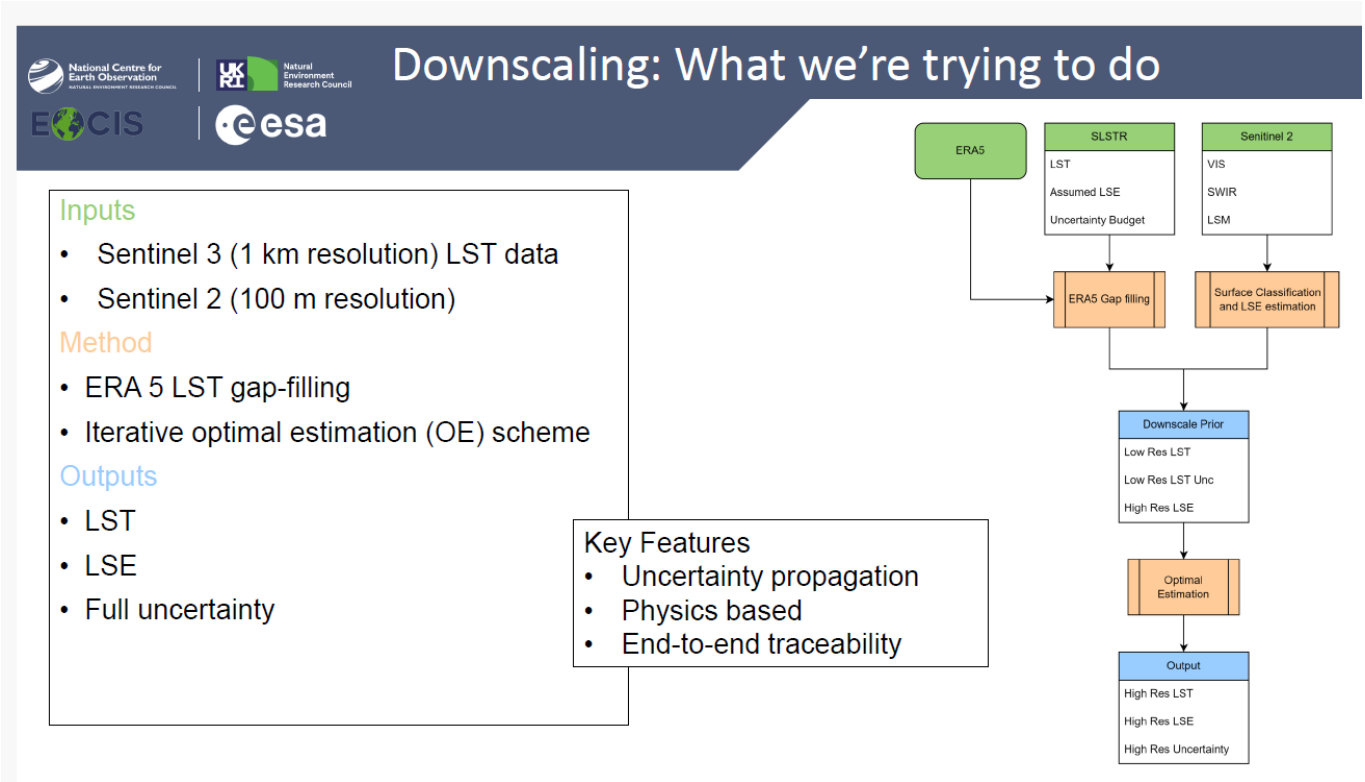


Figure 16. Physics-based LST-downscaling workflow combining Sentinel-3 thermal information, a Sentinel-2-derived surface representation and ERA5 gap filling within iterative optimal estimation. Outputs comprise fine-resolution LST, land surface emissivity and propagated uncertainty.

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Mikaël Maes (OECD): Incorporating EO data for a more comprehensive assessment of Risk.

Mikaël J. A. Maes, Environmental Data Scientist in the Environmental Performance and Information Division of the OECD Environment Directorate, presented a project measuring population vulnerability and risk to extreme heat and air pollution in Japan. The project combines a review of existing risk measurement frameworks and vulnerability indices with detailed environmental and georeferenced sociodemographic data to construct national and subnational hazard, hazard-exposure and risk indicators. It also tests whether global datasets can replace high-quality national sources sufficiently well to support harmonised comparisons across countries and regions. The transparent separation of hazard, exposure and vulnerability components into potential risk and realised impact was a key theme of the presentation.

The method followed six linked steps, as shown in Figure 17:

1. Identify national data sources for defining the hazard, the exposed asset and its vulnerability
2. Define how to measure the relevant hazard(s)
3. Conduct hazard-exposure analyses
4. Undertake an epidemiological review to identify key vulnerability factors
5. Develop risk indicators
6. Validate the risk estimates

For extreme heat, the authors used a dual threshold intended to be both locally meaningful and objectively hot, combining both absolute and relative threshold measurements. A hot day was defined as one exceeding both the 95th percentile of daily maximum temperatures over the local reference period and 30°C. Municipality-level hazard-exposure was then calculated as the population-weighted number of hot days, using Japan's approximately one-kilometre census grid to align population with gridded meteorological data. Finally, the population-weighted number of hot days was combined with the share of residents aged 65 or over to produce a heat risk index for the elderly with five ordinal classes. Results for

2020 showed a distinct distribution between rural and urban municipalities, while regression analysis supported age structure as an important vulnerability factor.

The scaling assessment replaced Japanese national data sources with three global geospatial data sources: NARO temperature data with ERA5-Land surface air temperature, census population with population data from the Global Human Settlement Layer and census age structure with WorldPop age-structured population. The assessment showed that moving from national to global data sources produced systematically lower population-weighted hot-day counts for many municipalities, showing that global coverage and harmonisation do not eliminate differences in variable definition, resolution, calibration or threshold exceedance, indicating that further research is required.

The authors concluded that the method could help identify municipalities warranting closer attention, although it should not be presented as a measure of realised impact, and that cross-country scaling requires stronger comparability tests and a broader vulnerability framework.

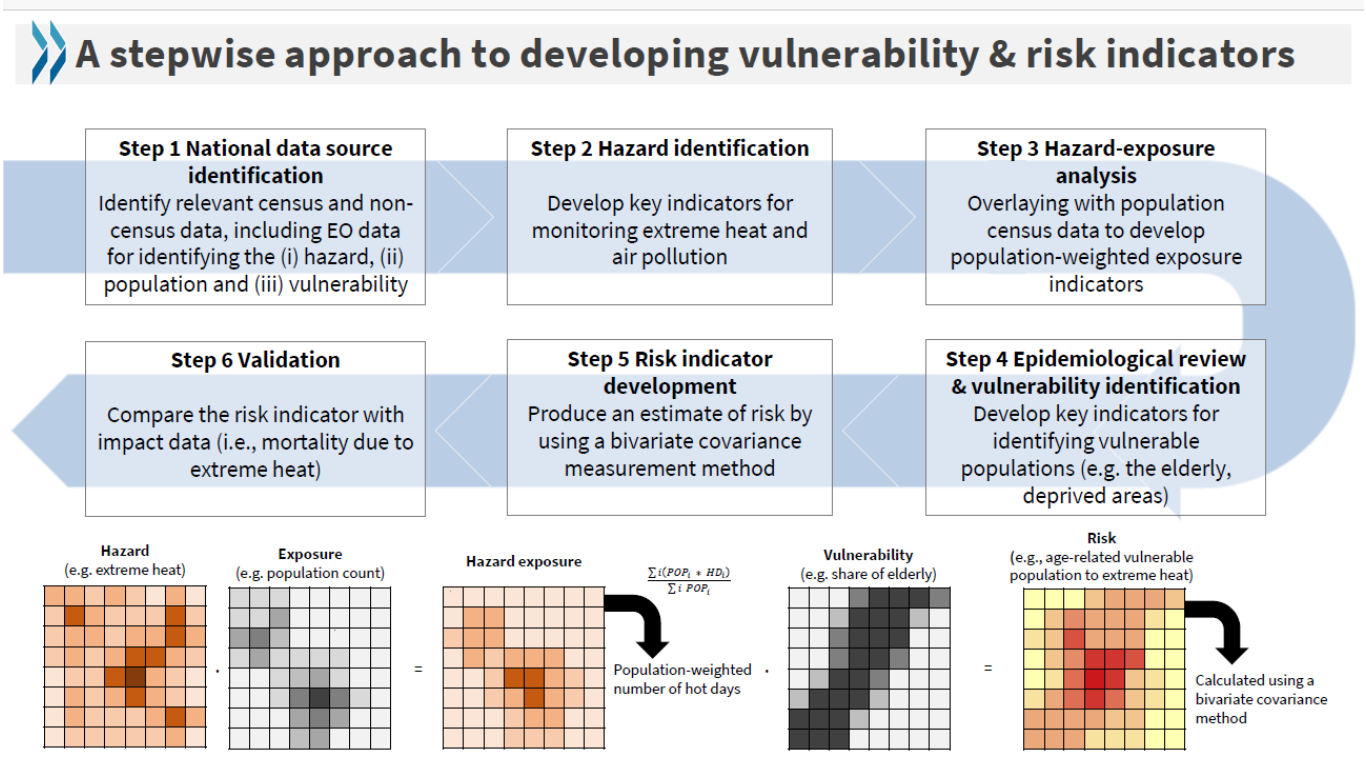


Figure 17. Six-step framework linking data-source identification, hazard measurement, population-weighted exposure, vulnerability selection, bivariate potential-risk estimation and validation against observed impacts.

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Thorsten Fehr (ESA): Adaptation Action – Potential from the new ESA EO missions

Thorsten Fehr, Head of the Earth Science Division of the European Space Agency (ESA) presented how existing and future satellite missions can strengthen the observational basis for climate adaptation. The presentation connected the evolution of ESA's EO fleet with information needs relevant for adaptation. Fehr began by linking satellite development to user and scientific requirements. User needs and objectives are translated into mission requirements, while satellite observations are processed into higher-level products and ultimately actionable information. This relationship establishes a practical test for new capabilities: improvements in resolution, coverage or measurement sensitivity are useful for adaptation when they address a defined information need. The thematic examples included surface-water variability, drought and flood occurrence, groundwater-storage anomalies, crop-productivity variability, ecosystem extent and condition, settlement exposure, urban heat and land subsidence.

The overview of ESA's mission portfolio emphasised both continuity and expansion. Existing observational records provide the baseline against which environmental change can be assessed, while future missions offer additional measurements and improved sampling. Fehr also highlighted the International Charter "Space and Major Disasters" as an established operational mechanism for translating satellite capacity into emergency support. The Charter coordinates satellite imagery for disaster response, damage assessment and crisis management, illustrating the importance of rapid access, coordinated acquisition and delivery to civil-protection and humanitarian users.

As illustrated in Figure 18, the six new Copernicus Sentinel Expansion missions extend the observing system across complementary spectral and measurement domains. Their applications connect new satellite capabilities with adaptation-relevant needs in agriculture, water management, ecosystem monitoring and the cryosphere, alongside emissions monitoring primarily serving mitigation. Alongside these expansion missions, Fehr described how the next generation of existing Sentinel missions could enhance observational continuity and performance. Sentinel-1 Next Generation was presented as improving radar coverage and spatial detail, including more frequent global coverage and closure of the North Pole observation gap. Sentinel-2 Next Generation would strengthen continuity in high-resolution optical imaging through improved spatial sampling, additional spectral bands, better noise performance and expanded coastal coverage. The proposed sampling reaches five metres for several visible and near-infrared bands, while additional spectral information could improve the characterisation of vegetation, water and surface materials. These enhancements increase the potential to resolve local environmental differences, although their usefulness for an adaptation application still depends on the resulting product and its validation.

Several applications illustrated the connection between observations and adaptation decisions. Sentinel-3 land-surface-temperature imagery was used to show spatial patterns of extreme surface heat, with the Land Surface Temperature Monitoring mission (LSTM) and Sentinel-3 Next Generation identified as future extensions of thermal observing capability. Ocean-altimetry observations illustrated the monitoring of sea-level change and wave height, with continuity and enhancement through missions including Sentinel-6 Next Generation, Sentinel-3 Next Generation and CRISTAL. The locust-monitoring example combined Sentinel-2

and WorldCover information on vegetation and crop conditions with frequent Sentinel-3 observations of rainfall-related vegetation change. Its relevance lay in supporting early detection and targeted action, demonstrating that an operational response depends on combining complementary observations with knowledge of the hazard.

WIVERN, the newest Earth Explorer mission, was presented as a prospective source of global in-cloud wind observations and vertical information on clouds and precipitation, supporting improvements in severe-weather forecasting. Biomass was presented as providing information on forest biomass, carbon stocks and change, with applications in forest-resource management, ecosystem services and Earth-system modelling.

Fehr concluded that global coverage, traceability, quality assurance and open access make satellite observations an important foundation for adaptation, while mission development progressively improves the available evidence. Translating those capabilities into credible GGA reporting requires suitable products, validated methods and integration with the administrative, socioeconomic and other evidence needed to assess implementation, resilience and adaptation outcomes.

Figure

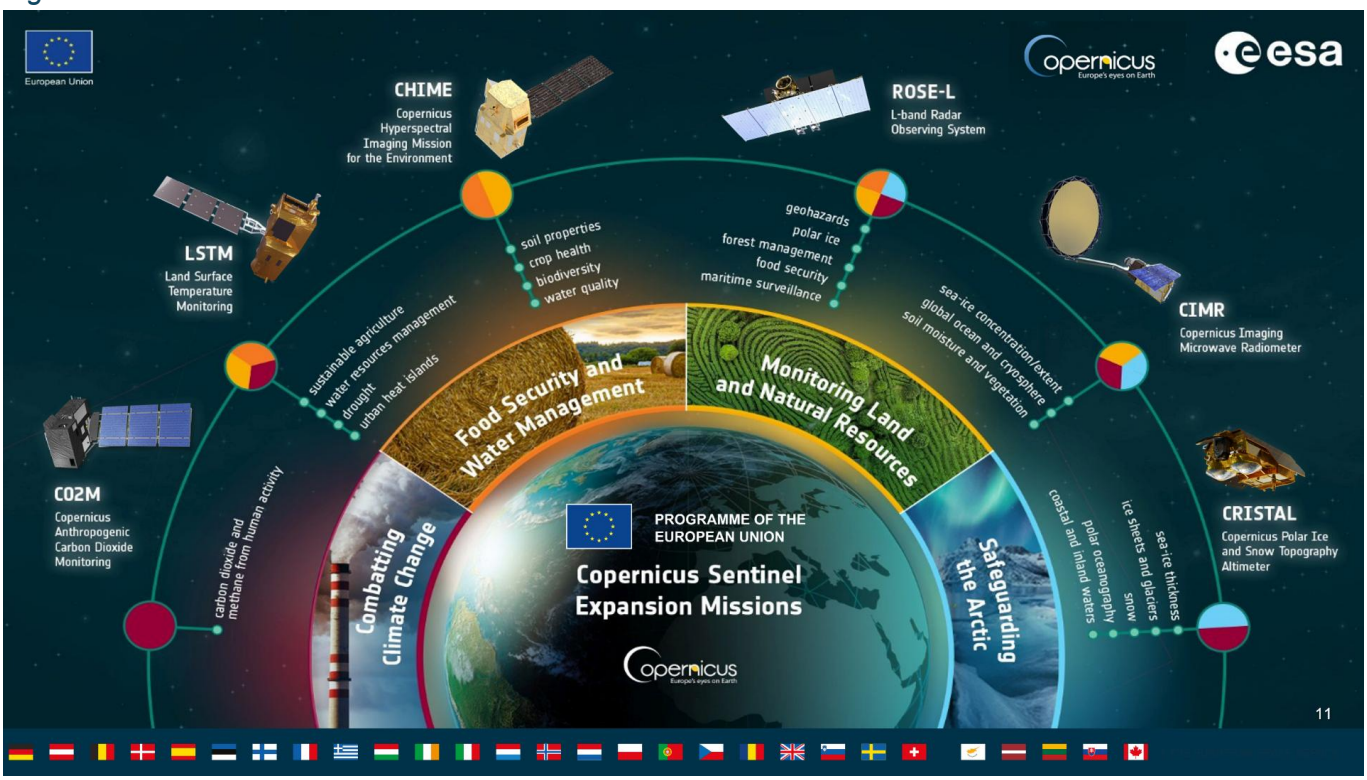


Figure 18. The six Copernicus Sentinel Expansion missions and their principal application domains, including food security, water management, land and natural resources monitoring, and the Arctic.

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Peter Thorne (GCOS): Observations for adaptation: a GCOS perspective

Peter Thorne, Vice-Chair of the Global Climate Observing System (GCOS) and Chair of the Irish Climate Change Advisory Council's Adaptation Committee, argued that the most immediately effective adaptation action is often an early warning. Warnings enable citizens, businesses and public authorities to protect lives and livelihoods, but their quality depends on trusted dissemination, high-quality numerical weather prediction (NWP) or other types of forecasting and, beneath both, observations delivered to forecasting centres in near-real time. Thorne therefore framed satellite and in situ observations as a single operational system rather than competing sources.

The presentation translated this dependency into a concrete investment agenda for GCOS and its community. As summarised in Figure 19 for GCOS, Thorne called for:

- the continuity of key EO missions;
- maintenance of the in situ backbone;
- filling persistent geographic observation gaps through full implementation of the Global Basic Observing Network (GBON), long-term support for the Systematic Observations Financing Facility (SOFF) and more suitable tropical and processing orbital configurations;
- adequate funding for GCOS and WMO coordination;
- sustained production of reanalyses;
- rescue and reprocessing of historical satellite and paper records;
- attention to radio-frequency interference, data-exchange mechanisms, assimilation methods and models.

The message was institutional as much as technical: comparability, exchange, archival and long-term availability determine whether observations can support adaptation.

The same logic extends beyond short-range warning to initialized seasonal-to-decadal predictions. For example, in much of Sub-Saharan Africa, such predictions can inform crop-planting and sectoral planning, but they require observations of boundary conditions that are not fully captured by routine surface networks, particularly the stratosphere and the full-depth ocean state. Climate projections likewise depend on global and historical datasets for model validation, while local adaptation planning generally requires consistent downscaling from larger-scale models.

Evidence from the GCOS Adaptation Task Team (GATT) reinforced the need for integration. Its case studies on forest-wildfire management, pluvial flood risk in urban areas and ocean extremes showed that adaptation questions normally draw on multiple Essential Climate Variables (ECVs) and several observing-platform types. Reanalysis acts as an integrator across sensors and time scales, turning heterogeneous observations into spatially complete fields; operational forecasts and extremes need daily global data; and higher-resolution exchanges such as Daily Climate Data Exchange (DAYCLI) are especially relevant for local applications.

Thorne also stressed the limits of geophysical observation for tracking whether adaptation works. Effectiveness involves social, economic, health, equity, justice and wellbeing outcomes; maladaptation must be identified; a credible counterfactual is needed to infer what would have happened without the intervention; and much household- or community-level adaptation is poorly documented. EO and ECVs can characterise hazards and environmental responses, but effectiveness and causality require administrative records, surveys, evaluation designs and local knowledge.

The next revision of GCOS requirements is expected to retain its categories of Threshold, Breakthrough and Goal levels for the 41 ECVs and 176 ECV quantities. Thorne suggested that adaptation needs would be fully met at Goal level and partially met at Breakthrough level, while also noting that adaptation is likely to impose particularly demanding requirements for spatial and temporal resolution and timeliness.

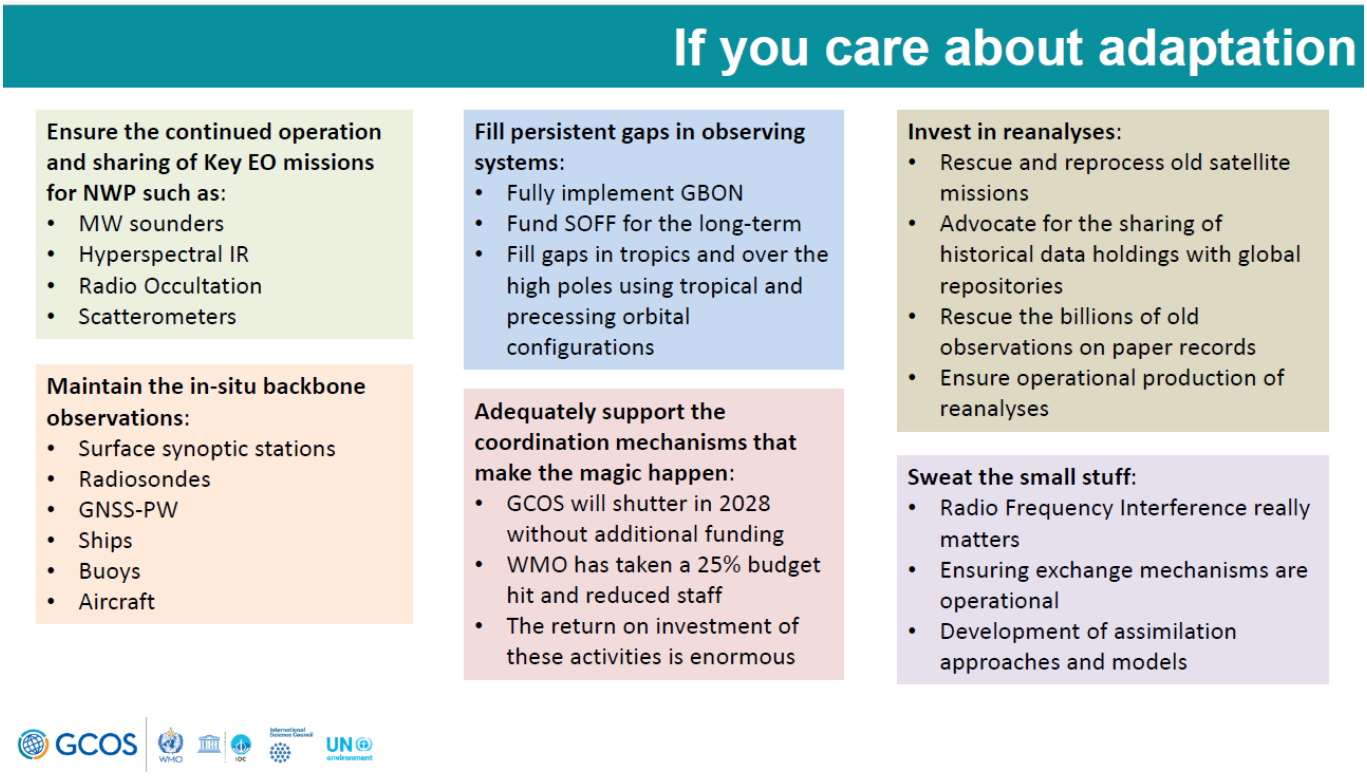


Figure 19. Observing-system priorities for adaptation identified by GCOS: continuity and sharing of key EO missions; maintenance of surface, upper-air, marine and aircraft observations; implementation and financing of gap-filling networks; sustained coordination; rescue and operational production of reanalyses; and protection of frequencies, exchange mechanisms, assimilation methods and models.

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Carlo Buontempo (C3S): Copernicus Climate Change Service perspective

Carlo Buontempo, Director of the Copernicus Climate Change Service (C3S) at the European Centre for Medium-Range Weather Forecasts (ECMWF), presented the C3S that combines observations, reanalysis, seasonal forecasts and climate projections to provide authoritative information for climate monitoring, mitigation and adaptation, and the presentation reported more than 300,000 direct users with global reach.

Buontempo emphasised that satellite and in situ observations form a complementary global observing system. Polar-orbiting satellites provide global coverage through repeated overpasses, while geostationary platforms deliver frequent regional imagery. Microwave and infrared sounders constrain atmospheric temperature and humidity; scatterometers retrieve ocean-surface winds; radio occultation provides vertically resolved atmospheric information; and synthetic-aperture radar and altimetry observe land, ice and ocean properties. These data are combined with surface stations, radiosondes, Argo floats, drifting buoys and aircraft observations, which remain indispensable for vertical structure, subsurface ocean conditions, calibration and validation.

Furthermore, C3S converts heterogeneous observations into consistent climate data records organised around the Essential Climate Variables (ECVs) defined by GCOS. Its portfolio covers 29 ECVs and more than 45 ECV quantities across multiple components of the Earth system, including the atmosphere, ocean, land, cryosphere and hydrosphere (Figure 20). Future Sentinel Expansion Missions (see Thorsten Fehr's presentation summary) are expected to increase the diversity, quality and maturity of this portfolio.

For adaptation, the most operational example was a hazard-screening and assessment tool scheduled in the presentation for October 2026. It flags hazards when projected or observed change exceeds current-climate variability and produces a downloadable summary report. The interface illustrated metrics such as heatwave days above 35 degrees C (TX35) and marine-heatwave days above the local 90th percentile of sea-surface temperature. These are derived hazard indicators: EO and reanalysis provide climatic inputs, but thresholds, baselines, scenario periods and uncertainty treatment determine the resulting flag. They describe changes in hazard rather than exposure, vulnerability, implemented adaptation or its effectiveness.

The final slides introduced the accelerated evolution that AI is bringing to prediction. Buontempo presented AI Direct Observation Prediction (AI-DOP), an experimental route for learning forecasts directly from observations and for producing a much faster prototype reanalysis. A quick approximately 40-year

reconstruction showed broadly similar global-mean temperature-anomaly evolution to ERA5, while the presentation explicitly cautioned that significant validation is still required.

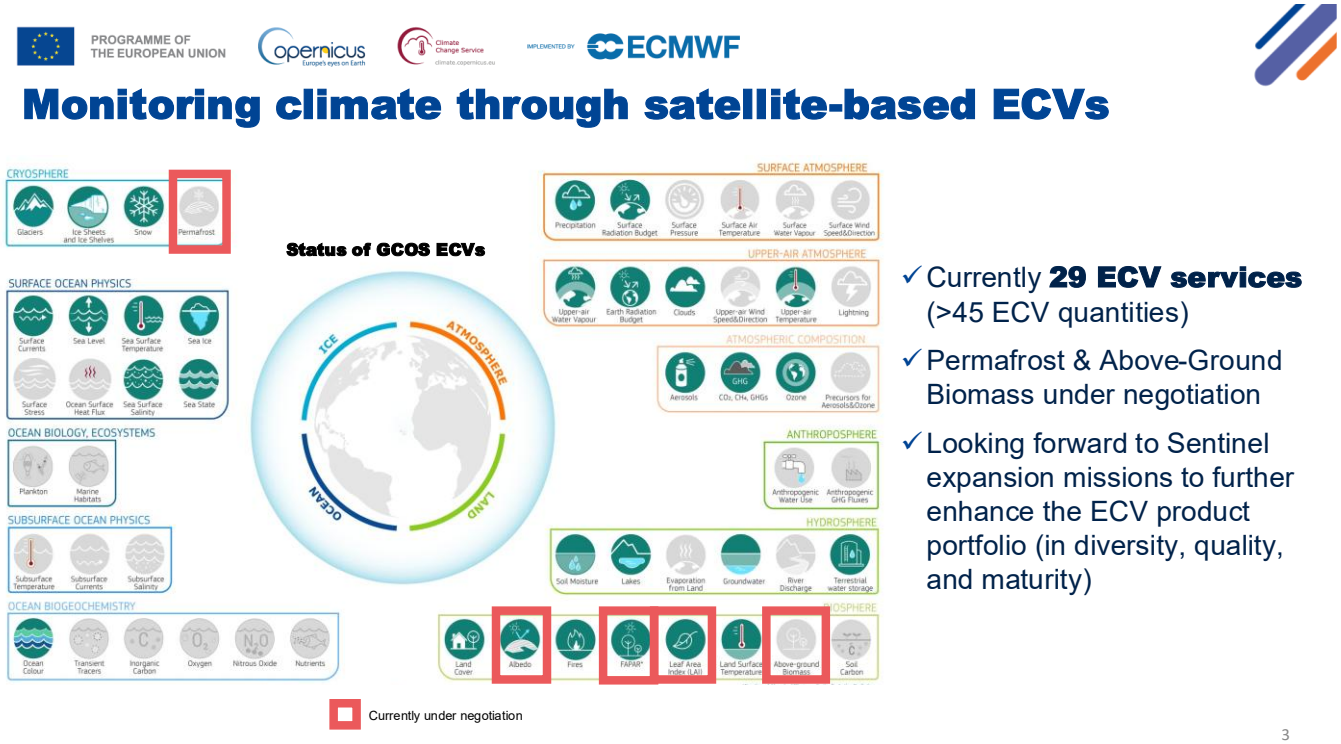


Figure 20: Status and thematic coverage of the satellite-based GCOS Essential Climate Variable services supported by C3S. Red outlines identify services under negotiation.

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- Copernicus Climate Change Service. C3S data - observations, reanalysis and seasonal forecasts. https://climate.copernicus.eu/data
- Copernicus Climate Change Service. C3S monthly Climate Bulletins. https://climate.copernicus.eu/climate-bulletin
- Copernicus Climate Change Service. European State of the Climate. https://climate.copernicus.eu/ESOTC
- Copernicus Climate Change Service. Copernicus Interactive Climate Atlas. https://climate.copernicus.eu/copernicus-interactive-climate-atlas-guide-powerful-new-c3s-tool
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Session 7: Adaptation Action – regional and local users

Chair: Sarah Connors (ESA)

Jean Dusart (European Commission DG RTD): European Commission's Mission on Climate Adaptation

Jean Dusart, Policy Officer in the Environmental Observations Sector of the European Commission Directorate-General for Research and Innovation (DG RTD), presented the EU Mission on Adaptation to Climate Change as a place-based, systemic and inclusive instrument for turning European research and innovation into climate-resilience action. The Mission is placed within the European Green Deal, the European Climate Law and the 2021 EU Adaptation Strategy and aims to support at least 150 European regions and communities towards climate resilience by 2030.

The Mission is organised as a progression from understanding climate risk to planning and implementation. The first level helps citizens, communities and regions assess and prepare for hazards such as heatwaves, forest fires, droughts, floods and storms. The second supports at least 150 communities and regions in developing visions, innovation pathways and enabling conditions. The third seeks to upscale solutions capable of triggering transformation, with 75 demonstration regions currently identified in the Mission objectives. This architecture treats adaptation as a territorial transition rather than as a collection of isolated technical measures.

As shown in Figure 21, operational support follows the same sequence: assess current and future pressing climate risks, develop specific plans and then develop, test and deploy innovative resilience solutions. Achievements to date include:

- more than 600 regional and local authorities (RLAs) engaged through technical assistance, projects or the Charter (almost double the initial objective)
- political commitments covering about 280 million citizens across 333 RLAs;
- tailored technical and financial assistance to 292 authorities;
- 185 demonstrators testing adaptation solutions in real-world settings.

The presentation also positioned the Mission as an input to the European Integrated Framework for Climate Resilience announced for the fourth quarter of 2026. Four contributions were highlighted:

- catalysing action and the solutions side of the framework,
- leveraging research and innovation tools developed by the Mission
- supporting multilevel governance
- linking innovation and demand-side measures with competitiveness.

Horizon Europe calls for 2026-2027 extend this agenda across soil resilience, climate services, cultural heritage, inland waterways, disaster-risk management, financing, cross-border resilience, wastewater, urban nature, artificial intelligence and health.

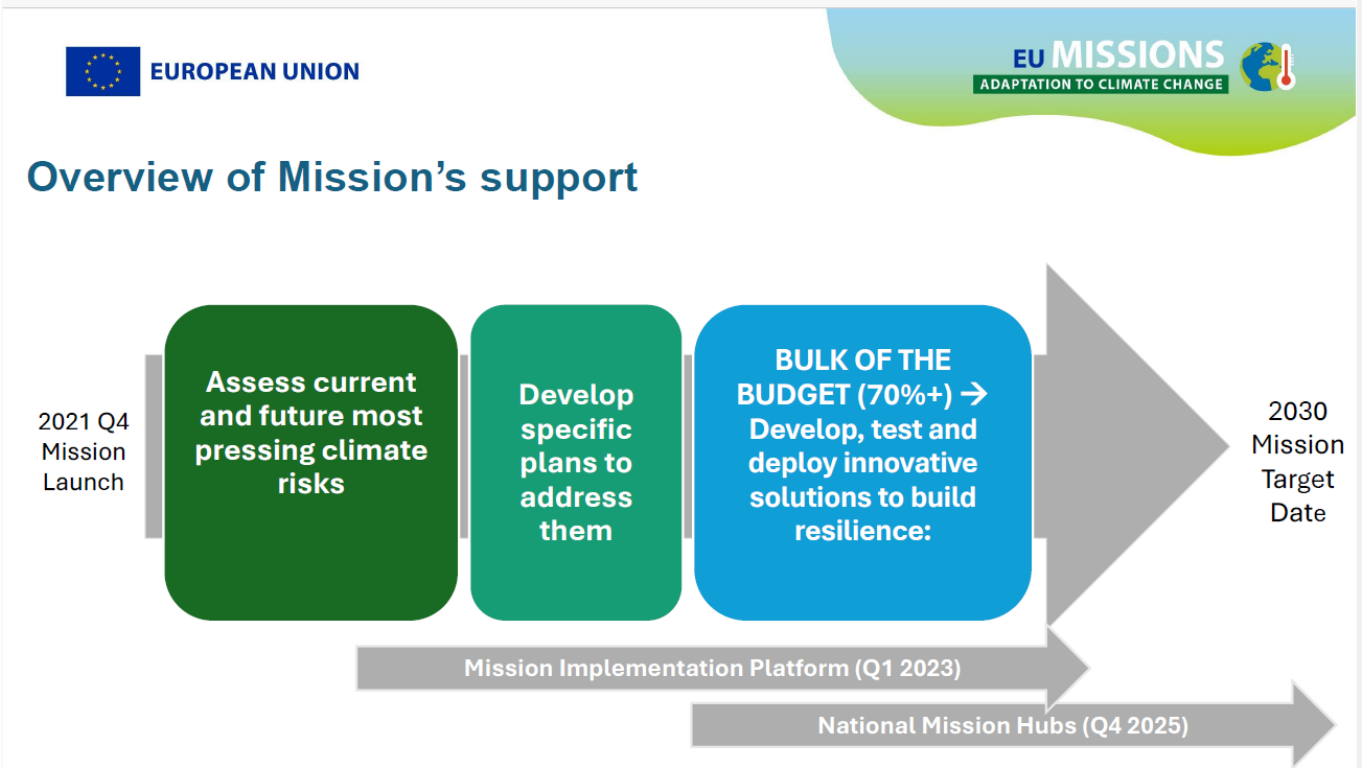


Figure 21. Operational sequence of support under the EU Mission on Adaptation to Climate Change from its 2021 launch to the 2030 target.

Presentation references and related links

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- European Commission. EU Mission: Adaptation to Climate Change. https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/adaptation-climate-change_en
- MIP4Adapt. EU Mission Adaptation Portal. https://mission-adaptation-portal.ec.europa.eu/
- European Environment Agency and European Commission. Technical Assistance. https://climate-adapt.eea.europa.eu/en/mission-inactive/community-of-practice-inactive/technical-assistance
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- European Commission. European Climate Law. https://climate.ec.europa.eu/eu-action/european-climate-law_en
- Group on Earth Observations. Jean Dusart: speaker profile. https://earthobservations.org/about-us/events/2026-geo-symposium-geo-21-plenary/track/2026-geo-symposium-geo-21-plenary-obasi

Marie-Claire Greening (ESA) and Stephen Ward (Symbios Communications, CEOS): The CEOS EO for Adaptation Handbook: Case Studies from across the globe

Stephen Ward, founder and principal of Symbios Communications and long-standing author and editor of the CEOS Earth Observation Handbook, and Marie-Claire Greening, Programme Coordinator in the European Space Agency Programme and Coordination Office and contributor to the CEOS Missions, Instruments and Measurements database team, presented the 2026 Handbook on behalf of the ESA EO Handbook Team. The handbook is designed to communicate how satellite Earth observation supports adaptation and resilience.

The Committee on Earth Observation Satellites (CEOS), whose membership encompasses the major civil EO agencies (including ESA) and programmes has been producing Handbooks for major policy events and priority themes since the 1992 Rio Conference. The 2026 edition combines two complementary parts. Part I explains the different ways in which EO data can support adaptation and resilience. Part II is a global case-study atlas organised under agriculture, disasters, economic security and infrastructure, ecosystems, health and well-being, and water. More than 100 case-study offers were received from the scientific and practitioner communities across the globe. Twenty were selected for the printed edition and a further 23 for the website, producing 43 web case studies. The selection was intended to cover diverse organisations, geographies, narrators and thematic categories, with emphasis on clearly identified users, human impacts, contacts and reusable guidance.

Ward presented one of the selected case studies looking at crop yields in Malawi. The Malawi food-security example illustrates the Handbook's decision-led value chain. As shown in Figure 22, it works backwards from assessing drought impacts on yields and targeting responses, through the NASA Harvest GEOCIF application and environmental products, to the MODIS, VIIRS and SMAP observations underpinning them. Feedback loops show that user needs and performance evidence should iteratively shape services, products and observations. The selected model (GEOCIF) combines satellite and environmental time series with crop calendars, masks and historical subnational production data to forecast crop- and region-specific yields. In 2024, NASA Harvest and FAO adapted it for Malawi's Ministry of Agriculture, providing monthly district-level maize-yield forecasts. These gave earlier, broader evidence of potential shortfalls, supported food-security early warnings and validated the Ministry's crop survey. The National Committee on Crop Estimates recommended integrating the model into the survey for early warning and crop monitoring.

The Handbook demonstrates how context-specific evidence chains can connect observations to products, services, decisions and societal outcomes. Many surface variables, for example leaf area index, are directly retrieved or derived from EO; precipitation, soil moisture and temperature products often integrate satellite, model and in situ information; and yield forecasts are modelled estimates calibrated against crop statistics and field evidence. Food-security action, institutional adoption and adaptation effectiveness remain indirect outcomes that require administrative records, local knowledge, survey data, uncertainty analysis and evaluation alongside EO.

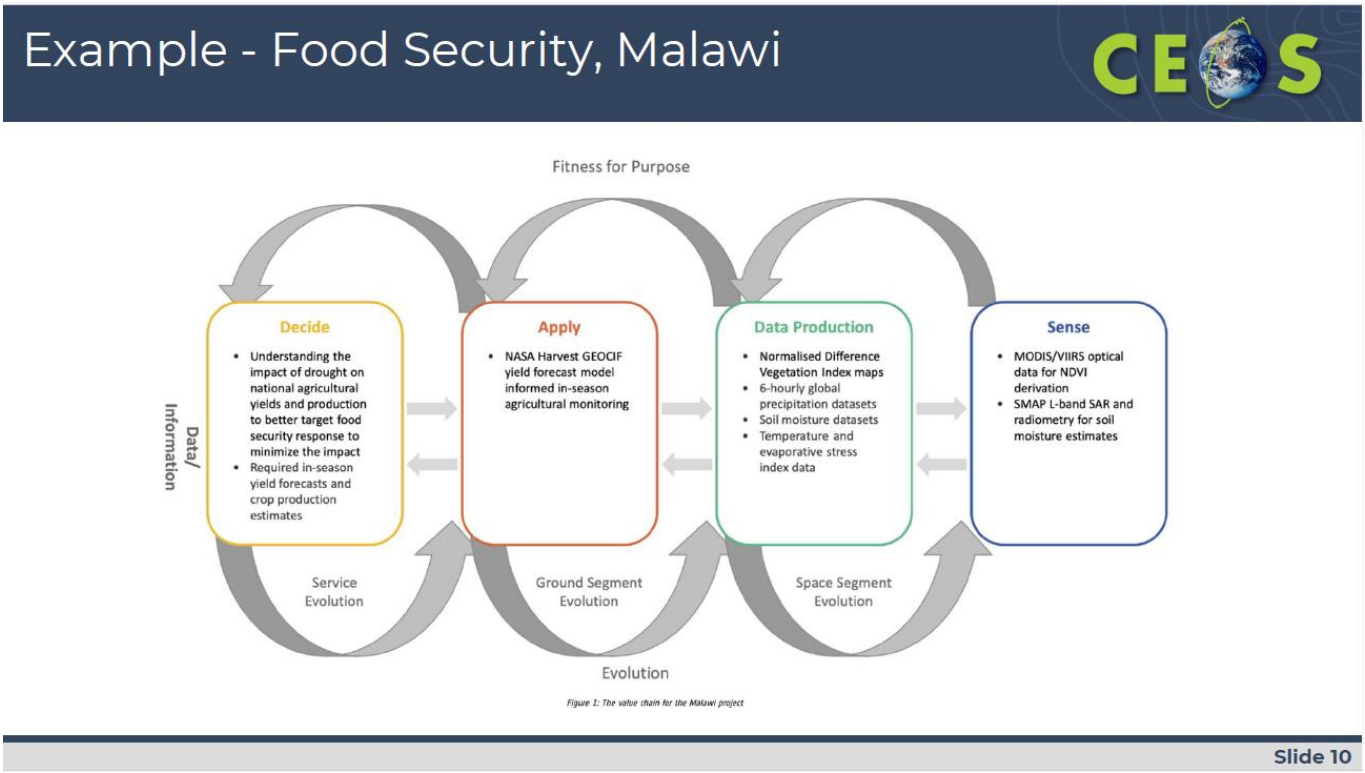


Figure 22. Decision-led EO value chain for in-season yield forecasting and food-security action in Malawi.

Presentation references and related links

- Climate Hazards Center. CHIRPS. https://www.chc.ucsb.edu/data/chirps
- CEOS. 2026 Adaptation and Resilience case-study atlas. https://eohandbook.com/2026casestudies/
- CEOS. In Season Yield Forecasting for Decision Making in Malawi. https://eohandbook.com/2026casestudies/malawi.html
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- NASA Harvest. GEOCIF crop-yield modelling and agrometeorological inputs. https://www.nasaharvest.org/news/a-hrefhttpsnasaharvestorgnewsnasa-harvest-leads-crop-yield-modeling-workshopnasa-harvest-leads-crop-yield-modeling-workshopa
- GEOGLAM Crop Monitor. Agmet Indicator Tool. https://cropmonitortools.org/tools/agmets/
- HarvestStat. Subnational crop production data. https://www.harveststat.org/
- FAO GIEWS. Special Alert No. 352: Southern Africa drought. https://openknowledge.fao.org/bitstreams/d2a838e2-70a0-437e-ac25-7ebe5a0bd927/download
- NASA/JPL. SMAP mission and data. https://smap.jpl.nasa.gov/data/
- WMO. Marie-Claire Greening, Programme Coordinator, ESA Programme and Coordination Office. https://community.wmo.int/events/15th-session-of-consultative-meetings-high-level-policy-satellite-matters-cm-15

Ramraj Narasimhan (CDRI): Disaster Risk Reduction through Earth Observation and Climate Services

Ramraj Narasimhan, Senior Director of Programme Management & Technical Support at the Coalition for Disaster Resilient Infrastructure (CDRI), presented a regional perspective on how Earth observation and climate services can strengthen disaster-risk reduction and infrastructure resilience in South Asia. Narasimhan identified priority EO products, operational application chains and the technical and institutional conditions required to convert observations into decisions.

The presentation demonstrated South Asia as one of the world's most hazard-exposed regions, with approximately two billion people living within a hazard footprint, more than 750 million people affected by disasters during the previous two decades and estimated annual disaster losses of about USD 150 billion. Floods, cyclones, heatwaves, landslides, glacial lake outburst floods (GLOFs), earthquakes, drought and coastal hazards increasingly interact as compound and cascading risks. EO maturity across the region was characterised as uneven across the seven countries considered. India was classified as advanced; Pakistan and Bangladesh as moderate; Sri Lanka, Nepal and Bhutan as emerging; and the Maldives as limited. National agencies and systems already coexist with services supplied through ISRO, ICIMOD, international missions and donor-supported programmes, but most countries remain dependent on external products. Regional readiness therefore cannot be inferred from sensor availability alone: it also depends on national processing capacity, institutional ownership, continuity of funding and the routine incorporation of products into disaster-management workflows.

As shown in Figure 23, the central bottleneck is the gap between Earth-observation data, information products and operational decisions. The presentation grouped the barriers into four sets:

- limited expertise in SAR, InSAR, AI/ML and cloud processing;
- fragmented institutional responsibilities and weak product operationalisation;
- restricted access to commercial imagery and inadequate sustained funding;
- missing decision products, including asset-exposure databases, infrastructure-risk products, national digital twins and multi-hazard analytics.

This framing is important for indicator readiness because an observable hazard variable may be technically mature while the complete risk or resilience indicator remains non-operational.

Six climate topics were highlighted as regional priorities but priorities differed between the seven individual countries: flood mapping, heat monitoring, landslide monitoring, GLOF monitoring, coastal monitoring and infrastructure-risk screening. The last was the only product marked as needed in all seven countries. The broader opportunity was organised around three decision domains: risk-informed planning, including exposure mapping, resilience screening and climate stress testing; multi-hazard early warning for floods, landslides, heat, GLOFs and cyclones; and post-disaster assessment through damage mapping, recovery monitoring and loss estimation.

The technical chains rely on complementary observing modes. Radar supports all-weather flood mapping, surface deformation and accessibility analysis; optical and thermal imagery supports land-cover, urban growth, infrastructure inventory, damage classification and heat-hotspot mapping; altimetry and ocean observations contribute to coastal and storm-surge applications; and precipitation, soil-moisture, vegetation and elevation products feed flood, drought, landslide and GLOF services. However, exposure, vulnerability, asset criticality, losses, service disruption, recovery and resilience are not measured from space alone. They require administrative asset registers, demographic and economic data, engineering vulnerability functions, field validation, forecast models, decision thresholds and institutional records. EO should therefore be treated as a direct or derived input to many hazard and damage metrics, but as only one component of complete risk, early-warning and adaptation-effectiveness indicators.

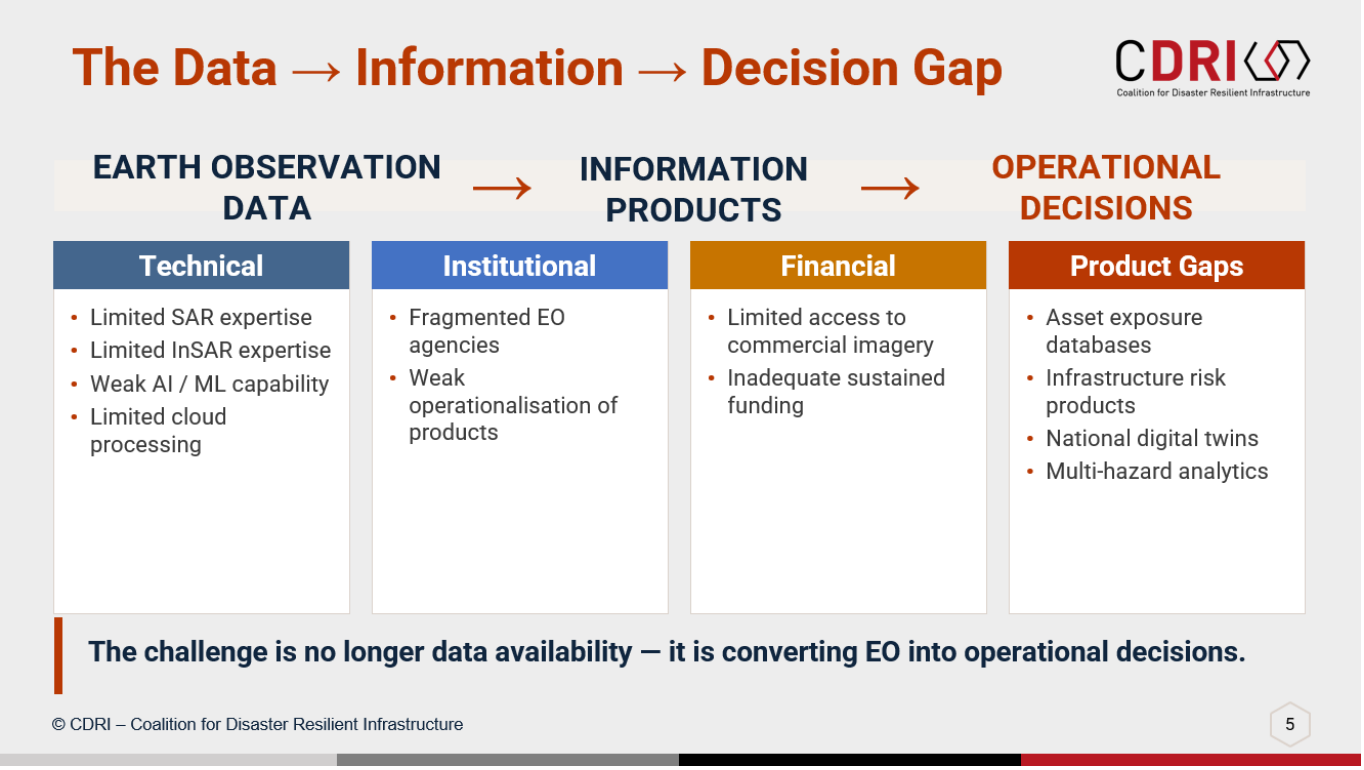


Figure 23. The Earth-observation data-to-information-to-decision gap in South Asia.

Presentation references and related links

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- CDRI. Ramraj Narasimhan - Senior Director, Programme Management & Technical Support. https://cdri.world/cdri-team/ramraj-narsimhan/
- CDRI. Coalition for Disaster Resilient Infrastructure. https://cdri.world/
- Copernicus Data Space Ecosystem. Copernicus Sentinel missions and data access. https://dataspace.copernicus.eu/data-collections/copernicus-sentinel-missions
- U.S. Geological Survey. Landsat data access. https://www.usgs.gov/landsat-missions/landsat-data-access
- NASA Earthdata. Global Precipitation Measurement mission and resources. https://www.earthdata.nasa.gov/data/platforms/space-based-platforms/gpm/resources
- NASA Earthdata. ECOSTRESS data collections. https://www.earthdata.nasa.gov/data/instruments/ecostress

Fernando J. Díaz López (HEC): Mission-ADAPT: UNDERPIN Measuring Progress on Resilience Project

Fernando J. Diaz Lopez, Executive Director of the Climate & Earth Center at HEC Paris, presented the EU's Mission ADAPT Project, UNDERPIN, of which he is Principal Investigator. Launched in September 2025, UNDERPIN (oUtcome iNDicators to mEasuRe Progress on climate resilience) is a flagship project under the EU Mission on Adaptation to Climate Change and is highly involved in furthering alignment on topics related to Monitoring, Evaluation, and Learning (MEL) as part of the MIP4Adapt Community of Practice.

UNDERPIN addresses critical gaps in MEL for climate adaptation across Europe. It will design, develop, and validate an outcome-oriented framework that enhances existing frameworks for assessing climate resilience. This framework will include operationalised process and outcome indicators to track adaptation progress at local, regional, and national levels. A major challenge is the lack of standardised indicators

capturing the effectiveness of adaptation efforts. Existing frameworks often focus on processes but fail to assess long-term resilience outcomes.

Indicator selection began with manual review of scientific and grey literature and a database of more than 3,500 candidate indicators. An application-readiness screen retained 595 candidates; a further inclusion check left 477, which were clustered into 69 similarity groups. Selection of one indicator per relevant subgroup yielded a 46-indicator shortlist, assessed against policy relevance, scientific robustness and operationalisability. The framework is intended to remain iterative: an initial set of roughly 50 outcome-oriented indicators is expected to expand towards approximately 200 after expert consultation, regional pilots and pan-European testing.

Indicators were mapped to their data availability, as shown in Figure 24. Red denotes no data availability; pale green denotes data availability that still requires a methodological processing approach; green denotes direct data availability. The assessment identified, respectively, 23/12/10 environmental, 38/7/2 climate and 38/11/1 socioeconomic indicator-data relationships across the three readiness classes. Counts are domain-specific and should not be summed as unique indicators because a single indicator may depend on multiple domains.

Twenty-two indicators were described as potentially operationalisable using EO data. They cover agricultural drought and crop diversity; ecosystems, forest condition, wildfire, protected areas and land degradation; access to green and blue space; impervious surfaces and river restoration; damage to buildings and infrastructure; agricultural losses; water status, irrigation and storage; and compound biodiversity or forest trends. EO support ranges from direct mapping to model-integrated evidence. Many complete indicators still require administrative boundaries, crop and forest inventories, ecological field observations, asset registers, damage and loss records, water accounts or national statistics.

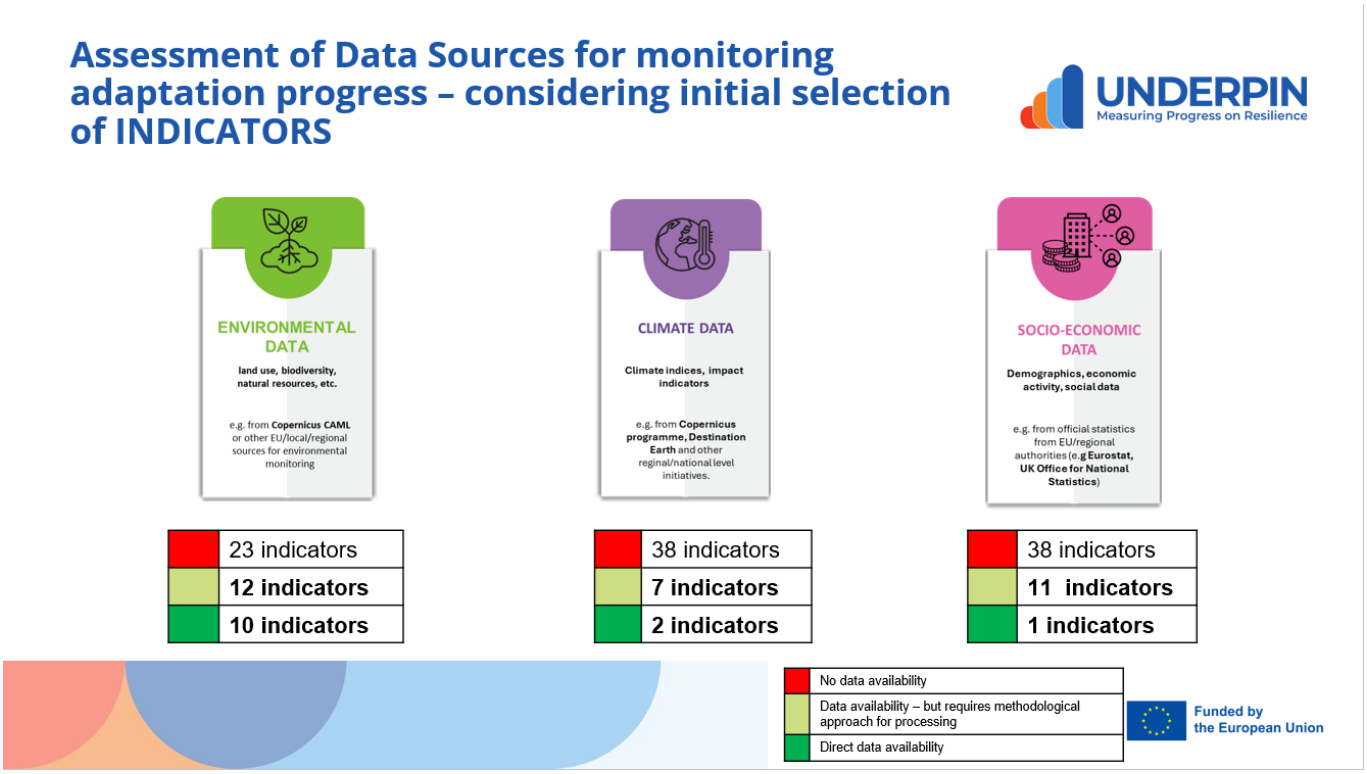


Figure 24. Initial UNDERPIN assessment of data-source readiness for monitoring adaptation progress. Red denotes no data availability; pale green denotes data availability that still requires a methodological processing approach; green denotes direct data availability.

Presentation references and related links

- Copernicus Climate Change Service. ERA5-Land hourly data from 1950 to present. Dataset. https://cds.climate.copernicus.eu/datasets/reanalysis-era5-land
- UNDERPIN. Project website. https://www.underpinclimate.eu/
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- HEC Paris. Climate & Earth Center: Fernando J. Díaz López. https://www.hec.edu/en/institutes-and-centers-expertise/sustainability-organizations/climate-and-earth/think
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- IPCC (2022). Climate Change 2022: Impacts, Adaptation and Vulnerability. Chapter 17: Decision-Making Options for Managing Risk. https://www.ipcc.ch/report/ar6/wg2/chapter/chapter-17/
- Copernicus Land Monitoring Service. High Resolution Layer Croplands. https://land.copernicus.eu/en/products/high-resolution-layer-croplands
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Miguel Vallejo Orti (JRC): European urban climate adaptation – Knowledge Centre on Earth Observation (KCEO) perspective

Miguel Vallejo Orti, researcher at the European Commission's Joint Research Centre contributing to the Knowledge Centre on Earth Observation (KCEO), presented the KCEO Urban Climate Adaptation Deep Dive project results with the emerging Global Goal on Adaptation (GGA) indicator framework. The assessment tested how an existing inventory of city-level adaptation indicators and EO application needs could be mapped to the GGA and translated into policy-ready services.

The Deep Dive follows a policy-to-observation workflow: identify key actors; collect and assess policy needs; analyse the EO value chain; translate needs into technical requirements; assess the fitness for purpose of existing products and services; and identify gaps and recommendations. Five policy-oriented use cases were selected, spanning urban greening, coastal adaptation, urban heat islands, urban drought and flooding and water-quality/quantity monitoring, and sustainable urban development.

The underlying KCEO mapping consolidated more than 500 indicators from urban adaptation frameworks. More than 200 were addressable by EO in some form and approximately 100 were described as directly approachable through EO. The exploratory crosswalk then compared 217 KCEO indicators with a 100-item pre-COP30 GGA working set using semantic matching and metadata alignment, including consideration of thematic domain, adaptation dimension, indicator type, scale, context and EO applicability. Resulting classifications were no match, proxy match, partial match or full match.

The crosswalk found 71.4% with no KCEO correspondence, 26.7% proxy matches and 1.9% partial matches; no full-match share was visible in the reported distribution. Only 28.6% of the GGA working indicators were considered EO-observable. Within that EO-covered subset, 41.9% were assigned direct EO support and 58.1% proxy support. The presentation recommends repeating and documenting the crosswalk against the final 59 Belém indicators.

Orti presented an urban-greening use case to demonstrate the operational gap. Copernicus Land Monitoring Service products provide Urban Atlas land-cover and land-use information, as well as the Street Tree Layer, Tree Cover Density, vegetation, small woody feature, riparian-zone and coastal-zone information. However, several products lack the spatial detail, update frequency or spectral discrimination

required for individual-tree and species-level monitoring. The presentation recommends sub-metre Copernicus Contributing Mission imagery for urban vegetation mapping, annual updates for monitoring green-cover dynamics and future hyperspectral observations for assessing vegetation health and identifying drought-resistant native plants. These EO sources need to be combined with in situ, aerial, LiDAR, municipal and socioeconomic data.

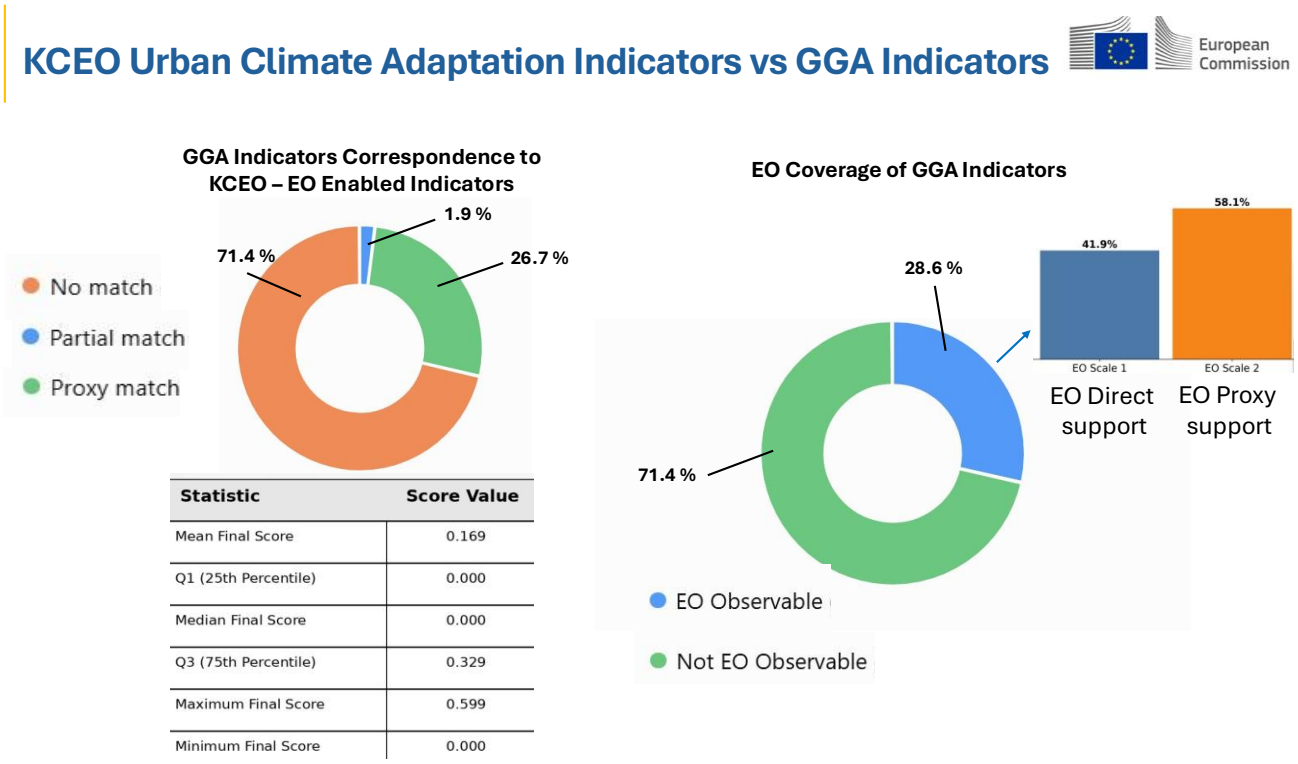


Figure 25. Overview of the mapping of the Urban Knowledge Centre on Earth Observation (KCEO) indicators vs the GGA indicator and to what extent EO can support.

Presentation references and related links

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- Dowell, M., et al. (2025). Earth Observation in support of EU policies for urban climate adaptation. Joint Research Centre, JRC140369. https://publications.jrc.ec.europa.eu/repository/handle/JRC140369
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- European Environment Agency and European Commission. Climate-ADAPT - Key Type Measures and adaptation options. https://climate-adapt.eea.europa.eu/en/knowledge/adaptation-information/adaptation-options

Session 8: Discussion and Consolidation

Chair: Susanne Mecklenburg (ESA)

Panel: Jean Dusart (DG RTD), Johanna Nalau (Griffith University), Carlo Buontempo (C3S), Theresa Wong (IPCC), Maryam Navi (UNFCCC) - Reflections Panel on the discussions so far and next steps

The closing panel brought together representatives from ESA, the European Commission Joint Research Centre, UNFCCC, ECMWF/C3S, IPCC WGII and academia to reflect on three days of discussion and to chart a way forward.

Mark Dowell's (JRC) introductory framing set the tone for the session: rather than reinventing processes, the EO community should simplify the end user's experience by leveraging existing indicators and mechanisms. He reiterated that around 30% of GGA indicators can be addressed to some degree with Earth observation and highlighted two cross-cutting priorities — applying a "measure once, use many times" logic so that a single EO observation chain can serve the GGA, SDGs and the CBD/GBF framework simultaneously, and not losing sight of the ten headline target indicators amid the disaggregated technical work.

The panel converged on a balanced message: EO's contribution to the GGA framework is probably far greater than currently recognised or used, underpinning hazard baselines and near-term outlooks—through products such as ERA5 and C3S seasonal forecasts—across almost every indicator. However, its role should not be overstated. Early warning systems remain among the most cost-effective adaptation measures, and the priority is to combine complementary information streams rather than rely on established methods alone. EO is most valuable when integrated with socioeconomic data and designed around adaptation needs. The forthcoming update to the EU climate adaptation strategy could help mainstream adaptation across policy domains. Participants also highlighted inconsistencies in how agencies and statistical systems feed data into indicators and called for timely action, potentially through the anticipated technical task force. A peer-reviewed paper drawing on the workshop findings was also proposed.

Communication was identified as a central challenge: EO's contribution to the GGA must be framed in terms that resonate with Parties and the political process. Its strengths should be presented alongside its limitations, since adaptive capacity, governance and access to finance cannot be captured through EO alone. Over-reliance on EO-based indicators could under-represent lower-capacity countries. EO should therefore be positioned as a critical but partial component of a broader evidence base, complementing rather than replacing established reporting procedures.

The discussion also addressed implementation gaps. Participants identified a substantial capacity-building deficit at local and municipal levels, including limited expertise in interpreting complex EO information and monitoring adaptation progress over time. They called for stronger links between EO, policy and private-sector processes, using a long-term vision of how countries might ideally use EO by 2045 to guide near-term priorities. Practical needs included timely, service-based delivery rather than one-off products, and data formats compatible with standardised national reporting channels. Concerns were also raised about reconciling growing demand for EO-based adaptation evidence with the long-term continuity of observing systems.

The panel identified several concrete next steps:

- potentially establishing a technical task force around COP31 to develop shared metadata and traceability standards;
- preparing a short-term policy brief translating technical findings for policymakers;
- producing a longer-term peer-reviewed publication capturing the workshop's conclusions, with the CEOS Adaptation and Resilience Handbook as a practical reference.

The closing discussion framed COP as an opportunity to communicate clearly what EO can and cannot deliver and proposed a roadmap for tailoring messages about indicator-level EO applicability to different audiences. The session ended by recognising the workshop's collaborative spirit and affirming a shared commitment to advance this work towards COP31 in Türkiye.

Acronyms

Acronym	Definition
AI	Artificial intelligence
AI-DOP	Artificial Intelligence Direct Observation Prediction
AR6	Sixth Assessment Report
AR7	Seventh Assessment Report
ARIES	Artificial Intelligence for Environment and Sustainability
BAR	Baku Adaptation Road Map
BERI	Bioclimatic Ecosystem Resilience Index
C3S	Copernicus Climate Change Service
CAI	Climate Adaptation Insights
CBD	Convention on Biological Diversity
CCI	Climate Change Initiative
CDRI	Coalition for Disaster Resilient Infrastructure
CEOS	Committee on Earth Observation Satellites
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CLIMADA	CLIMate ADAptation
CMA	Conference of the Parties serving as the meeting of the Parties to the Paris Agreement
CMIP5	Coupled Model Intercomparison Project Phase 5
CO2M	Copernicus Anthropogenic Carbon Dioxide Monitoring mission
COP	Conference of the Parties
CRISTAL	Copernicus Polar Ice and Snow Topography Altimeter
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAYCLI	Daily Climate Data Exchange
DestinE	Destination Earth
DG AGRI	Directorate-General for Agriculture and Rural Development
DG CLIMA	Directorate-General for Climate Action
DG DEFIS	Directorate-General for Defence Industry and Space
DG ENV	Directorate-General for Environment
DG RTD	Directorate-General for Research and Innovation
DLR	German Aerospace Center
EC	European Commission
ECMWF	European Centre for Medium-Range Weather Forecasts
ECOSTRESS	ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station
ECSAT	European Centre for Space Applications and Telecommunications
ECV	Essential Climate Variable
EEA	European Environment Agency
EIFFEL	Revealing the Role of GEOSS as the Default Digital Portal for Building Climate Change Adaptation and Mitigation Applications
EO	Earth observation
EO4SDG	Earth Observation for the Sustainable Development Goals
EOCIS	Earth Observation Climate Information Service
EOP	Earth Observation Programmes

ERA5	Fifth-generation ECMWF atmospheric reanalysis
ESA	European Space Agency
ET	Evapotranspiration
EU	European Union
EURO-CORDEX	European branch of the Coordinated Regional Climate Downscaling Experiment
EVI	Enhanced Vegetation Index
FAIR	Findable, Accessible, Interoperable and Reusable
FAO	Food and Agriculture Organization of the United Nations
FAPAR	Fraction of Absorbed Photosynthetically Active Radiation
GATT	GCOS Adaptation Task Team
GBF	Kunming–Montreal Global Biodiversity Framework
GBON	Global Basic Observing Network
GCOS	Global Climate Observing System
GEO	Group on Earth Observations
GEOCIF	Global Earth Observations for Crop Intelligence Framework
GEOGLAM	Group on Earth Observations Global Agricultural Monitoring
GGA	Global Goal on Adaptation
GHG	Greenhouse Gas
GHSL	Global Human Settlement Layer
GHS-OBAT	Global Human Settlement–Open Building Attribute data
GLOF	Glacial lake outburst flood
GPM IMERG	Global Precipitation Measurement Integrated Multi-satellitE Retrievals
GRACE	Gravity Recovery and Climate Experiment
GRACE-FO	Gravity Recovery and Climate Experiment Follow-On
HEC	HEC Paris
InSAR	Interferometric Synthetic Aperture Radar
IPCC	Intergovernmental Panel on Climate Change
ISRO	Indian Space Research Organisation
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre
KCEO	Knowledge Centre on Earth Observation
LAI	Leaf Area Index
LDC	Least Developed Country
LiDAR	Light Detection and Ranging
LPIS	Land Parcel Identification System
LSE	Land surface emissivity
LST	Land surface temperature
LSTM	Land Surface Temperature Monitoring mission
MEL	Monitoring, evaluation and learning
MICAM	Monitoring the Impact of Climate Adaptation Measures
MIP4Adapt	Mission Implementation Platform for Adaptation to Climate Change
MODIS	Moderate Resolution Imaging Spectroradiometer
NAP	National Adaptation Plan
NAPX	National Adaptation Plan Exchange
NARO	National Agriculture and Food Research Organization
NASA	National Aeronautics and Space Administration
NCEO	National Centre for Earth Observation
NDVI	Normalized Difference Vegetation Index
NOA	National Observatory of Athens
NPP	Net Primary Production
NWP	Numerical weather prediction
OECD	Organisation for Economic Co-operation and Development
PRAIS	Performance Review and Assessment of Implementation System
RCP8.5	Representative Concentration Pathway 8.5
RLA	Regional and local authority
SAR	Synthetic aperture radar
SB	Subsidiary Bodies
SDG	Sustainable Development Goal

SEEA	System of Environmental-Economic Accounting
SIDS	Small Island Developing States
SIF	Solar-Induced Fluorescence
SLSTR	Sea and Land Surface Temperature Radiometer
SMAP	Soil Moisture Active Passive
SOC	Soil organic carbon
SOFF	Systematic Observations Financing Facility
SPI-12	12-month Standardized Precipitation Index
TSU	Technical Support Unit
UAE	United Arab Emirates
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
VIIRS	Visible Infrared Imaging Radiometer Suite
WASH	Water, Sanitation and Hygiene
WGII	Working Group II
WHO	World Health Organization
WIVERN	WInd VElocity Radar Nephoscope
WMO	World Meteorological Organization
WSF	World Settlement Footprint

Annex 1: Workshop Agenda

Overview:

Time	Day 1 (23rd June)	Time	Day 2 (24th June)	Time	Day 3 (25th June)
		09.00-11.00	Session 3: GGA Targets, Indicators & EO capabilities	09.00-10.30	Session 7: Adaptation Action – regional and local users
		11.00-11.30	Coffee	10.30-11.00	Coffee
		11.30-13.00	Session 4: Compiling Indicators – lessons learned from past practice & indicator mapping	11.00-12.00	Session 8: Discussion and Consolidation
		13.00-14.00	Lunch	12.00-13.00	Lunch
12.30-13.30	Registration				
13.30-14.30	Session 1: Welcomes	14.00-15.00	Session 5: Adaptation planning and implementation at the national level		
14.30-15.00	Coffee	15.00-15.30	Coffee		
15.00-16.30	Session 2: Introduction to Climate Adaptation and the UNFCCC's Global Goal on Adaptation – Policy Context	15.30-17.30	Session 6: Adaptation Action – How to make EO more useful for adaptation?		
	Ice breaker		*Workshop Dinner*		

Detailed:

Day 1

Time	Title	Speaker
11.45 *12.30-13.30*	*Buses depart Oxford* *Registration*	
13.30-14.30	**Session 1: Welcome** Chair: Susanne Mecklenburg and Mark Dowell	
	Welcome by hosts & introduction to the workshop objectives	Susanne Mecklenburg and Mark Dowell
	ESA Welcome	Simonetta Cheli (ESA)
	EC-JRC Welcome	Alessandra Zampieri (EC-JRC)
	EC-DEFIS Welcome	Hugo Zunker (EC DG DEFIS)
	CEOS priorities for adaptation	Alex Held (CEOS Chair/CSIRO)
	Workshop overview and logistics	Sarah Connors (ESA)
14.30-15.00	*Coffee*	
15.00-16.30	**Session 2: Introduction to Climate Adaptation and the UNFCCC's Global Goal on Adaptation – Policy Context** Chair: Susanne Mecklenburg	
15.00 (20mins+5 Qs)	The Global Goal on Adaptation – Process to date • From the Paris Agreement to Belém.	Maryam Navi (UNFCCC)
15.25 (20mins+5 Qs)	Framing EU (update EU Climate Adaptation Strategy)	Elena Saggioro (DG CLIMA)
15.50 (20mins+5 Qs)	Unpacking the 59 GGA indicators • 11 Targets and associated indicators • 4 Policy cycle targets and 7 Themes	Karina Von Schuckmann (MERCATOR)
16.15 (10mins+5 Qs)	Framing EO Science capabilities	Sarah Connors (ESA)

16.30-17.30	Ice breaker Reception on site	
17.45	Buses depart to Oxford	

Day 2

Time	Title	Speaker
08.00	Buses Depart Oxford	
09.00-11.00	**Session 3: GGA Targets, Indicators & EO capabilities** Chair: Sarah Connors	
09.00 (15mins+5 Qs)	Mapping of EO to the indicators – first steps • Overview of the initial mapping	Mark Dowell (EC-JRC)
09.20 (15mins+5 Qs)	Using EO for specific GGA Targets: Forests and Agriculture	Chiara Corbari (POLIMI) – ESA MICAM project
09.40 (15mins+5 Qs)	Using EO for specific GGA Targets: Water	Orestis Speyer (NOA, GR) EIFFEL Project
10.00 (15mins+5 Qs)	Using EO for specific GGA Targets: Infrastructure	Thomas Kemper (EC-JRC)
10.20 (15mins+5 Qs)		
10.40	DestinE Adaptation Demonstrator: Using Destination Earth Data to calculate GGA indicators Interactive Discussion	Nicolas Monzali (MEWS)
11.00-11.30	Coffee	
11.30-13.00	**Session 4: Compiling Indicators – lessons learned from past practice & indicator mapping on the national level** Chair: Mark Dowell	
11.30 (10mins+5 Qs)	From data to decisions: lessons learned from EEA indicator practice	Julie Berckmans (EEA)
11.45 (10mins+5 Qs)	StatEO: Report back from the ESA StatEO conference (inc. lessons learned from the SDGs)	Giuseppe Ottavianelli (ESA)
12.00 (10mins+5 Qs)	Earth Observation for SDG Indicator 15.3.1 and Drought: The UNCCD Perspective	Brian O'Connor (UNCCD)
12.15	Interactive Activity: Indicator Mapping	All participants
13.00-14.00	Lunch *Demonstration of the DestinE Climate Information for Adaptation Demonstrator (plenary room)*	
14.00-15.30	**Session 5: Adaptation planning and implementation at the national level** Chair: Sarah Connors	
14.00 (15mins +5 Qs)	National Adaptation Plans – Overview and entry points Learning from NAP support programmes Panel Discussion: what working with countries has taught us - Perspective from global support programmes - Perspective from the agriculture sector	Paul V. Desanker (UNFCCC)

	Panellists: • Rohini Kohli (UNDP) • Theresa Wong (IPCC WGII TSU) • Sven Gilliams (GEOGLAM) • Rory Scarrott (GEO Blue Planet) Discussion	
15.30-16.00	Coffee	
16.00-17.30	**Session 6: Adaptation Action – How to make EO more useful for adaptation?** Chair: Susanne Mecklenburg	
16.00 (10mins+5 Qs)	User requirements from the Adaptation community for scientific assessment	Johanna Nalau (Griffith University)
16.15 (10mins+5 Qs)	Super Resolution EO / Downscaling EO – capabilities and risks, strengths and weaknesses	Mike Perry (University of Leicester)
16.30 (10mins+5 Qs)	Incorporating EO data for a more comprehensive assessment of Risk.	Mikaël Maes (OECD)
16.45 (10mins+5 Qs)	Potential from the new missions	Thorsten Fehr (ESA)
17.00 (10mins+5 Qs)	GCOS Essential Climate Variables (ECVs) – Adaptation requirements	Peter Thorne (GCOS)
17.15 (10mins+5 Qs)	Copernicus Climate Change Service (C3S) perspective	Carlo Buontempo (C3S)
17.45	Buses Depart to Oxford	
19.00	Reception Dinner at the Ashmolean Museum	

Day 3

Time	Title	Speaker
08.00	Buses Depart Oxford	
09.00-10.30	**Session 7: Adaptation Action – regional and local users** Chair: Sarah Connors	
09.00 (15mins+5 Qs)	European Commission's Mission on Climate Adaptation	Jean Dusart (EC DG-RTD)
09.20 (15mins+5 Qs)	The CEOS EO for Adaptation Handbook: Case Studies from across the globe	Marie-Claire Greening (ESA) and Stephen Ward (CEOS)
09.40 (10mins each +10 overall for Qs)	End user uptake cases presentations • Disaster Risk Reduction through Earth Observation and Climate Services • Mission-ADAPT: UNDERPIN Measuring Progress on Resilience Project • European urban climate adaptation – Knowledge Centre on Earth Observation (KCEO) perspective	Ramraj Narasimhan (CDRI) Fernando J. Díaz López (HEC) Miguel Vallejo Orti (JRC)
10.30-11.00	Coffee	
11.00-12.00	**Session 8: Discussion and Consolidation** Chair: Susanne Mecklenburg Reflections Panel on the discussions so far and next steps • Chair: Susanne Mecklenburg • Rapporteur: Mark Dowell • + Panellists Discussion and Q&A with audience	Jean Dusart, Johanna Nalau, Carlo Buontempo, Theresa Wong, Maryam Navi.

	Meeting Close	
12.00-13.00	Lunch	
13.05	Buses Depart to Oxford	