How Can GCOS Best Support Adaptation in the UNFCCC Space?

A report from the GCOS Adaptation Task Team

Table of Contents

1 Purpose of this Report and Key Questions

In light of recent international agreements, in particular the UNFCCC's Paris Agreement and the 2030 Agenda on Sustainable Development Goals, the purpose of this report is to determine how global climate observations can best support climate resilient development through adaptation to climate change, and to provide a work plan to achieve this outcome. Given GCOS responsibilities in relation to the UNFCCC and associated activities, the report is focused on the UNFCCC space rather than the wider adaptation space.

Key questions considered in this report are:

1. How can GCOS develop a mechanism that, moving forward, continuously evaluates the suitability (in terms of spatial and temporal resolution) of existing GCOS ECVs for adaptation application (observations for and of adaptation)?[1]
2. What are the current observation capabilities for ECV parameters that might become useful in specific adaptation contexts?
3. Are there any additional parameters (not in the current GCOS suite of ECVs) that are needed for adaptation and that future global observations could support?

Both 1. and 2. will require a process for upgrading the observations in terms of temporal and spatial resolution if required.

2 A Brief Background

A key purpose of GCOS when it was established in 1992 was to report on the adequacy of the current climate observing system to the UNFCCC. Until now, GCOS has been substantially involved in support of activities of Working Group 1 (WGI) of the IPCC, but since the Paris Agreement priorities have changed, with a more urgent requirement to additionally support the activity of Working Group 2 (WGII), especially in relation to addressing the issues of impacts (including extremes) and adaptation.

The Paris Agreement established the Global Stocktake as a tool to track global efforts on climate change, including adaptation. Article 14 specifies that the Global Stocktake shall; *recognize adaptation efforts of developing countries; enhance the implementation of adaptation action taking into account adaptation communication; review the adequacy and effectiveness of adaptation and support provided for adaptation;* and *review the overall progress made in achieving the Global Goal on Adaptation in light of global climate goals.* In response to this agenda, GCOS included two adaptation-relevant actions in its 2016 Implementation Plan (GCOS-200): Action G1 – *Produce guidance and best practice for adaptation observations*; Action G2 – *Identify indicators for adaptation and risk*.

---

[1] Broadly in the areas of model data requirements, climate risk assessments, and assessment of progress in adaptation as defined earlier.

GCOS in 2019 formed a small scoping group to help develop a way forward, including identification of how current ECVs could be used or modified to inform the adaptation community. This group identified three clear areas of GCOS contribution using existing ECVs through the provision of bio-geophysical data that leads to:

A. improved understanding of climate change impacts and climate related risks and hence adaptation needs[2] (observations **for** adaptation);
B. information on the development of adaptation[3] (observations **of** adaptation - or the more commonly used term M & E (monitoring and evaluation frameworks assess the effectiveness of various approaches to adapt to climate change) for a limited number of examples.

The scoping group also raised the possibility, should it be necessary, of establishing new ECVs or ECV products to provide information on human adaptation (i.e., observations **of** adaptation) for certain examples[4] – these might be related to existing ECVs or could be completely new ECVs, not necessarily physical/climate related. In 2021, GCOS established the GCOS Adaptation Task Team (GATT) to broaden the effort to include the other two GCOS Panels.

The latest GCOS Implementation Plan (GCOS-IP 2022) gave increasing importance to Adaptation with at least five relevant Actions, as listed here below:

- C4. New and improved reanalysis products
- E1. Foster regional engagement in GCOS
- F1. Responding to user needs for higher resolution, real time data
- F3. Improve monitoring of coastal and Exclusive Economic Zones
- F4. Improve climate monitoring of urban areas

2.1 Adaptation

Adaptation aims to limit the consequences of a warming climate, and requires among many other elements, climate information about the hazards. The combination of hazard, exposure, vulnerability to the impact and adaptive capacity define the climate risk[5]. The release of the reports of WG1 and WG2 of AR6 in late 2021 and early 2022 have highlighted the need for

---

[2] For example, input to regional climate models, agro-ecological models, coastal and flood risk models (relevant ECVs could include sea-level, soil moisture, LULC change, etc.).

[3] For example, shifts in LULC (ECVs reflecting changes in agricultural patterns, urban land cover change), anthropogenic use of fire, prescribed burning (active fire ECV), etc.

[4] For example, tracking green cover in cities, tracking national budgets on adaptation, investment in coastal infrastructure, mapping development of coastal defences, etc.

[5] The IPCC WGII 6th Assessment Report has evolved the concept of climate risk to one of climate resilient development. Climate resilient development requires society and ecosystems to “transition” to a more resilient state. The recognition of climate risks can strengthen adaptation and mitigation actions and transitions that reduce the risks.

urgent action in the adaptation space. The following two high-level statements from the IPCC WGII 6th Assessment Report SPM (February 2022) are particularly pertinent (confidence statements removed). **SPM.B.1** *Over decades, human-induced climate change has had substantial adverse impacts on nature and people in all regions, particularly affecting the most vulnerable people and ecosystems. Without current adaptation efforts, these impacts would have been substantially worse.* **SPM.B.3** *Increased frequency, intensity, and duration of climate-change-induced extreme weather events are causing widespread and severe impacts on people, settlements, and infrastructure as well as ecosystems and their services. Increases in extremes are surpassing the resilience of some ecological and human systems, and challenging their adaptive capacities, leading to irreversible impacts.*

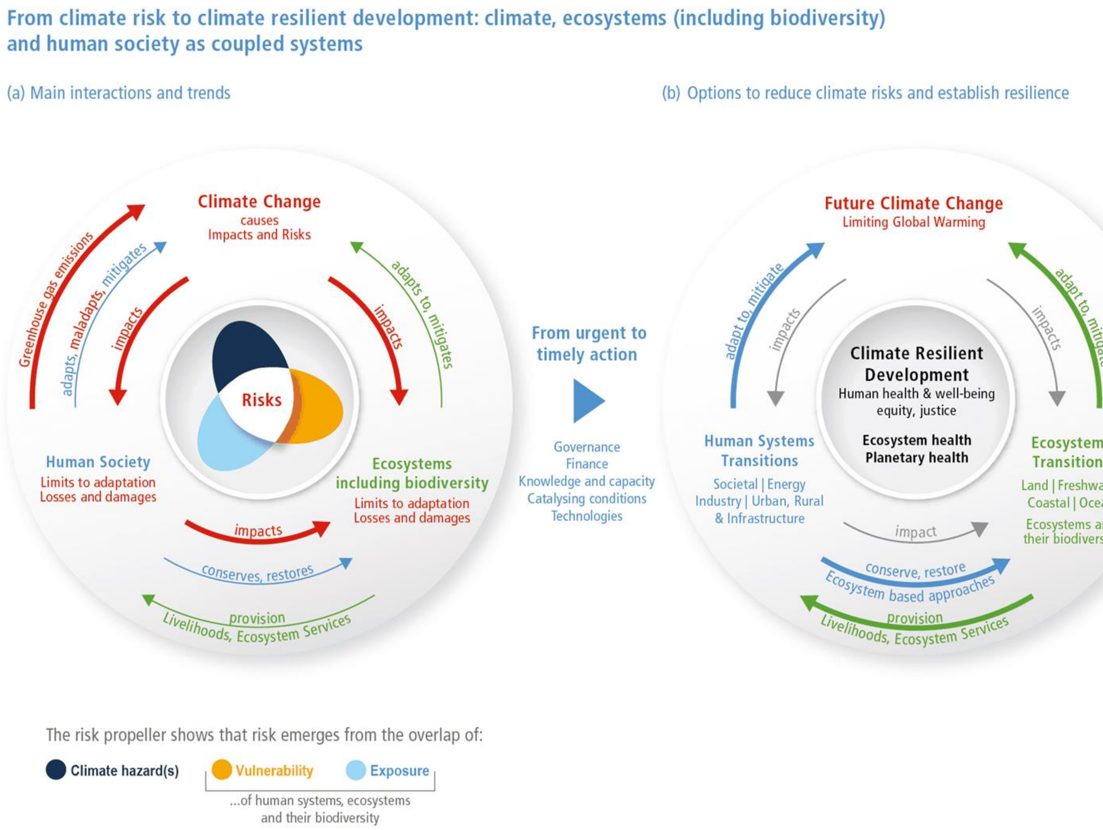


Figure 1. The concept of climate resilient development, based on interactions between climate, ecosystems, and human society. Source: IPCC AR6 WGII.

Adaptation has the effect to reduce exposure to hazards and/or reduce vulnerability, but these are concepts normally applied at the local level. High-resolution observations and model data are useful for providing the local context for adaptation, and local observations are needed to complement and validate top-down generated products, but they need to be put in the context of larger, often transboundary scales. Connecting the global, regional and local scales is the challenge of bridging between a ''top-down'' approach to climate information on the global scale, and local decision contexts which necessarily take a ''bottom-up'' perspective, in which climate change is just one factor among many to consider. If the task is to make the information from these data available in a form and at scales that support adaptation decision-making at all levels and in all regions of the world, the overarching question is – what is the utility of global data sets for local adaptation applications?

3 Global Data Sets

The Task Team has identified a key role for global datasets of the kind that GCOS supports. These are:

- All adaptation requires an understanding of how the climate is likely to change. Global and regional models, following the approach of NWP, require global data as inputs for calibration and validation. Local, higher resolution, models, as used for adaptation planning, will be nested within these larger scale models. Downscaling from these global models is used to ensure consistency. Thus all forecasts, from global to local depend on reliable, accurate global observations.

- Reanalysis is used to provide information without the gaps in space and time that often occur in the instrumental record. Reanalysis is the often most suitable source of data for many applications such as the initialization of impact models. Action C4 in the IP 2022 on new and improved reanalysis products focuses on providing higher resolution data and approaches to regionalization, with improved bias characterisation and reduced errors, making the reanalysis even more relevant to the adaptation context.

It is clear that the global datasets that are used as input into global and regional climate models and reanalysis are key information needed to support adaptation. Improvements in the completeness, accuracy and resolution promoted by GCOS should improve these products. Further improvements can be expected by models and reanalysis utilising additional ECV, e.g. land cover.

4 Three Case Studies

Three broad case studies in critical sectors have been identified in this report (see below and Appendix A):

(i) forest wildfire management (hereafter referred to as wildfire);

(ii) pluvial flood risk assessment in urban areas;

(iii) ocean extremes.

These case studies have allowed the identification of common challenges and needs:

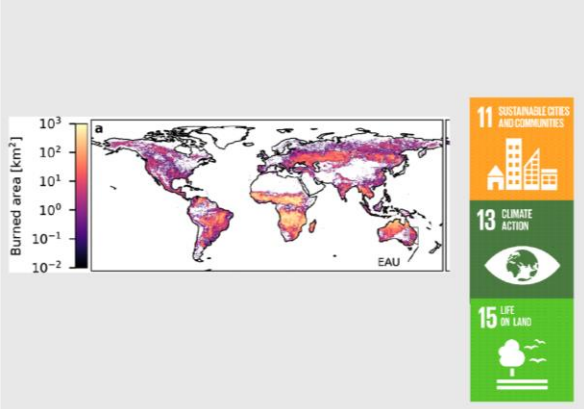
- Adaptation actions are local in nature, and need data at high resolution in time and space together with local data, often needed to characterise climate extremes. This local information must be put in a larger context, requiring consistency at least at the regional scale.
- Observational requirements for characterising and monitoring compounding extremes and cascading impacts have to be addressed as well.
- The basic recognized requirements for observations of climate-related hazards for adaptation purposes, other than specific high resolution in space and time, include characteristics such as spatial and temporal homogeneity, information on drifts and breakpoints, long term time availability and consistency, availability of data in near-real time.
- Reanalysis acts as an integrator of observations, providing information with no gaps in

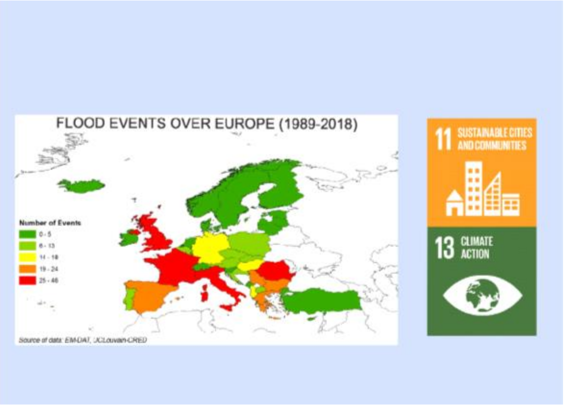
space and time and is the most relevant source of data for many adaptation applications. Reanalysis are used in various ways in the adaptation context, including the initialization of impact models. Action C4 in the IP 2022 on new and improved reanalysis products focuses on providing higher resolution data and approaches to regionalization, with improved bias characterisation and reduced errors, making the reanalysis even more relevant to the adaptation context.

- In the context of adaptation, observational data need to interoperate with diversified and specialised non-climatic (e.g. socio-economic, demographic, technological and environmental) data sources, data of different nature with strong requirements for standards-based data interoperability. Therefore, aspects such as completeness of documentation, accessibility, long-term maintenance, information on independent evaluation, overall assessment of data fitness for purpose and examples of use are essential requirements for a data product to become relevant in the adaptation context. Many of the actions in Theme D, *Managing Data*, of the 2022 GCOS Implementation Plan address these issues.

4.1 General description of the case studies

Three broad case studies in critical sectors have been identified in this report (Figure 2), in order to: evaluate the suitability of existing ECVs for adaptation based on current space and time requirements; address whether there are any current observation capabilities for ECV parameters that might become useful in specific adaptation contexts; identify any new ECVs (parameters not in current GCOS suite) and any additional GCOS observation capabilities relevant for adaptation, that future global observations could support.





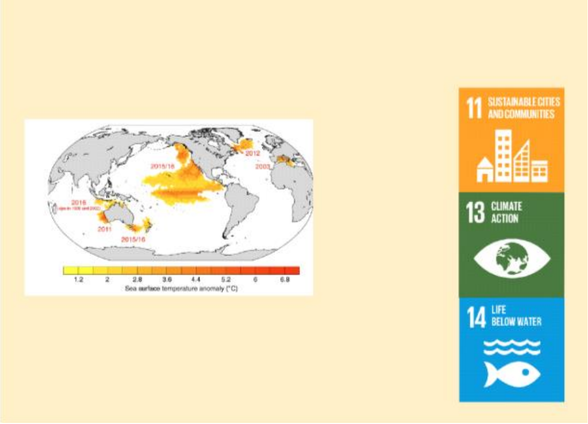


Figure 2. The 3 adaptation case studies addressed in this report: Case 1 – forest wildfire management; Case 2 – pluvial flood risk assessment in urban areas; Case 3 – ocean extremes.

The purpose of the case studies is to provide the context of the connection between the observation capability dimension (the ECVs parameters and their identified or new requirements) to the adaptation application space, within different sectors. These cases cover the three areas of GCOS Panel expertise and common adaptation issues, as identified in National Adaptation Plans and include observations in support of:

i) forest wildfire management (hereafter referred to as wildfire);
ii) pluvial flood risk assessment in urban areas;
iii) ocean extremes.

Appendix A describes each of the case studies in more detail. A list of selected observational data needed for relevant stakeholders in these sectors to effectively address adaptation needs are presented in the case studies.

The structure used to develop these case studies adopts the following approach:

- First, the key adaptation observations needed for each case study are identified based on discussions with a range of experts and stakeholders.
- Second, existing ECVs and/or ECV products are scanned (GCOS IP 2022) to see which might match those adaptation observation needs identified.
- Third, the temporal and spatial resolution of each adaptation observation are compared to that of the existing ECV and/or ECV products as reported in the GCOS IP 2022 ECVs requirements Tables.
- This information is then compiled (e.g. the last column of Table 1) summarising the adequacy of the current observational system to address the specific adaptation need. Each of these steps requires considerable time/effort.

Together with an assessment of the adequacy of the observing system, the case studies report a list of the main adaptation stakeholders (for example, for the wildfire case: national and local government, landscape managers, emergency services including fire agencies, and the insurance sector) and put the case study in the context of the relevant Sustainable Development Goals (for example, for the wildfire case: SDG 11 - Sustainable cities and communities; SDG 13 - Climate action; SDG 15 - Life on land).

Relevant ECVs and/or ECV products are identified in each case (details on the case studies are reported in the Appendix to this report).

The wildfire case study is the most fully developed with **17 ECVs** and **~30 ECV products** identified to date. The current spatial and temporal requirements (GCOS IP 2022) are identified as adequate for adaptation for many of these, while for others higher spatial and temporal resolution is required[6]. Important progress is also made on the urban pluvial flooding and ocean extremes (Tables 2 and 3). The wildfire case is described in more detail below.

4.2 Description of the Wildfire case study

Context: Events in recent years in multiple global regions reveal the vulnerability of both human settlements and natural ecosystems to climate-related severe wildfire events along with documented trends in wildfire severity, impact and extent. Further, the IPCC AR6 has projected that the risk of wildfires is likely to increase in the future due in particular to increases in temperature and changes in the frequency, intensity and duration of drought events. Severe wildfires can also be a major perturbation for local, regional and global carbon budgets.

---

[6] The tables do not address other requirements, such as the length of the timeseries, availability in near real time or accessibility.

However, there are significant adaptation opportunities for forest management to minimize wildfire risk to communities and ecosystems and to mitigate emissions provided the relevant observations are made and are available to the global community. The information is of direct relevance for national and local government, landscape managers, civil protection services including fire agencies and medical services, forest companies, rural economies and the insurance sector among others.

Summary of Data Needs: A variety of geospatial data relevant to enhancing understanding of wildfire risk at global to local scales were identified (Table 1 – appendix A). These included data that can be used to enhance the capacity to model the spatial and temporal evolution of wildfire risk and impact at multiple geographic scales, to understand how that risk could change in the future in response to climate change and other forcing, and then to help evaluate whether wildfire risk and impacts have actually changed over time in response to adaptation actions. More specifically data needs related to ECVs and/or ECV products were identified for variables that can be used in modelling and simulation of wildfire risk, particularly atmospheric and land ECVs such as temperature, precipitation, water vapour, soil moisture, and wind speeds as well as land cover variables that represent potential vegetation fire fuel loads. In the absence of modelling, similar variables were identified that can be used to construct wildfire vulnerability and exposure indices. In addition, wildfire indicators such as the burned area or active fire maps could also be used to calibrate and/or validate wildfire danger models or vulnerability indices. Variables that indicate vegetation recovery from wildfire in burned areas, forest health as an indication of forest adaptation to changing climate, measures to reduce fire damage to communities (buffer zones around communities), and smoke modelling for health services preparedness were identified. Those are examples of observations of adaptation.

To summarise, data needs for the wildfire case study cover four major adaptation application area:

- Monitor changes in fire regimes over space & time[7]
- Model the spatial and temporal evolution of wildfire risk at multiple scales and how that risk could change in the future.
- Construct wildfire vulnerability and exposure indices.
- Calibrate and/or validate wildfire risk assessment models, including danger, exposure and vulnerability indices.

4.2.1 Detailed description of the Wildfire case study

Relevant GCOS ECVs and ECV products for assessing the impact s of and adaptation to changes in wildfire events are presented in Table 1 in appendix A. Overall there were 17 ECVs and ~30 ECV products that were identified as relevant for forest wildfire adaptation.

These include ECVs and products that can be used as indicators of impact and/or efficacy of adaptation, as well as ECVs and products that can be used for models of wildfire risk.

---

[7] Monitoring activities requires long datasets and availability of information in near real time. For the fire monitoring, remotely sensed observations have been available for decades but fire occurrence has only been reliably monitored since early 2000, and only for relatively large fires (>500 ha).

The current ECV requirements for spatial and temporal resolution (The 2022 GCOS ECVs Requirements (GCOS 245)) are shown in Table 1 along with an initial evaluation of their suitability for wildfire adaptation. In many cases the current resolution (especially the highest resolution) is adequate, but where higher resolution is needed it is specified in the text.

It should be kept in mind that temporal and spatial scales needed depend on the specific use. For example, for fire managers this need is for daily or even hourly data, particularly when atmospheric or fuel conditions may lead to extreme fire behaviour, however data can be monthly to seasonal if used for determining seasonal risk. The spatial scale for fire prediction needs to be high to detect fuel moisture gradients relevant to vegetation type (30m). However, for strategic or regional risk assessment 100s of meters to 1km will suffice. Temporal coverage can be coarser for longer term monitoring of adaptation however spatial resolution still needs to be high to detect change.

4.2.2 Two specific examples

The first example (Table 1) is monitoring fire detection and behaviour, for not only assessing current fire risk (information for adaptation), but also monitoring over time (years to decades) the efficacy of fire adaptation actions. In this case, two ECVs (Fire and Cloud properties) and six associated ECV projects were identified as relevant to fire detection and behaviour. The current spatial and temporal requirements of the fire ECV products (GCOS IP 2022) were evaluated as adequate, however higher resolution would be needed for the Cloud properties.

Use	**Application**	**Description for Adaptation**	**ECV**	**ECV Products**	**Adequacy, based on current requirements[3]**
ASSIST FIRE AGENCIES to adapt and respond to implications of climate change (i.e., more severe fires)	FIRE DETECTION AND BEHAVIOR: Faster and more accurate detection of fire and behaviour can enable more effective response by fire agencies	The location and time of fire ignitions	Fire	Active fires	Y
		Is the area burned increase/decreasing with time and where	Fire	Burned area	Y
		Are fire regimes changing? Are fires being larger, more persistent, more energetic or outside of the traditional fire season?	Fire	Burned area and Active Fires and FRP	
		number and size of PyroCb occurrence - can indicate erratic fire behaviour	Cloud properties	cloud top height and temperature, cloud optical depth	N
		Is the intensity of fire changing with time and where	Fire	Fire radiative power	Y

Table 1. Monitoring fire detection and behaviour for adaptation, assessing current fire risk but also monitoring over time the efficacy of fire adaptation actions.

A second example (Table 2) is data required for detecting the efficacy of adaptation actions to reduce wildfire fuel loads. In this case three ECVs and multiple ECV products were identified as relevant. The current spatial and temporal requirements (GCOS IP 2022) of three ECV products were evaluated as adequate (fire radiative power, maps of key IPC land use and maps of high resolution land cover), however higher resolution would be needed for ECV Biomass and in some cases Land Cover.

Use	**Application**	**Description for Adaptation**	**ECV**	**Specific Landcover class**	**ECV products**	**Adequacy, based on current requirements[3]**
Monitor evidence of climate adaptation actions by fire agencies and communities	Fuel load reduction	Clearing of forests around buildings decreases wildfire hazard for built environment; observing increases/ decreases indicates adaptation/ maladaptation	Land cover	cover fraction forest/tree or bare or grass	maps of high resolution land cover	N (also need species vegetation to assess fire adapted and fire resilient species)
			Land cover	urban/built-up / wildland urban interface	maps of key IPCC land use, related changes and land management types	Y
		Fire breaks can help stop the spread of wildfires	Land cover	bare ground / impervious surfaces	maps of high resolution land cover & maps of key IPCC land use, related changes and land management types	N (likely need <5m spatial resolution)
		Tree thinning	Land cover	canopy cover	maps of high resolution land cover	Y
		Prescribed burning effectiveness	Fire		fire radiative power	Y

		Prescribed burning effectiveness	Above ground biomass		Above ground biomass	N (Now only includes tree biomass, but shrub and grass would also be required)

Table 2. Required ECVs for detecting the efficacy of adaptation actions to reduce wildfire fuel loads.

4.2.3 Gaps and Future Opportunities

Much of the concern regarding wildfires and climate change is associated with the potential impacts of wildfires on sensitive ecosystems or human settlements. Furthermore, wildfires release large amounts of GHGs and thus have mitigation implications. As such, effectively using GCOS ECVs in risk assessment would necessitate integrating ECVs with other data resources with more direct information on human settlement types, demographics, critical infrastructure or other assets of interest. Moreover, wildfires tend to be local in their manifestation, and thus modelling needs will be best served by high resolution data that faithfully presents spatial gradients in fuel structure and conditions (moisture), topography and land cover as well as weather and climate. To that end, continuing to support the development of high-resolution data products for ECVs is an important aspect of enabling GCOS to make meaningful contributions to risk assessment and adaptation planning for wildfires.

5 Stakeholders and Critical Sectors

5.1 Key Stakeholders

Within the UNFCCC frame, global earth observations and climate data are used in the deliberations of the IPCC WGI (The Physical Science Basis) and WGII (Impacts, Adaptation and Vulnerability), as well as the various country actions in response to climate change, for example in:

1. The science basis for the formulation of NAPs (adaptation planning)
2. The science basis for the development of adaptation projects (adaptation implementation)
3. The science basis for risk management policies (DRR; EWS; climate insurance)

These relate to the provision of observations **for** adaptation (see Section 2 above). As evaluation of progress towards adaptation is required, observational datasets relating to observations **of** adaptation will also be needed, e.g.

4. The science basis for assessment of implementation of adaptation (adaptation documentation).

In relation to IPCC Working Groups it is interesting to note that for AR6 WGI a very comprehensive summary of observational products used (many of them GCOS ECVs) is provided in tabular form in Annex I[8]. No such table is available for AR6 WGII where the datasets used to define impacts, adaptation and vulnerability are extraordinarily complex and diverse, noting that the report is a synthesis of a massive and diverse literature that includes both physical as well as social/built dimensions. Although a huge and complex task, it might be useful to consider identifying which GCOS ECVs contributed to AR6 WGII.

5.1.1 NAP Formulation

Climate data are needed to conduct current climate risks and vulnerability assessments. As the time frame of the NAP process is medium- to long-term, the analysis is then extended to identify future climate impacts through the application of climate change scenarios.

The analysis of climate data provides a scientific, quantitative basis for identifying how the climate is changing. The results of such analyses can inform adaptation measures that require concrete data, such as in the case of designing irrigation schemes, or management of water flows in dams.[9]

5.1.2 NAP Implementation

The Green Climate Fund (GCF) proposal requirements are representative of the data and data quality necessary for NAP implementation (see Box 1).

Box 1. Data Requirements for a Successful GCF Proposal

To be successful, GCF proposals need a strong and robust climate rationale (i.e., an explanation of the climate impacts and risks to be addressed). Despite wide recognition of Less Developed Countries (LDCs) and other developing countries' high climate vulnerability, if project proposals don't provide a sound climate rationale description, they will not meet GCF requirements and thus will not be approved. Failing to build a firm climate rationale is therefore an impediment to accessing climate finance for implementing climate adaptation action.

To build the climate rationale, countries need access to climate data. For adaptation project proposals, the climate rationale relies on clear information on climate risks, vulnerabilities and impacts and the proposal should explain how the proposed interventions will address such risks and vulnerabilities.[10] However, in many cases LDCs do not have access to data needed to build a strong and robust climate rationale due to capacity and resource constraints, especially in the case of historical climate data. It is

---

[8] IPCC, 2021: Annex I: Observational Products [Trewin, B. (ed.)]. In Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, et al., (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 2061–2086, doi:10.1017/9781009157896.015.

[9] https://unfccc.int/files/adaptation/cancun_adaptation_framework/application/pdf/naptechguidelines_eng_high__res.pdf

[10] https://climateanalytics.org/media/enhancing_the_climate_rationale_in_gcf_proposals_final_03.30.2020.pdf

therefore sometimes extremely difficult for LDCs to include the kind of scientific evidence requested by the GCF. A key question is how can GCOS assist countries to address this challenge?

The observations supported by GCOS improve climate research. Current ECVs and/or new ones can improve the understanding of climate change risks and impacts, which can inform the design of a concrete climate justification for adaptation project proposals, thus enhancing access to climate finance.

5.2 Disaster Risk Reduction (DRR) and Early Warning Systems (EWS)

The literature is replete with recent examples of the need for DRR and EWS, for example with the recent floods in Pakistan and Eastern Australia. Climate data are needed to generate flood risk scenarios that will feed into flood early warning systems to enable dissemination of daily flash floods warning signals. Setting up climate insurance requires weather and climate data such as air temperature, rainfall, wind speed, and river flow. Historical climatological records, including extreme events, are required to create the index and pricing or to inform catastrophe risk models that are needed to evaluate the risk. These data are not readily available in LDCs and SIDS (Small Island Developing States). Global and regional datasets from climate and impact models and satellite agencies are significant sources of data.[11]

At the highest-level it is individual national governments that are the key stakeholders, but other important stakeholders are the IPCC/UNFCCC responsible for assessing and addressing the issues of climate change, and the various entities involved in processing and using the observational data within countries, whether for scientific purposes or for engagement in the UNFCCC processes (e.g., developing and providing NAPs or accessing the GCF). These stakeholders could include international and national research organisations, universities, and consultants. Note that for LDCs and SIDS there are some simple tools available to provide, for example, historical and projected climate data and local sea level rise data that utilise some GCOS ECVs (see footnote 9).

5.3 Critical Sectors

The identification and allocation of relevant GCOS ECVs and ECV products across various critical sectors for purposes of adaptation and risk reduction is an important task, and one that of necessity should be done in full consultation with stakeholders. To this point in time, this has not been done within GCOS and will be a key component of the Work Plan going forward. In work done by the GCOS Terrestrial, Ocean and Atmosphere Panels for the GCOS IP 2022, a table was produced that, based on their expert judgement and without recourse to stakeholders/users, identified ECVs deemed to be relevant to matters of climate adaptation and extremes. Although useful for internal discussions, this table does nothing to identify key users or critical sectors and has no clear criteria for identification of whether, in their judgement, the ECV/ECV product meets requirements for use (nor can it, since the users have not been consulted).

---

[11] https://ane4bf-datap1.s3-eu-west-1.amazonaws.com/wmocrews/s3fs-public/ckeditor/files/infdoc7_6th_Steering_Committee_CREWS_Cooperation_with_Insuresilience_0.pdf?.B8sRw1YU55OpDzs6stcxM3iwhIcDMnM

A review of NAPs, for which a climate science basis for adaptation action is needed, indicates several critical sectors that are frequently prioritised:

- Agriculture (climatic information on precipitation, temperature, soil moisture, etc.).
- Water resources (river flow, lake, and reservoir storage).
- Cities, settlements, and infrastructure (climatic information on precipitation patterns, floods, temperature, etc.).
- Coastal zones (climatic information on sea level rise, storm surge, etc.)
- Health and well-being.
- Ecosystems services and biodiversity.
- Energy systems.
- Disaster risk reduction.

The type of climate data required include historical trends, variability and extremes, and projected future changes. These critical sectors closely align, for example, with those previously identified by the US EPA as being most relevant for determining climate change impacts.[12]

A further relevant way of identifying the critical sectors for adaptation and impact is that applied in the AR6 WGII Summary for Policymakers (Figure SPM 4)[13]. That table identifies critical system transitions across representative key risk areas that closely map to the critical sectors identified above and is the basis for Table 3 below. Table 3 also identifies some specific adaptation options along with relevant Sustainable Development Goals (SDGs). All are ultimately linked to climate resilient development and are therefore highly relevant to the current thinking/terminology/narrative in the IPCC/UNFCCC space. The key point being made above is that application of GCOS observations is so complex that it is necessary to find some way to prioritise critical areas.

---

[12] https://19january2017snapshot.epa.gov/climate-impacts/climate-change-impacts-sector_.html

[13] https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf

Table 3. Climate adaptation options for up to 1.5°C global warming, organised by system transitions and Representative Key Risks (RKRs). Relevant SDGs and example stakeholders are also included (modified from AR6 WGII SPM, 2022, Figure SPM 4).

SYSTEM TRANSITIONS	REPRESENTATIVE KEY RISKS	NEAR-TERM ADAPTATION OPTIONS	RELEVANT SDGs[1]	EXAMPLE STAKEHOLDERS
LAND & OCEAN ECOSYSTEMS	Coastal socio-ecological systems	Coastal defence and hardening Integrated coastal zone management	9,13 1,11,13,14,15	National, state & local/city governments; coastal landholders and asset owners; subsistence and small-scale aquaculture, fishers; commercial aquaculture, fishers; ecosystem & coastal zone managers; insurance sector; relevant UN agencies
	Terrestrial & ocean ecosystem services	Sustainable forest management[2] Sustainable aquaculture Agroforestry Biodiversity management and ecosystem connectivity	1,2,3,5,6,10,11,12,13,15 1,2,3,5,6,8,9,10,11,12,13,14,15 1,2,3,5,6,7,8,10,11,12,13,15 3,6,11,12,13,15	National, state & local/city governments; subsistence and small-scale aquaculture, fishers, agriculture; commercial aquaculture, fishers, agriculture; landscape fire and emergency services agencies; insurance sector; forest managers; ecosystem & coastal zone managers; relevant UN agencies
	Water security	Sustainable water management Water use efficiency & water resource management	3,6,8,9,10,11,13 3,5,6,7,10,11,12,13,15,16	National, state & local/city governments; water agencies including allocators; relevant UN Agencies
	Food security	Improved cropland management, including weather and climate forecasting Crop insurance Transformational adaptation (e.g., relocation) Efficient livestock systems and supply chains	1,2,5,6,7,8,9,10,12,13,16 1,2,3,5,8,12,13,15	National governments; food security policymakers (national and relevant UN agencies); rural & subsistence producers; commercial producers; insurance sector; supply chain managers
URBAN & INFRASTRUCTURE SYSTEMS	Critical infrastructure networks & services	Green infrastructure & ecosystem services Sustainable land use and urban	3,6,8,9,10,11,12,13	National, state & local/city governments – specifically those areas associated with planning, health, & community well-being; relevant UN

SYSTEM TRANSITIONS	REPRESENTATIVE KEY RISKS	NEAR-TERM ADAPTATION OPTIONS	RELEVANT SDGs[1]	EXAMPLE STAKEHOLDERS
		planning	3,6,8,9,10,11,13	agencies
ENERGY SYSTEMS	Water security	Improved water use efficiencies	1,2,3,4,5,6,7,10,13,15	National governments; water and power suppliers/generators; relevant UN agencies
	Critical infrastructure networks and services	Resilient power systems Energy reliability	1,2,3,4,5,6,7,10,13,15 1,2,3,4,5,6,7,10,13,15	National, state & local/city governments; power suppliers/generators; insurance sector; relevant UN agencies
CROSS-SECTORAL	Human health	Population health & health systems	1,2,3,4,5,6,7,8,10,1113,14,15, 17	National, state & local/city governments – specifically those areas associated with planning, health, & community well-being; relevant UN agencies
	Living standards and equity	Livelihood diversification	1,2,3,4,5,6,7,8,9,10,12,13,15	National, state & local/city governments; relevant UN agencies
	Peace and human mobility	Planned relocation & resettlement Human migration & displacement	13,16 1,2,3,4,5,8,10,11,13,16	National, state & local/city governments; relevant UN agencies
	Other cross-cutting risks	Disaster risk management Climate services Social safety nets Risk spreading & sharing	1,2,3,4,5,6,9,10,11,13,16 1,2,3,5,9,10,11,13,15,16,17 1,2,3,4,8,10,11,13 1,2,3,8,9,12,13,15	National, state & local/city governments; national meteorological agencies; relevant UN agencies

[1] **Sustainable Development Goals**: 1-No poverty, 2- Zero hunger, 3-Good health & well-being, 4-Quality education, 5-Gender equity, 6-Clean water & sanitation, 7-Affordable & clean energy, 8-Decent work & economic growth, 9-Industry, innovation & infrastructure, 10-Reduced inequality, 11-Sustainable cities & communities, 12-Responsible production & consumption, 13-Climate action, 14-Life below water, 15-Life on land, 16-Peace, justice & strong institutions, 17-Partnerships for the goals

[2] **See the Wildfire Case Study** for a detailed example of the provision of GCOS ECVs for climate adaptation for sustainable forest management.

6 Summary and Way Forward

6.1 Summary of key findings

1) Many ECVs and products are relevant for adaptation.
2) The case studies identify that information for adaptation:
    i. Is often local in nature
    ii. Often needs high resolution in time and space and local data, to observe climate extremes
    iii. Must be put in a larger context, requiring consistency at least at the regional scale.
    iv. Should be spatially and temporally homogenous, with long term time consistency
    v. Should be available in near-real time
    vi. Have quality aspects such as completeness of documentation, accessibility, long-term maintenance, information on independent evaluation, overall assessment of their fitness for purpose and examples of use
    vii. Needs to be compatible with non-climatic (e.g. socio-economic, demographic, technological and environmental) data sources

3) Global Datasets of ECV supporting climate models and reanalysis are vital for adaptation, providing the global and regional information they need and often, through reanalysis providing complete local information.
4) The example Wildfire Case Study shows just how complex and involved is the full provision of GCOS climate data for adaptation and the critical need for the relevant GCOS climate data.
5) Although the Wildfire case study is more developed than the other, all three case studies require completion - this activity should be extended and maintained.
6) There are important issues of scale to be considered: the impacts of extremes and need for adaptation information are substantially at the local scale, whereas GCOS data considerations have traditionally been at the regional to global scale.
7) Reanalysis acts as an integrator of observations, providing consistent information with no gaps in space and time. This makes it one of the most relevant dataset for many adaptation applications. GCOS actions to improve reanalysis products should be prioritised (see GCOS action C4), including increasing resolution, improving biases, supporting the development and implementation of regional reanalysis and approaches to regionalisation, as well as reducing data latency
8) The performed review of critical sectors by the GATT showed that a complete assessment cannot be done by GCOS alone. Thus, there is a need that GCOS develops a process of prioritising areas for action.

6.2 Recommendations

The GATT team agreed then on the following short-term (i.e. until July 2023) recommendations to GCOS SC arising from the key messages:

Recommendation 1: to request the GATT members to continue their analysis for the wildfire use case and to finalise the assessment of the GCOS ECVS. The aim should be to present the results for the joint-GCOS Panel meeting in June 2023.

Recommendation 2: to request the GATT to perform likewise steps for the Ocean Heatwave and Pluvial Flooding use cases. One or more thematic papers could be considered for submission to BAMS journal. The GATT should engage, if needed, other people from the key stakeholders in this activity.

For a longer-term perspective, the GATT team agreed the following recommendations to GCOS SC.

Recommendation 3:

a) GCOS should ensure that there is enough expertise in adaptation in each of the panels and that a coherent and consistent approach for adaptation is followed by the three panels. It is suggested that at least two panel members in AOPC, OOPC and TOPC should have some expertise in adaptation and engagement in adaptation work. The panels should continue to report on the adequacy of reanalysis systems and their gaps for adaptation applications.

Recommendation 4:

a) GCOS should hold an Adaptation workshop (or a set of workshops around key adaptation concerns) in 2023/4 with major implementers and supporters of adaptation (see point c of this Recommendation) as well as thematic experts. The aim of this workshop will be to identify, from their point of view, what are the most important datasets and climate information they need, what are the major gaps across critical sectors, and whether the existing GCOS ECVs/products including their spatial and temporal specifications are adequate for adaptation.
b) In preparation for this workshop the GCOS Secretariat should hold consultations with those key organisations that will participate in the workshop (see Box below).
c) The key organisations involved in the consultations and in the workshop could include:
    i. Bodies with links to GCOS (e.g. Copernicus, UNESCO, UNEP, NOAA)
    ii. UN bodies implementing adaptation (e.g. UNDP and FAO)
    iii. UNFCCC
    iv. National bodies funding adaptation.
    v. Relevant Independent organisations (e.g. PIK Potsdam Institute for Climate Impact Research)
    vi. EEA (Climate-ADAPT)
    vii. WMO SERCOM/GFCS
d) A group of experts will be mobilised to produce a report with the conclusions of the workshop. This group will include (but not be limited to) members of the GCOS panels and will be supported by GCOS Secretariat.
e) Following the workshop, the GCOS Steering Committee should consider the workshop conclusions and decide on the next steps.

A possible way forward for the consultations is described below:

- The aim is to identify what they see as the most important data they need, (observations, interpolations, reanalysis, forecasts etc) and what statistics of the variables are needed (e.g., average temp, max temp, max night-time temp, etc.) and where the most significant gaps are.

- The uses of the data and the Societal Benefit Areas they support should be noted as well.
- The consultation should be held with each organisation separately and may be held electronically.
- The consultations should be held without any pre-conceived ideas from GCOS on the importance of various variables.
- The GCOS secretariat should prepare a report on the most important information required and distribute it to consultees and GATT.

Annex A

Members of the GCOS Adaptation Task Team

Chiara Cagnazzo (European Centre for Medium-Range Weather Forecasts (ECMWF))

Nigel Tapper (Monash University, Australia)

Sybil Seitzinger (Pacific Institute for Climate Solutions, University of Victoria, Canada)

Rainer Hollman (Deutscher Wetterdienst, Germany)

Paul Desanker (UNFCCC)

Thelma Krug (National Institute for Space Research (INPE), Brazil)

Chiara Fiorino (UN Climate Change)

Han Dolman (GCOS Steering Committee Chair, NIOZ, the Netherlands)

Martin Herold (Deutsches GeoForschungsZentrum (GFZ), Germany)

Elizabeth Kent (National Oceanography Centre (NOCS), UK)

Roxy M. Koll (Indian Institute of Tropical Meteorology (IITM))

Hartwig Kremer (UNEP)

Joanna Post (UNFCCC)

Regina Rodrigues (Federal University of Santa Catarina, Brazil)

Matilde Rusticucci (Universidad de Buenos Aires, Argentina)

Sabrina Speich (GCOS Scientific Committee Chair)

Antony Rea (GCOS Director, WMO)

Antonio Bombelli (GCOS Secretariat)

Simon Eggleston (GCOS Secretariat)

Belen Martin Miguez (GCOS Secretariat)

Caterina Tassone (GCOS Secretariat)

Additional Members

Emilio Chuvieco (Universidad de Alcala, Spain)

Sarah Harris (Bushfire Management, Country Fire Authority, Burwood East, Victoria, Australia)

Appendix to the GCOS Adaptation Task Team Report

Case 1. Observations in support of forest wildfire management and adaptation

Context

Events in recent years in multiple global regions reveal the vulnerability of both human settlements and natural ecosystems to climate-related severe wildfire events along with documented trends in wildfire severity, impact and extent. Further, the IPCC AR6 has projected that the risk of wildfires is likely to increase in the future due in particular to increases in temperature and changes in the frequency, intensity, and duration of drought events. Severe wildfires can also be a major perturbation for local, regional and global carbon budgets. However, there are significant opportunities for forest management (adaptation) to minimize wildfire risk and mitigate emissions provided the relevant observations are made and are available to the global community. The information is of direct relevance for national and local government, landscape managers, emergency services including fire agencies and medical services, and the insurance sector.

Relevant UN Sustainable Development Goals are:

SDG#11 Sustainable Cities and Communities

Target 11.5 refers to enhancing resilience to disasters (such as wildfires) Target 11.6 refers to managing air quality

Target 11.A refers to supporting positive economic, social and environmental links between urban, peri-urban and rural areas

SDG#13 Take urgent action to combat climate change and its impacts

Target 13.1 refers to strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

Target 13.2 refers to integrating climate change measures into national policies, strategies and planning

Target 13.3 refers to improving human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning

SDG#15 Life on Land

Target 15.1 refers to ensuring the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests,

Target 15.2 refers to promoting the implementation of sustainable management of all types of forests,

Target 15.4 refers to ensuring the conservation of mountain ecosystems, including their biodiversity

Target 15.5 refers to taking urgent action to reduce the degradation of natural habitats, halt the loss of biodiversity, and protect and prevent the extinction of threatened species

Data Needs

A variety of geospatial data are relevant to enhancing understanding of wildfire risk at global to local scales. These data can be divided into two different categories of needs. The first need is for data that can be used as indicators to monitor changes in wildfires over space and time. For example, longitudinal data on burned areas can be used to identify locations where the extent of area burned is increasing over time and thus prioritize where there is a particular need for adaptation interventions to respond to wildfire risk. In principle, these data could also be used as a source of evidence for evaluating the effectiveness of adaptation interventions to reduce risk (so-called indicators of adaptation). For example, areas of planned burns for fuel reduction can be mapped.

The second need is for data that can be used to enhance the capacity to model the spatial and temporal evolution of wildfire risk at multiple geographic scales and how that risk could change in the future in response to climate change and other forcing. This includes data for variables that can be used in modelling and simulation of wildfire risk, particularly atmospheric and land ECVs such as temperature, precipitation, water vapor, soil moisture, and wind speeds as well as land cover variables that represent potential vegetation fuel loads. In the absence of modelling, similar variables can be used to construct wildfire vulnerability indices. In addition, wildfire indicators such as the burnt area or active fire maps could also be used to calibrate and/or validate wildfire models or vulnerability indices. Variables that indicate vegetation recovery from wildfire in burned areas, forest health as an indication of forest adaptation to changing climate, measures to reduce fire damage to communities (buffer zones around communities), and smoke modelling for health services preparedness are needed.

Currently Available ECVs and Products

Relevant GCOS ECVs for assessing the impacts of and adaptation to changes in wildfire events are presented in Table A1. These include ECVs and products that can be used as indicators of impact and/or efficacy of adaptation, as well as ECVs and products that can be used for models of wildfire risk. The current (GCOS IP 2022) requirements for spatial and temporal resolution are given. An initial evaluation of the suitability for wildfire adaptation is indicated. In many cases the current resolution (especially the highest resolution (G)) is adequate, but where higher resolution is needed, this is indicated in the table ("> resol. Needed" and in italics). It should be kept in mind that temporal and spatial scales needed depend on the specific use. For example, for fire managers this is daily leading up to a 'spike' day, however data can be monthly to seasonal if used for determining seasonal risk. The spatial scale for fire prediction needs to be high to detect fuel moisture gradients relevant to vegetation type (30m). However, for landscape risk assessment 100s to 1km will suffice. Temporal coverage can be courser for longer term monitoring of adaptation however spatial resolution still needs to be high to detect change.

In addition to higher spatial and /or temporal resolution of existing ECVs, additional ECVs or ECV Products not currently included in GCOS-245 were identified as needed for adaptation. For example, Combustion completeness/also termed Burning efficiency is currently not included as an ECV but would be important for monitoring fuel load reduction, prescribed burning effectivenss, and changes over time in fire intensity indicating adaptation or lack of adaptation actions. Enhancement of the Land Cover ECV to include species composition is needed to better access fuel load as some species are more or less resilient to fire. Enhancement of the Above ground biomass ECV now only includes trees biomass, but shrub and grasses would also be required to better evaluate Prescribed burning effectiveness.

Gaps and Future Opportunities

Much of the concern regarding wildfires and climate change is associated with the potential impacts of wildfires on sensitive ecosystems or human settlements. As such, effectively using GCOS ECVs in risk assessment would necessitate integrating ECVs with other data resources with more direct information on human settlement types, demographics, critical infrastructure or other assets of interest. Moreover, wildfires tend to be local in their manifestation, and thus modelling needs will be best served by high resolution data that faithfully presents spatial gradients in fuel structure and conditions (moisture), topography and land cover as well as weather and climate. To that end, continuing to support the development of high-resolution data products for ECVs is an important aspect of enabling GCOS to make meaningful contributions to risk assessment and adaptation planning for wildfires.

As the science of climate adaptation evolves continued interaction with experts will be needed. What we have presented here is an initial assessment.

Table A1. Wildfire adaptation. Current requirements for spatial and temporal resolution of existing ECVs and ECV Products as defined in GCOS -245 2022 are listed. An intial assessment suggests that in many cases the highest resolution (G) is needed for adaptation; even higher resolution is needed in others (*noted in italics*). Generally the intermediate (B) and lowest (T) resolution is not adequate.

ECVs TO ASSIST FIRE AGENCIES TO ADAPT AND RESPOND TO IMPLICATIONS OF CLIMATE CHANGE (I.E., MORE SEVERE FIRES)

Application: FIRE DETECTION AND BEHAVIOR: Faster and more accurate detection of fire and behaviour can enable more effective response by fire agencies

Description for Adaptation	*ECV*	*ECV Products*	*Spatial resolution requirements[4] of existing ECV/product (GCOS 2022) except where noted in italics*	*Temporal resolution requirements[4] of existing ECV/product (GCOS 2022) except where noted in italics*
The location and time of fire ignitions	Fire	active fires	50 m (G) fire managers/extinction services; 250 m (B) fire risk assessment; 5,000 m (T)	5 min (G) fire management; active fire detection; 120 min (B) 720 min (T)
Is the area burned increase/decreasing with time and where	Fire	burned area	10 m (G); 100 m (B); 1,000 (T)	1 d (G); 10 d (B); 30 d (T).
Is the fire season more frequent or more extended.	Fire	burned area	10 m (G); 100 m (B); 1,000 (T)	30 d (T) would be enough for this study
Number and size of PyroCb occurrence - can indicate erratic fire behaviour	Cloud properties	cloud top temperature	25 km (G); 100km (B); 500 km (T); *> resol. needed for PyroCb*	1 h (G); 24 h (B); 720 h (T) ; *> resol. needed for PyroCb ?*
	Cloud properties	cloud optical depth	25 km (G); 100 km (B); 500 km (T); *> resol. needed for PyroCb*	1 h (G); 24 h (B); 720 h (T) ; *> resol. needed for PyroCb*
	Cloud properties	cloud top height	25 km (G); 100km (B); 500 km (T); *> resol. needed for PyroCb*	1 h (G); 24 h (B); 720 h (T) ; > resol. needed for PyroCb?
Is the intensity of fire changing with time and where	Fire	fire radiative power	50 m (G) fire managers/extinction services; 250 (B) fire risk assessment; 5,000 (T)	5 min (G) fire management; active fire detection; 120 min (B); 720 min (T)

Application: FIRE DANGER MODELING: prediction of fire allowing fire managers to better prepare – resource allocation, community engagement

Description for Adaptation	*ECV*	*ECV Products*	*Spatial resolution requirements[4] of existing ECV/product (GCOS 2022) except where noted in italics*	*Temporal resolution requirements[4] of existing ECV/product (GCOS 2022) except where noted in italics*
Fire danger	Temperature (surface)	land temperature (surface)	<1 km (G); <1 km (B) 1 km (T)	<1 h(G); 1 h (B); 6 h (T)
Fire danger	Surface wind speed and direction	surface wind speed and surface wind direction	10 km(G); 100 km(B); 500 km (T)	<1 h (G); 1 h (B); 3 h (T)
Fire danger	Precipitation	accumulated precipitation	50km (G); 125 km (B); 250 km (T) > *resol. needed*	daily or weekly values
Fire danger	Soil moisture	surface soil moisture	1 km to fully resolve highly-dynamic processes at land-atmos. interface (G); 10 km (B); 50 km (T)	6 h to fully resolve highly-dyamic processes at land-atmos. interface (G); 24 h closing water balance daily scales (B); 48 h drying/wetting trends can be depicted (T). ALSO 3 h improved preparedness (g); 6 h assessment of on-going extreme events
Fire propagation	Above ground biomass Wind Precipitation Temperature Upper-air stability	Above ground biomass See above See above See above See above	100 m, required for fire propagation potential	Monthly/Annual
Fire weather risk: Stability of atmosphere (Risk of pyrocb/convective fires)	Upper-air temperature	atmospheric temperature in boundary layer	15 km (G); 100 km (B); 500 km (T); > *resol. needed to resolve PyCu convection need ideally below 1 km;*	<1 h (G); 6 h (B); 12 h (T) > *resol. needed to resolve PyCu convection*
	Upper-air water vapour	relative humidity in boundary layer	Horizontal 15 km (G); 100 km (B); 500 km (T); > *resol. Needed to resolve PyCu convection need ideally below 1 km;* Vertical 1 m (G); 10 m (B); 100 m (T)	<1 h (G); 6 h (B); 12 h (T) > *resol. needed to resolve PyCu convection*

	Upper-air water vapour	specific humidity in the boundary layer	Horizontal 15 km (G); 100 km (B); 500 km (T); > *resol. needed to resolve PyCu convection need ideally below 1 km;* Vertical 1 m (G); 10 m (B); 100 m (T)	<1 (G); 1 h (B); 3 h (T) > *resol. Needed to resolve PyCu convection*
	Upper-air water vapour	Water vapour mixing ratio in the upper troposphere and lower stratosphere	Horizontal 50 km (G); 500 km (B); 1500 km (T); >*resol. needed to resolve PyCu convection need ideally below 1 km;* Vertical 0.5 m (G); 1 m (B); 3 m (T)	3 h (G); 6 h (B); 72h (T) >*resol. needed to resolve PyCu convection*
Landscape dryness; is the landscape dry enough to carry fire?	Soil moisture	surface soil moisture	Horizontal: 1 km (G); 10 km (B); 50 km (T) Vertical: 10 cm (G); 50 cm (B); 100 cm (T)	6 h (G); 24 (B); 48 h (T). *ALSO 3 h improved preparedness* (G); 6 h assessment on- going extreme events (droughts/extreme wetness)
	Soil moisture	root-zone soil moisture	Horizontal: 1 km (G); 10 km (B); 50 km (T) Vertical: 10 cm (G); 50 cm (B); 100 cm (T)	6 h (G); 24 (B); 48 h (T). *ALSO 3 h improved preparedness (G);* 6 h assessment on- going extreme events (droughts/extreme wetness)
	Surface water vapor	relative humidity near surface	10 km (G); 100 km (B); 500 km (T)	<1 h (G); 1 h (B); 3 h (T)
	Evaporation from land	Transpiration	0.1 km (G); 1 km (B); 25 km (T)	1 h (G); 6 h (B); 24 h (T)
	Land cover	maps of high resolution land cover	<10 m (G); 10-30 m (B); 30-100 m (T); very high resolution land cover (30-300m) to identify fuel continuity; 10km useful for fire danger forecast	1 month (G); 12 months (B); 60 months (T)
	Land cover	maps of key IPCC land classes, related changes & land mgmnt types	10-300 m (G); 300-1000 m (B); 1000 m -1 degree (T); > *resol. Needed*	1 month (G); 12 months (B); 60 months (T)
	Above ground biomass	above ground biomass *(also need shrubs & grass)*	10 m (G); 100m(B); 1000 m (T)	0.5 yr (G); 1-2 yrs (B); 5-10 yrs (T)
	Leaf Area Index	LAI	10m (G); 100 m (B); 250 m (T)	1 d (G); N/A (B); 10 d (T)

Ignition/Dry lightning potential	Lightning	Number of lightnings Degree pixels	0.1 x 0.1 (G); 0.25 x 0.25 (B); 1 X 1 (T)	1/24 d (G); 1 d for interseasonal variations (B); 30 d global seasonal/annual variation (T)
Recently burned forest areas lower fuel load	Fire	burned areas	10 m (G); 100 m (B); 1000 m (T)	1 d (G); 10 d (B); 30 d (T).

Application: REGIONAL SMOKE MODELING: important for health authority and individual preparedness and emergency response, as well as for implementing prescribed burns - to avoid impacts on industry, communities

Description for Adaptation	*ECV*	*ECV Products*	*Spatial resolution requirements[4] of existing ECV/product (GCOS 2022) except where noted in italics*	*Temporal resolution requirements[4] of existing ECV/product (GCOS 2022) except where noted in italics*
Human health; emergency response	Fire	active fire	50 m (G); 250 m (B); 500 (T)	5 min (G); 120 min (B); 720 min (T)
		burned area	10 m (G); 100 m (B) 1000 m (T)	15 min (G); 120 min (B); 1 d (T)
	Aerosol Properties	multi-wavelength aerosol optical depth	20 km(G); 100 km(B); 500 km (T);	0.01 day (G); 1 day (B); 30 day (T)
	Surface wind speed and direction	surface wind speed, thickness layer, and direction	10 km(G); 100 km(B); 500 km (T)	<1 h (G); 1 h (B); 3 h (T)
Smoke transport regionally and smoke transport to stratosphere - indicator of large fires and remote impacts	See Stability of atmosphere above			
	Upper air wind speed and direction	upper air wind speed and direction	15 km(G); 100 km(B); 500 km (T)	30 min(G); 60 min (B); 720 min (T)

ECVs TO MONITOR EVIDENCE OF CLIMATE ADAPTATION ACTIONS BY FIRE AGENCIES AND COMMUNITIES

Description for Adaptation	*ECV*	*ECV Products*	*Spatial resolution requirements[4] of existing ECV/product (GCOS 2022) except where noted in italics*	*Temporal resolution requirements[4] of existing ECV/product (GCOS 2022) except where noted in italics*

Clearing of forests around buildings decreases wildfire hazard for built environment; observing increases/decreases indicates adaptation/maladaptation	Land cover *(needed: vegetation species to assess fire adapted and fire resilience)*	maps of high resolution land cover	<10 m (G); 10-30 m (B); 30-100 m (T)	1 month (G); 12 months (B); 60 months (T)
	Land cover (urban/built-up)	maps of key IPCC land use, related changes and land management types	100-300 m (G); 300-	monthly (G); yearly (B); 5- yearly (T)
Fire breaks can help stop the spread of wildfires	Land cover (bare ground/impervious surfaces)	maps of high-resolution land cover & maps of key IPCC land use, related changes and land management types	for adaptation likely need <5 m resolution	yearly
Tree thinning	Land Cover	land cover (canopy cover)	100-300 m (G); 300-1000 m (B); 1000 m (T)	1 month (G); 12 months (B); 60 months (T)
Prescribed burning effectiveness	Fire	fire radiative power	50 m (G); 250 m (B); 5,000m (T)	5 min (G); 120 min (B) 720 min (T)
	Above-ground biomass	above ground biomass *(also need shrubs & grass)*	10 m (G); 100m(B); 1000 m (T)	0.5 yr (G); 1-2 yrs
Smoke transport prediction to plan prescribed burning - refer to smoke modeling above				

Application: CHANGE IN IMPACTS DUE TO WILDFIRES ON COMMUNITIES: Post-fire are buildings destroyed that pre-fire had large set-backs from forest?

Description for Adaptation	*ECV*	*ECV Products*	*Spatial resolution requirements[4] of existing ECV/product (GCOS 2022) except where noted in italics*	*Temporal resolution requirements[4] of existing ECV/product (GCOS 2022) except where noted in italics*
Burnt area surrounding buildings	Fire	burned areas	10 m (G); 100 m (B); 1000 m (T) *probably need higher resolution than 10 m for adaptation evaluation*	1 d (G); 10 d (B); 30 d (T).

Cover fraction forest/tree or bare or grass around buildings	Land cover	maps of high-resolution land cover	<10 m (G); 10-30 m (B); 30-100 m (T)	monthly (G); yearly (B); 5-yearly (T)
Buildings, urban/built-up/exposure/vulnerability	Land cover	maps of key IPCC land use, related changes and land mngmt types	10-300 m (G); 300-1000 m (B); 1000 m -1 degree (T) - *for adaptation likely need <5 m resolution*	monthly (G); yearly (B); 5-yearly (T)
Vegetation primary productivity	FAPAR	FAPAR	10 m(G) assess primary productivity of canopies; N/A (B); 250 m (T)	1 d (G); N/A (B); 10 d (T)
Smoke transport prediction - is the smoke quantity and distribution relative to buildings increasing/decreasing over time - refer to smoke modeling above				

Application: CLIMATE ADAPTED FORESTS (changes in forest "health" with or without human intervention)

Description for Adaptation	*ECV*	*ECV Products*	*Spatial resolution requirements[4] of existing ECV/product (GCOS 2022) except where noted in italics*	*Temporal resolution requirements[4] of existing ECV/product (GCOS 2022) except where noted in italics*
Forest degradation	Land cover (loss/gain of above ground biomass)	maps of high resolution land cover & maps of key IPCC land use, related changes and land management types	see land cover info above	see land cover info above
	FAPAR	FAPAR	10 m(G) assess primary productivity of canopies; N/A (B); 250 m (T)	1 d (G); N/A (B); 10 d (T)
	LAI	LAI	10m (G); 100 m (B); 250 m (T)	1 d (G); N/A (B); 10 d (T)

Vegetation recovery after wildfire	Land cover	maps of high resolution land cover & maps of key IPCC land use, related changes and land management types	see land cover info above	see land cover info above
	Above-ground biomass	above-ground biomass (trees, shrubs and grass)	10 m (G); 100 m (B); 1000 m (T)	intra-annual (G); 1-2 yrs(B); 5-10 yrs (T)
	FAPAR	FAPAR	10 m(G) assess primary productivity of canopies; N/A (B); 250 m (T)	1 d (G); N/A (B); 10 d (T)
	LAI	LAI	10m (G); 100 m (B); 250 m (T)	1 d (G); N/A (B); 10 d (T)
	Land Cover	land cover (canopy cover)	100-300 m (G); 300-1000 m (B); 1000 m (T)	1 month (G); 12 months (B); 60 months (T)

Application: CHANGE IN INTENSITY, NUMBER, AND EXTENT OF WILDFIRES

Description for Adaptation	*ECV*	*ECV Products*	*Spatial resolution requirements[4] of existing ECV/product (GCOS 2022) except where noted in italics*	*Temporal resolution requirements[4] of existing ECV/product (GCOS 2022) except where noted in italics*
Decreases (increases) over time in fire occurrence can indicate adaptation (lack of adaptation)	Fire	burned areas	10 m (G); 100 m (B); 1000 m (T)	1 d (G); 10 d (B); 30 d (T)
	Fire	Radiative fire power	50 m (G; 250 m (B; 5000 m (T)	5 min (G); 120 min (B); 720 min (T)
Number and size of PyroCb occurrence		See PyroCb under Fire detection and behaviour above		

[4] Requirements for spatial and temporal resolution of existing ECV/product are taken from the GCOS- 245 (2022 GCOS ECV requirements).

(G): Goal, an ideal requirement above which further improvements are not necessary.

(B): Breakthrough, an intermediate level between threshold and goal which, if achieved, would result in a significant improvement for the targeted application. The breakthrough value may also indicate the level at which specified uses within climate monitoring become possible. It may be appropriate to have different breakthrough values for different uses.

(T): Threshold, the minimum requirement to be met to ensure that data are useful.

Partial list of References

Chuvieco et al. 2020. Satellite remote sensing contributions to wildland fire science and management. Current Forestry Reports 6:81-96.

Chuvieco, E., Mouillot, F., van der Werf, G.R., San Miguel, J., Tanasse, M., Koutsias, N., García, M., Yebra, M., Padilla, M., Gitas, I., Heil, A., Hawbaker, T.J., & Giglio, L. (2019). Historical background and current developments for mapping burned area from satellite Earth observation. Remote Sensing of Environment, 225, 45-64

Coop, et al.2020. Wildfire-driven forest conversion in Western North American landscapes. BioScience 70 (8): 659-673.

Dunn, C.J., D O'Connor, C., Abrams, J., Thompson, M.P., Calkin, D.E., Johnston, J.D., Stratton, R., & Gilbertson-Day, J. (2020). Wildfire risk science facilitates adaptation of fire-prone social-ecological systems to the new fire reality. Environmental Research Letters, 15, 025001

Giuseppe et al. 2016. The potential predictability of fire danger provided by numerical weather prediction. Journal of Applied Meteorology and Climatology 55:2469-2491.

Heil, A. (2019). ESA CCI ECV Fire Disturbance: D1.1 User requirements document, version 6.0. In. Available from: https://www.esa-fire-cci.org/documents

Hessburg, et al. 2021. Wildfire and climate change adaptation of western North American forests: a case for itentional management. Ecological Applications 31(8): e02432

Parisien, M-A. et al. 2020. Fire deficit increases wildfire risk for many communities in the Canadian boreal forest. Nature Communications 11:2121 | https://doi.org/10.1038/s41467- 020-15961-y.

Sample, M., Thode, A.E., Peterson, C., Gallagher, M.R., Flatley, W., Friggens, M., Evans, A., Loehman, R., Hedwall, S., Brandt, L., Janowiak, M., & Swanston, C. (2022). Adaptation Strategies and Approaches for Managing Fire in a Changing Climate. Climate, 10, 5

Peterson, et al. 2021. Australia's Black Summer pyrocumulonimbus super outbreak reveals potential for increasingly extreme stratospheric smoke events. Climate and Atmospheric Science 4:38 https://doi.org/10.1038/s41612-021-00192-9

Povak et al. 2022. Evaluating basin-scale forest adaptation scenarios: wildfire, streamflow, biomass and economic recovery synergies and trade-offs. Frontiers in Forests and Global Change. https://doi.org/10.3389/ffgc.2022.805179

Skakun, et al. 2022. Extending the National Burned Area Composite Time Series of wildfires in Canada. Remote Sensing 14:3030. https://doi.org/10.3390/rs14133050

Yao & Henderson An empirical model to estimate daily forest fire smoke exposure over a large geographic area using air quality, meteorological, and remote sensing dataJournal of Exposure Science and Environmental Epidemiology (2014) 24, 328–335; doi:10.1038/jes.2013.87

Whitman, E., Rapaport, E., and Sherren, K. 2013. Modeling fire susceptibility to delineate wildland-urban interface for municipal-scale fire risk management. Environmental Management 52: 1427-1439

Case 2. Observations in support of pluvial flood risk assessment in urban areas

Context

Extreme precipitation is an important hazard for many sectors, including transport and disaster risk management. Heavy precipitation and pluvial flood are included in the high-relevance Climate Impact Drivers (CDIs) within the AR6 IPCC WGI Report, as most prominent and widely studied CDIs for their direct connection to assets.

Since the middle of the past century, an increase in the frequency or intensity of extreme precipitation events has been reported over North America, Europe and Asia and the number of flood events has been increasing over recent decades. It is projected that more people in urban areas will suffer from higher flooding risk in the near future due to the expected variations of weather-related extremes and demographic shifts. At 1.5°C global warming, heavy precipitation and associated flooding are projected to intensify and be more frequent in most regions in Africa and Asia (high confidence), North America (medium to high confidence) and Europe (medium confidence). In the absence of adaptation, this will substantially increase the risks associated with urban pluvial flooding, with negative consequences for people and assets.

Urban pluvial flooding happens when intense and/or prolonged rainfall overwhelms the capacity of the drainage system. The larger the area of sealed surface to reduce water infiltration and increase runoff and velocity, the greater the vulnerability of the urban area. Ongoing variations in frequency and magnitude of heavy precipitation events are significantly contributing to increases in the occurrence and severity of these phenomena, with negative consequences especially in those urban contexts characterized by a high exposure of people and assets. In this perspective, assessing past heavy precipitation trends and flood risk in cities is crucial for advising policy decisions on adaptation to climate change, reducing economic losses and socio-environmental impacts. This information is of direct relevance for planners, civil servants, civil protection, administrators and the insurance sector, among others.

Relevant Sustainable Development Goals are:

SDG#11 Sustainable Cities and Communities

Target 11.5 refers to by 2030 significantly reducing the number of deaths and the number of people affected and substantially decreasing the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations.

#13 Take urgent action to combat climate change and its impacts

Target 13.1 refers to strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

Target 13.3 refers to improving human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.

Data Needs

Several geospatial datasets are relevant to clearly identify the areas historically more impacted by heavy precipitation events and to provide detailed information about the severity and probability of occurrence of heavy precipitation in recent decades. Moreover, there is an urgent need for models and tools for an expeditious but reliable assessment to detect the urban areas potentially impacted by pluvial flooding.

Observations for adaptation, based on precipitation ECVs:

High-resolution hourly precipitation datasets at the city level are needed for use as input for pluvial flooding risk analysis. In relation to impact data, high-resolution exposure and impact data by state-of-the-art hazard, loss, and recovery modelling are needed to complement them. Modeling chain: very high-resolution hourly precipitation data are used as input for model-based risk analysis. Digital Elevation Models (DEM) based rainfall-runoff models are adopted to derive flood extent and water depth, while risk assessment models are used to quantify related damages.

The following indicators can then computed from precipitation ECV:

'Total precipitation': Changes in total annual and seasonal precipitation are often used as headline indices in regional climate change assessments and for various sectoral applications.

'Maximum consecutive five-day precipitation' (i.e. the greatest precipitation total over five consecutive days in a year). It accounts for the magnitude of the event, is of easy interpretability and is widely used in hydrological applications.

'Extreme precipitation total' (i.e. the sum of precipitation values on all days above a fixed threshold defined over a reference period). It accounts for the frequency and magnitude of unusual precipitation events identified with respect to the baseline conditions.

'Frequency of extreme precipitation' (i.e. the number of days with precipitation above the threshold defined over a reference period). It may be more easily understandable than the previous one but uses less information.

Other ECVs relevant to urban area flooding include:

- Soil moisture that significantly influences processes like runoff, flooding, evaporation, infiltration, and groundwater recharge. Soil moisture observations are used to validate state-of-the-art land surface models, reanalysis products, and large-scale hydrological models (source ESA SM ECV PUG)
- Land Use/Land Cover maps to identify the geographical location and extent of the urban area

Observations of Adaptation

Land Use/Land Cover, may possibly be used to identify adaptation using increased urban greening and perviousness as indicators - currently these indicators are not ECVs

Flood mapping and monitoring (e.g. ESA Sentinel) - currently not an ECV

Land Surface Temperature may possibly be used to monitor the impact of urban expansion. However this may be more relevant for monitoring urban heat than flooding.

Available ECVs and Products

Current relevant GCOS ECVs for assessing the impacts of and for adaptation to pluvial flood risk in urban areas, including changes in extreme precipitation events are presented in Table 2.

Gaps and Future Opportunities

Much of the concern regarding urban pluvial flooding and climate change is associated with the potential impacts of extreme precipitation and flooding events on sensitive ecosystems or vulnerable human settlements. As such, effectively using GCOS ECVs in risk assessment would necessitate integrating ECVs with other data resources with more direct information on human settlement types, demographics, critical infrastructure or other assets of interest. Moreover, modelling needs will be best served by high resolution data that faithfully presents spatial gradients in topography and land cover as well as weather and climate. To that end, continuing to support the development of high-resolution data products for ECVs is an important aspect of enabling GCOS to make meaningful contributions to risk assessment and adaptation planning.

Table 2 GCOS ECVs and products relevant to observations of impact, adaptation, model development, calibration and validation for urban pluvial flooding

Applications	**Related ECV**	**Products**	**Suitability (e.g spatial/temporal resolution)**
Indicators	Precipitation (Derived relevant indices: Total precipitation; Maximum consecutive five-day precipitation; Extreme precipitation total; Frequency of extreme precipitation.)	. Estimates of liquid and solid precipitation	?
	River discharge	. River discharge	?
Modelling Inputs **(flood and hydraulic modelling)**	Soil moisture	. Surface soil moisture . Surface inundation . Root zone soil moisture	Y Y Y
	Land Surface Temperature	. Maps of land surface temperature	?
	Leaf Area Index	. Maps of leaf area Index for adaptation	Y
	Land cover	. Maps of land cover . Maps of high resolution land cover · Maps of key IPCC land use, related changes and land management types	? Y Y

Case 3. Observations in support of ocean extremes

Context

While the ocean's role in mitigating the effects of climate change is well understood, its importance for adaptation strategies is less so. The ocean plays an integral part in the water, energy, and carbon cycles. It absorbs 93% of the excess heat from manmade climate change and one third of the CO2 emissions. Consequently, marine heatwaves, extreme events of ocean acidification and depletion of oxygen are getting more frequent and intense, having a devastating effect on marine ecosystems and local coastal communities. At the same time, the ocean provides heat and moisture to the atmosphere and, as such, is also responsible for an increase in extremes of precipitation, temperature and wind over the sea and land intensifying storms, wave conditions, floods, droughts, tropical and extratropical cyclones, heatwaves and cold spells.

The context of ocean extremes is critical as the ocean and sea coasts are home to approximately 40% of the world's population, and 75% of the largest metropolitan areas lie in coastal areas. Consequently, a significant proportion of global economic activity is dependent on ocean and sea coasts, ranging from fishing and agriculture to exploitation of natural resources. In addition, ocean and sea coasts are responsible for renewable and non-renewable energy generation and the shipping of 80% of the goods traded globally. They also offer protection from climate-related coastal risks such as storm surges. Climate change will exacerbate existing vulnerability and impacts, mainly through sea-level rise and ocean extremes such as coastal storm surges, extreme storminess (high winds accompanied by extreme wave height), extreme tropical and extratropical cyclones, marine heatwaves, extreme deoxygenation and acidification events. These ocean extremes impact marine ecosystems, food availability, and thus local and global economies. As growing ocean extremes pose increasing challenges to coastal areas, climate adaptation and coastal resilience should be key objectives in the planning and implementing coastal zone policies.

Successful adaptation draws on a wide range of capabilities, from science-based modelling to local community knowledge and covers many types of interventions, from engineered structures to nature-based solutions. In particular, next-generation climate and weather models will provide unprecedented detail on local climate impacts. These will help improve early warning systems and can be integrated into disaster preparedness and long-term adaptation. Investment in in-situ observational platforms is necessary to improve initial forecast conditions, and to provide "ground truth" for forecasts and model projections. Solutions that adapt to climate change can yield multiple co-benefits, including progress towards the UN Sustainable Development Goals (SDGs). Interdisciplinary research is essential to identifying the co-benefits and trade-offs of adaptation strategies to optimise design and implementation.

<u>Relevant UN Sustainable Development Goals are</u>:

SDG#11 Sustainable Cities and Communities

Target 11.5 refers to enhancing resilience to disasters (such as storm surges)

Target 11.A refers to supporting positive economic, social and environmental links between urban, peri-urban and rural areas

Target 11.B refers to adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels

SDG#13 Take urgent action to combat climate change and its impacts

Target 13.1 refers to strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

Target 13.2 refers to integrating climate change measures into national policies, strategies, and planning

Target 13.3 refers to improving human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning

SDG#14 Life below water

Target 14.1 refers to refers to reducing marine pollution

Target 14.2 refers to managing and protecting marine and coastal ecosystems

Target 14.3 refers to addressing the impacts of ocean acidification

Target 14.4 refers to refers to regulating harvesting and ending overfishing, illegal, unreported and unregulated fishing and destructive fishing practices

Target 14.5 refers to conserving at least 10 per cent of coastal and marine areas

Target 14.6 refers to refers to reducing marine pollution

Target 14.A refers to increasing scientific knowledge, develop research capacity and transfer marine technology, considering the IOC Criteria and Guidelines on the Transfer of Marine Technology, to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries

Target 14.A refers to enhancing the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS

Data Needs

Various types of data can be used for improving understanding, modelling, and forecasting ocean extremes. Data can be used as indicators to monitor changes in ocean extremes over space and time. In particular, atmospheric and ocean ECVs such as ocean temperature, ocean salinity, ocean currents, oceanic rainfall, ocean pH, surface winds and wave height can be used to identify more vulnerable coastal areas that need adaptation interventions to respond to these extremes. These data can also be used as indicators of adaptation to reduce risk. Data are also important to develop early warning systems.

Currently Available ECVs and Products

Relevant GCOS ECVs for assessing the impacts of and adaptation to changes in ocean extreme events are presented in Table 1. These include ECVs and products that can be used as indicators of impact and/or efficacy of adaptation, as well as ECVs and products that can be used for models and early warning system.

Gaps and Future Opportunities

Subsurface oceanic conditions and mixed-layer processes are key for monitoring, understanding, and forecasting oceanic extremes like cyclones, marine heatwaves and extreme episodes of climate modes, such as El Niño and Indian Ocean Dipole, which in turn impact the climate of many continental areas. However, gaps in the subsurface in situ data has limited our efforts in this direction. For example, in situ measurements are essential for providing data of the subsurface oceanic conditions important to tropical cyclone intensification, particularly since cooling under the cyclone is not well observed by satellite remote sensing, even by microwave radiometers, due to strong precipitation. As a result, forecasting the rapid intensification of cyclones is still a major challenge. The presence of marine heatwaves is observed in the subsurface too, but we do not have a comprehensive or quantitative understanding of these subsurface heatwaves, or how they interact with the weather and climate system. Changes in oxygen minimum zones (e.g., subsurface depletion of oxygen is happening in some basins, leading to hypoxia characterized by extremely low oxygen zones) and chlorophyll at subsurface levels are also not clearly quantified to corroborate extreme responses due to rapid climate change. These uncertainties due to data gaps point to enhancing our subsurface in situ measurements.

Table 3 GCOS EOVs and ECVs relevant to observations of impact, adaptation, numerical modelling, and early warning system for ocean extremes.

Phenomena	Essential Variables	Resolution (km)				Platforms
	(EOVs, ECVs)	Z	M	V	T	
monitoring, numerical modelling, and early warning systems	Sea surface temperature	25	25	S	D	Satellites/Ships/Moorings/Argo floats/XBTs/XCTDs/AOVs
	Subsurface temperature	25	25		D	Ships/Moorings/Argo floats/XBTs/XCTDs/AOVs
	Sea surface salinity	25	25	S	D	Satellites/Ships/Moorings/Argo floats/XCTDs/AOVs
	Subsurface salinity	25	25		D	Ships/Moorings/Argo floats/XCTDs/AOVs
	Surface currents	25	25	S	D	Satellite/Moorings/Argo floats/Drifters/AOVs
	Subsurface currents	500	500		D	Moorings/Argo floats/AOVs
	Sea surface height	25	25	S	D	Satellites
	Ocean surface stress	25	25	S	D	Satellites/Ships/Drifters/ Moorings/AOVs
	Inorganic Carbon	25	25	S	D	Satellites/Ships/Moorings/ AOVs
	Ocean Colour	25	25	S	D	Satellites
	Ocean surface heat flux	25	25	S	H	Satellites/Ships/Moorings/ AOVs
	Wind direction and intensity (near surface)	25	25	S	H	Satellites/Ships/Drifters/ Moorings/AOVs
	Air surface pressure	25	25	S	H	Ships/Drifters/Moorings/ AOVs
	Water vapor (near surface)	25	25	S	H	Ships/Drifters/Moorings/ AOVs
	Air temperature (near surface)	25	25	S	H	Satellites/ Drifters/Moorings/ AOVs

	Surface radiation budget	25	25	S	H	Satellites/Ships/Drifters/ Moorings/AOVs
	Precipitation (near surface)	25	25	S	H	Satellites/Ships
	3D wind (air column)	25	25	1	H	Ships
	Air Temperature (air column)	25	25	1	H	Ships
	Water vapor (air column)	25	25	1	H	Ships
	Cloud properties	25	25	1	H	Satellites/Ships
	Aerosol properties	25	25	1	H	Satellites/Ships
	Sea state	25	25	S	H	Satellites

Z=Zonal, M=Meridional, V=Vertical, T=Temporal, S=Surface, D=Daily, H=Hourly.