Adaptation Committee

AC/2020/10

19 March 2020
Agenda item 8(c)

Seventeenth meeting of the Adaptation Committee
Bonn, Germany 24 to 27 March 2020

Draft technical paper on data for adaptation at different spatial and temporal scales

Recommended action by the Adaptation Committee
The Adaptation Committee (AC), at its 17th meeting, will be invited to consider the draft technical paper and provide recommendations for its finalization.

Table of Contents

1. Executive summary

1. Effective adaptation to climate risks follows a continuous and iterative process consisting of the following stages: (i) assessing climate risks, (ii) planning adaptation, (iii) implementing adaptation measures, and (iv) monitoring and reviewing such measures. Implementing these stages requires different combinations of observational, projected, and historical data of both climate and socio-economic processes.

2. The demand for data for adaptation is growing due to developments at different spatial scales and in response to different political and practical needs. At national and associated sub-national scales, adaptation, following the process of formulating and implementing national adaptation plans (NAPs) or other national plans and strategies, has entered the planning and implementation stage. This requires increasingly diversified and specialized data and related data products. Correspondingly, support institutions, such as the Green Climate Fund, have taken steps to increase the climate rationale of the programmes and projects they support, which means that the justification of these programmes will require sound scientific evidence supported by data.

3. With regard to the data categories required to support the adaptation process, observational data is required to support the assessment as well as the implementation and monitoring stages. It includes observations of the Essential Climate Variables (ECVs), covering the atmosphere, land and ocean, as well as of socio-economic processes. The planning stage requires information from climate and socio-economic outlooks for different planning horizons. Climate outlooks are mainly provided in the form of forecasts, predictions, and projections, which are relevant for the planning of short-, medium-, and long-term adaptation measures, respectively. Historical data complements recent observations and outlooks to form the basis of understanding climate processes and their impacts on and vulnerability of society and nature at all scales from the past into the future.

4. The global provision of data within all the categories is facilitated by the interaction of different spatial scales. The provision of climate data is further enabled through international coordination, the setting of quality standards and capacity building while socio-economic data is provided by a multitude of sources without global coordination. Observational climate data on all ECVs is collected and provided by data centres at the national, regional and global levels and synthesized into data products that meet different user needs across spatial and temporal scales. Some of these products also assist in closing gaps in observational coverage. Historical climate data is also stored and digitized by these centres. Projected data is provided for different time scales on the basis of global models. Global, regional and national climate centres produce such data at different time intervals and assess user needs through the participation in regional and national climate outlook forums. The new approach of using Representative Concentration Pathways for generating long-term climate projections has facilitated the development of socio-economic scenarios to explore feedbacks between climate change and socio-economic factors and to allow for better climate impact studies. Local-level stakeholders play an increasingly important role in applying projections for climate impacts studies and in validating downscaled scenarios.

5. Climate services provide an important bridge between data supply and demand. Based on the close interaction of data providers, service providers and end users, climate services may help in generating, interpreting and presenting climate and socio-economic data in a way that meets specific user needs and enables better adaptation decision-making, planning and implementation. The Global Framework for Climate Services plays an important role in guiding the development and application of such services and is implemented by climate centres and organizations at regional and national scales.

6. The availability and accessibility of data for adaptation are increasingly improving, but there are still several critical gaps at all scales. Gaps in the global coverage of in situ observations are most critical in regions where populations are at elevated risks or where local changes have global impacts. Socio-economic observations are mostly available independent from climate-observations, although collocated observations would be most useful for the identification of climate risks. Gaps in climate outlooks refer to the scale of global climate model outputs, which are often inadequate to support local decision making. Gaps in historical data remain concerning its recovery in all regions of the world.

7. Challenges regarding the provision and use of adaptation-relevant data exist with regard to applying innovative technologies and approaches to exploit the big data that is being provided by global observations, models and reanalysis. Another challenge is how to match this rapidly increasing amount of

available data and products with the simultaneously growing and diversifying data requirements at various scales. Addressing this challenge requires vast coordination on the provision of climate services, which is still a young field with mostly uncoordinated actors and activities. Another problem is how to guarantee the interoperability of observing systems and compatibility of climate data that are essential for open data exchange. Challenges posed by a lack of human, infrastructural and financial capacity required to make use of existing data necessary to take specific sectoral or local adaptation decisions also remain critical, particularly in most vulnerable countries.

8. Stronger international cooperation and coordination is necessary to manage growing amounts of data and data products, ensure their quality and to match them to specific national and local adaptation needs. The accelerated and coordinated provision of climate services at all levels as well as appropriate funding of respective international and national programmes to do so is important to this end. Finally, financial, technical, and capacity-building support to vulnerable developing countries to allow them to consistently manage their observational systems and develop nationally, locally, and sector-relevant data products to support all stages of the adaptation cycle is critical.

9. In addition to the adaptation at a national and sub-national scales, the international community is now tasked to assess the progress on adaptation globally. Parties to the UNFCCC, through the Paris Agreement established the global goal on adaptation and a process to review progress towards the goal at regular intervals. Methodologies for the review are under development and might require additional data.

2. Background

10. The Adaptation Committee (AC), at its fifteenth meeting, agreed to prepare a paper on connecting short-, medium- and long-term adaptation planning at the national and subnational level, including data, financial flows and others. This paper was included in its flexible workplan for 2019-2021.

11. At its sixteenth meeting, the AC considered a concept note for this new paper and decided to reduce it to focus only on data, taking into account short- medium- and long-term perspectives and linkages of data needs to various stages in the adaptation process. It requested the secretariat to present a draft for consideration at its seventeenth meeting.

3. Introduction

12. The demand for data for adaptation is growing due to developments at different spatial and temporal scales responding to different political and practical needs.

13. At the global level, the Paris Agreement includes several provisions which implicate increasing needs for adaptation-relevant data. Parties acknowledged that adaptation action should be based on and guided by the best available science and that Parties should strengthen their cooperation in this regard. These provisions build on those contained in the 2010 Cancun Adaptation Framework, through which Parties were invited to "[…] strengthen data, information and knowledge systems […] in order to provide decision makers at the national and regional levels with improved climate-related data and information". They are also supported by ongoing work under UNFCCC Articles 4.1(g, h) and 5 and the agenda item on research and systematic observation under the Subsidiary Body for Scientific and Technological Advice.

14. At the national as well as regional and subnational levels, stakeholders have realized adaptation needs and have, to different degrees, entered into adaptation planning and implementation processes. The process to formulate and implement national adaptation plans (NAP process), established under the Cancun Adaptation Framework of the UNFCCC in 2010,[1] is increasingly being taken up by countries. These adaptation processes require data in order to be planned, implemented and monitored.

15. Linking both the global provisions as well as the emerging adaptation efforts at other scales, the Green Climate Fund (GCF), the largest provider of adaptation finance among the operating entities of the Financial Mechanism of the Convention, has taken steps to enhance the climate rationale for the projects and

[1] Decision 1/CP.16, paragraphs 15-18.

programmes it supports.[2] This means that adaptation proposals require sound scientific evidence of their response to climate change.[3]

16. As a particular challenge, the international community is now tasked to assess the progress on adaptation globally. Parties to the UNFCCC, through Article 7 of the Paris Agreement, established the global goal on adaptation and a process to review progress towards the goal at regular intervals.[4] Methodologies for the review are under development and might require additional data.[5]

17. Considering these developments, the paper provides an overview of data required and provided for adaptation across different scales. It starts off by introducing key characteristics of climate risks and deriving different categories of data required at the iterative stages of the adaptation process (chapter 4). Chapter 5 describes the sources and processes through which these categories of data are provides across different scales. Chapter 6 introduces the concept of climate services as the bridge between data demand and supply. Finally, chapter 7 discusses remaining gaps, challenges and needs.

4. Overview of data categories to support adaptation

18. In its contribution to the Fifth Assessment Report (2014), Working Group II (WG II) of the Intergovernmental Panel on Climate Change (IPCC) describes two characteristics of climate risks that are key when deriving the categories of data required to adequately support adaptation to these risks.[6]

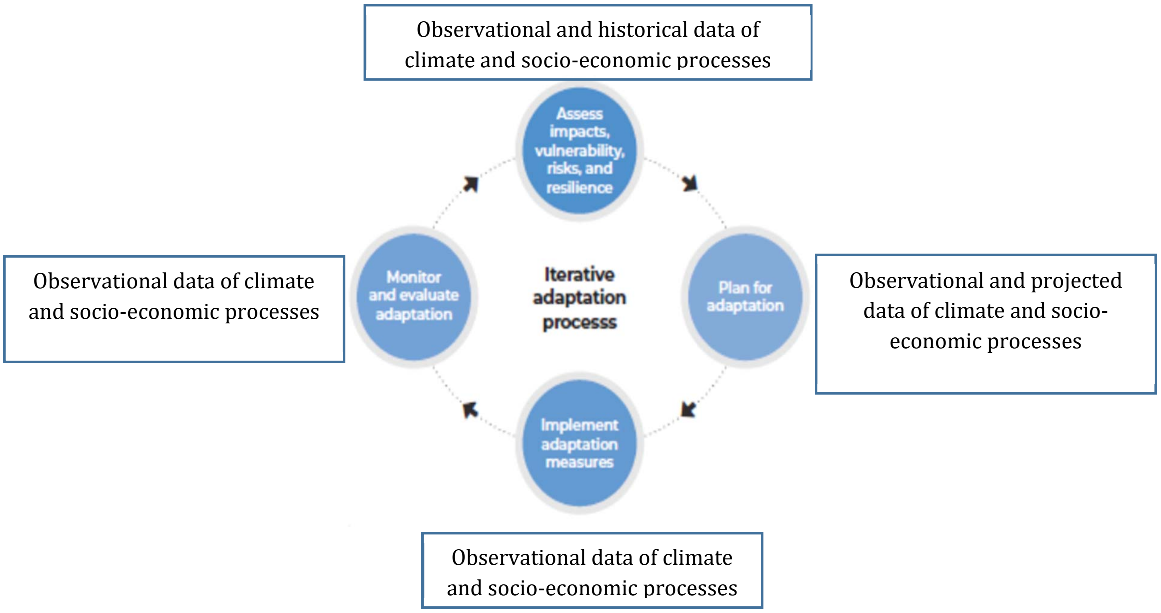
19. The first characteristic is the **composite nature of climate risks**: climate risks exist due to the interaction of climate-related hazards (including sudden-onset events and trends) with the exposure and vulnerability of human and natural systems. Hazards, exposure and vulnerability, in turn, are driven by climate and socio-economic processes. Taking adaptation decisions in order to reduce climate risks thus requires data and information on both climate as well as socio-economic aspects.[7]

20. The second characteristic is the **dynamic and complex nature of climate risks**: climate risks are evolving over time due to changes in both the climate and socio-economic systems. In order to account for these changes, adaptation to such risks must be a continuous, progressive and iterative process.[8] It is often described as containing four core and revolving stages: (i) assessing climate risks, (ii) planning adaptation, (iii) implementing adaptation measures, and (iv) monitoring and reviewing such measures (figure 1). Effective implementation of these stages requires information from observations and projections of climate and socio-economic processes as well as from experience with past climate impacts and respective socio-economic responses.

21. The composite, dynamic and complex nature of climate risks thus lead to the following categories of data required to support adaptation: observational, projected and historical data of climate and socio-economic processes. This data needs to be collected continuously and made available at spatial and temporal resolutions adequate to support the adaptation process at different spatial scales and for different planning horizons.

[2] Decision B.19/06.
[3] GCF/B.21/Inf.08.
[4] Article 7, paragraphs 1 and 14 of the Paris Agreement.
[5] Further information on this work is available at https://unfccc.int/topics/adaptation-and-resilience/groups-committees/adaptation-committee/joint-ac-and-leg-mandates-in-support-of-the-paris-agreement.
[6] Field, C.B. et al. 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the IPCC. Available at https://www.ipcc.ch/report/ar5/wg2/.
[7] Note that this paper focuses primarily on climate and socio-economic data as opposed to information. Climate data, for example, is defined as "historical and real-time climate observations along with direct model outputs covering historical and future periods" (WMO. 2014. Implementation Plan of the Global Framework for Climate Services.). However, as raw observations and model outputs need to be processed into information in order to be useful for adaptation decision-making, the paper also touches upon data products and climate services which represent a fluent transition from pure data to climate information and knowledge.
[8] As agreed by Parties to the UNFCCC in decision5/CP.17, paragraph 2.

Figure 1. The iterative adaptation process including four core stages and respective data needs



Source: Adapted from UNFCCC. 2019. 25 Years of Adaptation under the UNFCCC. Report by the Adaptation Committee. Available at https://unfccc.int/sites/default/files/resource/AC_25%20Years%20of%20Adaptation%20Under%20the%20UNFCCC_2019.pdf.

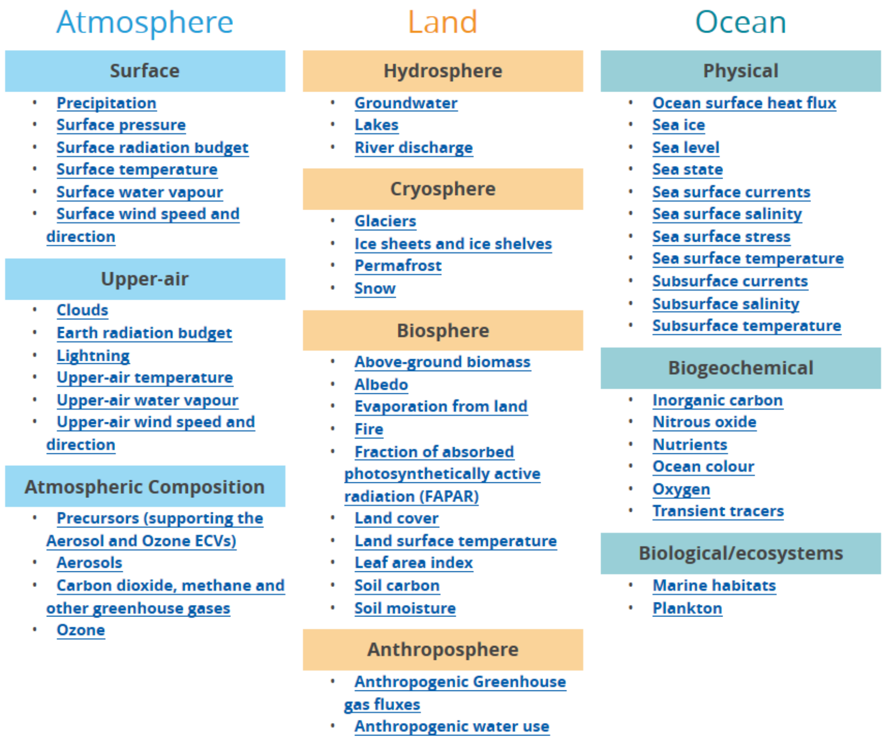
4.1. Observational data

22. Observational data provides evidence of the recent or present-day situation of the climate as well as on environmental and socio-economic conditions. It thus helps to identify the climate vulnerability of a particular social or natural system (assessment stage of the adaptation process).[9] This data is also used to establish climate and socio-economic baselines when modelling future conditions and as references when evaluating adaptation options (planning stage). During the implementation of adaptation measures, observational data is compared to the prior projections and hence serves to monitor the effectiveness of the measures (implementation and monitoring stage). Observations therefore build the core of the data required to support the adaptation process.

23. In order to systematically observe changes in the climate system expert panels of the Global Climate Observing System (GCOS) have identified a set of 54 Essential Climate Variables (ECVs) (see figure 2).[10] Data on these are collected through real-time observations of the atmosphere, land and ocean via in situ or remote-sensing measurements.[11]

[9] Note that this paper will focus on data for the adaptation of socio-economic systems and will not include specific data requirements to assess climate risks for natural systems and their adaptation needs.
[10] More information on GCOS and the ECVs is available at https://gcos.wmo.int/.
[11] For a detailed overview of existing ECV data records see https://gcos.wmo.int/en/essential-climate-variables and http://climatemonitoring.info/ecvinventory/.

Figure 2. The GCOS Essential Climate Variables to observe the atmosphere, land and ocean



Source: Available at https://gcos.wmo.int/en/essential-climate-variables/ecv-factsheets.

24. Examples of general and sector-specific observational socio-economic data include the following:[12]

a) **Population data** that reflects total number, distribution, structure and inequalities including, for example, total population, population density, urban population (including in coastal cities), age and gender structure, ethnic and religious affiliation;

b) **Economic data** that reflects wealth and its distribution including gross domestic product (GDP) per capita, GDP annual growth rate and GDP from agriculture, industry and services;

c) **Land cover/ land use data** that reflects the distribution of land use including total land area, arable and permanent cropland, permanent pasture, forest and woodland, other land;

d) **Data on water** that reflects water resources and use including water resources per capita, annual withdrawal for domestic, industrial and agricultural use;

e) **Data on agriculture/food** that reflects the socio-economic value of the agricultural sector including irrigated land, agricultural labour force, total labour force, stocks of different production animals.

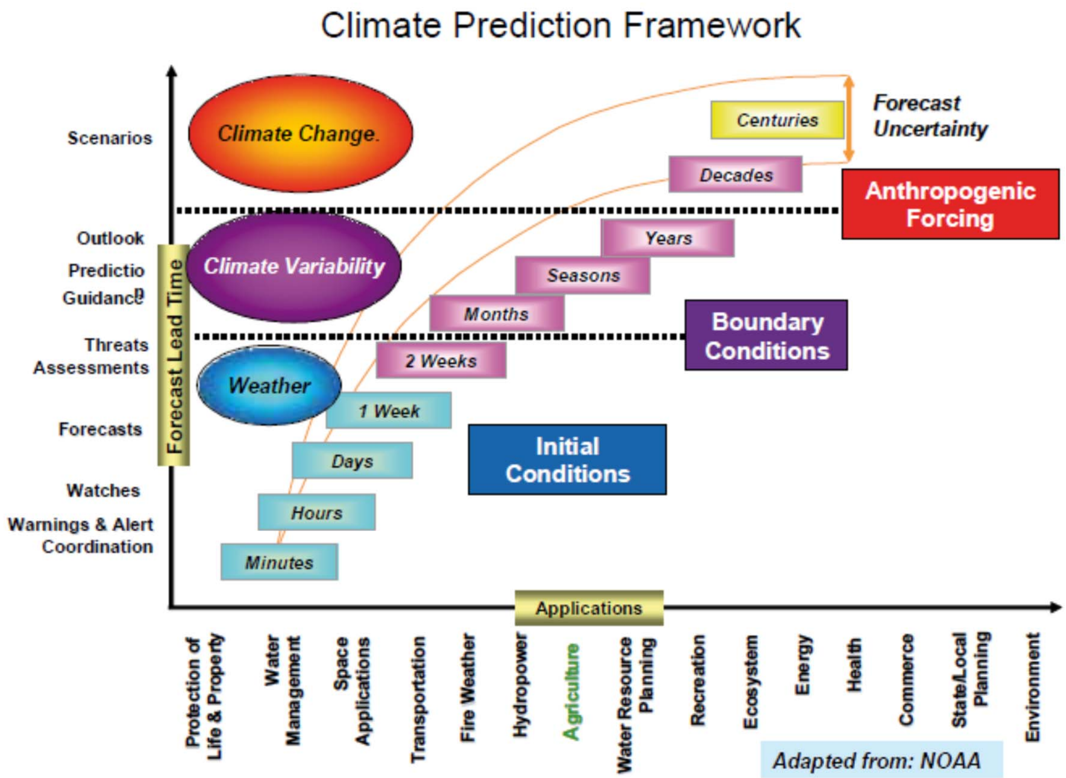
4.2. Forecasts, predictions and projections

25. While observational climate and socio-economic data is required to assess current vulnerabilities and to monitor the implementation process, the planning of future adaptation activities requires estimations of how the climate and socio-economic future may unfold. In order to support the full range of adaptation

[12] Based on IPCC TGICA, 2007, General Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment. Available at http://www.ipcc-data.org/guidelines/index.html#general which disseminates socio-economic data and information describing the present-day situation which serves as the basis to derive socio-economic scenarios for the future.

activities across all temporal scales, from short-term implementation of evacuation plans to long-term policy planning, different kinds of weather, climate and socio-economic outlooks are required. The provision of these is sometimes called seamless hydro-meteorological and climate services (see figure 3).

Figure 3. Seamless hydrometeorological and climate services



Source: WMO. Climate Services for Supporting Climate Change Adaptation. Supplement to the Technical Guidelines for the NAP Process. Available at https://www4.unfccc.int/sites/NAPC/Documents%20NAP/Supplements/WMO_climate%20change%20services%20for%20climate%20change%20adaptation.pdf.

26. The range of climate outlooks are produced by various climate models around the globe and can be summarized into the following three main categories:[13]

a) **Weather forecasts** make use of enormous quantities of information on the observed state of the atmosphere and calculate, using the laws of physics, how this state will evolve during the next few days. Weather forecasts are particularly relevant in the case of extreme weather that requires the implementation of an evacuation plan or other safety measures. They provide the basis for issuing alerts.

b) **Climate predictions** are outputs of a model that computes the evolution of targeted parameters from initial conditions up to the final state at seasonal, annual or decadal timescales. It is most influenced by the current conditions that are known through observations (initial conditions) and (scientifically based) assumptions about the physical processes that will determine future evolutions of climate variability. They do not take into account assumptions or scenarios of human influence on the climate (boundary conditions). Most predictions are probabilistic, thus

[13] The descriptions are based on the following sources: IPCC TGICA, 2007, General Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment. Available at http://www.ipcc-data.org/guidelines/index.html#general and WMO. 2018. Guide to Climatological Practices (WMO-No. 100). Geneva. Available at http://www.wmo.int/pages/prog/wcp/ccl/guide/guide_climat_practices.php.

consisting of several individual forecasts from a climate model starting with slightly different initial conditions (both atmospheric and oceanic) and generating a set (or ensemble) of forecasts. This way, uncertainties linked to the prediction are accounted for. Predictions are produced at different time intervals (e.g. monthly or seasonally) and are useful for medium- to longer-term strategic adaptation planning, such as infrastructure planning and land zoning.

c) **Climate projections** are statements about the likelihood that something will happen several decades to centuries in the future, if certain influential conditions develop (e.g. significant changes in the boundary conditions through human influence, for example the increase in greenhouse gas concentrations). For this, scenarios are developed containing certain (realistic) assumptions about future climate and socio-economic developments which then serve as the initial conditions in a climate model. The outputs of the model then provide information on the likely consequences of such developments in terms of climate change. By using different scenarios and different models, each with its own particular climate sensitivity, a range of reasonable possibilities of both societal development and climate behaviour is accounted for. These long-term projections are particularly relevant for climate negotiations and their implications for national adaptation policy making.

27. The climate elements typically forecasted in climate outlooks include average surface air temperature and total precipitation, but increasingly also include other parameters such as the number of days with precipitation, snowfall, the frequency of tropical cyclones and the onset and cessation of monsoon seasons, which are needed for increasingly specific adaptation planning.

28. Socio-economic variables are not accounted for by weather forecasts and climate predictions. As such, these must be assessed and predicted separately when undertaking impact studies and planning adaptation for the short- to medium-term. Climate projections, however, do already include assumptions on socio-economic developments as these are contained in the global scenarios that form their basis. Care needs to be taken when undertaking long-term impact studies and adaptation planning to ensure that the socio-economic scenarios underpinning these studies are consistent with those assumed for the climate scenarios.[14]

4.3. Historical data

29. Historical data forms part of observational data but has been recorded by in situ instruments before the digital revolution 40-50 years ago. It supports the assessment, the planning and the implementation stages of the adaptation process. It helps in understanding long-term climate processes and to capture extremes. It may also provide information on the way past climate events have impacted social systems, including differences in impacts on men and women, and thus on their respective vulnerability and adaptive capacity. If combined with effective short-term forecasting, this information might often suffice to derive useful coping strategies for similar future events, thus making costly climate predictions unnecessary.

30. This early instrumental data of temperature, precipitation and sometimes other variables covers much of the globe, however sparsely. It has been stored on paper or obsolete media mainly by National Meteorological and Hydrological Services or other national agencies. Monthly station averages of historical data have in many cases already been digitized. However, digitization of daily and sub-daily station data is also urgently required in order to support adaptation processes.[15] Reanalysis is used in part to make up for gaps in historical data.

4.4. Data requirements at different spatial scales

31. The planning and implementation of adaptation at different spatial scales requires climate and socio-economic data at different spatial and temporal resolutions and for increasingly specific adaptation contexts. For example, when developing, implementing and monitoring national adaptation plans,

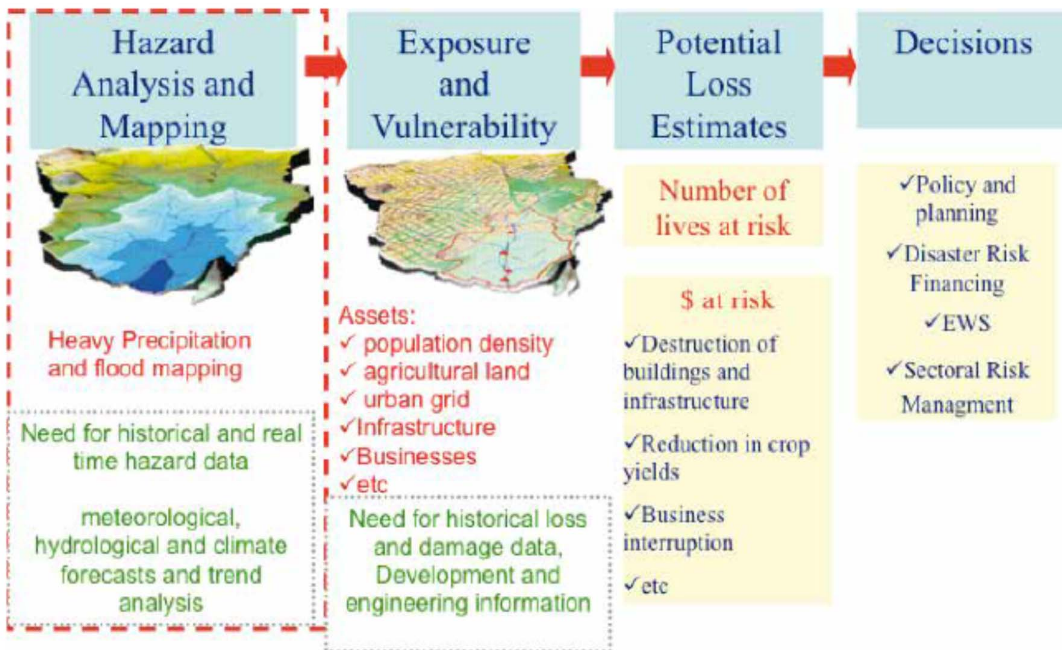
[14] IPCC Task Group on Data and Scenario Support for Impact and Climate Assessment (TGICA). 2007. General Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment. Version 2. Available at: http://www.ipcc-data.org/guidelines/index.html#general.

[15] GCOS, 195. Status of the Global Observing System for Climate. WMO, 2015. Available at https://library.wmo.int/doc_num.php?explnum_id=7213.

stakeholders at this level not only need to take into account the distribution of geographical particularities and socio-economic activities within their national territory, but also address regional interests which concern, for example, transboundary ecosystems. As such, they do not only require data at national resolution, but also data from regional and sub-national scales. In addition, they increasingly need data on specific climate hazards or trends, such as floods, El Niño or sea level rise, and particular indices, such as drought or monsoon indices, in order to meet ever more specific demands from individual sectors.

32. Box 1 provides an example of data requirements at the national level for undertaking climate risk and vulnerability assessments and figure 4 illustrates data requirements for planning adaptation to flood risks.

Figure 4. Example of hazard and vulnerability analyses related to flood risk and according data requirements for adaptation decision-making, as facilitated by the Global Framework for Climate Services



Source: WMO. Climate Services for Supporting Climate Change Adaptation. Supplement to the Technical Guidelines for the NAP Process. Available at https://www4.unfccc.int/sites/NAPC/Documents%20NAP/Supplements/WMO_climate%20change%20services%20for%20climate%20change%20adaptation.pdf.

33. Data for local adaptation planning and implementation also needs to meet some important particularities. Most importantly, data needs to be available at appropriate spatial and temporal scales. For example, climate data on temperature and precipitation may be required for specific times of the day or periods of the year. It may also be required at specific spatial resolution, e.g. urban environments where increasing parts of the world population resides and climate impacts take particular shapes. Similarly, complementary socio-economic data is needed at these scales to allow for specific impact and vulnerability studies. General population trends for the national level, for example, may mask important trends in migration at local scales, e.g. from rural to urban, and nationally-averaged scenarios of per capita income may obscure local disparities between rich and poor or men and women.

Box 1. Data requirements and sources for assessing climate risks and vulnerabilities under Saint Lucia's NAP process

Required data	Sources
Socio-economic	2010 Population and Housing Census, Country Poverty Assessment (CPA) and UNDP's Human Development Index
Meteorological	St. Lucia's Meteorological Service which provides 24-hour meteorological forecasting and observations from two stations and rainfall records from 31 secondary stations
Climate change modelling	Projections from NGOs and research groups based on GCMs and RCMs, most comprehensively undertaken by CARIBSAVE for its Climate Change Risk Atlas
Land use, land cover and natural hazard mapping and assessment	Various risk assessment and national land use plans, with specific assessments for landslide risk and the agricultural sector
Information on natural resources and their management	Natural resource inventories and assessments e.g. website of the Government of St. Lucia's Biodiversity Resources
Sector-relevant information	For example, Assessment of the Economic Impact of Climate Change on the Agricultural Sector supported by ECLAC, Impact Assessment of Climate Risks to the Tourism Sector, Country Document for Disaster Risk Reduction

On the basis of its stocktake and vulnerability analysis, St. Lucia has identified a list of pressing data and information needs, including, for example, wind hazard information, local climate extreme indices, sea level rise modelling and coastal flood and erosion mapping, among others.

Further information on these activities can be found in St. Lucia's National Adaptation Plan Stocktaking, Climate Risk and Vulnerability Assessment Report available at https://www.climatechange.govt.lc/wp-content/uploads/2018/04/Saint-Lucia_Stocktaking-climate-report_FINAL.pdf.

34. Apart from the appropriate resolution, the local level might require data in addition to what is required at the global or national levels. This may include, for example, information on specific weather or air-quality variables such as on the frequency and intensity of fog, which is not included in global ECV observations.[16]

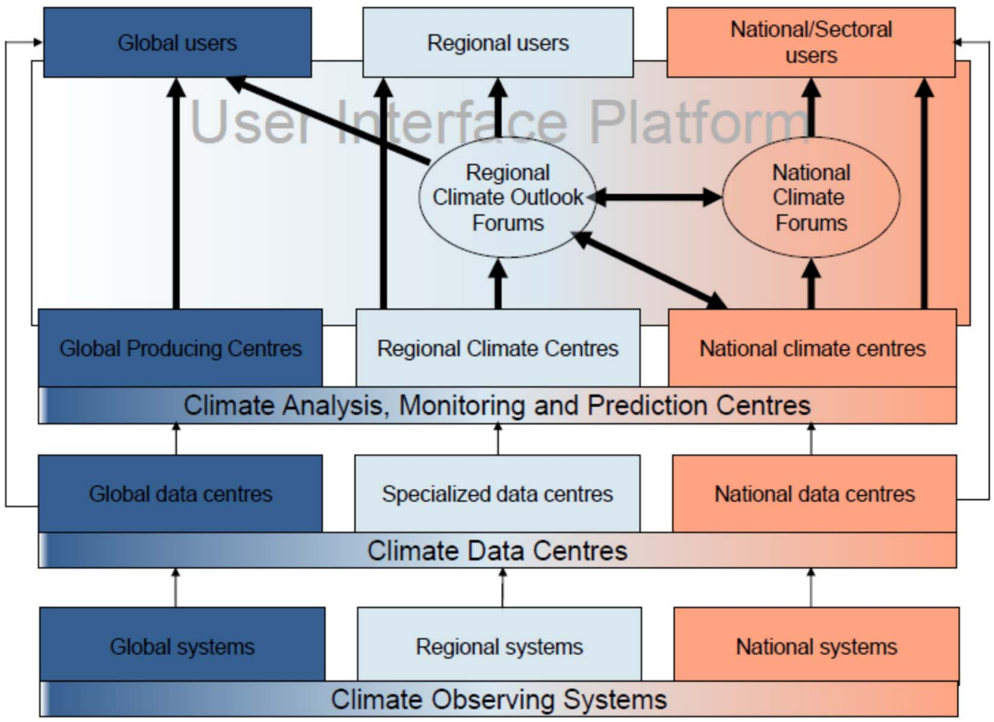
5. Provision of data for adaptation across different spatial scales

35. In parallel to the growing demand for data to support adaptation, the supply has also been increasing rapidly in the past years. Observational systems have been expanding and are providing data in near real-

[16] GCOS, 195. Status of the Global Observing System for Climate. WMO, 2015. Available at https://library.wmo.int/doc_num.php?explnum_id=7213.

time, satellite data is contributing a wealth of information on all Essential Climate Variables, and global climate models produce ever more detailed projections of the future climate and its impacts. This explosion of global data availability has been made possible through increased computer capacities and other technological developments on the one hand, and advances in global cooperation and coordination regarding research, systematic observation and modelling on the other hand. Figure 5 illustrates the exchange of data and information between the different spatial scales.

Figure 5. Data and information exchange as part of the Climate Service Information System (CSIS) of the Global Framework for Climate Services



Source: Presentation by the WMO on the CSIS available at https://gfcs.wmo.int//sites/default/files/Rupa%20Kumar%20Kolli%20CSIS.pdf.

5.1. Observational data

36. Observational data is produced by the climate observing systems composed of national, regional and global sub-systems. Thereby, the national level plays a central role. National-level bodies such as National Meteorological and Hydrological Services (NMHSs), oceanographic institutions and space agencies are the largest providers of climate observations.[17] Other sources may include national agencies, commercial entities or development agencies. The approximately 191 NMHSs around the world stand out since they are the official authoritative source, and often the single source, as well as guardians of weather and climate data in their respective countries. In addition, they provide their data and products to regional and global data centres for archiving and further processing. According to the WMO Guide to Climatological Practice, a NMHS must be able to anticipate, investigate and understand the needs for climatological information among government departments, research institutions and academia, commerce, industry and the general public; promote and market the use of the information; make available its expertise to interpret the data; and advise on the use of the data. Thus, through their work, NMHSs form the basis of global climate monitoring and analysis.

[17] GCOS: Status of the Global Observing System for Climate. WMO, 2015. Available at https://library.wmo.int/doc_num.php?explnum_id=7213.

37. Regional and national observational systems provide their data to regional or specialized climate centres (RCCs). These are centres of excellence designated by WMO to strengthen the capacity of WMO Members in a given region to deliver better climate services to national users.[18] Examples include the Climate Services Centre of the Southern African Development Community in Botswana, the Beijing Climate Centre in China, the Regional Climate Centre for Western South America in Ecuador or the Caribbean Institute for Meteorology and Hydrology for the Caribbean.[19] The mandatory functions of RCCs include: (i) operational activities for long-range forecasting; (ii) operational activities for climate monitoring; (iii) operational data services; and (iv) training in the use of operational RCC products and services. RCCs are also encouraged to take up non-operational data services such as coordination, training and capacity building, and research and development.

38. Data from the different observing systems is usually submitted to global data centres which further process the data and make it publicly available. Such data centres hold basic archives of in situ observational data, for example relating to individual Essential Climate Variables (ECVs) or groups of them, and sometimes of satellite data. The scales for which this data is available range from near- real time to million-year-old proxy records and from global to sub-national and sector-specific scales. According to GCOS's 2015 Status of the Global Observing System for Climate, great progress has been made, for example, in terms of global coverage of ECV data availability whereby in situ and space-based observing systems complement each other.[20] An important function of the global data centres is the preservation of valuable data sets which might otherwise occasionally be lost due to inadequate archiving and management.

39. Global data centres are designated by WMO and include, for example, the National Centers for Environmental Information (NCEI) and the Climate Prediction Centre of NoAA as well as the National Center for Atmospheric Research (NCAR) in the US; the National Geoscience Data Centre in the UK; the Climate Data Store of the European Copernicus Climate Change Service, the World Data Centre for Climate (WDCC) and the World Data Center for Remote Sensing of the Atmosphere in Germany.[21]

40. Sub-national sources also contribute to the global provision of observational climate data. These include local public agencies, the private sector or international development projects.

41. Altogether, the different observing systems and data centres hold a vast array of observational data. In order to make the data useful for their end users, including adaptation planners and decision-makers, climatologists at the various centres analyse and synthesize the data into a variety of data products. These products provide climate information at spatial scales and for time intervals that meet the requirements of specific adaptation contexts. A range of statistical methods is applied to arrive at these products, some of which also help in closing gaps in observational coverage.

42. Climate data products may take the following formats:[22]

a) **Climate atlases:** publication for particular regions or the entire globe with several kinds of visualization and descriptive text;

b) **Online databases** with software tools that allow customers to produce statistics and visualization according to their needs;

c) **Climatological data periodicals:** routinely (monthly or annually, sometimes weekly or seasonally) published bulletins containing data from a selection of stations within particular areas or a country and providing information on e.g. maximum and minimum temperature and total precipitation for each day, temperatures at fixed hours, together with the associated humidity values; daily mean wind speed and prevailing direction, duration of bright sunshine, or other locally important data (such as heating, cooling and growing degree-days); monthly averages and extremes and other statistical data, if available;

[18] https://public.wmo.int/en/our-mandate/climate/regional-climate-centres.

[19] For a full list of designated centres refer to https://cpdb.wmo.int/regions/africa/regional_centres.

[20] GCOS, 195. Status of the Global Observing System for Climate. WMO, 2015. Available at https://library.wmo.int/doc_num.php?explnum_id=7213.

[21] For a full list of global data centres refer to https://community.wmo.int/meetings/world-data-centres.

[22] Further information on climate products is available at WMO. 2018. Guide to Climatological Practices (WMO-No. 100). Geneva. Available at http://www.wmo.int/pages/prog/wcp/ccl/guide/guide_climat_practices.php.

d) **Occasional publications:** produced as the need arises, for example to support the planning of large, long-term investments or to explain unusual events, such as extreme weather or to describe and update an important predicted event such as a strong El Niño; they may also be published on long-term, continuous and homogeneous series of data (e.g. on temperature and precipitation) which are of great value for comparative climatological studies and for research on climatic fluctuations, trends and changes; historical climatological data series are sometimes summarized in yearbooks or annual bulletins;

e) **Standard products:** fill the gap between the climate data periodicals and those tailored to individual users and are produced containing certain types of data (e.g. degree-day products) to satisfy the needs of various users, particularly at the local level; cost-sharing among users is an important aspect of standard products;

f) **Specialized products:** transform the observations into a value-added product for particular recipients by analysing the data and presenting the information with a focus on the specifications that will enable the user to gain optimum benefit from the application of the information; the use of the product usually dictates the types of analysis and methods to generate the product;

g) **Climate monitoring products:** summarized information on the current climate conditions, including local variations, of a country, put in context of the regional and/or global climate system;

h) **Indices:** characterize features of the climate at a particular station or for an area, usually combining several elements into characteristics of, for example, droughts, continentality, phenological plant phases, heating degree-days, large-scale circulation patterns and teleconnections; examples of indices include the El Niño Southern Oscillation (ENSO) Index; the North Atlantic Oscillation Index; descriptors such as the moisture availability index, used for deriving crop planning strategies; agrometeorological indices such as the Palmer Drought Severity Index, aridity index and leaf area index, which are used for describing and monitoring moisture availability; and the mean monsoon index, which summarizes areas of droughts and floods;[23]

43. The following are data products and statistical methods that assist in closing gaps in observational coverage:

a) **Gridded data**: gridded climate data products are values of surface or upper-air climate variables (for example, air temperature, atmospheric moisture or sea surface temperature) or indices (for example, number of frost days), arranged on a regular grid with coverage ranging from the local to regional to global. Spatial resolution of gridded data varies from a few square metres in the case of sub-urban datasets to 200-300km as found in global scale datasets. Temporal resolution varies from the sub-hourly to annual timescale. Gridded data is derived from original observations (surface or satellite-based) using interpolation techniques or from the output of numerical or statistical climate models. They fill data gaps that arise due to an uneven geographical and temporal distribution of climate observations. Gridded datasets facilitate the spatial analysis of climate variables and the static or dynamic visualisation of climate patterns and trends;

b) **Reanalysis**: process through which numerical weather prediction is done retroactively by using the same prediction model but incorporating a more complete set of observations that had not been available at the time of the original weather prediction. The output is on a uniform grid without any missing data. The result is an integrated historical record of the state of the atmospheric environment for which all the data have been processed in the same manner. The reanalysis values are not "real" data, but estimates of real data based on unevenly distributed observational data. There are still challenges of localizing reanalysis to spatial and temporal scales finer than the reanalysis grid;

[23] The construction and evaluation of indices specific to climate change detection, climate variability and climate extremes is discussed in Guidelines on Analysis of Extremes in a Changing Climate in Support of Informed Decisions for Adaptation (WMO/TD-No. 1500, WCDMP-No. 72).

c) **Reprocessing:** method through which data from different types of observations or different instruments is reprocessed in order to achieve homogenization or intercalibration; this method benefits from improved knowledge of instrument characteristics or better methods of generating gridded data products from the raw measurements.

44. Regarding the collection and management of observational data of socio -economic processes, there is no international coordination comparable to that on climate data. In contrast, such data is collected and held by a wide variety of sources at all spatial scales that mainly collect the data for other purposes. This separate collection of socio-economic and climate data often makes an attribution of observed socio-economic changes to a cause, such as climate change, difficult. As long as more collocated time series of climate observations and socio-economic parameters are not available, socio-economic data for vulnerability assessments and adaptation planning, implementation and monitoring must be collected from the existing sources for each individual adaptation context.

45. At the global level, these sources include UN organizations, such as the Department of Economic and Social Affairs (e.g. UN Statistics Division, population division and databases, division for economic analysis), the World Bank, and specialized research institutions, such as the Socioeconomic Data and Applications Center of NASA and the International Institute for Applied Systems Analysis (IIASA) in Austria, to name just a few.

46. At the regional level, such data is provided by UN regional economic commissions or regional development banks, among others.

47. Socio-economic data for the national level can be obtained primarily from national statistical centres or from line ministries, often gender disaggregated. For data on smaller spatial scales within a country, agencies, universities or other archives at local levels may be consulted. Socio-economic microdata, including on individuals, households, or firms may also be obtained from surveys or company details. In addition, qualitative and anecdotal information from local resource managers, policy makers and other stakeholders can provide very useful supplementary materials.

48. Socio-economic data is often provided in the form of specific products such as statistical yearbooks, online databases providing the opportunity of customization, or region-specific atlases. Taking into account the difference in the way climate impacts may affect men and women, gender disaggregation of the data is desirable.

5.2. Projected data

49. Using the described observations as a basis, the different spatial levels also interact in providing weather and climate forecasts, predictions and projections for different spatial and temporal scales.

50. Regarding long-range forecasts and predictions, the WMO Global Data-processing and Forecasting System produces seasonal forecasts on a monthly or at least quarterly basis. The system is composed of thirteen Global Producing Centres for Long-range Forecasts (GPCLRFs),[24] Regional Specialized Meteorological (Climate) Centres and NMHSs. The three interact in such a way that forecasts and predictions generated from a global climate model are downscaled to the regional level (for a limited area and up to a resolution of a few kilometres) and further to the national level (see figure 5 above). The downscaling methods can be either dynamical (using the larger-scale information from a GCM to simulate a regional climate) or statistical (creating statistical relationships between the large-scale variables and observed regional and local variables), or a combination of the two. NMHSs produce different forms of national climate outlooks, such as 8-14 days probabilistic outlooks, monthly, seasonal and annual climate outlooks or specific outlooks such as monthly and seasonal drought outlooks or weekly regional hazards outlooks for food security.[25]

[24] For a full list of GPCLRFs refer to https://community.wmo.int/global-producing-centres-long-range-forecasts.

[25] WMO. Climate Services for Supporting Climate Change Adaptation. Supplement to the Technical Guidelines for the NAP Process. Available at https://www4.unfccc.int/sites/NAPC/Documents%20NAP/Supplements/WMO_climate%20change%20services%20for%20climate%20change%20adaptation.pdf.

51. WMO Regional Climate Outlook Forums play a particularly important role in the provision of climate outlooks and their distribution.[26] They produce consensus-based, user-relevant climate outlook products in real time for the coming season in sectors of critical socio-economic significance for the region in question. Forums bring together national, regional and international climate experts, on an operational basis, to produce regional climate outlooks based on climate predictions from all participants. By bringing together countries with common climatological characteristics, the Forums ensure consistency in the access to, and interpretation of, climate information. Through interaction with users in the key economic sectors of each region, extension agencies and policymakers, the Forums assess the likely implications of the outlooks on the most pertinent socio-economic sectors in the given region and explore the ways these outlooks could be used by them. They also offer training workshops on seasonal climate prediction to strengthen the capacity of national and regional climate scientists. Based on the needs of specific sectors, specialized, sector-oriented outlook forums, such as the Malaria Outlook Forums (MALOFs) in Africa, are being held in conjunction with the regional forums. The regional forums are usually followed by national forums to develop detailed national-scale climate outlooks and risk information, including warnings for communication to decision-makers and the public. NHMSs are key participants in these forums through which they provide their products and services and enter into a dialogue with end users. Local and sectoral stakeholders, in turn, may use this platform to raise awareness for their particular data needs.

52. In addition to forecasts and predictions, long-term projections are also produced on the basis of Global Climate Models. Global centres that provide such projections include the Hadley Centre of the UK Met Office or the European Copernicus Climate Change Service. While formerly emission scenarios were used to arrive at climate projections, a new approach has been adopted in the IPCC's Fifth Assessment Report (2014). This new approach uses Representative Concentration Pathways (RCPs) to describe possible radiative forcing trajectories resulting from different combinations of economic, technological, demographic, policy and institutional futures to arrive at four pre-defined radiative forcing levels in the year 2100.[27] This new approach has enabled the climate and impact research communities to work in parallel and develop, for example, socio-economic scenarios that explore important socio-economic uncertainties affecting both adaptation and mitigation in relation to the four RCPs. In this context, Shared Socio-Economic Pathways (SSPs) have been used alongside the RCPs to analyse the feedbacks between climate change and socioeconomic factors, such as world population growth, economic development and technological progress.[28] The integration of RCPs and SSPs, in turn, has allowed for improved climate impact studies, such as those undertaken by the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP) which aims to improve global and regional risk management by advancing knowledge of the risks of climate change through integrating climate impacts across sectors and scales in a multi-impact model framework.[29] Global Climate Model Outputs, based on the RCPs, need to be downscaled to regional and national levels in order to be useful for adaptation planning at these scales (see case study in box 2). The IPCC Data Distribution Centre makes freely available a number of recent global data sets of baseline and scenario information on climatic, environmental and socio-economic conditions.[30]

Box 2. Sudan's approach to develop regional climate projections

At the time Sudan conducted its NAP process (2011-2014), no regional climate projections had been available. In order to undertake effective vulnerability assessments and adaptation planning, the Sudanese government decided that such projections were required and undertook the following steps as part of the NAP process:

1. <u>Building technical capacity</u> by establishing a collaborative relationship between Sudanese meteorologists and international experts, as well as convening on-site and remote capacity strengthening programmes;

---

[26] https://public.wmo.int/en/our-mandate/climate/regional-climate-outlook-products.

[27] Further information on the RCP approach is available at https://www.nature.com/articles/nature08823 and a good description of models and scenarios is available at: https://www.climatescenarios.org/primer/.

[28] More information on the SSPs is available at https://iiasa.ac.at/web/home/research/researchPrograms/Energy/SSP_Scenario_Database.html.

[29] Further information on the ISIMIP is available at https://www.isimip.org/about/#mission.

[30] http://www.ipcc-data.org/. For a good description of models and scenarios see also: https://www.climatescenarios.org/primer/.

2. Defining current climate trends by summarizing observed precipitation and temperature characteristics from six stations over Sudan for the period 1961-2010;
3. Obtaining most recent GCM outputs from IPCC AR5 model runs for a region including Sudan and for the four Representative Concentration Pathways (RCPs) used in AR5;
4. Developing future regional climatic projections by applying statistical downscaling techniques to define future climate at a finer spatial resolution (12-km) and correlate these with historical regional climate (using also proxy data if required) to arrive at monthly, gridded (50km) time series of precipitation and minimum and maximum temperature for the period 1950 – 2100;
5. Producing maps and charts that illustrate how climate change would unfold in Sudan at the six stations (plotted for annual average temperature and annual total precipitation for the period 2006 – 2100);
6. Addressing uncertainty by characterizing the multiple contributors to uncertainty, including future climate drivers such as greenhouse gas emissions, choice of climate models, and choice of downscaling method.

Further information on these activities can be found in Sudan's National Adaptation Plan (2016), available at https://www4.unfccc.int/sites/NAPC/Pages/national-adaptation-plans.aspx.

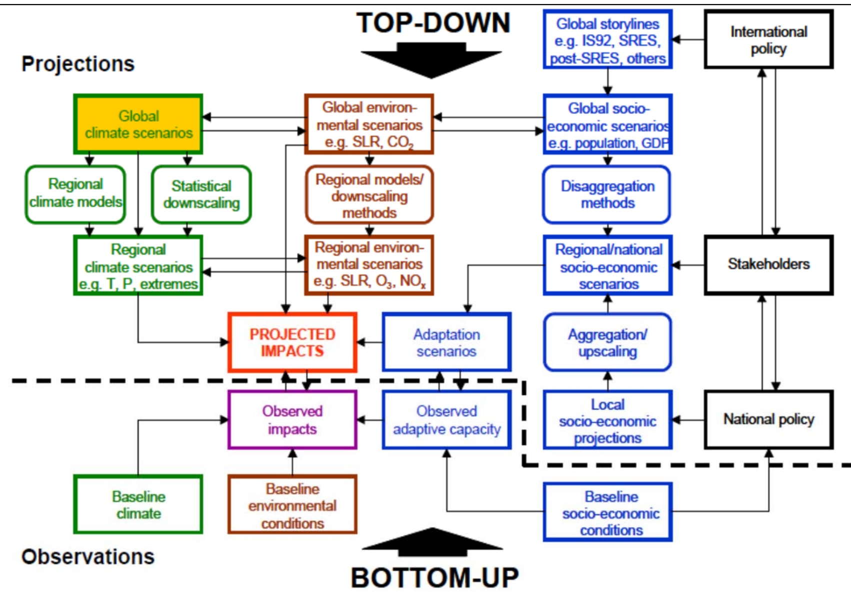
53. As illustrated in box 3, there are usually two approaches when applying projections for climate impact studies and adaptation planning: a "top-down" and a "bottom-up" approach. The latter is increasingly recognized as being more practical since it uses the knowledge of local experts and decision-makers on the prevailing vulnerability and adaptation contexts and assesses how climate change might affect related policy plans and goals. In fact, both approaches are complementary, and their combined application allows local experts to evaluate the plausibility and credibility of national climate projections that are downscaled from global scenarios. The new approach of using Representative Concentration Pathways is assumed to better address both the top –down and the bottom-up methodologies.

Box 3. Top-down and bottom-up approaches to projections for climate impact studies

If applying projections for climate impact studies and adaptation planning, there are generally two alternative and often complementary pathways for carrying out scenario-based assessments: a "top-down" or "predict-then-act" approach and a "bottom-up" or "assess-risk-of-policy" approach (see figure below). The "top down" approach involves the interpretation and downscaling of global-scale climate and socio-economic scenarios to lower levels. These are then applied to assess which impacts they might have on particular systems of interest, followed by the formulation of adaptation strategies and options.

The "bottom-up" approach builds scenarios by aggregating from the local to higher scales. It starts with the vulnerability and adaptation decision-making context and then assesses how climate change might affect certain policy plans and goals. It uses observational or even historical data and closely involves local resource managers and decision-makers with access to local knowledge whereas the top-down approach predominantly applies projected data to different contexts.

In the past, most vulnerability and impact assessments have applied the top-down approach, mostly for defining major projected climate change impacts and prioritizing interventions. However, the bottom-up approach is increasingly recognised to be more practical. In fact, these two approaches are complementary. The political scale at, and specific purpose for which an adaptation decision is taken will determine how much of a "top-down" or "bottom-up" approach is applied. The Representative Concentration Pathway (RCP) scenarios, succeeding the SRES scenarios in IPCC reports, are most likely better able to address both approaches.



Top-down and bottom-up approaches to climate projections. Source: IPCC Task Group on Data and Scenario Support for Impact and Climate Assessment (TGICA). 2007. General Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment. Version 2. Available at: http://www.ipcc-data.org/guidelines/index.html#general.

Further information on these approaches is available in: IPCC Task Group on Data and Scenario Support for Impact and Climate Assessment (TGICA). 2007. General Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment. Version 2. Available at: http://www.ipcc-data.org/guidelines/index.html#general and in Field, C.B. et al. 2014. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the IPCC. Available at https://www.ipcc.ch/report/ar5/wg2/.

5.3. Historical data

54. The storage and provision of historical data is also a shared responsibility among the different spatial scales. Many global data centres play an important role in archiving and redistributing historical data. In addition, the International Data Rescue Portal (I-DARE)[31] of WMO and the Global Framework for Climate Services (GFCS) serves as a global centre of excellence in recovering climate heritage and making it available in the state of art and digital format for research, applications and climate services. It particularly focuses on filling gaps, and extending time-series, of the GCOS Essential Climate Variables. It provides a single-entry point for accessing information on the status of historical climate data being digitized or in need of recovery and digitization so that support can be found to accelerate data rescue.

55. Most NMHSs also hold historical data. Many NMHSs carry out significant digitization of their data records, particularly regarding monthly data on temperature and precipitation, and other records have at least been scanned. However, these efforts require more (international) support in order to meet the requirements for historical climate analysis relevant for adaptation planning.

56. Regional Climate Centres are encouraged to take up non-operational data services which include data rescue and data homogenization.

[31] https://idare-portal.org/.

5.4. Enabling data provision through international coordination, quality standards and capacity-building

5.4.1. International coordination

57. A major contribution to the global provision of climate data and derived products are international arrangements for coordination and collaboration. These arrangements have been established under the understanding that no single nation is able to generate the data and information required to understand the global climate system. In contrast, it is to the benefit of all countries and increasingly diversified user needs to join the myriad of local, national and international observing systems into a global observing system. This requires coordination in terms of interoperability of the systems and compatibility of climate data and products. The international arrangements promote the free and open exchange of climate-relevant data and set standards for data collection, archiving and exchange. They also maintain publicly available databases and promote further research and collaboration in areas where they identify gaps. Finally, they provide financial and technical support to developing countries in order to enhance their data management capacity.

58. The arrangements are manifold and often overlap in terms of members, sponsors or joint programmes. The following is a brief introduction to the main arrangements, further information on each of them is available in the annex.

59. The **World Climate Services Programme (WCSP)** contributes to improving the availability and access to reliable data, advancement of the knowledge in the area of climate data management and climate analysis, definition of the technical and scientific standards, and development of activities to support them in countries.

60. The **Global Climate Observing System (GCOS)** programme, established in 1992, promotes the taking of needed observations by national or international organizations for their own interests as well as for common goals (e.g. under the UNFCCC). The GCOS programme does not directly make observations nor generate data products. In contrast, its overarching aim is to ensure that the observations and information needed to address climate-related issues (e.g. data, climate services and climate indicators) are obtained and made available to all potential users.

61. The **World Climate Research Programme (WCRP)** facilitates the analysis and prediction of Earth system variability and change for use in an increasing range of practical applications, including the design of adaptation and mitigation strategies. The WCRP mobilizes and coordinates the broader research community on specific activities by organizing meetings, workshops and conferences. The research itself is done by individual scientists working in national and regional institutes, laboratories and universities.

62. The **World Adaptation Science Programme (WASP)**, which succeeded the **Global Programme of Research on Climate Change Vulnerability, Impacts and Adaptations (PROVIA)** in 2018, focuses primarily on the provision of climate science and policy services to support the UNFCCC, the Intergovernmental Panel on Climate Change (IPCC) and the Green Climate Fund.

63. The **Group on Earth Observation (GEO)** is a partnership of more than 100 national governments and more than 100 participating organizations with a focus on observations. Together, they are creating a Global Earth Observation System of Systems (GEOSS) to better integrate observing systems and share data by connecting existing infrastructures and using common standards.

64. The **Intergovernmental Panel on Climate Change (IPCC)** is the UN body for assessing the science related to climate change. It does not conduct its own research but determines the state of knowledge on climate change, its impacts and future risks, and options for adaptation and mitigation through its assessment reports. The IPCC has established a Data Distribution Centre (DDC) which provides climate, socio-economic and environmental data, both from the past and also in scenarios projected to the future.

65. Many of the global arrangements have created regional sub-programmes or initiatives that focus on the particular regional needs. For example, the Group on Earth Observation has four regional initiatives which provide regional data resources and promote collaboration and coordination among the GEO members of the particular region. The World Climate Research Programme has established a particular

framework to evaluate regional climate model performance through a set of experiments aiming at producing regional climate projections through climate downscaling.[32]

5.4.2. Quality standards

66. As the global cooperation on data generation and use requires the open sharing of data between the many component systems and institutions, standard setting has become indispensable to enable the interoperability of systems and the compatibility of data and products as well as to ensure their highest quality of the data. This ultimately allows the end users to have confidence in the data and adequately deal with the naturally associated uncertainties.

67. The WMO, as one of its core purposes, has adopted a range of global standards, technical regulations and supplementary guides for carrying out observations and providing the required metadata in order to make observations transparent and reduce uncertainties. The principal areas of standardization include: (i) instruments and methods of observation across all components, including surface-based and space-based elements (observations and their metadata); WMO Information System (WIS) exchange as well as discovery, access and retrieval services; and data management (data processing, quality control, monitoring and archiving).[33] From time to time, WMO publishes the Guide to Climatological Practices,[34] which describes, in a convenient form, the practices, procedures and specifications that WMO Members are expected to follow when developing climate services. Member countries and organizations of the WMO, in their own interest, have committed to adhere to these standards and follow the guidelines when establishing and maintaining observing systems and generating, archiving and sharing their data. The global observation of the GCOS Essential Climate Variables is also quality controlled according to these standards.

68. The IPCC Data Distribution Centre (DDC) provides technical guidelines on the selection and use of different types of climate and socio-economic data and scenarios in research as well as climate impact and adaptation assessment with the aim of improving consistency in this regard.[35]

5.4.3. Capacity-building

69. The generation of data in accordance with the quality standards as well as their interpretation and use require capacity on the part of data producers and end users. This capacity is often lacking, particularly in developing and least developed countries.

70. Many of the international arrangements therefore offer capacity development programmes. These include, for example, the WMO Education and Training Programme with a focus on capacity-building necessary for well-functioning meteorological, hydrological and climate services.[36] The GCOS Cooperation Mechanism involves focused capacity-building and improvement of infrastructure in least developed countries and small island developing States in order to support critical networks. In some cases, this programme also includes funding of operating expenses.[37] The IPCC Task Group on Data and Scenario Support for Impact and Climate Analysis (TGICA) contributes to building capacity in the use of data and scenarios for climate-related research in developing and transition-economy regions and countries. It does this through the data and guidance provided via the Data Distribution Centre, by convening expert meetings on an as-needed basis, and by maintaining and updating a global list of networks for outreach.[38]

---

[32] https://www.cordex.org/about/what-is-regional-downscaling/.
[33] WMO Integrated Global Observing System (WIGOS) website. Available at https://public.wmo.int/en/resources/bulletin/wmo-integrated-global-observing-system-wigos.
[34] Available at https://public.wmo.int/en/resources/library/guide-climatological-practices-wmo-100.
[35] IPCC Task Group on Data and Scenario Support for Impact and Climate Assessment (TGICA). 2007. General Guidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment. Version 2. Available at: http://www.ipcc-data.org/guidelines/index.html#general.
[36] https://public.wmo.int/en/programmes/education-and-training-programme.
[37] GCOS, 195. Status of the Global Observing System for Climate. WMO, 2015. Available at https://library.wmo.int/doc_num.php?explnum_id=7213.
[38] IPCC TGICA website https://archive.ipcc.ch/activities/tgica.shtml.

6. Climate services as the bridge between data supply and demand

71. Observational, projected and historical data provide a solid scientific basis for the adaptation process. However, they are meaningless without being interpreted to derive decision-relevant information for policy makers and those people potentially affected by respective risks. Responding to the need for a bridge between scientifically generated data supply and the demand of end users for information that supports decision-making in their particular adaptation context has led to the establishment of the concept of climate services.

72. Through climate services, science-based and user-specific information is developed and provided relating to past, present and potential future climate and affected sectors. Climate services connect natural and socio-economic data and modelling with practice by transforming climate-related data – together with socio-economic variables, e.g. on agricultural production, health trends, population distribution in high-risk areas– into customised products such as projections, trends, economic analysis and services to the user communities.[39] They help users to identify from the vast array of available datasets those that meet their needs, interpret the various data products and clearly communicate the uncertainties related to them. The generation of the various observational data products described in section 5.1 and the turning of climate model outputs into climate predictions and projections can thus already be seen as part of the provision of climate services.

73. The provision and use of climate services requires the cooperation of many different actors as well as related skills and capacity in order to translate petabytes of available data into useful end products. Data providers need to be able to adhere to global quality standards in order to provide data that is authoritative; service providers such as regional organizations must be able to transform these data into products that meet increasingly specific user needs; and end users such as consultancies and local decision-makers need to be able to interpret the data with the help of their local knowledge as a basis for decision-making.

74. The **Global Framework for Climate Services (GFCS),** established between 2009 and 2012, is a UN-led initiative spearheaded by WMO to guide the development and application of science-based climate information and services in support of decision-making in climate sensitive sectors at national, regional and global levels. Through its five components, the GFCS provides, among others, observational and projected climate data from national and international databases, combined with socio-economic variables, as needed, and related products such as vulnerability and risk assessments, maps, and long-term projections.[40]

75. One of the components is a user interface platform, through which users can communicate their needs and ensure that climate services respond to them, thus promoting the co-production of knowledge between providers and end users. Another important component is capacity development which will support the systematic development of the institutions, infrastructure and human resources needed for effective climate services. Priority is thereby given to climate-vulnerable developing countries. Capacity is aimed to be built in the areas of governance, management, human resources development, education and training, leadership, partnership creation, science communication, service delivery, resource mobilization and infrastructure.[41]

76. The GFCS also facilitates regional workshops that address gaps and needs related to the development and application of climate services at the regional level, and defines respective implementation priorities.[42] Besides the designated Regional Climate Centres, other regional organizations and research centres play an

[39] WMO. Climate Services for Supporting Climate Change Adaptation. Supplement to the Technical Guidelines for the NAP Process. Available at https://www4.unfccc.int/sites/NAPC/Documents%20NAP/Supplements/WMO_climate%20change%20services%20for%20climate%20change%20adaptation.pdf; website of the Global Framework for Climate Services available at http://www.gfcs-climate.org/what_are_climate_weather_services/.

[40] Further details on the GFCS are provided in the annex and available at https://gfcs.wmo.int//.

[41] https://gfcs.wmo.int//.

[42] http://www.gfcs-climate.org/regional_workshops/.

important role in contributing adaptation data and services to the countries of a region (see case study in box 4).[43]

77. National Meteorological and Hydrological Services also act as implementers of the GFCS, for example, by mainstreaming their services into national processes such as the process to formulate and implement NAPs (see case study in box 5). For this, they are encouraged to develop National Frameworks for Climate Services (NFCS) as complements to NAPs, which may also help them in meeting the requirements of the Green Climate Fund regarding the provision of a climate rationale when applying for funding.[44]

Box 4. Connecting space to village in the Hindu Kush Himalaya region

SERVIR is a partnership of the NASA, the US Agency for International Development (USAID) and leading technical organizations which helps developing countries in all regions of the world use satellite data to address challenges in food security, land use and natural disasters. The International Centre for Integrated Mountain Development (ICIMOD) implements the initiative in the Hindu Kush Himalaya (HKH) region (Afghanistan, Bangladesh, Myanmar, Nepal, and Pakistan).

SERVIR-HKH activities include:

- Using data from a collection of Earth observation satellites, ground-based data and advanced geospatial information technology in innovative ways to support evidence-based decision-making in four thematic areas: agriculture and food security; land cover, land use change and ecosystems; water resources and hydro-climatic disasters; and weather and climate services;
- Regarding weather and climate services: implementing weather research and long-and short-term forecasting models and deploying climate services for consumption across other service areas (agriculture and droughts); monitoring extreme weather in the HKH;
- Building and institutionalizing technical capacity of decision makers, partner institutions and individuals to integrate Earth observation information and geospatial analysis into their decision-making, planning, and communication processes;
- Making available all data, tools and applications online on the SERVIR-HKH website (servir.icimod.org) and on the Mountain Geoportal (geoportal.icimod.org).
- Leveraging partnerships by engaging stakeholders in data sharing and management, developing and adopting standards of practice and developing or strengthening platforms for sustained upscaling and product uptake; strategic private sector partnerships with technology companies that provide access to cutting-edge technologies;
- Supporting the integration of gender concerns in its design and implementation as well as its monitoring and evaluation processes across its services.

More information on the initiative is available at servir.icimod.org or the global SERVIR website servirglobal.net.

[43] Examples of such organizations include the International Centre for Integrated Mountain Development (ICIMOD) for the Hindu Kush Himalaya region, the Caribbean Community Climate Change Centre (CCCCC), and the Secretariat of the Pacific Regional Environment Programme (SPREP), among others.

[44] https://gfcs.wmo.int/national-frameworks-for-climate-services and for further information on the GCF climate rationale: GCF Board decision B.19/06 and presentations made at the GCF International Technical workshop on the Adaptation Rationale in 2018, available at https://www.greenclimate.fund/meetings/2018/adaptation.

Box 5. Climate services for a resilient infrastructure in Viet Nam

Protecting long-term infrastructure against the effects of climate change is vital in Viet Nam. In compliance with its commitment to achieve goal 9 (Industry, Innovation and Infrastructure) of the SDGs and as part of its NAP and Nationally Determined Contribution (NDC), efforts are being made to increase resilience of infrastructure nationwide.

Viet Nam has realized that for this the provision of climate services through a strong collaboration between a competent service provider and the infrastructure planners and investors is key. It has therefore upgraded its National Hydrological and Meteorological Service to a Hydrological Meteorological Administration (HMA), providing it with the possibility to participate in the strengthening of the policy framework, national standards and capacity for a better provision of climate services. As part of its service provision, HMA concentrates on the collection of high quality data, including a structured, centralized and quality-controlled archiving of climate data as well as on the development of a processing-structure to be able to provide demanded products in a timely and efficient manner.

To further strengthen HMA's service delivery as well as national climate risk assessment capacities, Viet Nam is participating in the global project "Enhancing climate services for infrastructure investment (CSI)" (2017-2020), supported by GIZ. The project is contributing to Viet Nam's own efforts in the following areas:

1. Improving HMA's service delivery capacity

The CSI project has trained climate experts of HMA in data entry, digitalization and processing and in the application of the Climate Change Hazards Information Portal developed by a Canadian consultancy. It will further strengthen their capacity to develop tailor-made climate products as well as an interface between users and providers of climate services (e.g. through a website, software, dialogue fora).

2. Improving climate risk assessment capacities

In collaboration with the CSI project, Viet Nam's Ministry of Agriculture and Rural Development (MARD) has undertaken a pilot study to identify the climate risk for a specific infrastructure investment project. HMA experts, in collaboration with engineers of the infrastructure project, collected climate and hydrological data and developed a risk matrix for the project for both historical conditions and future projections. This resulted in recommendations regarding the detailed design, construction drawing design, and operation and management of the project.

3. Developing risk assessment guidelines for future infrastructure projects

Based on the results of the pilot study, climate risk assessment guidelines for the planning of infrastructure projects are being developed in cooperation with end users at different levels.

Source: Mai, P.H. et al. 2019. Climate Services for a Resilient Infrastructure: Planning Perspectives for a Sustainable Future of Viet Nam. In: Journal of Economy Forecast Review, No. 7, Volume 03/2019, pp. 10-15.

7. Gaps, challenges and needs

78. Despite great progress in international collaboration and technologies for data generation, some important gaps and challenges regarding the provision of data and data products for adaptation remain. These and the resulting further needs are summarized in the following sections.[45]

7.1. Gaps

79. The availability of data for adaptation at all scales remains the main gap.

80. Gaps regarding observational data include the following:

a) Coverage of in situ observation systems is insufficient in some regions of the world, most critically in areas where populations are at elevated risks (e.g. small islands, coastal areas) and where local changes have global impacts (e.g. melting of ice-sheet outlet glaciers and its contribution to sea-level rise), but also in least developed countries and remote areas such as the southern ocean and mountainous areas;

b) Satellite-based data products can help in increasing observational coverage, but are not always available in the spatial resolution required;

c) Downscaling, reanalysis and gridded data techniques also assist in closing some of the gaps. However, they need in situ stations for reference purposes at minimum density and with minimum time series of data which, in some regions, are not available;

d) Observations of socio-economic variables are only available independent from climate observations. Long and collocated time series of climate observations and socio-economic parameters would be required to identify risks and attribute changes.

81. Gaps regarding forecasts, predictions and projections comprise the following:

a) An important gap exists regarding near-term climate predictions (1-2 decades), which require the combination of practices for climate projections (taking into account human-forced climate change) with those for seasonal-to-inter-annual climate predictions (only taking into account natural climate variability). As this information is urgently needed by sectors such as agriculture, urban planning, and health, this gap has been defined as a Grand Challenge by the World Climate Research Programme;[46]

b) Global Climate Model outputs are only available as monthly means whereby adaptation requires information on much smaller timescales;

c) Outputs of GCMs are often not downscaled to spatial scales relevant to the local levels, including due to the lack of local capacity (see section 7.2).

82. Gaps regarding historical data refer to the following:

a) Recovered datasets of early year observations only cover sparse areas of the globe;

b) Digitization has mostly been undertaken only for monthly station averages, whereas daily or sub daily station data is not available.

7.2. Challenges

83. The following challenges exist:

7.2.1. Big data

a) Finding clever ways of exploiting the big data being provided from satellite observations, climate models and climate reanalysis through intelligent and innovative solutions such as artificial

[45] The summary of the gaps and challenges are mainly based on GCOS, 195. Status of the Global Observing System for Climate. WMO, 2015. Available at https://library.wmo.int/doc_num.php?explnum_id=7213.

[46] Further information on the Grand Challenge is available at https://www.wcrp-climate.org/component/content/article/695-gc-near-term-climate-overview?catid=138&Itemid=538.

intelligence, machine learning, internet of things, and cloud and edge computing and supporting developing countries in applying these technologies;

b) Moving from open data to open science which might include sharing algorithms, tools and knowledge in addition to sharing data.

7.2.2. Coordination

a) Matching the rapidly growing and diversifying data needs at various scales with the simultaneously rapidly growing amounts of available data and products;

b) Coordinating programmes and research on climate services, which is still a young field with mostly uncoordinated actors and activities, in order to address capacity challenges and to provide information on climate risks in a user-friendly and decision-oriented way;

c) Ensuring the interoperability of observing systems and compatibility of climate data to allow for the required open international data exchange despite the multiplicity of national institutional arrangements for making the required measurements;

d) Overcoming restrictive data policies by some countries, institutions, commercial or development organizations that hamper open data exchange particularly concerning historical data series, transboundary or local data.

7.2.3. Quality standards

a) Meeting increasing requirements for adaptation data in terms of levels of measurement uncertainty, traceability to standards, timeliness of data supply, length and stability of data record, product generation and the like and at the same time maintaining quality standards (e.g. automation for timeliness of supply vs. quality);

7.2.4. Capacity (relating particularly to vulnerable developing countries)

a) Overcoming infrastructural problems, e.g. limited or prohibitively expensive bandwidth that makes data transfers extremely problematic;

b) Increasing the number of trained personnel to operate observing systems as well as to make good use of existing data and to develop new data products for specific adaptation situations;

c) Improving the ability of some NMHSs to effectively manage and secure their data.

7.2.5. Finance

a) Avoiding budget cuts that may hinder the recovery of historical climate data or the global sharing of observational data;

b) Sustaining national observing systems which are initiated with short-term research funding and which are not yet ready to be transferred to operational institutions with more sustainable financial flows;

c) Attracting long-term and sustainable external funding flows despite the multiplicity of national institutional arrangements for observations and data management.

7.2.6. Communication

a) Improving the communication to countries on the value of observations and derived data products for adaptation which would enhance their uptake;

b) Receiving information from countries on their specific challenges in obtaining data for risk and vulnerability analyses which could help streamlining support for its generation and use;

c) Supporting countries in dealing with uncertainty that is inherent to many of the climate data products.

7.2.7. Global assessment

a) Finding ways to apply existing and future data to assess the overall progress made by Parties to the UNFCCC to achieve the global goal on adaptation as set out in Article 7 of the Paris Agreement.

7.3. Needs

84. The following needs regarding data and data products for adaptation are identified based on the gaps and challenges described above:

a) Innovative solutions for exploiting the big data generated by a diverse set of satellite observations, climate models and climate reanalysis as well as for moving from open data to open science;

b) International cooperation and coordination to manage and ensure quality standards of growing amounts of data and data products for adaptation on the one hand and to help match these data to specific national and local adaptation needs on the other hand;

c) Stronger dialogue between policymakers/decision makers and the scientific community on the value of observations and data products as well as on specific data needs, e.g. through the NAP process and facilitated through boundary organizations/ climate services;

d) Increasing and accelerated provision of climate services at all levels, and appropriate funding of respective international and national programmes;

e) Financial, technical and capacity-building support, particularly for vulnerable developing countries, to allow for homogeneous, consistent practices for managing observational systems and data and to develop locally and sector-relevant data products;

f) Joint production or sharing of data between sectors and international processes (e.g. adaptation, disaster risk and sustainable development communities);

g) Long and collocated time series of climate observations and socio-economic parameters to support long-term impact studies;

h) National or sub-national dialogues with all relevant stakeholders on the interpretation of the data and their products which take into account different values and perspectives in order to take sustainable adaptation decisions.

8. Conclusions

85. – To be completed based on input from AC members

Annex: International arrangements for coordination and collaboration on the provision of climate data and services

1. World Climate Services Programme (WCSP)[47]

86. The WCSP contributes to improving the availability and access to reliable data, advancement of the knowledge in the area of climate data management and climate analysis, definition of the technical and scientific standards, and development of activities to support them in countries. Climate data management will include data rescue, development and coordination of a global climate data management system compatible with the WMO Information System (WIS). The WCSP coordinates (i) the development of high-quality climate datasets and related data management systems; (ii) systems, tools and products for monitoring and analysis of the climate system at various scales; (iii) methods and tools for operational climate predictions; and (iv) consensus-based climate updates and climate watches including the Statements on the State of the Global Climate. It facilitates (i) interactions between operational and research communities; (ii) the development of networks of global, regional and national climate centres; and the definition and standardization of operational climate prediction products. It also aims at developing and implementing climate services at the national level.

2. Global Climate Observing System (GCOS)[48]

87. The GCOS, established in 1992, stimulates, encourages, coordinates and facilitates the taking of needed observations by national or international organizations to support their own requirements as well as common goals (e.g. under the UNFCCC). Its expert panels have defined 54 Essential Climate Variables (ECVs) which are required to systematically observe Earth's changing climate. GCOS provides an operational framework for integrating and enhancing the observational systems of participating countries and organizations into a comprehensive system focused on the requirements for climate issues, including data, climate services and climate indicators. The GCOS programme does not directly make observations nor generate data products. In contrast, its overarching aim is to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users. It regularly publishes status reports of the global climate observing system as well as implementation plans containing detailed recommendations for its improvement, in particular regarding the ECVs and in consideration of the monitoring needs of the UNFCCC, other conventions and multilateral agreements. For each ECV, a factsheet is available which includes a list of openly accessible data sets with worldwide coverage.

3. World Climate Research Programme (WCRP)[49]

88. The WCRP facilitates the analysis and prediction of Earth system variability and change for use in an increasing range of practical applications, including the design of adaptation and mitigation strategies. The two overarching objectives of the WCRP are (i) to determine the predictability of climate; and (ii) to determine the effect of human activities on climate. Three of its five focus areas are of great relevance to adaptation and include the observation of changes in the components of the Earth system, the assessment and attribution of significant trends in global and regional climates and the development and improvement of numerical models that are capable of simulating and assessing the climate system for a wide range of space and time scales. The WCRP mobilizes the broader research community on specific activities by organizing meetings, workshops and conferences through which it coordinates and facilitates climate research. The research itself is done by individual scientists working in national and regional institutes, laboratories and universities.

[47] https://public.wmo.int/en/programmes/world-climate-services-programme.
[48] https://gcos.wmo.int/en/home.
[49] https://www.wcrp-climate.org/about-wcrp/wcrp-overview.

4. World Adaptation Science Programme (WASP)[50],

89. The WASP, which succeeded the Global Programme of Research on Climate Change Vulnerability, Impacts and Adaptations (PROVIA) in 2018, is hosted by the UN Environment Programme. It focuses primarily on the provision of climate science and policy services to support UNFCCC, Intergovernmental Panel on Climate Change (IPCC) and the Green Climate Fund. The WASP's aim is to promote science for climate change adaptation policy and action by (i) providing scientific data and knowledge on climate change vulnerabilities and impacts in conjunction with the consequences and risks of response actions verses inaction; (ii) facilitating knowledge transfer and sharing, and (iii) better linking the science to policy, finance and actions.

5. Group on Earth Observation (GEO)[51]

90. The GEO is another major international arrangement with a focus on observations. It is a partnership of more than 100 national governments and more than 100 participating organizations, including government institutions, academic and research institutions, data providers, businesses, engineers, scientists and experts. Together, they are creating a Global Earth Observation System of Systems (GEOSS) to better integrate observing systems and share data by connecting existing infrastructures using common standards. Through this system, GEO is already in a position to make available more than 400 million data and information resources through its GEOSS Portal. GEO focuses on three global priority engagement areas which are the UN 2030 Agenda for Sustainable Development, the Paris Agreement, and the Sendai Framework for Disaster Risk Reduction.

6. Intergovernmental Panel on Climate Change (IPCC)[52]

91. The IPCC is the UN body for assessing the science related to climate change. It does not conduct its own research but determines the state of knowledge on climate change, its impacts and future risks, and options for adaptation and mitigation through its assessment reports. The IPCC has established a Data Distribution Centre (DDC) which provides climate, socio-economic and environmental data, both from the past and also in scenarios projected to the future. These datasets are generated by different research groups and then supplied to the DDC where they undergo a quality check before being provided to the general public. One of the clear objectives of the DDC is to provide a consistent set of up-to-date scenarios of changes in climate and related environmental and socio-economic factors and, through their wide accessibility, encourage their application by new studies so that these may feed easier into the IPCC assessment process.

7. Global Framework for Climate Services (GFCS)[53]

92. The GFCS, established between 2009 and 2012, is a UN-led initiative spearheaded by WMO to guide the development and application of science-based climate information and services in support of decision-making in climate sensitive sectors at national, regional and global levels. With its various components and contributing programmes, it may serve as the primary go-to framework that may support adaptation decision-making at global to national levels, once fully implemented.[54] The services which are coordinated under the framework involve high-quality data from national and international databases on a selection of climate variables[55], as well as maps, risk and vulnerability analyses, assessments, and long-term projections and scenarios. Depending on the user's needs, these data and information products may be combined with socio-economic variables, such as agricultural production, health trends, population distributions in high-risk areas, and road and infrastructure maps for the delivery of goods.

[50] https://www.unenvironment.org/explore-topics/climate-change/what-we-do/climate-adaptation/world-adaptation-science-programme.
[51] http://www.earthobservations.org/index.php.
[52] https://www.ipcc.ch/.
[53] http://www.gfcs-climate.org/.
[54] For its current implementation plan see WMO. 2014. Implementation Plan of the Global Framework for Climate Services. Available at https://gfcs.wmo.int/implementation-plan.
[55] These include temperature, rainfall, wind, soil moisture and ocean conditions.

93. The GFCS has five components: (i) a user interface platform, through which users can communicate their needs and ensure that climate services respond to them; (ii) a climate services information system (CSIS), forming the operational core of the framework, which produces and distributes climate data and information products that address user needs, initially in the five priority areas agriculture and food security, disaster risk reduction, energy, health and water; (iii) observations and monitoring which promotes and coordinates the essential infrastructure for generating the necessary climate data; (iv) research, modelling and prediction, through which the science that is needed for improved climate services will be advanced; and (iv) capacity development which will support the systematic development of the institutions, infrastructure and human resources needed for effective climate services. The GFCS promotes the free and open exchange of climate-relevant observational data and has defined the building of capacity in climate vulnerable developing countries as one of its priorities.