GCOS

GLOBAL CLIMATE OBSERVING SYSTEM

http://gcos.wmo.int

WORLD METEOROLOGICAL ORGANIZATION

IOC

International Science Council

UN environment

WORLD METEOROLOGICAL ORGANIZATION

INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION

SYSTEMATIC OBSERVATIONS AND THE PARIS AGREEMENT

Report of the Task Team on the Paris Agreement

GCOS-222

UNITED NATIONS ENVIRONMENT PROGRAMME

INTERNATIONAL SCIENCE COUNCIL

Chair, Publications Board

World Meteorological Organization (WMO)

7 bis, avenue de la Paix

P.O. Box 2300

CH-1211 Geneva 2, Switzerland

Tel.: +41 (0) 22 730 84 03

Fax: +41 (0) 22 730 80 40

E-mail: Publications@wmo.int

Document Planning

Version			
A 0.1	Compiled by GCOS Secretariat	25 Jan 2018	
B 0.1	Compiled by UNFCCC (F. Vladu)	2 Feb 2018	
	Deadline for comments from GCOS Steering Committee	1 April 2018	
1.0	Merged version from A0.1, B0.1	15 May 2018	
1.1	Revised version	22 May 2018	
1.2	Revised with comments from Task Team	June 2018	
2.0	Revised version for Steering Committee	July 2018	
2.0	Approved by Steering `committee	October 2018	

Mandate of GCOS Task Team on Paris Agreement

In 2016 UNFCCCC (Decision 19/CP.22: Implementation of the global observing system for climate) welcomed the GCOS Implementation Plan and encouraged and invited Parties and United Nations organisations to work towards the full implementation of the Plan. In order to support the implementation of the Plan, the GCOS Steering Committee at its 25th meeting looked at how GCOS could contribute to the UNFCCC's Paris Agreement. The Steering Committee agreed to create a task force to do this. The Task Force will also develop a plan for observations for adaptation and investigate how to support mitigation. It might lead to the formation of a future GCOS panel on adaptation. The Task Force was given three months to develop a short position paper and will report back to the panel meetings in March 2018

The task team was charged with:

- Answering the Steering Committee question on how to support the Global Stocktake, basing the analysis on the text of the Paris agreement and on the presentation of Florin Vladu at the meeting;
- Identifying where existing and future observations for climate can support the ambitions of the Paris Agreement and subsequent COP decisions in relation to global stocktake, but also considering adaptation, mitigation, loss and damage as well as means of implementation (and any other relevant areas);
- Identifying within each of these areas the necessary actions for GCOS community together with identification of relevant timelines;
- Proposing initial actions which would respond to highest priority and feasibility;
- Taking into account that many final deliverables will be through the medium of climate services, and identifying which basic observations are needed for these;
- Identifying potential funding sources through, e.g. GCF and partnerships, including with Member States, in any proposal;
- Report to GCOS Panels in March 2018 on progress and actions identified to date;
- Report to SC-26 in 2018 on the proposed way forward.

The Task Team consists of Florin Vladu (UNFCCC) and Sybil Seitzinger, Youba Sokona, Qinchen Chao, Stephen Briggs, Han Dolman, Michel Verstraete form the GCOS Steering Committee

Contents

1. EXECUTIVE SUMMARY 6

2. INTRODUCTION 7

2.1. COSTS AND BENEFITS OF OBSERVATIONS 10

3. EARLIER GCOS CONSIDERATIONS OF ADAPTATION 12

3.1.1. Adaptation and the GCOS Implementation Plan 13

3.2. CLIMATE SERVICES 14

4. OVERVIEW OF THE PARIS AGREEMENT 16

5. ADAPTATION (ARTICLE 7) 19

5.1. MONITORING NEEDS: SUPPORTING ADAPTATION PLANNING 23

5.2. MONITORING NEEDS: URBAN AREAS 24

5.3. MONITORING NEEDS: EARLY WARNING 24

5.4. MONITORING NEEDS: DEVELOPMENT OF SENSORS 25

6. OTHER OBSERVATIONS AND THE PARIS AGREEMENT 26

6.1. AIMS (ARTICLE 2) 26

6.1.1. Monitoring Needs: Global Temperature. 26

6.2. NATIONALLY DETERMINED CONTRIBUTIONS (NDC) (ARTICLE 4) 26

6.2.1. Monitoring Needs: GHG Emissions and the Global Carbon Cycle 27

6.3. SINKS AND REDD+ (ARTICLE 5) 27

6.3.1. Monitoring Needs: Forests and REDD+ 28

6.4. TECHNOLOGY TRANSFER (ARTICLE 10) 28

6.4.1. Monitoring Needs: Technology Transfer (Article 10) 29

6.5. LOSS AND DAMAGE (ARTICLE 8) 29

6.5.1. Monitoring Needs: Loss and Damage 29

6.6. GLOBAL STOCKTAKE (ARTICLE 14) 29

6.6.1. Global Climate Indicators 32

6.6.2. Education and Public Awareness (Article 12) 38

6.6.3. Monitoring Needs: Hydrology and Ecosystems 38

7. OPEN ACCESS TO DATA. 39

8. CAPACITY DEVELOPMENT (ARTICLES 11, 9) 40

9. REPORTING: THE TRANSPARENCY FRAMEWORK (ARTICLE 13) 42

9.1. MONITORING NEEDS: TRANSPARENCY FRAMEWORK 43

10. CONCLUSIONS 45

11. GLOSSARY 48

12. BIBLIOGRAPHY 51

1. EXECUTIVE SUMMARY

The Paris Agreement will drive climate policy for many years to come. It establishes a science-based cycle of reporting (through the Transparency Framework), assessment (the Global Stocktake) and increasing ambition of action to address climate change (Nationally Determined Contributions, NDC). The Agreement has three main aims: to limit the global temperature increase, to increase the adaptive capabilities of the Parties, and to increase the making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

The Paris Agreement covers a range of national actions including setting nationally determined contributions, mitigation (greenhouse gas sinks and REDD+), adaptation, loss and damage, technology transfer, education and public awareness, the global stocktake, capacity building and financial support.

Some observations will need to be directly reported to the global stocktake including global temperature trends, the overall impact of NDC on the climate system as well as direct observations of atmospheric composition and emissions. Other observations will contribute indirectly by supporting and enabling adaptation and early warning systems, mitigation, and the transparency framework. The provision of capacity building and associated financial support should also be reported.

This document considers the Paris Agreement in some detail and suggests suitable activities that GCOS should undertake or support to assist in the implementation of the Agreement. The main findings are:

I. **Observations are vital to the success of the Paris Agreement** and their continuing acquisition should be supported. All countries need to make appropriate observations. Some observations may need support at an international level (see chapter 8 and Action 15). The cost of acquiring and analysing observations is small compared to the amounts envisaged for adaptation and mitigation (section 2.1)

II. GCOS should setup and lead a **specific activity to understand the observational needs of adaptation** and clearly spell out how those will be articulated with the existing global observational requirements. This will require the **direct involvement of adaptation experts** rather than relying solely on the observation experts traditionally associated with the GCOS Science panels, including those with financial, implementation and policy responsibilities for successful adaptation to climate change. The ability to understand and estimate risks, both current and future, will be vital to support adaptation planning and increase the resilience of societies to climate changes (chapter 5). This process may identify requirements for new observations methods and approaches and these needs (section 5.4) GCOS should consider the world-wide and regional observations that support or monitor adaptation, but not the detailed local observational needs, in line with its remit as a ***global*** observing system

III. **Monitoring Adaptation.** The implementation of some adaptation measures can be monitored remotely and GCOS will consider how this can be extended to other adaption actions. Conversely, this can be used to see where adaptation is needed but not being implement (e.g. urban development on flood plains). Reporting this information would give a valuable independent report on the status of adaptation (Chapter 5).

IV. **Free and Open Data.** It is clear that free, open and accessible data will increase the transparency and utility of the scientific inputs. This will allow wider review and use of the data and increase the transparency of any conclusions derived from the observations. Access to global data is essential for reanalysis and climate models while early warning systems need information unrestricted by national or institutional boundaries (Chapter 7).

V. **Atmospheric Concentrations and Emissions and Removals of GHG.** The use of atmospheric composition data and inverse models can support the emission and removal estimates submitted to the UNFCCC. They can also provide a global estimate of emission and removal as well as indicate changes in the natural sources and sinks that can impact the concentrations of GHG (section 6.2.1).

VI. The continued observations of many of the GCOS ECV will contribute to supporting adaptation either directly or through products generated by or derived from reanalysis and modelling. Therefore, **implementing the actions in the GCOS Implementation Plan remains an important target**.

2. INTRODUCTION

The 2015 UNFCCC's Paris Agreement[1] came into force on 4 November 2016. It has three main aims: to meet a temperature goal, to improve the ability to adapt to climate change, and to make finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development (see Box 1). The Paris Agreement also specifies a mechanism, *the global stocktake*, to periodically review progress and the adequacy of nationally determined contributions made by all parties.

In 2016 the UNFCCC welcomed the latest GCOS Implementation Plan[2] and encouraged Parties to work towards its full implementation and invited United Nations agencies and international organisations to support this work. It emphasised the need to maintain, strengthen and build capacities, especially in developing countries. The Implementation Plan emphasised the need to further develop climate observations to both close[3], through observations, the climate cycles (energy, water and carbon) and also to support adaptation measures. Both of these activities support the Paris Agreement:

- Enhanced observations of the climate cycles will lead to a better understanding of the changes that are occurring, monitor the effectiveness of the measures taken, and improve the projections and forecasts that underpin risk assessment and planning for adaptation.
- Additional observations and products will be needed to support local adaptation to climate change. GCOS should establish a specific activity to understand the data needs of adaptation efforts, and to recommend the best ways to implement these new observational requirements. This will need to direct involvement of adaptation experts rather than rely solely on the observation experts traditionally associated with the GCOS Science panels.

Box 1 - Article 2 of the UNFCCC Paris Agreement

1. This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

(a) Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognising that this would significantly reduce the risks and impacts of climate change;

(b) Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production; and

(c) Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.

2. This Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.

Systematic observation of the climate system provides the necessary foundation for science-based decisions in the UNFCCC process. The full value of climate observations is only derived through implementing actions grounded on a scientific understanding of the climate. Figure 1 below illustrates this chain, from observations to decision-making.

[1] UNFCCC Decision 1/CP.21
[2] The Global Observing System for Climate: Implementation Needs, GCOS-200, pub WMO, Geneva 2016
[3] The GCOS Implementation Plan (GCOS 2016) lays down targets for the observation of the climate cycles.

Figure 1 The global architecture for monitoring climate Note: The Data Records block in this figure corresponds to research and assessment in figure 2. The Decision-making block corresponds to SBSTA, COP, CMA in figure 2.

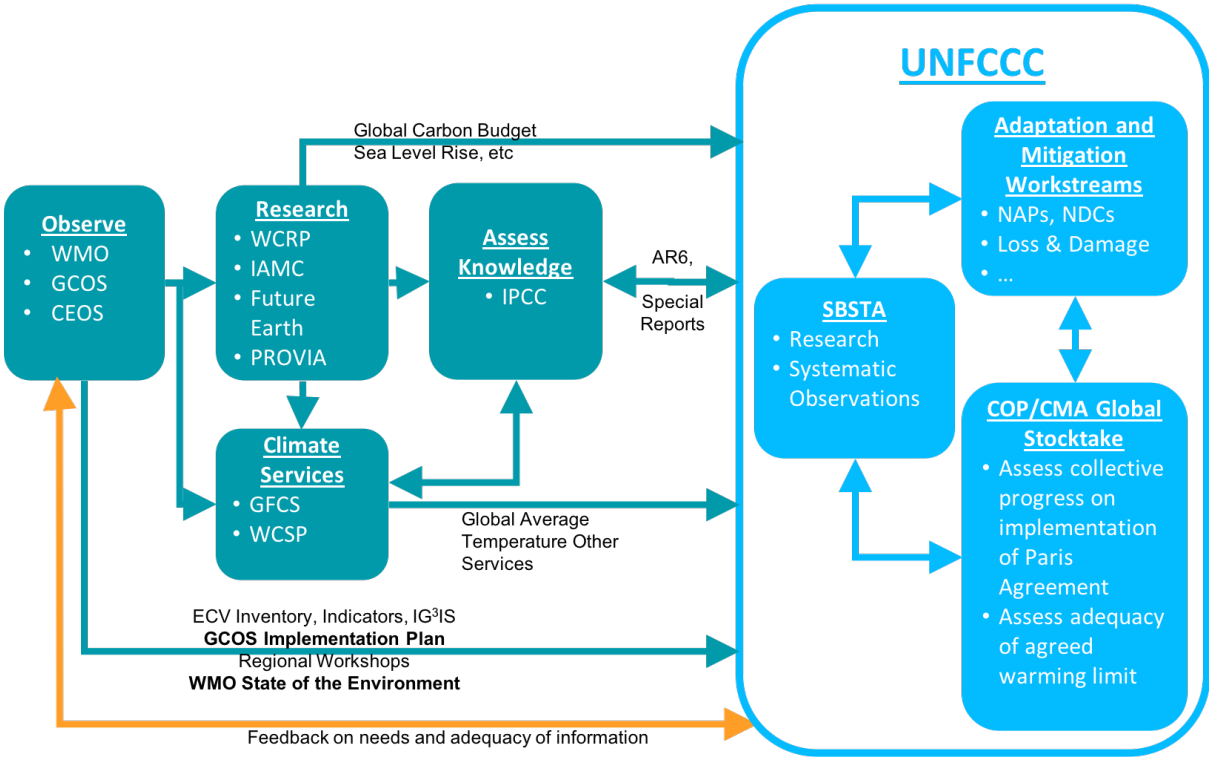


Figure 2 How science can drive climate policy and climate policy drive science. Note: the figure presents the main topics that have been considered at SBSTA 47 in Bonn (e.g. GCOS – IP and climate indicators, CEOS - ECV inventory, WMO - Regional Climate Centres).

The UNFCCC process is more complex (Figure 2) but still follows the basic outline (outlined in Figure 1. WMO, GCOS, CEOS, GEO and other organisations support the observations needed for climate research, climate services, assessment of climate change and the decision-making process.

GCOS plays a key role in defining and maintaining the essential climate variables (ECV); providing guidance on user requirements; observing principles, standards and guidelines for dataset generation; assessing the stat)us of the global observing system; preparing an implementation plan (GCOS 2016) to address gaps identified in the status report; and monitoring the implementation of this plan. Thus, GCOS is well positioned to undertake a similar role for climate adaptation observations.

Figure 2 below lists the GCOS *Essential Climate Variables (ECV)* grouped by measuring domain. These were originally determined to support climate science, but many will also be valuable for adaptation. The GCOS Implementation Plan indicates for each ECV the *ECV products* (quantity measured for each ECV), and provides user requirements (e.g. frequency, resolution, required measurement uncertainty, standards/references) and the actions needed to improve their global monitoring.

Table 1 GCOS ECV grouped by measuring domain and area covered

Measurement domain	Essential Climate Variables (ECV)
Atmospheric	Surface: air temperature, wind speed and direction, water vapour, pressure, precipitation, surface radiation budget Upper-air: temperature, wind speed and direction, water vapour, cloud properties, Earth radiation budget, lightning Composition: carbon dioxide (CO_2), methane (CH_4), other long-lived greenhouse gases, ozone, aerosol, precursors for aerosol and ozone
Oceanic	Physics: temperature: sea surface and subsurface; salinity: sea surface and subsurface; currents, surface currents, sea level, sea state, sea ice, ocean surface stress, ocean surface heat flux Biogeochemistry: inorganic carbon, oxygen, nutrients, transient tracers, nitrous oxide (N_2O), ocean colour Biology/ecosystems: plankton, marine habitat properties
Terrestrial	Hydrology: river discharge, groundwater, lakes, soil moisture Cryosphere: snow, glaciers, Ice sheets and Ice shelves, permafrost Biosphere: albedo, land cover, fraction of absorbed photosynthetically active radiation, leaf area index, above-ground biomass, soil carbon, fire, land surface temperature Human use of natural resources: water use, greenhouse gas fluxes

A wide range of groups makes the actual observations which underpin climate science, assessment and actions to address climate issues, including:

- The meteorological and many hydrological observations that underpin climate reanalysis, forecasts and prediction are made by National Meteorological and Hydrological Services are coordinated by WMO through its WIGOS. This can address issues such as heat waves, floods and droughts.
- Understanding and observing the oceans is key to forecasting and predicting the climate on many time scales and is increasingly input into climate projections and reanalysis. Climate changes in the oceans with direct impacts on humans include sea level, ocean acidity and temperature. Ocean observations are coordinated by JCOMM established jointly by the UNESCO-IOC and WMO.
- Satellite agencies make a comprehensive range of observations available for many parameters, with a near-global coverage and over varying periods of time, in some cases over decades, calibrated with in-situ observations. These observations are coordinated by the CEOS/CGMS Working Group on Climate

(WGClimate). Many of these observations are valuable in their own right, such as forest cover and land use, vital for mitigation.

- A wide variety of ground-based observations such as glacier observations, soil carbon and water are made by a wide range of independent organisations and groups who work to provide the information specified by GCOS.

It is extremely important that the data, both the observations and derived products, should freely an openly available for users to develop climate services and to support planning and policy development. The CEOS/CGMS Working Group on Climate (WGClimate) has prepared the online *ECV Inventory*[4] for all satellite-based ECV that describes which CDRs are currently planned or available for each GCOS ECV product observed from space. Currently there are over 900 CDRs listed, directly responding to the GCOS ECV requirements.

WGClimate has also performed a **gap analysis** on the ECV Inventory and used it to identify all missing ECV and ECV products, using the CEOS mission, instruments and measurements (MIM) and the WMO Observing Systems Capability Analysis and Review (OSCAR) databases. The group has analysed the reasons for missing products, including addressing the measurements used and needed; deployed a tool to identify shortcomings in all individual CDRs with respect to GCOS principles, guidelines and requirements; and performed an analysis on shortcomings with the support of domain expert teams.

The **IPCC** uses peer-reviewed publications on climate observations, assessments of observations and climate models (themselves based on observations) as the basis of their assessments. Thus, while the scientific community works to better understand, forecast and predict climate change, it is the IPCC that performs an overall assessment of their work. These assessments take several years and so the **WMO** publishes annual statements on the state of the climate to keep policy makers up-to-date.

2.1. COSTS AND BENEFITS OF OBSERVATIONS

The cost-effectiveness of various parts of GCOS has been demonstrated by a range of studies. Meteorological observations contribute to sustainable development[5] by providing services in agriculture, water resources and the natural environment; human health; tourism and human welfare; energy, transport and communications; urban settlements; and economics and financial services. WMO concluded[6] that "*available assessments show consistently that benefits of meteorological services far outweigh costs; also, users from different sectors confirm the benefits even if sometimes they are hard to quantify*". For example, a recent study[7] showed that the benefits of the Chinese Public Weather Service outweighed costs by a ratio of 26:1 (accounting for 0.22% of the Chinese gross domestic product (GDP) in 2006). Copernicus is a European system for delivering environmental information based on both satellite (the Sentinel series) and in situ observations. A cost-benefit study[8] showed that sustained investments in long-term continuity and data provision to users resulted in the best cost-benefit ratio. Discounted costs were estimated as €11.5 billion and benefits as €30.5 billion. Climate-related benefits exceeded costs while there were other, significant, non-climate benefits in areas such as resource management, security, humanitarian applications and industrial development.

These studies show that investments in climate observing systems are economically beneficial. In addition, they also show that there are many other benefits besides those that are directly climate-related and that investments in data access and stewardship significantly increase the benefits to society.

[4] https://climatemonitoring.info/ecvinventory

[5] WMO, 2009: Secure and Sustainable Living: The Findings of the International Conference on Secure and Sustainable Living: Social and Economic Benefits of Weather, Climate and Water Services. WMO-No 1034, WMO, Geneva, 2009.

[6] WMO, 2012: Conference on Social and Economic Benefits (SEB) of Weather, Climate and Water Services (Lucerne, Switzerland, 3-4 October 2011). PWS-23/ROE-1, WMO, Geneva.

[7] Huiling Yuan, et al. 2016, Assessment of the benefits of the Chinese Public Weather Service, Meteorol. Appl. 23: 132–139 DOI: 10.1002/met.1539.

[8] Booz & Co. 2011, *Cost-Benefit Analysis for GMES*, European Commission: Directorate-General for Enterprise and Industry, London, 19 September 2011, http://www.copernicus.eu/sites/default/files/library/ec_gmes_cba_final_en.pdf.

Observations need to be recognised as essential public goods, where the benefits of open global availability exceed any economic or strategic value to individual countries that might otherwise lead them to withhold national data. GCOS aims to ensure that these observations are undertaken and made readily available to users.

Not only are the financial resources needed to sustain climate observations small compared with those envisaged for adaptation and mitigation, they provide the science-based information to ensure that the most cost-effective choices are made in implementing adaptation.

3. EARLIER GCOS CONSIDERATIONS OF ADAPTATION

The last decade has seen an increasing demand for reliable climate information and services from key sectors, including insurance, agriculture, health, water management, energy and transportation. This demand is expected to grow further against the backdrop of a changing climate.

At recent GCOS workshops[9], a range of participants from governments, international organisations, the private sector and academia have discussed observational needs for adaptation. These workshops noted a flow of information from observations that produce data and then information which informs adaptation planning and better defines observational needs. GCOS's role in this chain was identified as facilitating and enhancing systematic observations. Some of the conclusions[10] were:

(a) The need to clearly describe the role of GCOS and other partners in enabling the flow of information described above;
(b) Good, publicly available and standardised data, in particular at regional, national and local levels on the vulnerability of key sectors to the impacts of climate change is essential. Terrestrial and ocean observations need improvement, in particular in coastal zones and mountain regions;
(c) Adaptation planning and assessment require a combination of baseline climate data and information, coupled with national data relevant to the specific aspects of adaptation (including different sectors) in question;
(d) The value of observations to adaptation should be clearly articulated;
(e) One or more well-described case studies in Non-Annex I Parties could be used to demonstrate the value of observations to adaptation;
(f) Guidance and guidelines (or references to other sources of advice such as WMO) on data collection and sources of products, as well as their limitations, are needed. A key role for GCOS will be to establish and maintain requirements at a global level to support the collection and dissemination of national observations. This material will cover specified quality standards (including latency, resolution and uncertainties), documentation required to accompany the data (including metadata), and the identification of where and how internationally available data can be accessed;
(g) Coordination among observation systems at different scales from subnational to global to inform adaptation should be promoted through relevant focal points and national coordinators, as well as Regional Climate Coordinators and alliances;
(h) The research and development community need to support the development of indicators linking physical and social drivers relating to exposure, vulnerability and improved resilience in line with national requirements.

The workshops also noted that, currently, global climate models and satellite-based observing systems are useful in supporting decisions from national to global scales but are inadequate for subnational to local decision-making as the spatial resolution of their products is too coarse. While in some cases such products can be downscaled with reference to ground-based in situ stations, there tends to be only a few, widely dispersed stations which often lack sufficiently long-time series of data. Satellite-based observation systems, reanalyses and global circulation models therefore need to move towards generating products with higher spatial resolution products. Further investments are

[9] The First GCOS Science Conference: Global Climate Observation: the Road to the Future. Amsterdam, Netherlands, March 2016 (http://www.gcos-science.org).

GCOS Workshop on Observations for Adaptation to Climate Variability and Change. Offenbach, Germany, 26–28 February 2013, http://www.wmo.int/pages/prog/gcos/Publications/gcos-185.pdf

Joint GCOS/GOFC-GOLD Workshop on Observations for Climate Change Mitigation. Geneva, 5-7 May 2014 http://www.wmo.int/pages/prog/gcos/documents/GCOS-191.pdf

GCOS Workshop on Enhancing Observation to Support Preparedness and Adaptation in a Changing Climate – Learning from the IPCC 5th Assessment Report. Bonn, Germany, 10–12 February 2015.

http://www.wmo.int/pages/prog/gcos/Publications/gcos-166.pdf

[10] See GCOS Workshop on Enhancing Observation to Support Preparedness and Adaptation in a Changing Climate (Footnote 7).

needed to improve the in-situ observations made by a range of parties: NMHSs, non-NMHS agencies such as agricultural departments, and even the general public (citizen scientists). The focus should be on efforts in regions where change is most rapid, or variability is more pronounced, and where the impact of climate on a sector is the largest and vulnerability is the highest, such as small island States, coastal regions and mountains.

In order to improve the availability of observations for adaptation it was recommended that relevant organisations and Parties:

(a) Identify priority observational needs; focus on regions where climate change will have significant sector effects and where there are vulnerable populations. Consider baseline climate data and information, coupled with sector-specific and other economic demographic data at regional, national and local scales;
(b) Provide sustainable resources to implement networks to meet the identified observational needs;
(c) Provide public access to high quality and standardised data on the vulnerability of key sectors to climate change impact that meets the GCOS Climate Monitoring Principles and any relevant GCOS Guidelines or product requirements;
(d) Develop infrastructure and governance to support sustained data rescue (historical data are highly valuable, but data rescue and distribution in accessible digital forms can potentially be very resource-intensive);
(e) Review, assess and evaluate the progress, achievements and limitations encountered by the relevant organisations in the process of improving availability of observations within specific time frames in order to foster knowledge exchange and support implementation.

3.1.1. Adaptation and the GCOS Implementation Plan

Addressing adaptation cuts across much of the GCOS Implementation Plan, and many of the actions described in the plan are just as appropriate for local adaptation issues as for global understanding of the climate (e.g. data stewardship, metadata and refinement of requirements). Table 4 lists the main actions needed to address adaptation discussed in the GCOS Implementation Plan and indicates where these are included in the Implementation Plan.

An important step will be defining the requirements for adaptation. Requirements are needed for local observations, high-resolution global datasets and data produced from modelling, downscaling and reanalysis.

One particular area of planned GCOS activities that has a considerable overlap with are the regional workshops. GCOS organised a Regional Workshop programme from 2000 to 2005 and has been invited again by UNFCCC SBSTA to collaborate with relevant partners to continue enhancing access to, and understanding and interpretation of, data products and information to support decision-making on adaptation and mitigation at national, regional and global scales. The regional work programme envisaged would be an ideal forum to discuss adaptation needs, promote guidance and best practice and design projects to improve observational networks;

Table 2 Actions for adaptation, taken from the GCOS Implementation Plan

	Action	Description	WHO	Related GCOS Actions
Requirements and guidance	Define user needs	GCOS and the observation community identify and understand the needs of user communities and issues they aim to serve. GCOS should work with user communities to define regional requirements.	GCOS	Regional workshops (G11) Development of requirements (G13) Communication plan (G12)
	Provide guidance	Produce and disseminate advice on using the global and regional requirements at national and local level, and guidance and best practice on prioritisation of observations, implementation, data stewardship and reporting. Promote the use of this guidance by parties and donors. Review the use of this guidance and requirements and revise as needed.	GCOS	Provide advice and guidance (G13-16, Part II, Chapters 2–4) Communication plan (G12) Regional workshops (G11)
Acquiring data	Produce high-resolution data	Encourage satellite-based observation systems, reanalyses and global circulation models to move towards generating spatially higher-resolution products.	GCOS	Development of requirements (G13)
	Data rescue	Communicate the value of historical data as a public good and promote data rescue as an essential task. (See Part II, Section 1.4.2).	WMO, GCOS	Data Rescue (G29-34) Communication plan (G12)

	Invest in observations	Investments are needed to improve the in-situ network of stations for climate, water, greenhouse-gas fluxes, biodiversity and others (Parties should invest in their own observations: support is also needed in countries with fewer resources. Part I Chapter 6).	Parties	GCOS cooperation mechanism (G9) Communication plan (G12)
Data	Improve data stewardship	Improve information on data availability, quality, traceability, uncertainty and limits of applicability, and establish and improve mechanisms to provide both access to data and information regarding data contents. Improve data management (see Part II, Section 2.3).	GCOS	Define and use metadata Mechanism to discover data, Open Data (Part II, Chapter 2.3)
Climate Services	Climate services	Present the information derived from the observations in a form that is relevant to the purposes of the diverse range of decision-makers and users addressing issues such as vulnerability and adaptation assessments, monitoring and evaluation, risk assessment and mitigation, development of early warning systems, adaptation and development planning and climate-proofing strategies within and across sectors.	GFCS	Indicators (Part 1 Chapter 3.3)
	GFCS	GFCS has a leading role in improving feedback mechanisms between data providers and users through the User Interface Platform, to inform GCOS in supporting the GFCS Observations and monitoring pillar.	GFCS	Refine requirements (G13)
Coordination	Coordination	There is a need to clarify responsibilities, define focal points for specific topics, build synergies and generally strengthen cooperation among UN programmes, as well as to consider how GCOS can use its reporting systems through WMO, UNFCCC, IOC and others to reach out to different communities and to be recognised as an authoritative source of validated information that is relevant to users' needs.	GCOS, GFCS, IOC, WMO, UNFCCC, Parties	Coordination actions (role of GCOS and its science panels)
	Long-term research and observations	Support research initiatives such as WCRP, UNEP's PROVIA and ICSU's Future Earth, as well as global and regional investments in observations likely to meet future needs for long-term data, such as the Monitoring for Environment and Security in Africa programme (MESA). Research is needed to define standards and reference-grade stations.	GCOS, ICSU, UNEP	Research actions (several actions in Part II, Chapters 2-4)

3.2. CLIMATE SERVICES

At the international level, the importance of high-quality, reliable and timely climate services has been recognised in the GFCS, a UN-led initiative instigated at World Climate Conference-3[11]. In the GFCS high-level plan[12], a climate service is defined as "climate information prepared and delivered to meet a user's needs". A climate service includes the timely production and delivery of science-based trustworthy climate data, information and knowledge to support policy- and other decision-making processes.

To be effective, climate services should be designed in collaboration with customers and stakeholders, be based on free and open access to essential data and include user feedback mechanisms. By exploiting the full potential of the climate observing system, climate research combined with improved climate modelling innovates and stimulates new areas of service development. Thus, GFCS has five pillars (components): User Interface Platform; Climate Services Information System; Observations and monitoring; Research, modelling and prediction; and Capacity development.

The value of GCOS's contribution to the Framework is clear, and its fundamental importance was recognised by Seventeenth World Meteorological in its Resolution 39 (Cg-17).

There are already initiatives at different scales whose observation and monitoring protocol and standards are often determined by GCOS requirements. One example is the Climate Change Service of the European Union's Copernicus programme. This service will give access to information for monitoring and predicting climate change and will,

[11] World climate conference-3, Geneva, 31 August – 4 September 2009, Conference statement and Conference declaration. http://www.wmo.int/gfcs/wwc_3

[12] WMO, 2011: Climate Knowledge for Action: a Global Framework for Climate Services – Empowering the Most Vulnerable. WMO-No. 1065, WMO, Geneva.

therefore, help to support adaptation and mitigation. It benefits from a sustained network of in situ[13] and satellite-based observations, reanalysis of the Earth's climate and modelling scenarios based on a variety of climate projections. The service will provide access to several climate indicators (temperature increase, sea level rise, ice sheet melting, ocean warming) and climate indices (based on records of temperature, precipitation, drought event) for both the identified climate drivers and the expected climate impacts. The European Union Copernicus Programme will also provide services for atmosphere, marine, land, climate, emergency, and security.

Additionally, at the national level, there have been many successful developments in the last five years. Notable examples are Climate Service UK, Deutscher Klimadienst (DKD), US National Weather Service Climate Services and the Swiss National Centre for Climate Services. The GFCS website also provides information about the Programme for implementing GFCS at Regional and National Scales which aims to enhance resilience in social, economic and environmental systems to climate variability and change[14]. Funded by a grant from Canada, the programme will implement GFCS in the Pacific, the Caribbean, South Asia and the Arctic. This will be achieved by providing improved climate information, predictions, products and services to support climate risk management and adaptation strategies, decision-making and actions at national and regional level.

The Climate Science for Service Partnership China (CSSP China) was established to meet an emerging demand in both China and the UK to develop climate science to underpin an enhanced range of climate services. By accelerating and enhancing collaborative science, CSSP China has built a strong foundation for services to support climate and weather resilient economic development and social welfare in China and the UK[15].

[13] For convenience, in situ in this publication refers to non-satellite observations, although this may include airborne and remote, ground-based observations.

[14] See http://www.wmo.int/gfcs/

[15] See https://link.springer.com/journal/376/35/8/page/1 and http://159.226.119.58/aas/EN/volumn/volumn_1339.shtml

4. OVERVIEW OF THE PARIS AGREEMENT

The Paris Agreement aims to address climate change issues by asking **all Parties** to the UNFCCC[16] to make voluntary commitments to reduce the total emission of greenhouse gases to the atmosphere (*mitigation*) and to support the improvement of Parties' resilience to the effects of climate change (*adaptation*). Developed countries have stricter requirements and undertake to provide significant financial and other support to developing country parties to achieve the goals of the Agreement.

The Paris Agreement has three aims; limiting temperature increases, improving adaptation and providing appropriate finance (Box 1).

These aims and the ways to achieve them are considered in Articles 3-15, while the remainder of the Agreement covers procedural matters. Figure 3 summarises the Articles in the Paris Agreement, which addresses mitigation and the commitments made by Parties (the Nationally Determined Contributions (NDCs)), adaptation, loss and damage, technology transfer, reporting and the financial support and capacity building needed to implement these ambitions.

While systematic observations are only directly mentioned once (Art. 7, para. 7(b)), they underpin many of the parts of the Agreement including reporting (including the transparency framework), monitoring and preserving sinks, supporting adaptation, understanding loss and damage, capacity building, education and public awareness and the global stocktake (Figure 4). The global stocktake itself will review these activities and progress under the Agreement.

A fundamental element of the Paris Agreement is that it should, via the Global Stocktake outlined in Figure 5, lead to the progressive reduction of greenhouse gas emissions which will in turn deliver the three objectives of the Agreement outlined above. Parties are expected to increase the ambition of their Nationally Determined Contributions (NDC) in response to the Global Stocktake. Negotiations are still underway on the details of the global stocktake and different models are possible. The inputs into the global stocktake are indicated in the Paris Agreement.

Observations will be needed to help plan adaptation strategies, to observe how effective those strategies are, and to provide information that could be used to modify strategies as climate change unfolds. Observations are needed by all Parties and the Paris Agreement applies equally to all Parties, although it does recognise the need for developed countries to support less developed Parties financially and through capacity building.

Observations are one part of ensuring the success of the Paris Agreement. In addition to the original observational data, derived products and any indicators, the development of tools and the interpretative skills needed to assess all this information will also be crucial to the success of the Agreement. This paper only considers the role of observations and GCOS; there are many other organisations whose role is to provide the support and capacity building to use the data successfully.

[16] Members of the WMO are parties to the UNFCCC.

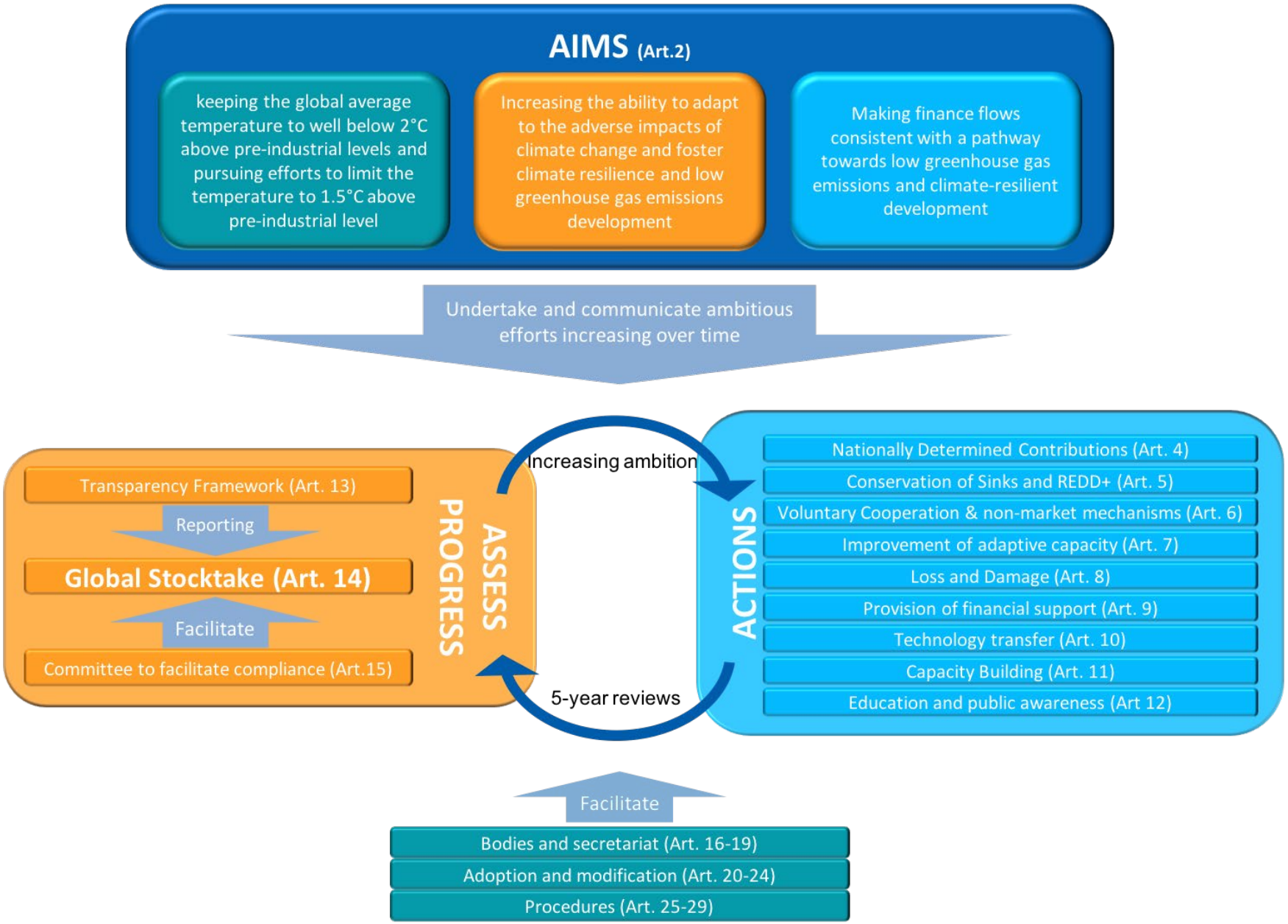


Figure 3 The Paris Agreement

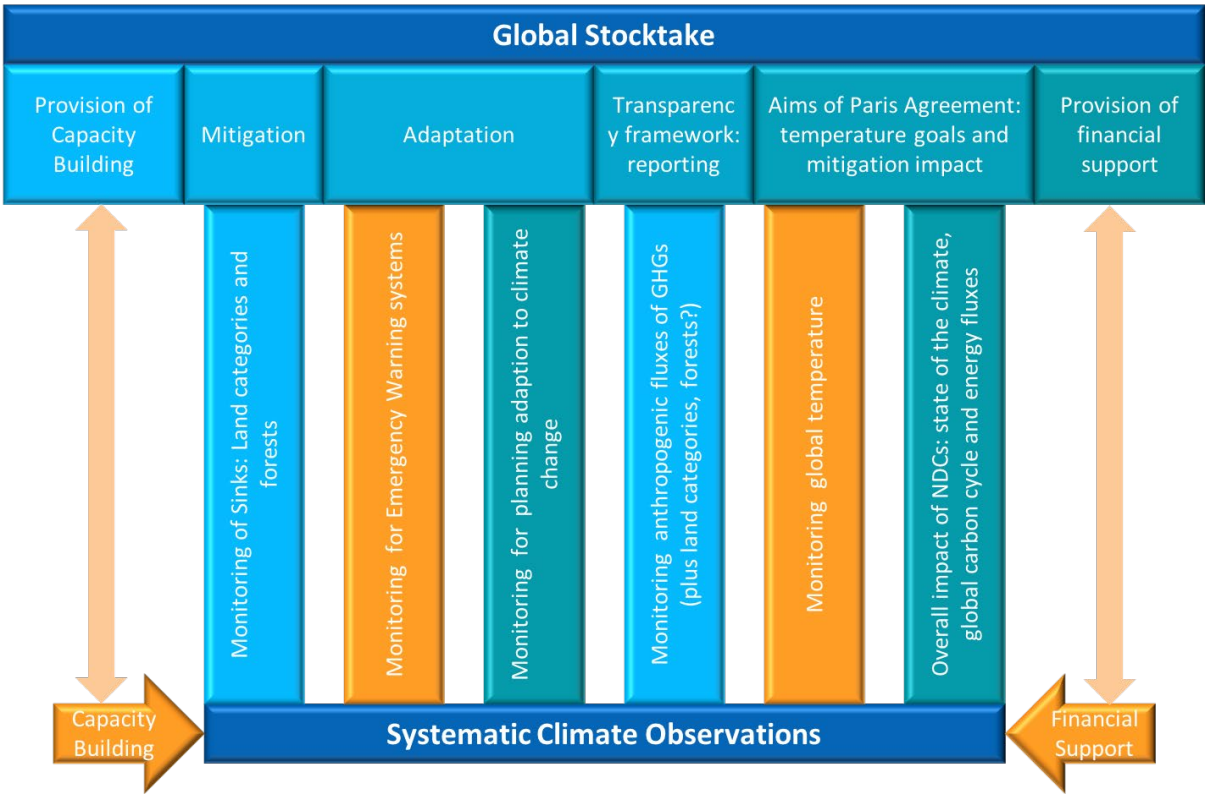


Figure 4 Systematic Climate Observations underpin many contributions to the Global Stocktake

Figure 5 Outline of Global Stocktake, Based on F Vladu (2017), UNFCCC

5. ADAPTATION (ARTICLE 7)

The Paris Agreement has a global goal to improve adaptive capacity:

> *Parties hereby establish the global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development and ensuring an adequate adaptation response in the context of the temperature goal referred to in Article 2.*
>
> *Art. 7, Para. 1*

Planning adaptation requires an understanding of the current climate, trends and future projections. All these require systematic observations. Early warning systems are a key element of climate resilience and directly depend on observations (e.g. flood and storm warnings). Other issues, so-called *slow onset events*, (e.g. drought warnings) require longer time series, sometimes over large areas. Changes to weather patterns such as the onset of the wet season need large scale monitoring across the globe. Thus, systematic observations are explicitly mentioned here in the Paris Agreement:

> *7. Parties should strengthen their cooperation on enhancing action on adaptation, taking into account the Cancun Adaptation Framework, including with regard to:*
>
> *(a) Sharing information, good practices, experiences and lessons learned, including, as appropriate, as these relate to science, planning, policies and implementation in relation to adaptation actions;*
>
> *(b) Strengthening institutional arrangements, including those under the Convention that serve this Agreement, to support the synthesis of relevant information and knowledge, and the provision of technical support and guidance to Parties;*
>
> *(c) Strengthening scientific knowledge on climate, including research, systematic observation of the climate system and early warning systems, in a manner that informs climate services and supports decision-making;*
>
> *(d) Assisting developing country Parties in identifying effective adaptation practices, adaptation needs, priorities, support provided and received for adaptation actions and efforts, and challenges and gaps, in a manner consistent with encouraging good practices; and*
>
> *(e) Improving the effectiveness and durability of adaptation actions.*
>
> *Art. 7, para. 7*

Planning adaptation actions requires a knowledge of the risks of climate impacts and how they are likely to change in the future. In their INDCs communicated by April 2016, 137 Parties included adaptation actions (FCCC/CP/2016/2). All adaptation components of the INDC include information on key impacts and vulnerabilities, in particular on observed changes or projections of future changes, the most vulnerable sectors or geographical zones, high-risk impacts and incurred costs resulting from the impacts of extreme events. In terms of climate hazards, the main sources of concern identified by most Parties are flooding, sea level rise and drought and higher temperatures (Figure 6).

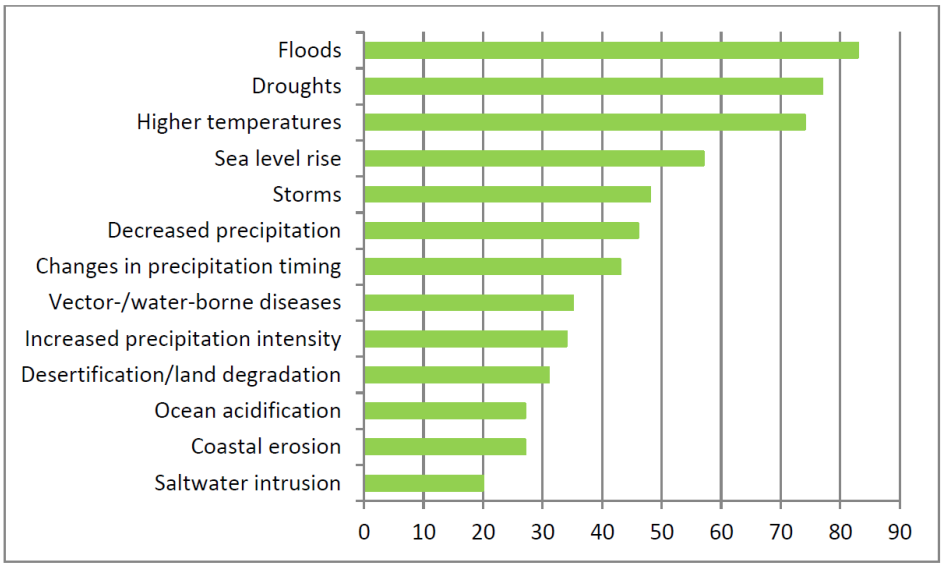


Figure 6 Key climate hazards identified in the adaptation component of the communicated intended nationally determined contributions (iNDCs)

Three case studies, below, show how the global climate observing system is essential to adaptation and how global observations, and products derived from them, can support local planning and adaptation.

The information provided in INDCs clearly demonstrates that Parties are actively planning, implementing and strengthening or scaling up existing adaptation efforts. Most Parties stated they were to developing nationwide adaptation plans and strategies (NAPs[17] or similar). Such national efforts are often accompanied by specific policies, measures and initiatives, with a priority on water, agriculture, health, ecosystems, forestry and infrastructure. A few Parties intend to undertake actions with regional or global impacts as they need to address transboundary issues. Developing country Parties are formulating NAPs with financial support from the Green Climate Fund (GCF) and with technical guidance and support through the Least Developed Countries Expert Group (LEG) and various partner organisations and bodies.

[17] http://www4.unfccc.int/nap/News/Pages/national_adaptation_plans.aspx

Adaptation Case Study 1 Health gains threatened by climate variability and change in sub-Saharan Africa (SOURCE: Risk Expands, But Opportunity Awaits: Emerging evidence on climate change and Health in Africa, April 2017 Prepared for: United States Agency for International Development Climate Change Adaptation, Thought Leadership and Assessments (ATLAS) Prepared by: Chemonics International Inc. Erin Martin and M. Fernanda Zermoglio,

Remarkable progress is being made across Sub-Saharan Africa on public health. Child mortality, rates of stunting, and incidence of diseases such as malaria and meningitis are dropping. But these gains may be lost as changes in climate and weather foster disease outbreaks and food insecurity. With climate change, Africa's most deadly health challenges are likely to persist—and even worsen. Potential impacts include:

Over the next several decades, ***malaria*** hot spots are likely to shift from West to Central to East Africa, with disease risk becoming seasonal in some areas and rising in others. By 2050, 45-65 million more people are expected to be at risk in East Africa alone.

With 10% more of the continent likely to become arid, the bacterium that causes ***meningococcal meningitis*** – associated with dry, dusty winds – may increase.

Already a top killer of children under 5, ***diarrheal disease*** risk is expected to rise 22% by 2100, due to higher temperatures. An increase of 1°C one day in a week increases incidence that same week by 1-6%.

Higher temperatures will create new habitat for snails that carry ***schistosomiasis***, with an estimated 20% rise in cases by 2050.

Predominantly an urban disease, ***dengue fever*** is expected to rise due to warming and humidity, with up to 56% of the world's population at risk by 2050. Africa, the world's most rapidly urbanising continent, is likely to see sharp increases in disease incidence.

Newly recognised as a major threat in Africa, ***heat stress*** is expected to increase mortality, especially among the elderly and very young.

Climate observations underpin these projections by allowing the prediction of the climatic changes (temperature, precipitation and moisture) that lead to changes in the distribution and spread of these diseases. Short term weather prediction contributes to early warning systems that can predict a disease outbreak and allow time to respond.

Adaptation Case Study 2 The Copernicus Windstorm Information Service (WISC) (SOURCE https://wisc.climate.copernicus.eu/wisc/#/)

The Wind Storm Information Service (WISC) aims to provide new data resources for the insurance sector that can be used to enhance the understanding of the nature of windstorms over the European continent. The main target group are insurers, reinsurers and insurance industry service providers who are interested in developing, running and analysing risk models. The information provided by WISC will also support planning for the impact of climate change in other sectors such as energy, transport, civil engineering and government.

WISC has generated several historic datasets that can be used to analyse the range and severity of windstorms in the past as well as their impact.

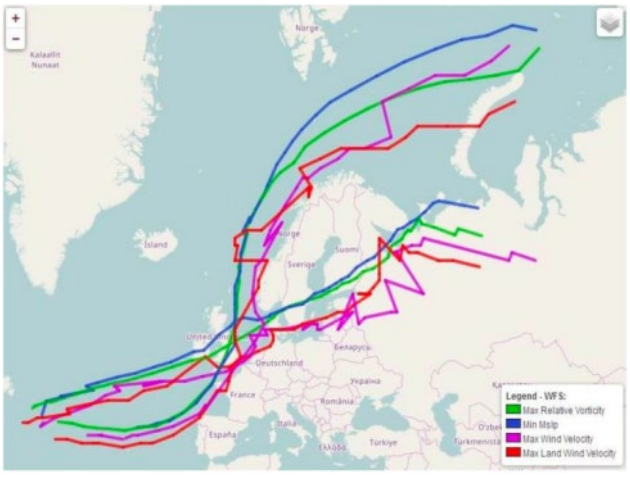


Figure 7 Great storm of 1987 and Storm Daria of 1990 showing four key variables

Adaptation Case Study 3 Global Crop Monitoring

(SOURCE: https://cropmonitor.org/)

Following the global food price hikes in 2007/8 and 2010, and as part of the Action Plan on Food Price Volatility and Agriculture, in 2011, the G20 Heads of States committed to improving market information and transparency to make international markets for agricultural commodities more effective and endorsed both the Global Agricultural Monitoring (GEOGLAM) and the Agricultural Market Information System (AMIS).

GEOGLAM's role is to coordinate satellite monitoring observation systems to enhance crop production projections and weather forecasting data. AMIS assesses global food supplies (focusing on wheat, maize, rice and soybeans) and provides a platform to coordinate policy action in times of market uncertainty.

GEOGLAM provides a framework which strengthens the international community's capacity to produce and disseminate relevant, timely and accurate forecasts of agricultural production at national, regional and global scales using Earth Observations (EO) including satellite and ground-based observations. This initiative is designed to build on existing agricultural monitoring programs and initiatives at national, regional and global levels and to enhance and strengthen them.

GEOGLAM developed the Crop Monitor reports which provide global crop condition assessments in support of the AMIS market monitoring activities. The Early Warning Crop Monitor brings together international, regional, and national organisations monitoring crop conditions within countries at risk of food insecurity.

The roles of both GEOGLAM and AMIS were reaffirmed by the 2016 G20 Agriculture Ministers meeting in Xi'an, China.

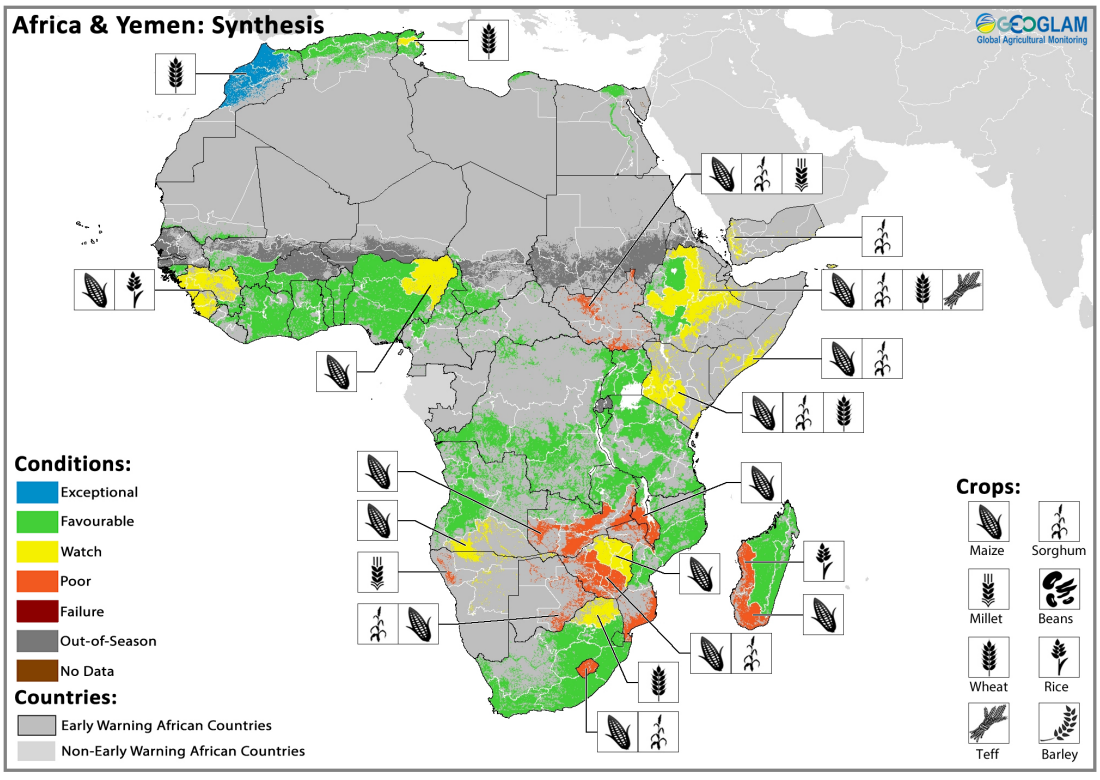


Figure 8 **Crop Monitor for Early Warning, June 2018, Africa & Yemen Synthesis Map** based on a combination of inputs including remotely sensed data, ground observations, field reports, national, and regional experts. Regions that are in other than favourable conditions are labelled on the map with a symbol representing the crop(s) affected.

While the discussion on how to assess collective progress on the Global Goal on Adaptation (GGA) is still to be initiated, it is evident that Earth observations could support the assessment of progress in reducing key climate risks through reducing exposure, hazards, and/or vulnerability. This could contribute to the assessment of baselines for the GGA and to monitor progress. For example, risk maps based on satellite information strengthen spatial planning and reduce exposure to climate hazards.

5.1. MONITORING NEEDS: SUPPORTING ADAPTATION PLANNING

Often adaptation planners use reanalysis outputs, long-term and seasonal forecasts and downscaled outputs rather than the observational data directly. Many of the current ECV should provide inputs but the requirements for the ECV may differ from those needed for climate modelling and science (e.g. understanding global scale sea level rise may require a coarser spatial resolution than that needed for planning coastal defences).

GCOS should ensure that the global ECV and their requirements allow for their use at local and national scales, directly or as the basis for reanalysis, climate and other models and downscaling.

Several countries identify ecosystem changes as a potentially important impact of climate change. Currently, several terrestrial ECV are related to ecosystems, while satellite observations of ocean colour as well as in situ buoy and ship observations monitor the distribution of plankton over oceanic regions. Work is progressing on monitoring specific ocean habitats. These are important for humans: fisheries provide a 16.7 percent of the global population's intake of animal protein and 6.5 percent of all protein consumed globally by humans[18]. Here GCOS works closely with the IOC-UNESCO Global Ocean Observing System (GOOS).

The impacts of climate change vary from place to place but are often related to extremes such as flooding, drought, extremes of precipitation, severe storms, and heat waves. The development of indicators, based on ECV, that can monitor changes in these factors will be important both to inform adaptation measures and to understand regional and global changes. Parameters such as night time temperature and length of the growing season may also be needed. GCOS is committed to develop climate indicators and has already started to look at changes in global temperature, sea ice and ocean heat content.

Some potentially very useful observations could include monitoring the changing density and boundaries of the *built environment*. For example, are buildings/communities moving away from current or predicted future flood zones, or areas where local sea level rise is predicted to increase the risk of sea level inundation or storm surges? GCOS should identify what observations can show that communities are becoming more resilient ("*averting, minimising … loss and damage … extreme weather events and slow onset events….*"). However, there is an urgent need to develop new approaches, sensors, and technologies for observations in support of adaptation.

Action 1) GCOS should establish a specific activity to understand the needs of adaptation and how to develop their observational requirements. This will require the direct involvement of adaptation experts rather than rely solely on the observation experts traditionally associated with the GCOS Science panels, including those with financial, implementation and policy responsibilities for successful adaptation to climate change. The ability to understand and estimate risks, both current and how they change in the future, will be vital to support adaptation planning and increase the resilience of societies to climate changes. GCOS should consider the world-wide and regional observations that support or monitor adaptation, but not the detailed local observational needs, in line with its remit as a ***global*** observing system.

[18] The State of the Worlds Fisheries and Aquaculture, FAO 2014, ISBN 978-92-5-108275-1

5.2. MONITORING NEEDS: URBAN AREAS

Over fifty percent of the global population now live in urban areas[19] while, traditionally, global climate monitoring has tended to concentrate more on "background" sites. However, with the increasing focus on adaptation and impacts of climate change, dedicated urban monitoring is needed. GCOS should consider how these long-term requirements can be met.

The frequency of extreme events is increasing: the IPCC 5th assessment report notes that it is very likely that human influence has contributed to the observed changes in the frequency and intensity of daily temperature extremes on the global scale since the mid-20th century and that Observations have showed a general increase in heavy precipitation at the global scale. These changes can occur at a faster rate than the changes in mean temperature and precipitation. In urban areas, the impacts of these extremes are intensified: higher temperatures combine with the urban heat island to produce even larger impacts; inadequate planning for floods can leave large numbers of the urban inhabitants at risk.

Observations, that may be practical now or in the near future, could demonstration how changes in urban climates can be measured and monitor the implementation and impact of adaptation and mitigation. They include:

- ***Adaptation in the built environment.*** To show whether or not buildings and/or communities are moving away from flood zones (current or predicted future flood zones), storm surge areas, and sea level inundation areas predicted from local sea level rise. This may need the combination of a number of observations and projections. Urban greening can be observed remotely and is a response to increasing intensity and frequency of heat waves.
- ***Track the land footprint of renewable energy***. The global footprint of wind and solar power and their associated infrastructure may be very large and could encroach on agricultural areas, for example the growth of photovoltaic power stations (so-called solar farms). Monitoring the footprint of renewables could provide some useful information on the trade-offs for mitigation and adaptation planning as well as showing areas where the technologies are being installed;
- ***Near ground level wind speed*** should be observed at heights relevant for energy production to document any change in the intensity or spatial distribution of this resource over time (scales of decades) to support better planning for locating wind energy placement;
- Repeated observations over long periods of time could measure increases or decreases in ***heat loss from groups of buildings*** (suggesting adaptation measures to changing temperatures) and monitor heat island effects.

Action 2) GCOS should explore how observations can be used in urban areas to monitor how the climate is changing in these areas, and to support and monitor the implementation of adaptation and mitigation.

5.3. MONITORING NEEDS: EARLY WARNING

Meteorological observations to allow reliable forecasts of precipitation and storms will depend on the timely sharing of meteorological data by National Meteorological and Hydrological Services, as well as other agents making the observations.

Gaps in the observing networks have been discussed in the GCOS Status report (GCOS 2015). Plans to fill these gaps have been put forward in the GCOS Implementation Plan (GCOS 2016). Parties to the UNFCCC (i.e.

[19] In 2017, the UN stated that in recent decades, the world has experienced unprecedented urban growth. In 2015, close to 4 billion people —54 per cent of the world's population —lived in cities and that number is projected to increase to about 5 billion people by 2030. Progress towards the Sustainable Development Goals, Report of the Secretary-General E/2017/66, UN 2017.

members of WMO) and international organisations were asked to assist in implementing these plans by the UNFCCC in 2016.

Action 3) Support the full implementation of the GCOS Implementation Plan. While this will not provide all the information needed for adaptation and early warning systems, it will provide the global, larger scale information they need (see the case studies for examples) .

Radar observations are one approach to observing rainfall intensity and distribution. The GCOS Task Team on Radar is looking at making these observations consistent (to allow trends and long-term changes to be discerned) and openly available with consistent metadata. Lightning observations, when included into weather models, can also improve for – and nowcasting of severe weather. In addition can lightning observations be used as proxy for precipitation intensity. Since lightning observations are simpler and cheaper than traditional weather radar, lightning observations have already proven in that they can be used to replace radar stations where not enough financial resources are available. A GCOS Task Team on Lightning should lead to these observations being available as well.

Action 4) Support and implement the outcomes of the GCOS Task Teams on Radar Observations and Lightning.

5.4. MONITORING NEEDS: DEVELOPMENT OF SENSORS

There is an urgent need to develop new sensors and approaches suitable for monitoring adaptation. While this is an ongoing activity across observations of the Earth system it is particularly important for adaptation where there is a pressing requirement for affordable solutions that can be used for local monitoring, and wide scale deployment. This needs the same level of effort as has been put into development of sensors for the global observations of ECV (such as the development of a wide range of sensors for ocean observations).

Action 5) Develop new sensors for the monitoring adaptation.

6. OTHER OBSERVATIONS AND THE PARIS AGREEMENT

6.1. AIMS (ARTICLE 2)

The first aim of the Paris Agreement is explicitly based on an ECV: surface temperature. However, the goal is not expressed as an absolute value, but as a change from pre-industrial conditions (*well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels*). Pre-industrial, perhaps intentionally, is not defined. WMO has noted that the instrumental temperature change extends back to 1880 (WMO 2017) and, while estimates of temperature change since pre-industrial times have been made, these estimates could, potentially, be improved.

The current approaches allow a good estimate of global temperature to be made annually (e.g. see the WMO Statement on the State of the Global Climate in 2017 (WMO-1212). However, these global observations are insufficiently detailed to adequately measure important changes at the regional/local level such as heat waves, day and night time temperature fluctuations, or shifts in the growing season which may have significant impacts.

6.1.1. Monitoring Needs: Global Temperature.

Action 6) Support the continued monitoring of global temperature, in particular, to ensure long-term observations and data availability into the future. Current monitoring, if maintained, is sufficient to provide an estimate of global average temperature.

Action 7) For adaptation, more detailed local information is needed, both to assess local risks and to measure the effectiveness of any actions. Some regions are less well observed, and more systematic observations should be developed, both through improving current observational capacity and by recovering past data (e.g. transferring old, decaying paper records into a digital form that can used more easily). In fact, extending the reliable record back in time may be essential to establish the baseline for current and future assessments.

Action 8) In order to explain and predict changes in the global average surface temperature, it is important to understand all components of the Earth's energy budget. Most of the net energy gain by the Earth is stored in the ocean (about 93%[20]) so small changes in its uptake by the ocean could have significant impacts. GCOS should identify observation gaps in global energy fluxes and develop plans to fill them. It should also consider if requirements and targets in the current GCOS Implementation Plan are adequate and update them as needed.

6.2. NATIONALLY DETERMINED CONTRIBUTIONS (NDC) (ARTICLE 4)

Each Party shall prepare, communicate and maintain successive nationally determined contributions (NDC) that it intends to achieve. Parties may revise NDC at any time, but each revision shall be more ambitious than previous ones. NDC shall be communicated every five years informed by the **global *stocktake.*** Developed countries shall take the lead in this process, providing support to other countries.

When accounting for anthropogenic emissions and removals corresponding to their nationally determined contributions, Parties shall promote environmental integrity, transparency, accuracy, completeness, comparability and consistency, and ensure the avoidance of double counting, in accordance with guidance adopted by the Conference of the Parties serving as the meeting of the Parties to this Agreement.

Reporting of emission will be part of the Transparency Framework discussed in section 9.

[20] The IPCC's 5th Assessment Report says "Warming of the ocean accounts for about 93% of the increase in the Earth's energy inventory between 1971 and 2010 (high certainty)". This has continued after 2010, see, for example, Improved estimates of ocean heat content from 1960 to 2015 Cheng L, et. al. Science Advances, 10 Mar 2017: Vol. 3, no. 3, e1601545, DOI: 10.1126/sciadv.1601545

6.2.1. Monitoring Needs: GHG Emissions and the Global Carbon Cycle

The developing field of using atmospheric concentrations and inverse modelling techniques to estimate GHG fluxes should be able to assist emission inventory compilers in improving their estimates. However, Article 13, paragraph 3 emphasises that the transparency framework shall ... *be implemented in a facilitative, non-intrusive, non-punitive manner, respectful of national sovereignty, and avoid*[ing] *placing undue burden on Parties*. This appears to rule out the use of these approaches as part of a formal checking and validation system: however, their use by the Parties themselves to check, validate and improve their estimates should continue to grow. These methods can also be used at a regional and global scale to check overall emissions and removals of GHG as well as changes in the natural land and ocean sinks.

Using composition data will provide emission estimates independent of the assumptions used by national inventory compilers. These approaches are developing with increasing accuracy and resolution (approaching country level). While not able to replicate the potential accuracy of estimates of emissions of CO_2 from fossil fuels, they can approach the accuracy of estimates of CH_4 and N_2O. Emission estimates of many of the other greenhouse gases such as HFCs, PFCs and SF_6 have large uncertainties as they often arise from unintentional leakages with are difficult to quantify and are very variable and the use of atmospheric composition data to check emission inventories, or to develop emission factors, has been demonstrated. Recent developments in satellite missions show promise in monitoring specific leakages, for example from industrial sources.

As noted above, these approaches are not intended to be used as an independent validation process but should be implemented to assist inventory compilers and facilitate improvements in national emission estimates. They would also provide an independent validation of the inventory uncertainty estimates and confirm that the overall impact of the NDC was as predicted.

In addition to the monitoring of anthropogenic greenhouse gases, the fluxes in the entire global carbon cycle need to be monitored to determine whether the reductions resulting from the NDC will be sufficient to stabilise or reduce the concentration of greenhouse gases in the atmosphere. It will be important to be able to show that atmospheric concentrations are stabilising, that reservoirs are being protected and that natural as well as anthropogenic sinks are maintained or improved. The carbon cycle is changing in response to a range of climate changes including continued emissions, CO_2 concentrations, increasing temperatures, changes in hydrological cycle, and changes in the oceans. Monitoring should show that existing long-term reservoirs of carbon are not leaking, sinks are maintained or increased, and new natural sources are not being stimulated by climate change.

Action 9) GCOS needs to strengthen the implementation of actions supporting estimates of GHG fluxes and the use of atmospheric composition data that are in the GCOS Implementation Plan (Actions T67-T71).

Observations of land use and land cover are needed to implement the IPCC Guidelines (IPCC 2006 & 2014) to estimate emissions and removals by land categories (such as forests) and are discussed below under Sinks and REDD+.

6.3. SINKS AND REDD+ (ARTICLE 5)

Parties should take action to conserve and enhance, as appropriate, sinks and reservoirs of greenhouse gases including forests.

Parties are encouraged to take action to implement and support REDD+[21] as already agreed under the Convention, including through results-based payments, as joint mitigation and adaptation approaches for the

[21] Reducing emissions from deforestation and forest degradation, and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries

integral and sustainable management of forests, and incentivising non-carbon benefits associated with such approaches.

6.3.1. Monitoring Needs: Forests and REDD+

Satellite measurements, combined with ground-based observations, contribute significantly to forest monitoring (e.g. GFOI 2016, IPCC 2006 & 2014). The use of other land categories as sinks (e.g. changing agricultural practices and preserving and restoring wetlands) can also be monitored in a similar way.

Observations of forests in support of REDD+ and other mitigation approaches are already underway with a combination of optical and radar satellite observations, supplemented with ground-based data (GFOI 2016) to provide information at a spatial resolution up to 10m. Land cover products have also been derived to account for emissions resulting from land use change, though at a coarser spatial resolution. Demonstration satellite missions using LIDAR[22] will soon be underway providing a better observation of the variability of biomass. These activities should be supported and continued.

Action 10) GCOS needs to strengthen the implementation of the actions on land cover, above-ground biomass, soils, permafrost and fires that are in the GCOS Implementation Plan (Actions T33,T34 and T47-64).

GCOS should also encourage the use of monitoring to determine whether existing forests (included or not in REDD+) are being ***encroached upon by buildings/agriculture***. Monitoring is also needed to assess any changes in the "health" of forests, possibly due to a lack of adaptation by ***forestry industry*** to changing climate (e.g.. planting species that are not adapted for changing temperature, hydrology, or pest resistance, etc.). Such effects can be very important in assessing the non-REDD+ aspects of forest benefit, e.g. to indigenous communities and as critical habitats.

More generally, monitoring of Land Use/Land Cover is also needed to ***monitor adaptation in agriculture***. To show whether or not the changing extent of agricultural land is consistent with changes in hydrology, temperature, etc. For instance: are crop types changing? is production changing? is irrigation changing consistent with water availability? These would be in addition to observations for agriculture that are already well established. WMO's Agricultural Meteorology Programme (AGMP) aims to assist WMO Members in the provision of meteorological and related services to the agricultural community to help develop sustainable and economically viable agricultural systems. GEOGLAM produces the Crop Monitor for the Agricultural Market Information System (AMIS), and coordinates Asia-Rice and the Rangelands and Pasture Productivity project based on remote sensing.

Action 11) GCOS should explore the possibilities for additional monitoring of changes in land cover, focussed on conversion of forests to the build environment or agriculture, forest health and monitoring adaptation in agriculture. GCOS should make specific proposals that may be based on existing data or require new observations.

6.4. TECHNOLOGY TRANSFER (ARTICLE 10)

The Paris Agreement contains provisions for encouraging and supporting technology transfer. These are focussed on *improving resilience to climate change and to reduce greenhouse gas emissions* (Art. 10, para 1). Support for monitoring technologies fits better in the section on support for capacity building (Section 8).

[22] NASA Global Ecosystem Dynamics Investigation (GEDI) is scheduled to be deployed on the International Space Station in late 2018 and ESA's Biomass satellite should be launched in 2020.

6.4.1. Monitoring Needs: Technology Transfer (Article 10)

As noted above (see section 5.2), it may be possible that observations could detect the uptake of technologies such as solar energy and wind turbines, and hence measure the rate of technology transfer. GCOS should identify indicators of technology change and how they can be monitored over time.

6.5. LOSS AND DAMAGE (ARTICLE 8)

> *Parties recognize the importance of averting, minimizing and addressing loss and damage associated with the adverse effects of climate change, including extreme weather events and slow onset events, and the role of sustainable development in reducing the risk of loss and damage.*
>
> *Art. 8 para. 1*

The agreement covers not just short-term events (e.g. flooding and storms) but also *slow onset events* and *events that may involve irreversible and permanent loss and damage*.

6.5.1. Monitoring Needs: Loss and Damage

Observations will be crucial to identify and *attribute*[23] events leading to loss and damage. They will allow comprehensive risk assessment and management, risk insurance facilities, climate risk pooling and other insurance solutions. There is also a need to consider non-economic losses and the resilience of communities, livelihoods and ecosystems.

Observations will underpin early warning systems and emergency preparedness, as well as allowing risk assessments are discussed above (Section Action 2)).

6.6. GLOBAL STOCKTAKE (ARTICLE 14)

The detailed nature and content of the global stocktake is not made clear in the Agreement. The global stocktake will *assess the collective progress towards achieving the purpose of this Agreement and its long-term goals*. It will consider *mitigation, adaptation and the means of implementation and support, … in the light of equity and the best available science* (Art. 14 para.1). The first global stocktake will be held in 2023 and they will continue every five years thereafter. *The outcome … shall inform Parties in updating and enhancing, …, their actions and support …, as well as in enhancing international cooperation for climate action.*

The transparency framework aims to provide a clear understanding of climate change action…, including clarity and tracking of progress towards achieving Parties' individual nationally determined contributions …, and Parties' adaptation actions …, including good practices, priorities, needs and gaps, to inform the global stocktake (Art. 13 para. 5).

The global stocktake shall, inter alia:

> *(a) Recognize adaptation efforts of developing country Parties;*
>
> *(b) Enhance the implementation of adaptation action taking into account the adaptation communication …;*

[23] Since the IPCC AR5, the attribution of extreme weather and climate events has been an emerging area in the science of climate change. … When an extreme weather event occurs, the question is often asked: was this event caused by climate change? A generally more appropriate framing for the question is whether climate change has altered the odds of occurrence of an extreme event like the one just experienced. Extreme event attribution studies to date have generally been concerned with answering the latter question. See Knutson, T. J.P. Kossin, C. Mears, J. Perlwitz, and M.F. Wehner, 2017: Detection and attribution of climate change. In: Climate Science Special Report: Fourth National Climate Assessment, Volume I [Wuebbles, D.J. D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 114-132, doi: 10.7930/J01834ND.

> *(c) Review the adequacy and effectiveness of adaptation and support provided for adaptation; and*
>
> *(d) Review the overall progress made in achieving the global goal on adaptation …*
>
> *(Art. 7 para. 14)*

Clearly, some observations will need to be directly reported to the global stocktake, including: global temperature trends, overall impact of NDC on the climate system, as well as direct observations of atmospheric composition and emissions. Other observations will contribute indirectly by supporting and enabling adaptation and early warning systems, mitigation, and the transparency framework. The provision of capacity building and associate financial support should also be reported.

Figure 9, below, illustrates the main components of the "ambition" cycle of the Paris Agreement: the Nationally Determined Contributions (NDCs), the Enhanced Transparency Framework (ETF) and the Global Stocktake (GST).

Figure 10 illustrates the on-going work by the UNFCCC on adaptation relevant for the Global Stocktake (GST). The main sources of information for the GST will come from Parties, constituted bodies and processes under the UNFCCC and the IPCC. On-going negotiations are considering information from other UN Agencies, regional organisations and non-Party stakeholders to complement this information.

The information from Parties could be grouped into two types:

- **communicated information** (i.e. information reported through mandatory reporting to the UNFCCC such as National Communications, National Adaptation Plans (NAPs) and Nationally Determined Contributions (NDCs); the upper part of the figure). The adaptation communication will summarise the contributions for adaptation and it may use any one of those three vehicles. The structure and content of the adaptation communication will be agreed upon at COP 24 in Poland in December 2018. For communicated information, Parties are negotiating the modalities, procedures and guidelines for an **enhanced transparency framework** (ETF). In contrast to mitigation, the UNFCCC decided that the adaptation component of the ETF will not include a technical expert review nor a multilateral facilitative consultation (dotted light blue rectangles).
- and **reported information** (i.e. other information beyond the mandatory reports; the lower part of the figure). The reported information will include climate change impacts and adaptation, and good practices, needs and gaps.

The information supplied to the GST (communicated – NDCs, and reported – ETF) are provided at national level, but the assessment of the progress towards the implementation of the Agreement is done at the collective (global) level. For adaptation, regional and local information is needed, and actions are mainly taken at local/community level.

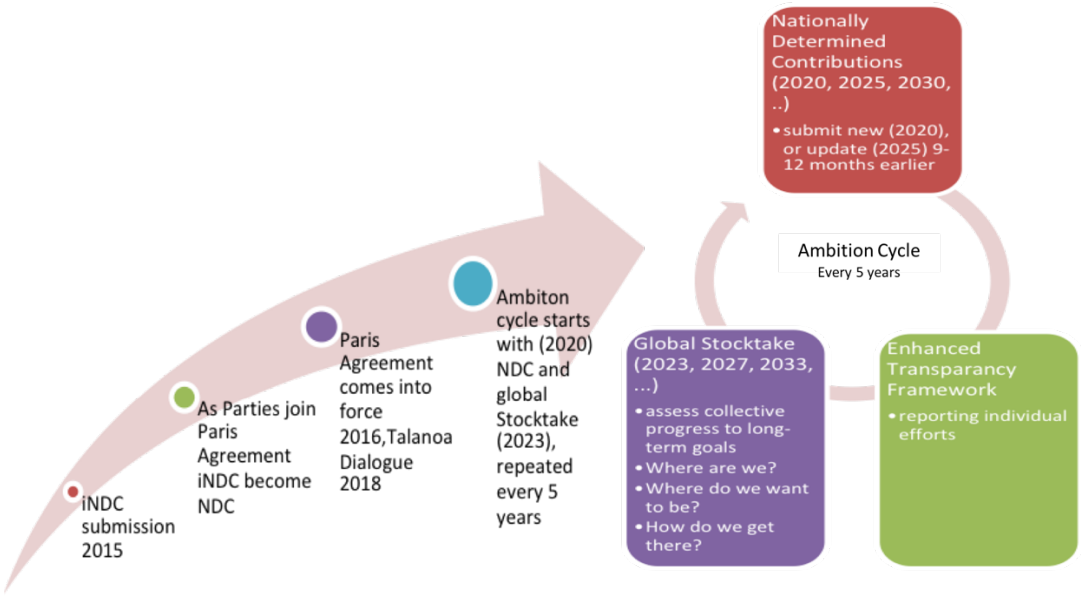


Figure 9 The ambition cycle of the Paris Agreement Note: The left part of describes initial actions needed for the preparation of the first ambition cycle.

This information is also likely to be very relevant to monitoring progress towards the Sustainable Development Goals (SDGs) of the UN (https://sustainabledevelopment.un.org/), notably in relation to environmental risk and resilience. Observations will be needed by all Parties, both developed and developing.

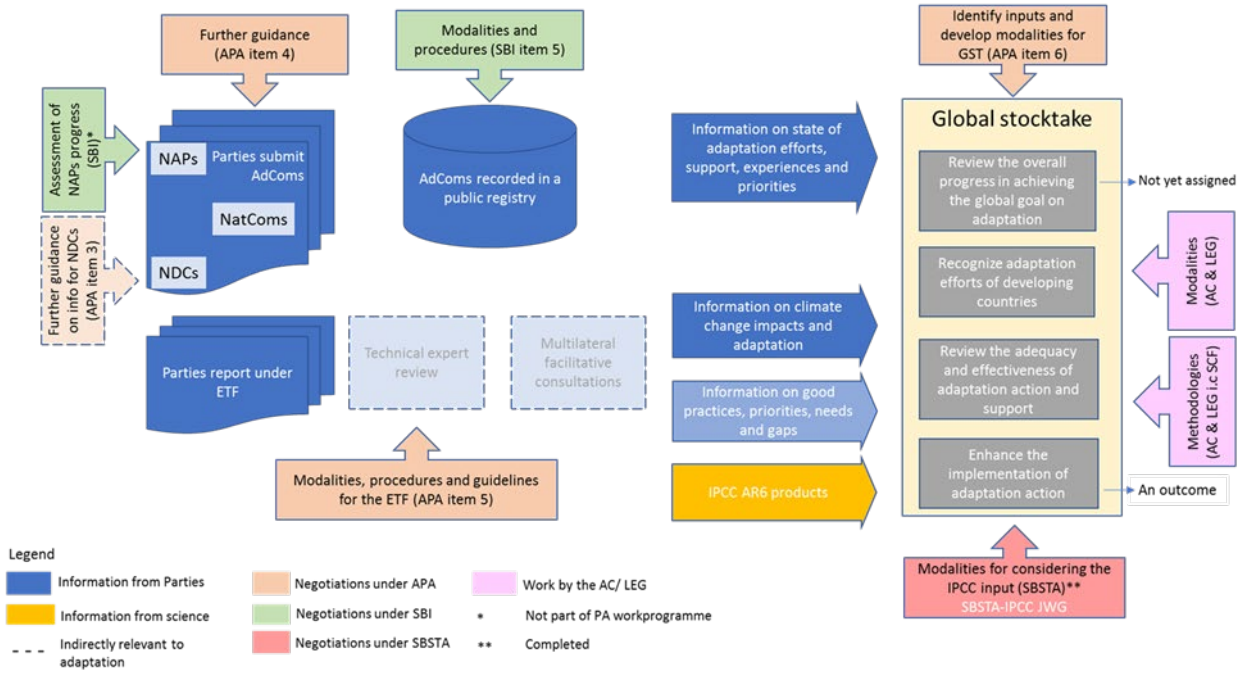


Figure 10 On-going UNFCCC work on adaptation relevant for identification of sources of inputs of and development of modalities for the global stocktake

The focus of the current negotiations on the GST is on the operational model for conducting it (e.g. phases, governance, duration, outputs). It is expected that the detailed methodological aspects of the GST will be discussed after 2018. The outcome of the GST will inform Parties on updating and enhancing, in a nationally

determined manner, their actions and support in accordance with the relevant provisions of the Agreement, as well as enhancing international cooperation for climate action.

Under the GST, GCOS products should be used at the global level to assess “where are we?” in terms of the state of the climate and to confirm collective progress in mitigation and adaptation.

6.6.1. Global Climate Indicators

The GST may benefit from using the GCOS climate indicators, identified to characterise the state of the climate and its trajectory. Figure 11 lists the agreed GCOS Global Climate indicators as well as indicating candidates being considered to cover extreme events and the biosphere while Figure 12 shows recent data for the indicators. Although the long-term global goal is defined in terms of the global average temperature, other long-term global goals, such as sea level rise or ocean acidification, were considered in the 2013-2015 review[24] and the limitations of working only with a temperature limit were recognised (Decision 10/CP.21[25]). It is therefore conceivable that such indicators will be considered under the GST and would give a more comprehensive and holistic perspective on the evolution of climate, beyond the limited focus on the global average temperature increase.

[24] In 2010 at COP 16, Parties agreed on a long-term global goal to reduce GHG emissions to hold the increase in global average temperature below 2°C above pre-industrial levels, and to periodically review the goal. The first periodic review, known as the 2013-2015 review, considered strengthening the long-term global goal, including in relation to a temperature rise of 1.5°C. (UFCCC/SB/2015/INF.1)

[25] UNFCCC Decision 10/CP.21, Paris 2015

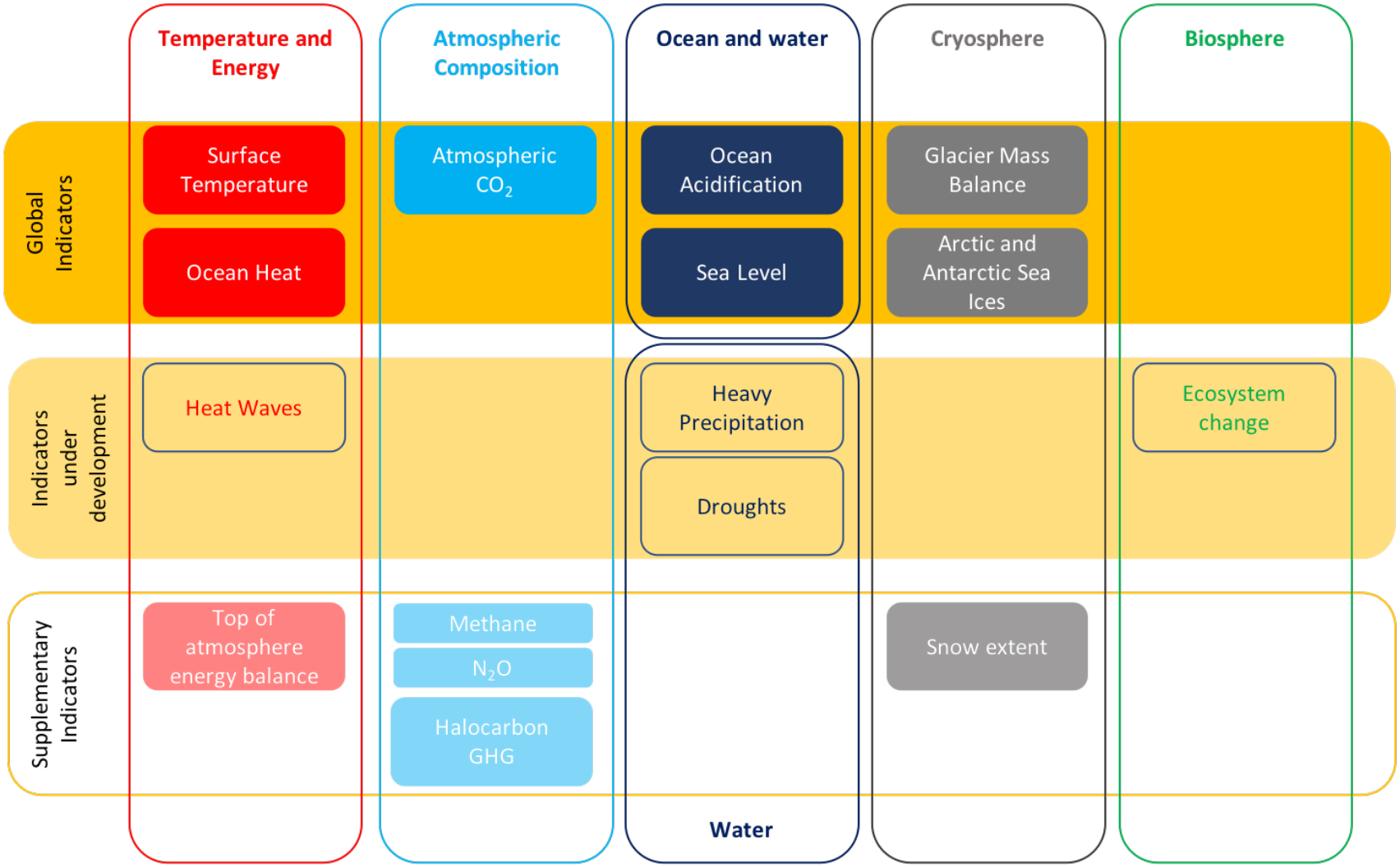
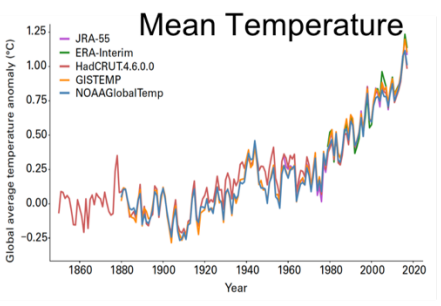
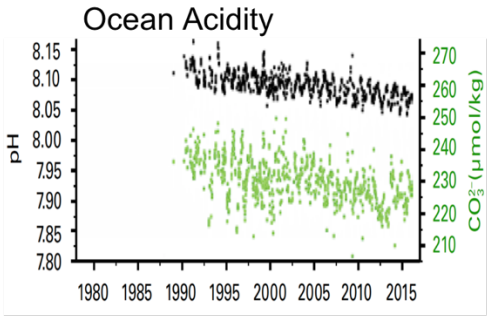


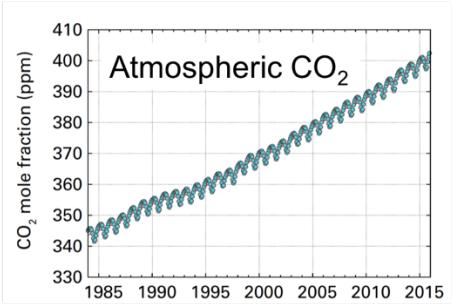
Figure 11 Climate indicators



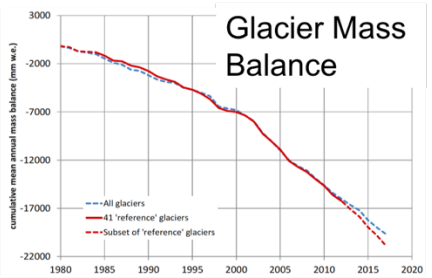
Global mean temperature anomalies, with respect to the 1850–1900 baseline, for the five global datasets (Source: UK Met Office Hadley Centre)



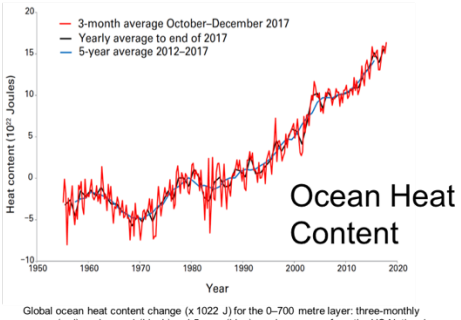
Trends in surface (< 50 m) ocean carbonate chemistry calculated from observations obtained at the Hawaii Ocean Timeseries (HOT) Program in the North Pacific over 1988–2015. Seawater pH (black points, primary y-axis) and carbonate ion concentration (green points, secondary y-axis). Ocean chemistry data were obtained from the Hawaii Ocean Timeseries Data Organization & Graphical System (HOT-DOGS). (Source: US National Oceanic and Atmospheric Administration (NOAA), Jewett and Romanou, 2017)



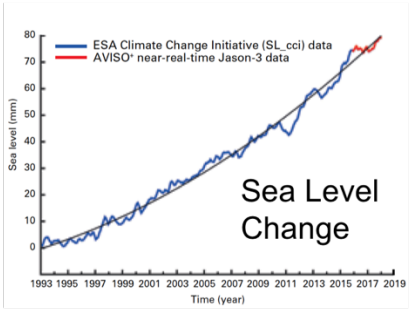
Globally averaged mole fraction (measure of concentration), from1984 to 2016, of CO2 in parts per million (left), CH4 in parts per billion (middle) and N2O in parts per billion (right). The red line is the monthly mean mole fraction with the seasonal variations removed; the blue dots and line depict the monthly averages. (Source: WMO Global Atmosphere Watch)



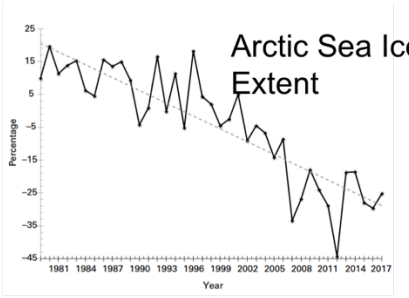
Mean cumulative mass balance of all reported glaciers (blue line) and the reference glaciers (red line). SOURCE: **world glacier monitoring service** http://wgms.ch/

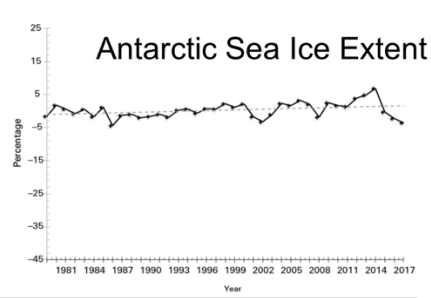


Global ocean heat content change (x 1022 J) for the 0–700 metre layer: three-monthly means (red), and annual (black) and 5-year (blue) running means, from the US National Oceanic and Atmospheric Administration (NOAA) dataset. (Source: prepared by WMO using data from NOAA National Centers for Environmental Information)



Global mean sea-level time series (with seasonal cycle removed), January 1993–January 2018, from satellite altimetry multi-missions. Data from AVISO (Source: Collecte- Localisation-Satellite (CLS) – Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS))





September sea-ice extent for the Arctic, and (right) September sea-ice extent for the Antarctic. Percentage of long-term average of the reference period 1981–2010 (Source: prepared by WMO using data from the US National Snow and Ice Data Center)

Figure 12 Global Climate Indicators collected and summarised annually by WMO

WMO, in partnership with other UN Agencies and organisations, uses the information collected on ECV to present these indicators (see Figure 12) as part of its annual Statement on the State of the Climate, which provides a comprehensive overview of **temperature** variability and trends, high-impact events, and long-term indicators of climate change such as increasing carbon dioxide concentrations, Arctic and Antarctic sea ice, sea level rise and ocean acidification.

These indicators are each produced from very large datasets. For example, for **surface temperature**, WMO uses datasets (based on **monthly climatological** data from observing sites) from the United States NOAA, NASA's Goddard Institute for Space Studies, and the UK's Met Office Hadley Centre and the University of East Anglia's Climatic Research Unit. It also uses **reanalysis** datasets from the European Centre for Medium Range Weather Forecasts, the European Union's Copernicus Climate Change Service, and the Japan Meteorological Agency. This results in combining millions of meteorological and marine observations, including from satellites, with models to produce a complete reanalysis of the atmosphere.

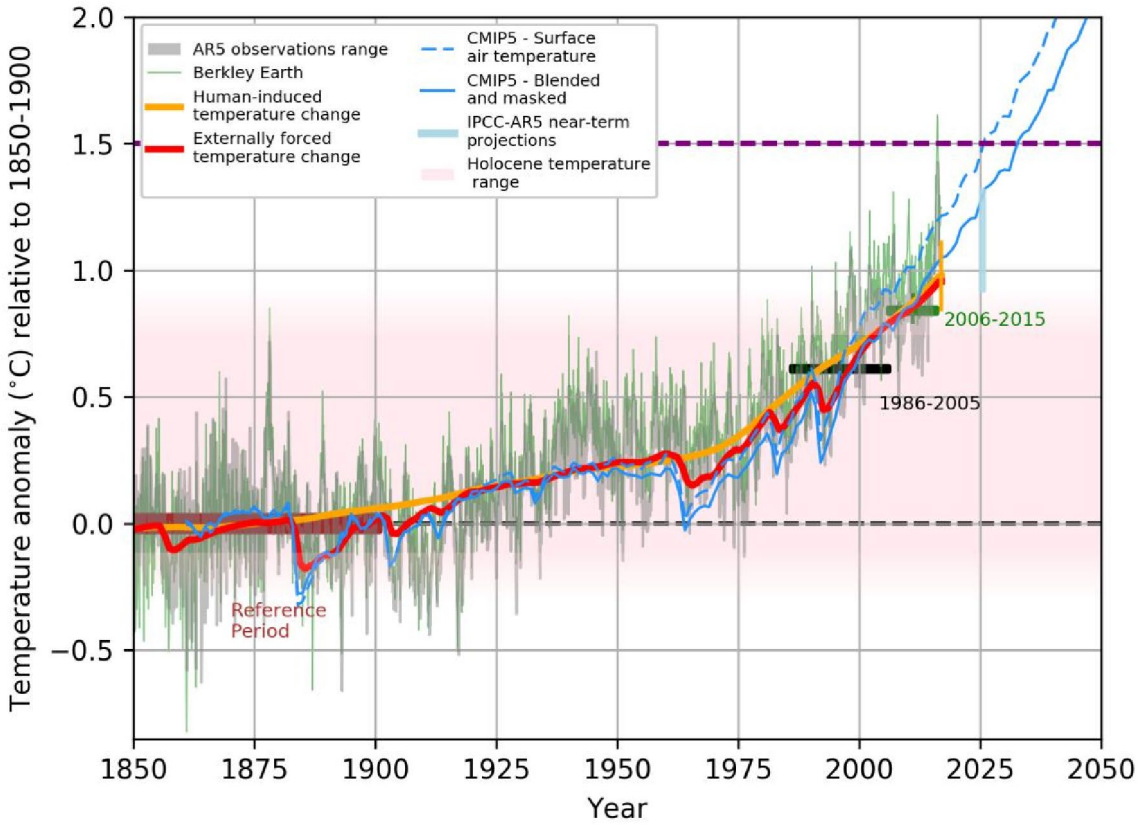


Figure 13 Evolution of global mean surface temperature over the period of instrumental observations Source: IPCC AR5

This data is also the basis for projections and comparison with targets. Figure 13 compares the global average temperature with projections. The plot starts with the beginning of the instrumental recording period (in the mid 1800s, similar to pre-industrial temperature estimates) and compares estimates of human induced temperature change (orange) with the total forcing (red) showing nearly all the change is human-induced. This also shows that currently the Earth's global mean temperature is about 1 °C above pre-industrial levels.

Many of these indicators vary across the planet: warming can be locally higher or lower than the global average. Similarly, changes in near-surface ocean salinity (see Figure 14), together with other ECV such as ocean acidity and temperature, are used to understand local and regional impacts, for instance on fisheries,

and as inputs into IPCC assessments. The map (Figure 15) showing changes in Arctic and Antarctic sea-ice was produced through a combination of satellite observations and reanalysis based on information provided by European and US sources.

Climate services would need to provide access to several climate indicators (e.g. temperature increase, sea level rise, ice sheet melting, warming up of the ocean) and climate indices (e.g. based on records of temperature, precipitation, drought event) for both the identified climate drivers and the expected climate impacts. In Europe, Copernicus develops such climate services for atmosphere, marine, land, climate, emergency, and security.

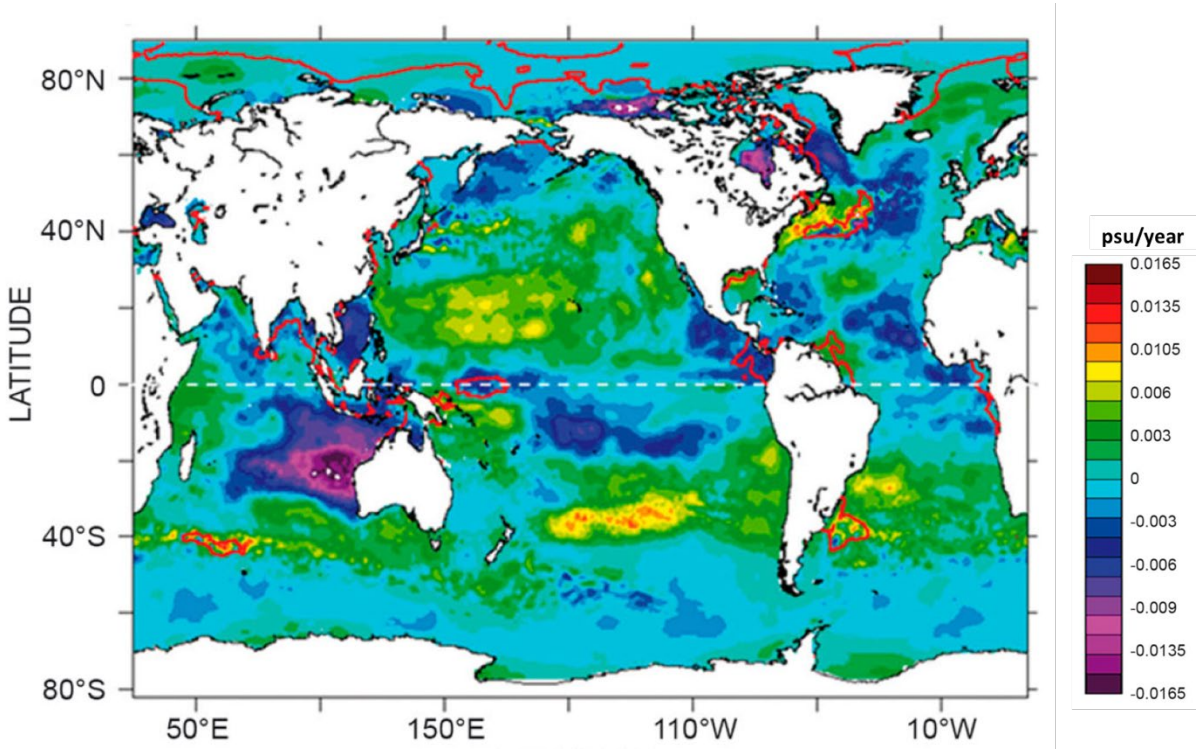
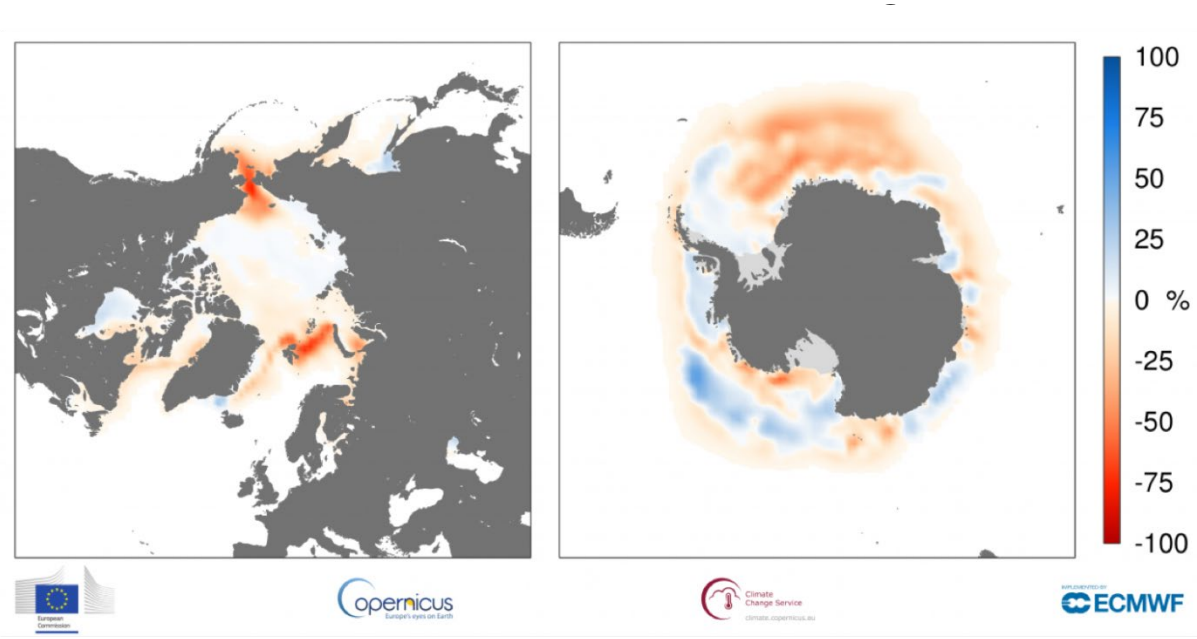


Figure 14 Near-surface (10 m) salinity trends during the period 1993–2015 (units are psu/year, the red line corresponds to the areas where the formal error adjustment of the least-square fit is greater than 0.001 psu/year). Ocean salinity is generally defined as the salt concentration (e.g. Sodium and Chloride) in sea water. It is measured in unit of psu (Practical Salinity Unit), which is a unit based on the properties of sea water conductivity. It is equivalent to g/kg. SOURCE *The Copernicus Marine Environment Monitoring Service Ocean State Report* Journal of Operational Oceanography ISSN: 1755-876X (Print) 1755-8778 (Online)



Sea-ice cover anomaly for December 2017 relative to the December average for the period 1981-2010. Source: ERA-Interim. (Credit: ECMWF Copernicus Climate Change Service)

Figure 15 Arctic and Antarctic Sea Ice Anomaly

Action 12) Identify and specify global climate indicators for extreme events and to quantify changes in the ecosystems. Continue to support and produce data form the Global Climate Indicators.

The Paris Agreement has increased the incentive to **improve reported anthropogenic carbon dioxide emissions using independent Earth system observations** and to better understand how these emissions relate to changes in atmospheric concentrations. For example, while emissions of CO_2 from fossil fuels, industry and land use change fell from 11.35 (GtC/yr) in 2015 to 11.15 (GtC/yr) in 2016 [26], there was a record increase in CO_2 concentration in the atmosphere [27]. Reliable verification requires a step change in our understanding of carbon cycle variability (see Section 6.2.1).

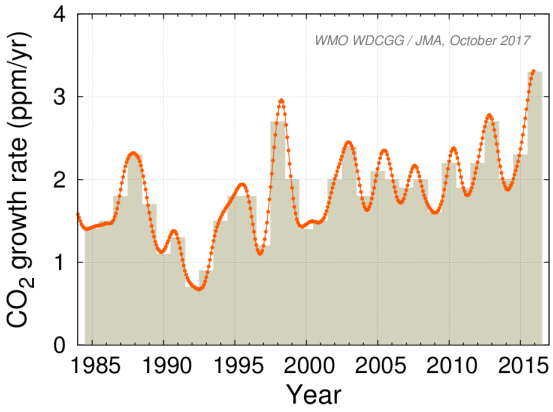


Figure 16 Atmospheric CO2 Growth Rate, SOURCE WMO WDCGG, JMA

In-situ and satellite observations, through integrative modelling approaches, could provide independent evidence of the effectiveness of collective action to address climate change, but this verification will only be possible if we can fully filter out the background variability in

[26] Global Carbon Project (2017) Carbon budget and trends 2017. [www.globalcarbonproject.org/carbonbudget] published on 13 November 2017 https://doi.org/10.5194/essd-2017-123.

[27] WMO (2017)The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2016 Greenhouse Gas Bulletin No. 13, 30 October 2017. ISSN 2078-0796

atmospheric CO_2 concentrations.[28] As noted above, this provides an opportunity to assess how GCOS products could be further developed or better used to confirm collective progress on mitigation at the global level.

6.6.2. Education and Public Awareness (Article 12)

The Paris Agreement recognises the importance of enhancing *climate change education, training, public awareness, public participation and public access to information* (Article 12) in its implementation. While open access to all the ECV is a GCOS requirement, the development of climate indicators will be a key component of this as these will provide information in a more easily understood setting (section 6.6.1).

6.6.3. Monitoring Needs: Hydrology and Ecosystems

In order to report to the Global Stocktake (GST) on the impact on the Earth's climate system, an understanding of the changes in ecosystems is needed. Several current ECV relate to terrestrial ecosystems including FAPAR, LAI, Albedo, Above-ground biomass, Fire, Anthropogenic Water Use, and Land Cover. These overlap with adaptation needs – detailed information is needed for adaptation and global overviews to inform the global stocktake. Work is needed to understand how these can be used to monitor changes to ecosystems.

It is very difficult to ascribe any specific changes in terrestrial ecosystems to climate change separately from other human induced impacts (although the current discussion on global greening[29] may be an exception). However, a good starting point will be a clear observational basis on what changes are occurring.

Ocean ecosystems also need to be monitored. While satellite-based Ocean Colour observations provide information about the distribution of phytoplankton, OOPC is discussing the precise definition of the requirements of the ECV called "Marine Habitat Properties". These ECV should be able to document the changes as they are occurring.

Action 13) Continue to improve the observations of the hydrosphere and biosphere as indicated in the GCOS Implementation Plan

[28] G. P. Peters, Towards real-time verification of CO_2 emissions, 2017.
[29] Zaichun Zhu et al, *Greening of the Earth and its drivers* Nature Climate Change volume 6, pages 791–795 (2016) | DOI: 10.1038/NCLIMATE3004

7. OPEN ACCESS TO DATA.

While improved monitoring is required, especially to address regional and national issues, it is also very important to allow open access to all climate data. If those dealing with climate impacts and adaptation cannot access the appropriate climate records, the impacts of the resulting poor planning and preparedness will be felt by the countries themselves.

Sharing of information is an important component of the Paris Agreement (e.g. *undertake and communicate* Art. 3, *Sharing Information* Art. 7 para. 7a, *public access to information* Art. 12, *provide information related to climate change impacts* Art. 13 para 8). It is clear that access to data is needed for emergency planning and response as well as to plan and implement adaptation. Open access to data for climate variables has also been mandated by the WMO Resolutions 25 (Cg-XIII), 40 (Cg-XII) and 60(Cg-17). The IPCC has identified lack of access to data as a significant issue for adaptation in some parts of the world such as Africa. GCOS has promoted open access to data in its latest plans (GCOS 2016) as much of the utility of these datasets comes from them being widely used. GCOS will continue to advocate for improved access to data. Data centres and data exchange infrastructures can by supported by using common metadata standards (where appropriate WIGOS standards should be used).

Open access to climate data is needed for many reasons, for example:

- Early warning systems will need information on the immediate upwind weather, even if this crosses a national boundary. Understanding river systems and predicting floods needs information about the entire river basin, even across national boundaries.
- Numerical weather prediction (NWP) that allows forecasting of storms and other events depends on a global system of shared data – no country can do this reliably on the basis of measurements obtained exclusively within their national territory.
- Global fluctuations of the climate such as El Niño Southern Oscillation (ENSO) may start with changes in one part of the globe but have global impacts. Predictions of ENSO are made based on measurements in the tropical Pacific.
- Reanalysis will provide many data fields and help fill gaps in observations, both historically and in the present. Similar to NWP, the accuracy and reliability of reanalysis depends on having a global set of observed data. The accuracy of reanalysis and modelling products in a country depends not just on that countries' observations but on the entire global monitoring system.
- In many countries, the observed data are not shared, even within the country. Observations are made by different institutions, and stored in different ways, often without due allowance for the maintenance of long-term archives.

Action 14) GCOS should strengthen its advocacy for the free and open sharing of data following the Paris Agreement and WMO regulations.

8. CAPACITY DEVELOPMENT (ARTICLES 11, 9)

The Paris Agreement is clear that Developed country Parties shall provide financial resources to assist developing country Parties with respect to both mitigation and adaptation (Article 9). Other parties are encouraged to contribute as well. Developed countries should report every two years on their support (both quantitative and qualitative information) and this will be considered as part of the global stocktake.

> *Capacity-building should enhance the capacity and ability of developing country Parties, in particular countries with the least capacity, … to take effective climate change action, including, … adaptation and mitigation actions, and should facilitate …, relevant aspects of education, training and public awareness, and the transparent, timely and accurate communication of information.*
>
> *Art. 11 para. 1*

Capacity building is needed for all parts of the Paris Agreement. Of particular interest to the observation and science communities are:

- Adaptation: assess which observations should serve as the basis for planning or for monitoring implementation
- Mitigation: monitoring of sources and sinks of GHG is vital to ensure accurate, credible estimates and to support transparent reporting
- Education and public awareness: access to basic data on climate observations is needed
- Accurate communication of information: inputs into the global stocktake

Capacity building is needed to improve not just the number and reliability of observations, but also to enhance data stewardship (archiving, accessing and distributing data). The GCOS Cooperation mechanism is set up to do just this and provides a clear way for GCOS to support this part of the Paris Agreement. In 2016 and 2017 the UNFCCC has asked countries to contribute to fulfilling the actions in the GCOS Implementation Plan (Decision 19/CP.22, FCCC/SBSTA/2017/L.21). GCOS needs to ensure that the ECV requirements are such that the global climate datasets can be used to achieve these aims. The financial resources needed to improve observations and provide the information needed are small compared to the size of funds being made available for climate issues.

Action 15) Use the GCOS Cooperation Mechanism to support improvements to observing systems. Increase the funding available to support these actions.

A recent GCOS regional workshop for the South Pacific Islands noted that to reduce the uncertainties in reanalysis and short-term forecasts in Europe, the most significant observational improvements would be to increase the number and coverage or upper air measurements (radiosondes) in the South Pacific. These observations also have significant local benefits (for example for cyclone prediction). Thus, a complete global system will lead to benefits nationally and locally, a fact which is not intuitively obvious, but which argues strongly for closer international cooperation and development assistance. On a more local basis early warning systems will depend on regional information beyond a country's borders to allow reliable forecasts. Two important conclusions of the workshop were:

- Sharing of data internationally is vital (following WMO regulations). A country sharing data with reanalysis and modelling centres will benefit through improved products for their countries.
- Maintenance of a global system for some upper air variables leads to benefits for all Parties. However, countries with few resources, such as Small Island Developing States (SIDS) and Least Developed Countries (LDCs), find the costs prohibitive and some kind of sustainable international support is needed.

Action 16) GCOS should continue to identify those observations that provide benefits globally for national adaptation and should look for ways to sustainably support these observations in countries without the necessary resources to do so themselves.

Much adaptation planning depends on model outputs (sometimes downscaled) and/or reanalysis results. Improving the number and quality of observations in poorly observed areas will improve the reliability of the information available for adaptation over many countries, and so some effort should be directed at this as well. As noted in the section above these observational improvements (e.g. upper air measurements) may have a positive effect over many countries and so support should be considered by NHMS members (perhaps jointly).

9. REPORTING: THE TRANSPARENCY FRAMEWORK (ARTICLE 13)

The transparency framework is an important part of the Paris Agreement. Many of the observations discussed above may needed to be reported or summarised. The aim of the Transparency Framework is that:

> *In order to build mutual trust and confidence and to promote effective implementation, an enhanced transparency framework for action and support, with built-in flexibility which takes into account Parties' different capacities and builds upon collective experience is hereby established.*
>
> *Art. 13, Para. 1*

The transparency framework covers both support and action and, like much of the Agreement, imposes tighter requirements on developed countries compared to developing countries. It includes national communications, biennial reports and biennial update reports, international assessment and review and international consultation and analysis. One of the aims of the transparency framework is to provide *clarity and tracking of progress towards achieving Parties' individual nationally determined contributions* (Art. 13 para. 5). This will inform the global stocktake.

Each party has to provide:

> *(a) A national inventory report of anthropogenic emissions by sources and removals by sinks of greenhouse gases, prepared using good practice methodologies accepted by the Intergovernmental Panel on Climate Change and agreed upon by the Conference of the Parties serving as the meeting of the Parties to this Agreement; and*
>
> *(b) Information necessary to track progress made in implementing and achieving its nationally determined contribution under Article 4.*
>
> *Art. 13 para. 7*
>
> *Each Party should also provide information related to climate change impacts and adaptation under Article 7, as appropriate.*
>
> *Art. 13 para. 8*

This information shall

> *… undergo a technical expert review, in accordance with decision 1/CP.21. For those developing country Parties that need it in the light of their capacities, the review process shall include assistance in identifying capacity-building needs. In addition, each Party shall participate in a facilitative, multilateral consideration of progress with respect to efforts under Article 9 [provision of financial support], and its respective implementation and achievement of its nationally determined contribution.*
>
> *Art. 13 para. 11*

Decision 1/CP.21 adopts the Paris Agreement and makes a number of decisions about actions needed to facilitate its implementation. For reporting fluxes of greenhouse gases, it states that:

> *(a) Parties account for anthropogenic emissions and removals in accordance with methodologies and common metrics assessed by the Intergovernmental Panel on Climate Change and adopted by the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement;*
>
> *(b) Parties ensure methodological consistency, including on baselines, between the communication and implementation of nationally determined contributions;*

> *(c) Parties strive to include all categories of anthropogenic emissions or removals in their nationally determined contributions and, once a source, sink or activity is included, continue to include it;*
>
> *(d) Parties shall provide an explanation of why any categories of anthropogenic emissions or removals are excluded;*
>
> *Decision 1/CP.21 para. 31*

With regard to review of these numbers it states the future review and Measurement, Reporting and Verification (MRV) process should build on existing arrangements:

> *Also decides that the modalities, procedures and guidelines of this transparency framework shall build upon and eventually supersede the measurement, reporting and verification system established by decision 1/CP.16, paragraphs 40–47 and 60–64, and decision 2/CP.17, paragraphs 12–62, immediately following the submission of the final biennial reports and biennial update reports;*
>
> *Decision 1/CP.21 para. 98*

Decision 1/CP.16, The Cancun Agreements, in paragraphs 40–47 decided to implement a process of reporting and review for developed countries of their anthropogenic emissions and removals, and in paragraphs 60–64 to enhance their national communications for all parties covering emissions and removals of greenhouse gases; MRV; as well as mitigation actions and policies.

Decision 2/CP.17 paragraphs 12–62, agreed in Durban in 2011, include:

- the UNFCCC biennial reporting guidelines for developed country Parties,
- the Modalities and procedures for international assessment and review (developed countries)
- the UNFCCC biennial update reporting guidelines for Parties not included in Annex I to the Convention.
- the registry of nationally appropriate mitigation actions
- the Modalities and guidelines for international consultation and analysis (developing countries)

9.1. MONITORING NEEDS: TRANSPARENCY FRAMEWORK

Many of the monitoring needs discussed above will be reported or contribute to the transparency framework. Therefore, this section does not list specific monitoring actions but instead indicates how the observations described above can contribute to the Transparency Framework.

- **Free and Open Data.** While the details of the Transparency Frameworks are under discussion, it is clear that free, open and accessible data will increase the transparency and utility of the scientific inputs. This will allow wider review and use of the data and increase the transparency of any conclusions derived from the observations (Chapter 7).
- **Atmospheric Concentrations and Emissions and Removals of GHG.** As noted above, the use of atmospheric composition data and inverse models can support the emission and removal estimates submitted to the UNFCCC. They can also provide a global estimate of emission and removal as well as indicate changes in the natural sources and sinks that can impact the concentrations of GHG (section 6.2.1).
- **Monitoring Adaptation.** Some adaptation measures can be monitored remotely and GCOS will consider how this can be extended to other adaptation actions. Conversely, this can be used to see where adaptation is needed but not being implement (e.g. urban development on flood plains). Reporting this information would give a valuable independent report on the status of adaptation (section 5).

- **Mitigation.** Observations can support some mitigation measures such as REDD+ and observations of land cover can give the assurance that the mitigation measures are being implemented (section 0).
- **Loss and Damage – Attribution.** While observations can give the scale and impact of a climate event, by attributing it to a specific climate cause will allow policy makers to take appropriate actions (section 6.5).

10. CONCLUSIONS

The Paris Agreement established a **science-based cyclical system of assessment** (the Global Stocktake) and improvement (updating NDC), with the ambition of limiting the impacts of climate change. One of the drivers of this system will be observation-based science inputs. Information will need to be reported to the Global Stocktake and the Transparency Framework will allow this to be done in an open and transparent way.

Observations are vital to the success of the Paris Agreement and their continuing acquisition should be supported. Some observations may need support at an international level (see chapter 8 and Action 15). The costs of observations are small compared to the amounts envisaged for adaptation and mitigation.

While many existing ECV will contribute to supporting adaptation, a major aim of the Paris Agreement, GCOS needs a specific activity to better **understand the needs of adaptation and how to develop their observational requirements**. This will require the **direct involvement of adaptation experts in addition to the observation experts traditionally associated with the GCOS Science panels**, including those with financial, implementation and policy responsibilities for successful adaptation to climate change. The ability to understand and estimate existing and future risks, as well as the benefits and limitations of current and upcoming technologies, will be vital to support adaptation planning and increase the resilience of societies to **climate changes.**

Open access to climate data and information will greatly increase the ability of countries to implement the Paris Agreement, adapt to climate change and better implement early warning systems.

Many of the details of the Paris Agreement are still being discussed, and GCOS will need to undertake a detailed consideration of adaptation efforts, however a series of improvements to the current global climate observing system can already be identified, both to report on the state of the climate system or to underpin specific actions in the Agreement. They have been identified in this document and are summarised in Figure 17. Most of these actions and monitoring needs contribute to several different issues including:

- Improving scientific understanding – inputs into to WCRP and IPCC
- Monitoring the State of the environment – reporting to UNFCCC and as input into the Global Stocktake
- Supporting Adaptation – both to help planning and to monitor implementation
- Supporting Emissions and Mitigation

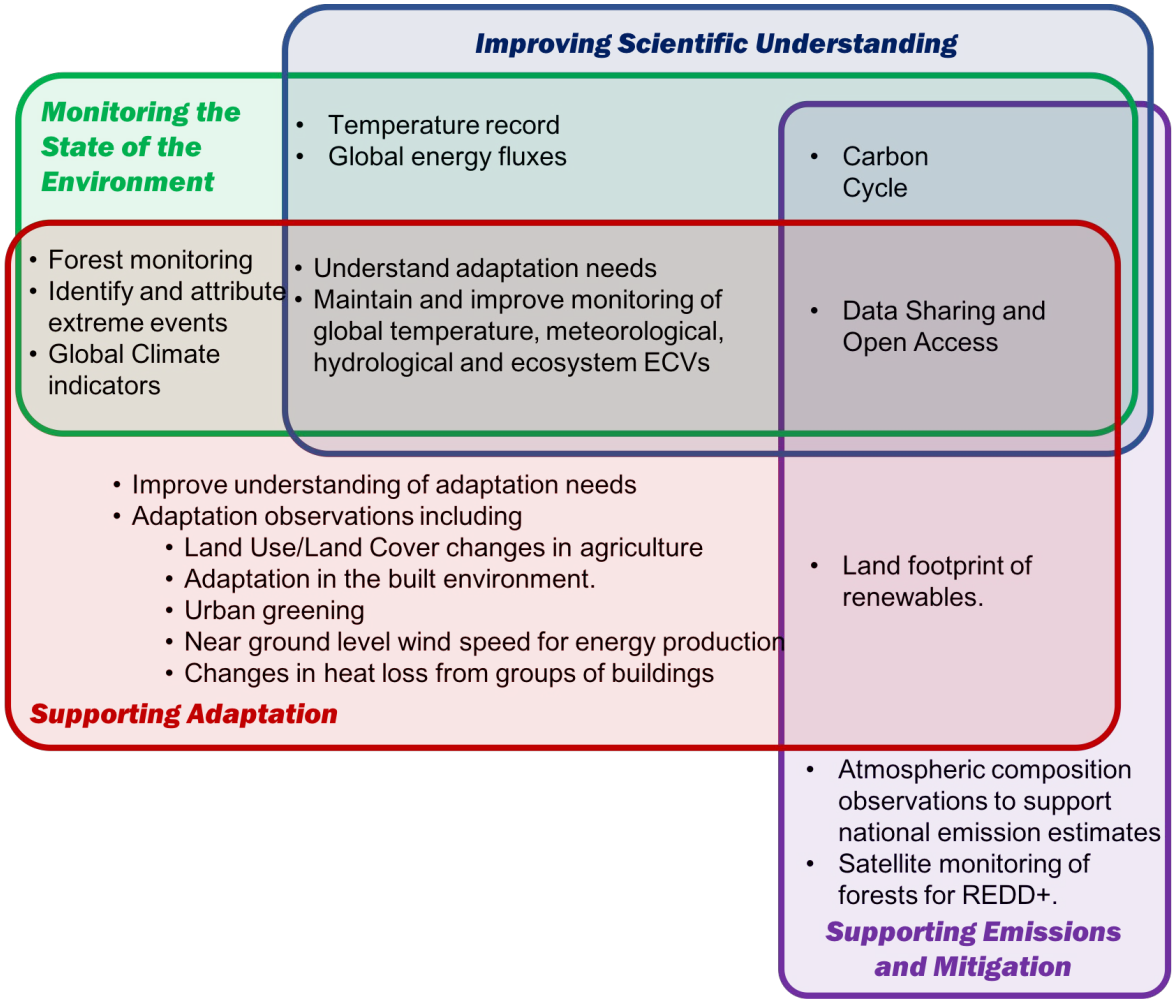


Figure 17 Summary of the monitoring needs identified in this report. GCOS will continue to develop an understanding of the data needs of adaptation efforts and how to develop their observational requirements

The improvements to the observing system identified in this report are:

Activity 1) GCOS should establish a specific activity to understand the needs of adaptation and how to develop their observational requirements. This will require the direct involvement of adaptation experts rather than rely solely on the observation experts traditionally associated with the GCOS Science panels, including those with financial, implementation and policy responsibilities for successful adaptation to climate change. The ability to understand and estimate risks, both current and how they change in the future, will be vital to support adaptation planning and increase the resilience of societies to climate changes. GCOS should consider the world-wide and regional observations that support or monitor adaptation, but not the detailed local observational needs, in line with its remit as a ***global*** observing system.

Activity 2) GCOS should explore how observations can be used in urban areas to monitor how the climate is changing in these areas, and to support and monitor the implementation of adaptation and mitigation..

Activity 3) Support the full implementation of the GCOS Implementation Plan. While this will not provide all the information needed for adaptation and early warning systems, it will provide the global, larger scale information they need (see the case studies for examples) .

Activity 4) Support and implement the outcomes of the GCOS Task Teams on Radar Observations and Lightning.

Activity 5) Develop new sensors for the monitoring adaptation.

Activity 6) Support the continued monitoring of global temperature, in particular, to ensure long-term observations and data availability into the future. Current monitoring, if maintained, is sufficient to provide an estimate of global average temperature.

Activity 7) For adaptation, more detailed local information is needed, both to assess local risks and to measure the effectiveness of any actions. Some regions are less well observed, and more systematic observations should be developed, both through improving current observational capacity and by recovering past data (e.g. transferring old, decaying paper records into a digital form that can used more easily). In fact, extending the reliable record back in time may be essential to establish the baseline for current and future assessments.

Activity 8) In order to explain and predict changes in the global average surface temperature, it is important to understand all components of the Earth's energy budget. Most of the net energy gain by the Earth is stored in the ocean (about 93%[30]) so small changes in its uptake by the ocean could have significant impacts. GCOS should identify observation gaps in global energy fluxes and develop plans to fill them. It should also consider if requirements and targets in the current GCOS Implementation Plan are adequate and update them as needed.

Activity 9) GCOS needs to strengthen the implementation of actions supporting estimates of GHG fluxes and the use of atmospheric composition data that are in the GCOS Implementation Plan (Actions T67-T71).

Activity 10) GCOS needs to strengthen the implementation of the actions on land cover, above-ground biomass, soils, permafrost and fires that are in the GCOS Implementation Plan (Actions T33,T34 and T47-64).

Activity 11) GCOS should explore the possibilities for additional monitoring of changes in land cover, focussed on conversion of forests to the build environment or agriculture, forest health and monitoring adaptation in agriculture. GCOS should make specific proposals that may be based on existing data or require new observations.

Activity 12) Identify and specify global climate indicators for extreme events and to quantify changes in the ecosystems. Continue to support and produce data form the Global Climate Indicators.

Activity 13) Continue to improve the observations of the hydrosphere and biosphere as indicated in the GCOS Implementation Plan

Activity 14) GCOS should strengthen its advocacy for the free and open sharing of data following the Paris Agreement and WMO regulations.

Activity 15) Use the GCOS Cooperation Mechanism to support improvements to observing systems. Increase the funding available to support these actions.

Activity 16) GCOS should continue to identify those observations that provide benefits globally for national adaptation and should look for ways to sustainably support these observations in countries without the necessary resources to do so themselves.

[30] The IPCC's 5th Assessment Report says "Warming of the ocean accounts for about 93% of the increase in the Earth's energy inventory between 1971 and 2010 (high certainty)". This has continued after 2010, see, for example, Improved estimates of ocean heat content from 1960 to 2015 Cheng L, et. al. Science Advances, 10 Mar 2017: Vol. 3, no. 3, e1601545, DOI: 10.1126/sciadv.1601545

11. GLOSSARY

AGMP	WMO's Agricultural Meteorology Programme
AMIS	GEOGLAM's Agricultural Market Information System
AR5	The IPCC's 5th assessment report
AR6	The IPCC's 6th assessment report
ATLAS	United States Agency for International Development Climate Change Adaptation, Thought Leadership and Assessments
CEOS	The Committee on Earth Observation Satellites
CGMS	The Coordination Group for Meteorological Satellites
CH_4	Methane
CMA	The UNFCCC Conference of the Parties serving as the meeting of the Parties to the Paris Agreement
CO_2	Carbon Dioxide
COP	The UNFCCC Conference of the Parties
DKD	Deutscher Klimadienst
ECV	Essential Climate Variable
ENSO	El Niño–Southern Oscillation
ETF	The Enhanced Transparency Framework of the Paris Agreement
FAO	The Agriculture and Food Organization of the United Nations
FAPAR	The Fraction of Absorbed Photosynthetically Active Radiation
GCF	The Green Climate Fund
GCOS	The Global Climate Observing System
GDP	Gross Domestic Product
GEO	The Group on Earth Observations
GEOGLAM	The Group on Earth Observations Global Agricultural Monitoring Initiative
GFCS	The Global Framework for Climate Services
GFOI	The Global Forest Observations Initiative
GGA	The Global Goal on Adaptation under the Paris Agreement
GHG	Greenhouse Gases

GMES	Global Monitoring for Environment and Security (GMES) which became Copernicus
GOFC-GOLD	Global Observations of Forest and Land Cover Dynamics
GOOS	Global Ocean Observing System
GST	Global Stocktake of the Paris Agreement
ICSU	International Council for Science (on 5 Jul 2018 merged with the International Social Science Council to become the International Science Council (ICS) https://council.science/)
IG3IS	WMO's Integrated Global Greenhouse Gas Information System
IOC	Intergovernmental Oceanographic Commission of UNESCO (IOC/UNESCO)
IPCC	Intergovernmental Panel on Climate Change
JCOMM	Joint Technical Commission for Oceanography and Marine Meteorology,
LAI	Leaf Area Index
LEG	The UNFCCC Least Developed Countries Expert Group
MESA	Monitoring for Environment and Security in Africa programme
MIM	The CEOS Missions, Instruments and Measurements database
MRV	Measurement, reporting and verification
NDC	Nationally Determined Contribution
NMHS	National Meteorological and Hydrological Agencies
NOAA	National Oceanic and Atmospheric Administration
NWP	Numerical Weather Prediction
OOPC	Ocean Observing Panel for Climate
OSCAR	WMO's Observing Systems Capability Analysis and Review Tool
PROVIA	Programme of Research on Climate Change Vulnerability, Impacts and Adaptation
REDD+	Reducing emissions from deforestation and forest degradation in developing countries, and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries
SB	UNFCCC Subsiduary Bodies
SBSTA	UNFCCC Subsiduary Body onScientific and Technical Advice
SF_6	Sulphur Hexaflouride
SIDS	Small Island Developing States
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization

UNFCCC	United Nations Framework Convention on Climate Change
WCRP	World Climate research Programme
WHO	World Health Organization
WIGOS	WMO Integrated Global Observing System
WISC	The Copernicus Wind Storm Information Service
WMO	World Meteorological Organization

12. BIBLIOGRAPHY

Booz & Co. (2011) *Cost-Benefit Analysis for GMES*, European Commission: Directorate-General for Enterprise and Industry, London, 19 September 2011, http://www.copernicus.eu/sites/default/files/library/ec_gmes_cba_final_en.pdf.

Cheng L, et. al. (2017) *Improved estimates of ocean heat content from 1960 to 2015*. Science Advances, 10 Mar 2017: Vol. 3, no. 3, e1601545, DOI: 10.1126/sciadv.1601545

FAO (2014) The State of the Worlds Fisheries and Aquaculture, ISBN 978-92-5-108275-1

GCOS (2013) *GCOS Workshop on Observations for Adaptation to Climate Variability and Change*. Offenbach, Germany, 26–28 February 2013, http://www.wmo.int/pages/prog/gcos/Publications/gcos-185.pdf.

GCOS (2014) *Joint GCOS/GOFC-GOLD Workshop on Observations for Climate Change Mitigation*. Geneva, 5-7 May 2014 http://www.wmo.int/pages/prog/gcos/documents/GCOS-191.pdf.

GCOS (2015 a) GCOS Workshop on Enhancing Observation to Support Preparedness and Adaptation in a Changing Climate – Learning from the IPCC 5th Assessment Report. Bonn, Germany, 10–12 February 2015.
http://www.wmo.int/pages/prog/gcos/Publications/gcos-166.pdf.

GCOS (2015 b) *Status of the Global Observing System for Climate*, October 2015, GCOS-195, pub WMO Geneva Switzerland.

GCOS (2016 a) *The First GCOS Science Conference: Global Climate Observation: the Road to the Future*. Amsterdam, Netherlands, March 2016 (http://www.gcos-science.org).

GCOS (2016 b) *The Global System for Climate: Implementation Needs*, GCOS -200 pub WMO Geneva Switzerland.

GFOI (2016) Integration of remote-sensing and ground-based observations for estimation of emissions and removals of greenhouse gases in forests: Methods and Guidance from the Global Forest Observations Initiative, Edition 2.0 Aug 2016, pub. Food and Agriculture Organization, Rome.

Global Carbon Project (2017) Carbon budget and trends 2017. [www.globalcarbonproject.org/carbonbudget] published on 13 November 2017 https://doi.org/10.5194/essd-2017-123.

Huiling Yuan, et al. (2016) Assessment of the benefits of the Chinese Public Weather Service, Meteorol. Appl. 23: 132–139 DOI: 10.1002/met.1539.

IPCC (2006), *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S. Buendia L. Miwa K. Ngara T. and Tanabe K. (eds). Published: IGES, Japan

IPCC (2014), 2013 *Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*, Hiraishi, T. Krug, T. Tanabe, K. Srivastava, N. Baasansuren, J. Fukuda, M. and Troxler, T.G. (eds). Published: IPCC, Switzerland

Knutson, et al, (2017) *Detection and attribution of climate change*. In: Climate Science Special Report: Fourth National Climate Assessment, Volume I. U.S. Global Change Research Program, Washington, DC, USA, pp. 114-132, doi: 10.7930/J01834ND.

Peters, G. P. (2017) Towards real-time verification of CO_2 emissions, 2017.

SBSTA (2017) Conclusions Research and systematic observation Draft conclusions proposed by the Chair FCCC/SBSTA/2017/L.21 , Bonn 2017

UN (2017) *Progress towards the Sustainable Development Goals*, Report of the Secretary-General E/2017/66, UN 2017.

UNFCCC (2010) Decision 1/CP.16 The Cancun Agreements: Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention Decision 2/CP.17, FCCC/CP/2010/7/Add.1 Cancun 2010

UNFCCC (2011) Decision 2/CP.17 Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention FCCC/CP/2011/9/Add.1 Durban 2011

UNFCCC (2015 a) *Paris Agreement*, Annex to FCCC/CP/2015/10/Add.1, Paris 2015,

UNFCCC (2015 b) *Decision 1/CP.21 Adoption of the Paris Agreement* FCCC/CP/2015/10/Add.1, Paris 2015

UNFCCC (2015 c) Report on the structured expert dialogue on the 2013 – 2015 review: Note by the co-facilitators of the structured expert dialogue SB/2015/INF.1 (Paris 2015)

UNFCCC (2015 d) *The 2013 – 2015 review* Decision 10/CP.21, Paris 2015

UNFCCC (2016) Decision 19/CP.22 Implementation of the global observing system for climate, Marrakesh 2016

Vladu, F, (2017) *Observation of the climate system under UNFCCC: Developments since SC-24*, Presentation given to the GCOS Steering Committee at its 25th session, Hangzhou, PR China. Available from: http://ane4bf-datap1.s3-eu-west-1.amazonaws.com/wmocms/s3fs-public/ckeditor/files/FV-SO-work-v01.pptx?jbPl50Kxp_qtKDA9lougnsF9s0PMxhvl

WMO (2009 a) Secure and Sustainable Living: The Findings of the International Conference on Secure and Sustainable Living: Social and Economic Benefits of Weather, Climate and Water Services. WMO-No 1034, WMO, Geneva, 2009.

WMO (2009 b) World climate conference-3, Geneva, 31 August – 4 September 2009, Conference statement and Conference declaration. http://www.wmo.int/gfcs/wwc_3

WMO (2011) Climate Knowledge for Action: a Global Framework for Climate Services – Empowering the Most Vulnerable. WMO-No. 1065, WMO, Geneva.

WMO (2012) Conference on Social and Economic Benefits (SEB) of Weather, Climate and Water Services (Lucerne, Switzerland, 3-4 October 2011). PWS-23/ROE-1, WMO, Geneva.

WMO (2017) WMO Statement on the State of the Global Climate in 2016 WMO-No. 1189 Pub WMO, Geneva

WMO (2017)The State of Greenhouse Gases in the Atmosphere Based on Global Observations through 2016 Greenhouse Gas Bulletin No. 13, 30 October 2017. ISSN 2078-0796

Zaichun Zhu et al, (2016) *Greening of the Earth and its drivers* Nature Climate Change volume 6, pages 791–795 (2016) | DOI: 10.1038/NCLIMATE3004

GCOS Secretariat
Global Climate Observing System
c/o World Meteorological Organization
7 *bis,* Avenue de la Paix
P.O. Box No. 2300
CH-1211 Geneva 2, Switzerland
Tel: +41 22 730 8275/8067
Fax: +41 22 730 8181
Email: gcos@wmo.int