Summary report on the ninth meeting of the research dialogue Bonn, Germany, 10 May 2017

Note by the Chair of the SBSTA

24 October 2017

I. Introduction

A. Mandate

1. The foundation for the research dialogue was given by the Conference of the Parties (COP) decision 9/CP.11.[1] The focus was provided by the Subsidiary Body for Scientific and Technological Advice (SBSTA) at its twenty-sixth session[2] which invited relevant research programmes and organizations to regularly inform the SBSTA of: emerging scientific findings; research planning activities, priorities and gaps and capacity building activities particularly in developing countries; regional climate change research networks; and relevant communication issues.

2. Furthermore, in decision 16/CP.17,[3] the COP urges Parties, in particular developing country Parties, and invites research programmes and organizations to utilize the research dialogue as a forum for: discussing needs for climate change research and research-related capacity-building, particularly those of developing countries; and conveying research findings and lessons learned from activities undertaken by regional and international research programmes and organizations.

3. SBSTA 44 noted the importance of addressing regional climate research and data needs. It encouraged research programmes and organizations to present their efforts and activities at the ninth research dialogue (RD9) so as to identify climate research and data information and gaps.[4] The SBSTA invited submissions on possible topics for consideration at RD9, taking into account this encouragement as well as the themes from previous meetings of the research dialogue.[5]

4. Submissions were received from Australia, Japan, Malta and the European Commission on behalf of the European Union and its member States, the Russian Federation and Turkey.[6]

5. In response to these mandates and submissions, RD9 was convened on 10 May 2017 in Bonn, Germany, during SBSTA 46.[7] This report provides a summary of the posters, presentations and ensuing dialogue.

B. Approach, themes and goal

6. In order to enable Parties to better prepare for RD9, the SBSTA Chair provided an information note in advance providing background information on: the relevant mandates; recent activities by relevant organizations including the World Climate Research Programme (WCRP), Intergovernmental Panel on Climate Change (IPCC), Global Climate Observing System (GCOS), World Meteorological Organization (WMO), Group on Earth Observations (GEO), modelling groups and data centres; and the themes, goal and approach of the meeting.[8]

7. The two themes for the meeting were:

(a) Regional climate research data and information, and gaps;

(b) Science to take stock and assess progress on mitigation.

[1] FCCC/CP/2005/5/Add.1, pages 19–20.
[2] FCCC/SBSTA/2007/4, paragraph 47.
[3] FCCC/CP/2011/9/Add.2, page 47.
[4] FCCC/SBSTA/2016/2, paragraph 34.
[5] See Annex I of the RD9 information note http://unfccc.int/files/science/workstreams/research/application/pdf/researchdialogue.2017.1.informationnote.pdf.
[6] Links to all submissions available on the research dialogue webpage http://unfccc.int/10154.
[7] http://unfccc.int/10154.
[8] http://unfccc.int/files/science/workstreams/research/application/pdf/researchdialogue.2017.1.informationnote.pdf.

8. The goal of the meeting was to provide a discussion forum on these two themes for communicating research findings and scientific knowledge, describing capacity building and science communication being undertaken, and identifying needs, in the light of the Convention and Paris Agreement.

II. Proceedings

9. RD9 took place on 10 May 2017, during SBSTA 46 at the World Conference Centre, Bonn, Germany.

10. The meeting was preceded by a 90-minute poster session where experts presented posters and delegates could discuss the content of these posters in detail with the experts.

11. The meeting began with two keynote presentations from Mr. David Carlson, WCRP and Mr. Chris Rapley, University College London (UCL), UK. The dialogue then proceeded with an opening presentation, overviews by experts on the key messages from their posters, and dialogue on each of the two themes in turn. Mr. Andre Kamga Foamouhoue, African Centre for Meteorological Applications for Development (ACMAD) gave the opening presentation on theme 1, and Mr. Jim Skea, Working Group III of the IPCC, gave the opening presentation on theme 2. In regards to theme 1, Mr. Adao Barbosa, Least Developed Countries Expert Group (LEG), gave a response identifying gaps and needs for the LDCs for the process to formulate and implement National Adaptation Plans (NAPs).

III. Summary of the dialogue

A. Keynote presentations

12. Mr. David Carlson, WCRP, opened the session by stating that atmospheric carbon dioxide (CO_2) concentrations at Mauna Loa are now exceeding **410 ppm** (for example 410.14 ppm on 5 May 2017). He also emphasized that, due to the lag in the climate system, the current global temperature is a result of CO_2 concentrations that have permeated through the atmosphere from 10 years ago and that the impact of current CO_2 concentrations on global temperature will not be felt until 10 years hence.

13. Mr. Carlson emphasized his key message was that of time and that there is an urgency in which anthropogenic climate change needs to be addressed, whilst considering five key scientific issues as presented below.

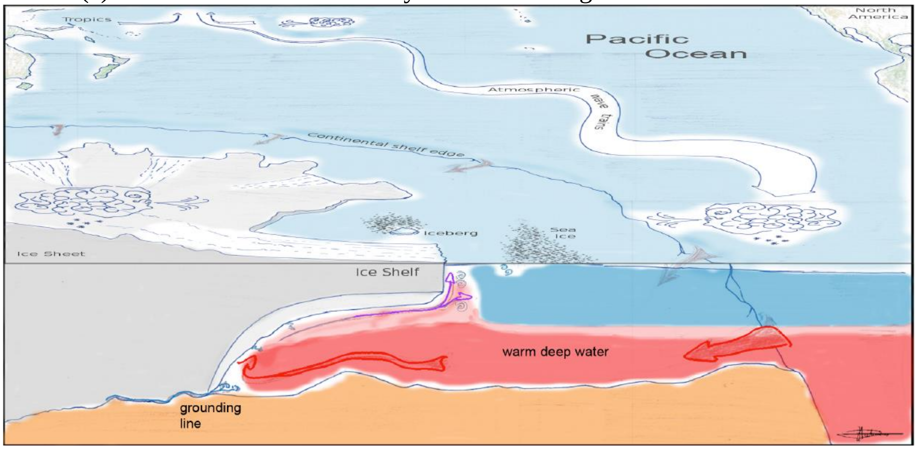
14. On **warm ocean under cold ice**, Mr. Carlson highlighted the situation in the West Antarctic Ice Sheet. In areas where the ice ground level is below sea level, deep sea water, which has warmed due to climate change, is melting the ice sheet from underneath and destabilising not just the ice sheet but the whole ice shelf (figure 1a). These issues are not currently included in climate models.

15. Mr. Carlson showed an image of Antarctic sea ice extent from 9 April 2017 to highlight the vulnerable areas of the ice sheets (figure 1b). Under the project “How Much, How Fast?” US and UK research communities are jointly investigating and quantifying changes in the West Antarctic which will improve understanding of marine ice sheet collapse and increase scientists’ skill at forecasting critical changes in the system and the resulting rates of sea-level rise. The plan focuses particularly in the area of the Thwaites Glacier and adjacent areas of the Amundsen Sea and at societally relevant timescales (decades to centuries).[9]

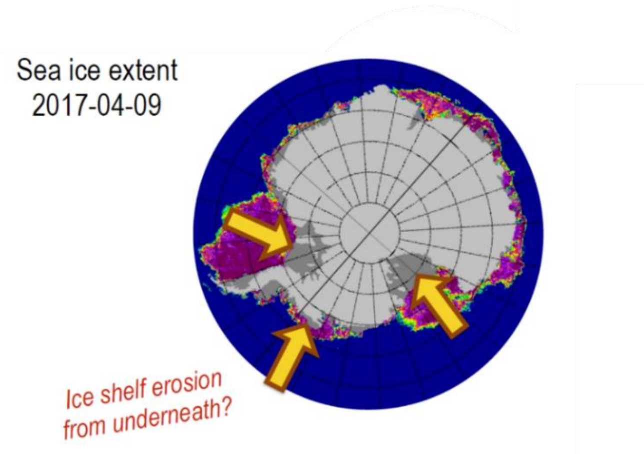
[9] How Much, How Fast? A Decadal Science Plan Quantifying the Rate of Change of the West Antarctic Ice Sheet Now and in the Future. https://nsidc.org/sites/nsidc.org/files/files/WAIS_SciPlanHMHF_final.pdf.

Figure 1
Warm ocean under cold ice

(a) The Thwaites-Amundsen system and its large-scale teleconnections



(b) Antarctic sea ice extent on 9 April 2017



Source: Slides 5 and 6 of the presentation by Mr. David Carlson.
Notes:
(a) Ice sheet changes are driven by the influence of both a warming ocean and a warming atmosphere. In the ocean, denser warm water moves toward the glacier fronts and ice-shelf gounding lines along troughs in the bathymetry, and causes greatly increased melting and retreat at the ice-ocean interfaces, thinning the ice from underneath and leading to faster ice flow causing more thinning and creating a positive feedback effect leading to marine ice sheet instability. Source: Figure 1 of reference provided in footnote 9 (Artwork by P Dutrieux and David Holland).
(b) Antarctic sea ice extent on 9 April 2017, data from the University of Bremen.[10] Particularly vulnerable areas impacted by warm water moving under the ice sheets are illustrated in dark grey.

16. On the **Southern Ocean**, Mr. Carlson displayed the Los Alamos National Laboratory visualisation of ocean currents and eddies in the Southern Ocean (figure 2). He highlighted some of the key processes occurring in this huge area of ocean south of 30 degrees South:

(a) Three quarters of nutrients used are created and flow northwards into the rest of the World's oceans supporting biological productivity including fisheries;

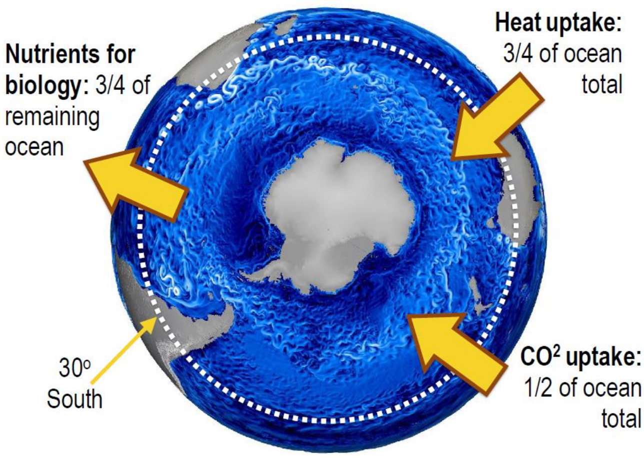
(b) Three quarters of heat from global warming is absorbed;

(c) Half of atmospheric CO_2 is absorbed.

17. Mr. Carlson highlighted that due to the relevance of the processes occurring in the Southern Ocean, more scientific understanding is needed in this region. The Southern Ocean Observing System (SOOS) is an international initiative working on observing and better understanding the southern ocean and impacts of the processes occurring on the global climate system.[11]

[10] https://seaice.uni-bremen.de/start/.
[11] http://www.soos.aq.

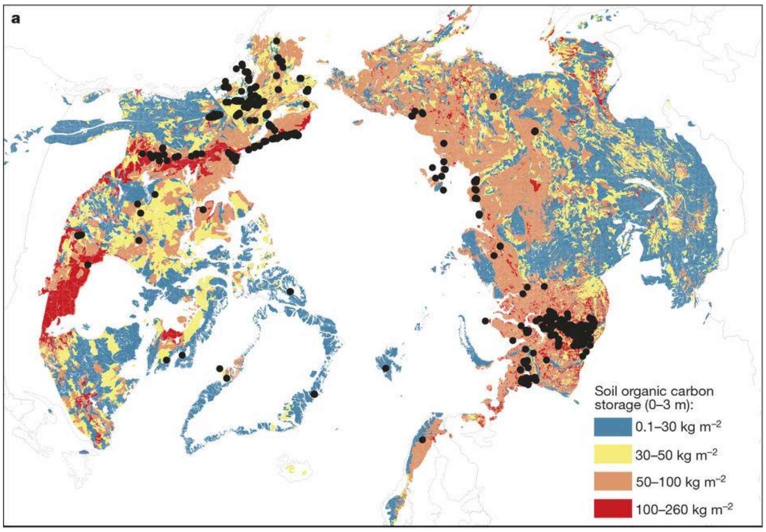
Figure 2
Southern Ocean



Source: Slide 8 of the presentation by Mr. David Carlson.
Notes: Visualisation by the Los Alamos National Laboratory (LSNL) of ocean currents and eddies using data from the LSNL Model For Prediction Across Scales-Ocean (MPAS-Ocean) to investigate the effects of climate change. Colours show speed, where white is fast and blue is slow. This high-resolution simulation includes 90 million grid cells, ranging from 10 to 30 km in horizontal width.[12]

18. On **carbon in permafrost**. Mr. Carlson presented a map of soil organic carbon in the permafrost (figure 3). He highlighted that papers in the last year indicate that carbon release from permafrost is happening faster than previously predicted, and that levels of CO_2 release previously thought to occur in 2050 are already happening in 2017. The permafrost carbon network[13] is working to understand the processes involved which are tied closely to the water cycle.

Figure 3
Carbon in permafrost



Source: Slide 11 of the presentation by Mr. David Carlson.
Notes: Soil organic carbon pool contained in the 0–3 m depth interval of the northern circumpolar permafrost zone, from Schuur et al. (2015).[14] Points show field site locations for 0–3 m depth carbon inventory measurements; field sites with 1 m carbon inventory measurements number in the thousands and are too numerous to show.

19. On **changes in hemispheric circulation.** Mr. Carlson highlighted data from NOAA first analysed and published by Francis and Vavrus (2015)[15] showing that there is a recent, greater than 30 per cent,

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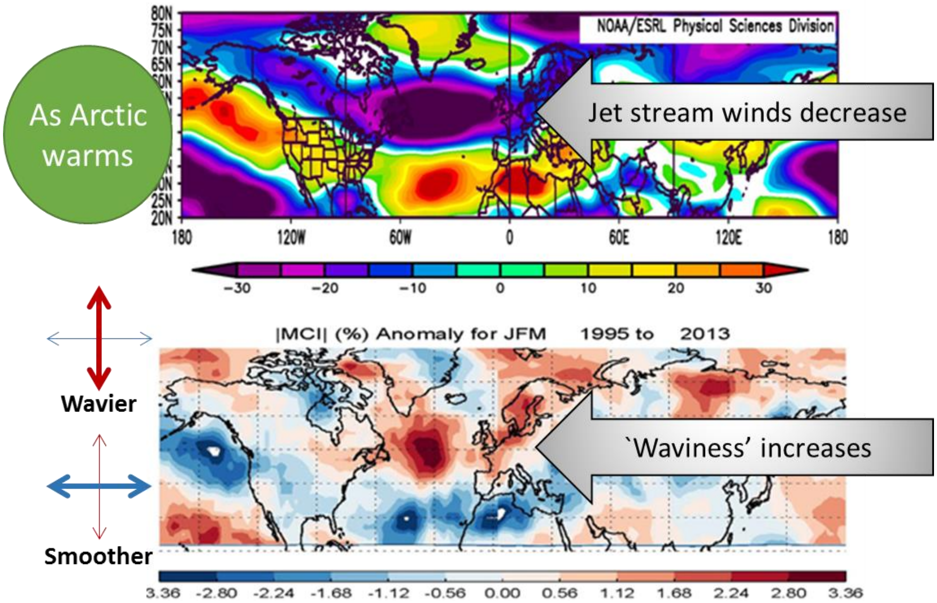
[12] http://www.lanl.gov/newsroom/picture-of-the-week/pic-week-9.php.
[13] http://www.permafrostcarbon.org.
[14] Schuur et al. (2015). Climate change and the permafrost carbon feedback, Nature 520, 171–179, doi:10.1038/nature14338.
[15] Francis and Vavrus (2015): Evidence for a waiver jet stream in response to rapid Arctic warming, Environ. Res. Lett. 10, 014005. http://iopscience.iop.org/1748-9326/10/1/014005.

decrease in jet stream winds over the North Atlantic Ocean with impacts on global air flow as a result. These changes occurring due to climate change are a completely new area of work and prove that the flow of air in the Northern hemisphere from west to east is becoming weaker, and north to south is becoming wavier causing more cold air to move south and more warm air to move north (figure 4). **Impacts for countries**, such as the UK, **include blocking of storm systems so that they stay in one place for a longer time**, and thus the events in these storm systems, including extreme events, have longer durations.

20. The outcomes of this work have been validated by several papers published since 2015 and a recent theoretical paper also provides indications of a framework into how these systems could be modelled. Mr. Carlson indicated that this change in hemispheric circulation is also likely to occur in the Southern hemisphere but it may be a longer time period before it is observed.

Figure 4
Changes in hemispheric circulation

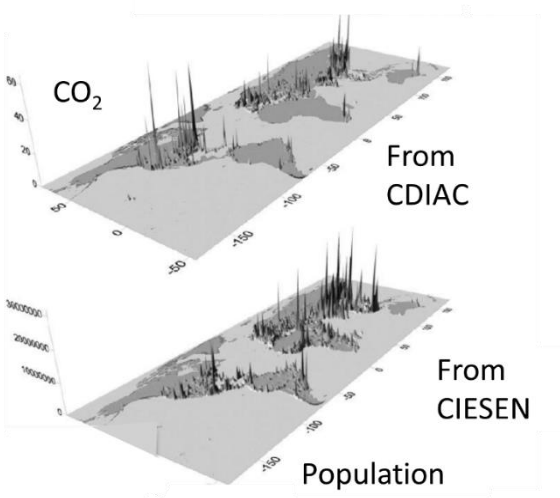


Source: Slide 15 of the presentation by Mr. David Carlson.
Notes: The upper figure shows change in zonal wind at 500 hPa (m s^{-1}) in Winter (January, February, March) during 1995–2013 relative to 1981–2010. Data obtained from NOAA/ESRL.[16]
The lower figure shows the absolute value of the change in waviness (meridional circulation index, MCI) during 1995–2013 relative to 1981–2010. See reference in footnote 15 for further information.

21. On **urban centres**. Mr. Carlson showed the spatial correlation between the CO_2 emissions on a 1 degree grid over land and the global population (figure 5). The peaks correspond to urban centres, most of which are based on coastlines. He highlighted that the figure represents a challenge to us as a community because climate change observations are usually taken away from population centres but emissions and solutions to climate change may well be in the population centres. There is a need for further understanding of the science of cities and climate change. The IPCC Cities conference in 2018 aims to address science understanding and gaps and stimulate research in regards to cities and climate change.[17]

[16] http://www.esrl.noaa.gov/psd.
[17] https://www.citiesipcc.org.

Figure 5
Urban centres – correlation between CO_2 emissions and population density



Source: Slide 17 of the presentation by Mr. David Carlson.
Notes: As highlighted by Mills et al (2015) in the WUADAPT project, in global climate change science, cities represent a critical scale owing to both the concentration of energy use and greenhouse gas emissions and their exposure to the projected effects of climate change. In addition they often have planning mechanisms to mitigate and to adapt. However, the lack of data is impediment to progress that has been recognized in the urban chapters of the 5th Assessment Report of the IPCC.[18]
Data in upper figure from Carbon Dioxide Information Analysis Center (CDIAC).[19]
Data in lower figure from Center for International Earth Science Information Network.[20]

22. Mr Chris Rapley, professor of climate science at University College London (UCL), gave the second keynote presentation entitled **Communicating Climate Changed. Why so toxic?** He is working on investigating and improving ways in which the science community intersects with policy and the general public.

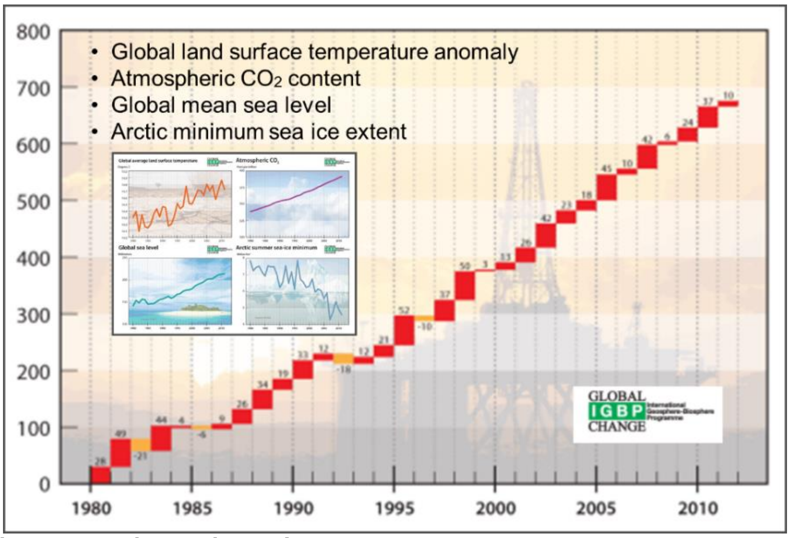
23. Mr. Rapley explained that the planet is the most complex system that humankind knows. In order to understand it, scientists need to understand the many complex interactions between all life on Earth, our own technological civilization, the atmosphere, ice, land, ocean and biosphere. He cited Einstein "*To tell a complex story make everything as simple as possible, but not simpler*" and stated that scientists, often, in attempting to communicate clear messages have made the messages on climate change simpler than they should be.

24. He noted that the tendency, in regards to communicating on climate change in the last 20–30 years, including in the Paris Agreement, has been to rely on one single variable, global surface temperature (GST), as a proxy for the Earth's system. On the one hand GST is a useful indicator, on the other hand it needs to be used in conjunction with several other variables to provide more meaning and prevent misunderstanding of the climate system. Mr. Rapley gave an analogy: if a doctor is checking the health of a person, they may start with the temperature but quickly move on to blood pressure, pulse, reflexes and other vital signs. A similar health check needs to be provided for our planet so as to better understand the changes occurring.

25. Scientists are developing a set of climate vital signs or indicators. These climate indicators will be easily accessible, provide information on the state of the planet, as well as help decision makers implement and improve ambition of nationally determined contributions (NDCs). Mr. Rapley elaborated that the topic of an indicator for climate change is not entirely new, the International Geosphere-Biosphere Programme (IGBP) previously had a climate change index which used 4 variables: global land surface temperature anomaly, atmospheric CO_2 content, global mean sea level and Arctic minimum sea ice extent (figure 6).

[18] http://www.wudapt.org. See also Mills et al. (2015). Introduction to the WUDAPT Project. the 9th International Conference on Urban Climate. Toulouse, France. http://www.wudapt.org/wp-content/uploads/2015/05/Mills_etal_ICUC9.pdf, and presentation: http://www.meteo.fr/icuc9/presentations/GD/GD2-1.pdf.
[19] http://cdiac.ornl.gov.
[20] http://sedac.ciesin.columbia.edu.

Figure 6
The IGBP Climate Change Index



Source: Slide 7 of the presentation by Mr. Chris Rapley.
Notes: The Climate Change Index works like the Dow Jones Index, but instead of providing a snapshot of financial markets, it gives an annual snapshot of how the planet's complex systems - the ice, the oceans, the land surface and the atmosphere - are changing.[21]

26. Mr. Rapley explained that GCOS, in collaboration with partners, and as part of its implementation plan,[22] is building on the routine and robust information provided by, or in development on, the essential climate variables (figure 7) to develop a clear set of Earth vital signs. A report on proposed vital signs will be presented to the GCOS steering meeting in late 2017 and consist of two types of indicators:

(a) **Historic indicators** - Metrics to characterise the Earth’s system and its evolution in order to support improved communication and dialogue with policy makers, practitioners and the public;

(b) **Future risk indicators** - To inform of societal impacts and to guide mitigation and adaptation policy and actions.

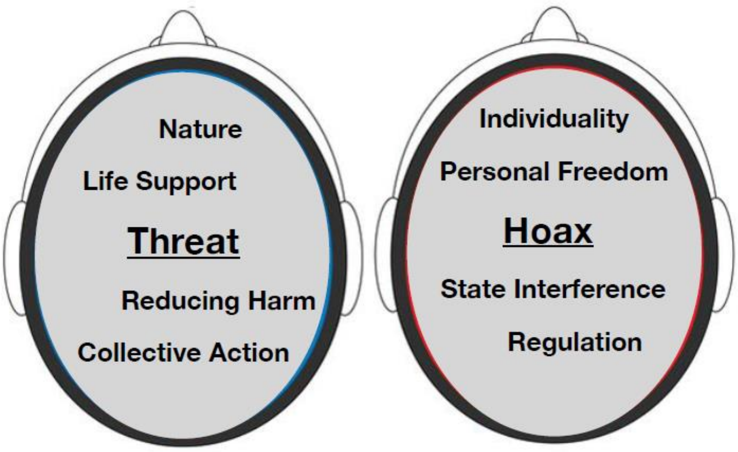
Figure 7
The Global Climate Observing System’s essential climate variables being used to develop a set of indicators for Earth’s vital signs

Source: Slide 6 of the presentation by Mr. Chris Rapley.
Notes: An ECV is a physical, chemical or biological variable or a group of linked variables that critically contributes to the characterization of Earth’ s climate.[23]

21 http://www.igbp.net/globalchange/climatechangeindex.4.56b5e28e137d8d8c09380002241.html.
22 https://library.wmo.int/opac/doc_num.php?explnum_id=3417.
23 https://public.wmo.int/en/programmes/global-climate-observing-system/essential-climate-variables.

27. Mr. Rapley then explained some of the challenging issues in regards to communicating on climate change. He said that the **difficulty for many scientists in talking about climate change is that it is not an emotionally neutral topic**, such as, for example, particle physics. Due to cognitive dissonance, which includes anxiety and stress, already generated in the public on the topic of climate change, an audience is open to messages that will reduce this cognitive dissonance (such as "don't worry, it's just the sun", "don't worry it's just the science community trying to gain power/influence/funds") which then allows people to relax and move on. Many scientists have not recognised the emotional content of climate change messages which in turn has developed into a backlash on the science community. Furthermore, the **messages in terms of the impacts and consequences of climate change are economic and political**, and thus consciously and/or unconsciously challenge strongly held values of belief and identity, particularly in the English-speaking world (figure 8). Scientists are not taught to deal with the reaction of an audience which is already emotionally charged.

Figure 8
Emotional responses to climate change



Source: Slide 10 of the presentation by Mr. Chris Rapley.
Notes: Emotional responses to climate change – people can consider climate change a threat or a hoax and respond emotionally depending on that perception.

28. Thus Mr. Rapley explained that there is a toxic environment into which urgent messages from the scientific community on climate change are injected, not a neutral environment, and scientists need to confront this problem. He discussed that it was not surprising that in the UN My World poll on peoples' concerns[24] action on climate change came below other concerns such as food, water, safety and education. Climate change is seen as disconnected, happening in the future somewhere else to someone else. People wanting to make a living often don't prioritise climate change and this is very unhelpful for political progress.

29. Scientists tend to deal with this conundrum by providing more and more facts, the so called information deficit mode, which provides more and more information to try and help people compute the information and change behaviour. However, there is much expert evidence to show that this method of information exchange doesn't work.

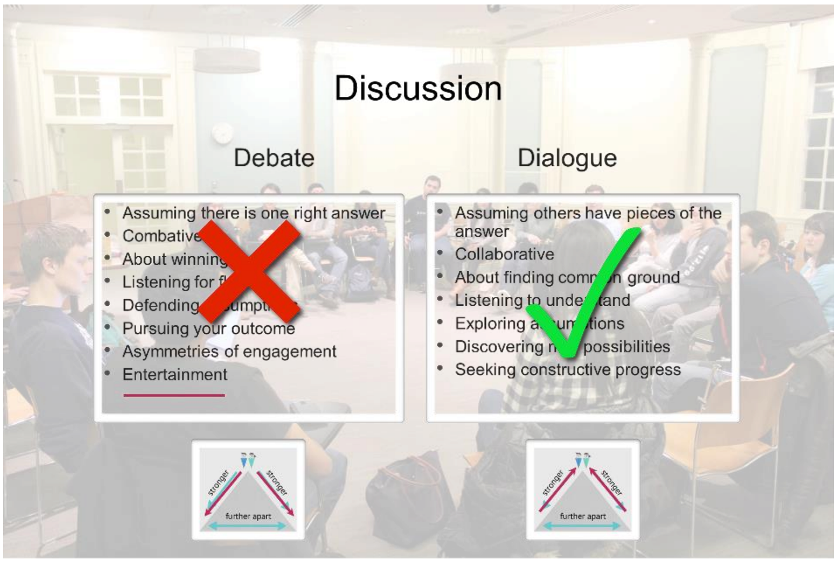
30. Mr. Rapley emphasized that there are ways to overcome the communication conundrum and, in many ways, this is a new area of research. Human beings have provided information to each other over centuries through **storytelling, which provides information that is: engaging, meaningful, hopeful, and actionable. It provides narrative tension and leaves the audience asking what happens next**. This is very different to the normal ways scientists communicate messages. He said that scientists have been engaging audiences through storytelling and experiential activities in theatres and museums. Allowing people to engage with an experience reduces obstacles to hearing what is presented.

31. Mr. Rapley also highlighted that, away from the storytelling and experiences and assuming that a group of people are having a public discussion, the traditional ways of dealing with issues of the day through debate forces opinion apart because it is combative, adversarial, and assumes that there is only one answer. People who already have a negative attitude will have the negative attitude hardened by engaging in a debate. Compounding the problems of debate, the media like to publish information from the debate point of view as it provides winners and losers and it is human nature to want to see who these winners and losers

[24] http://data.myworld2015.org.

are. On the other hand, Mr. Rapley explained, as understood by the ancient Greeks, **people can deal with complex issues through dialogue**. This is more respectful, there are many sides and people will find areas where they disagree and agree. If executed well the dialogue can draw people together and find a way forward regardless of differences (figure 9).

Figure 9
Communication of climate change through dialogue



Source: Slide 17 of the presentation by Mr. Chris Rapley.

32. Mr. Rapley concluded by identifying the role of the scientific community in promoting better communication on climate change (figure 10), explained in the 2014 report by the UCL Policy Commission on the Communication of Climate Science title Time for Change?[25] The UCL Commission has just reconvened and a new report will be available in early Summer 2018.

Figure 10
The role of scientists in communication climate change science

- **Pure Scientist** - generate facts and insights and deliver them to the pool of human knowledge
- **Science Arbiter** - answer factual (positive, not normative) questions about scientific output - arbitrate interpretation
- **Science Communicator** - communicate with society about results and implications directly or via intermediaries - to draw attention to issues judged important
- **Honest Broker** - engage co-productively in decision making to assist practitioners to fulfil their role
- **Informed Citizen** - actively intervene in society as informed citizen to promote dialectic based on expert knowledge and understanding

Source: Slide 18 of the presentation by Mr. Chris Rapley.

[25] https://www.ucl.ac.uk/public-policy/for-policy-professionals/commissions/communication-climate-science.

Summary of discussions

33. A Party asked about the level of certainty of changes (in terms of IPCC levels) to Northern hemispheric circulation described in paragraphs 19–20. Mr. Carlson explained that there is increasing scientific evidence that climate change is impacting the jet stream and this will be assessed as part of AR6 and likely to be covered in more detail than in AR5.

34. One Party emphasised that the roles of scientists are complex and embedded in institutional processes and that there are difficulties in breaching the gap to bring scientific knowledge into policy making. Furthermore, being an arbiter of information in isolation is difficult as a scientist may not be aware of a government's priorities, ways and procedures. Thus the science communicator role should be heavily linked to the policy context and a science communicator working for the government should have one eye on the relevant science and one eye on the policy making so as to bridge the different domains. Mr Rapley agreed and highlighted that often scientists can be asked questions which need more than the scientific disciplines to answer as the questions have moral, economic and political dimensions. **Co-production of knowledge is important in these situations**.

35. One Party asked about how the good examples of science communication can be used at different scales. Mr. Rapley replied that this is a challenge and that one of the key aspects is to continue to have direct conversations with the public as climate change touches on personal issues and personal conversations are a key aspect for moving understanding forward.

36. One Party asked whether there were communities that could help in communicating scientific information to the public and, if so, what can be done to encourage them. Mr. Rapley responded that there are information brokers but the problem is that, as mentioned in paragraph 28, the environment for introducing information is not neutral. Problems can arise when a broker may not be able to provide the same level of in-depth knowledge as a scientist. As climate change is extremely complex, many scientists who focus on one part of the puzzle may also find it difficult answering questions not in their specialist field. Mr Rapley encouraged delegates to talk in terms of risk, threat and increasing resilience which is a language that business people understand. Furthermore, although the science community may often research in detail specific issues, strategist may simply want to know what is the worst that can happen and plan for that.

B. Theme 1: Regional climate research data and information, and gaps

37. This section of the report provides a summary of information presented and discussed on theme 1, including: the introductory presentation by Mr. Andre Kamga Foamouhoue, ACMAD; the posters provided by experts; and the response from Mr. Adao Barbosa, a member of the Least Developed Countries Experts Group (LEG). There were 29 posters presented at RD9 on theme 1.

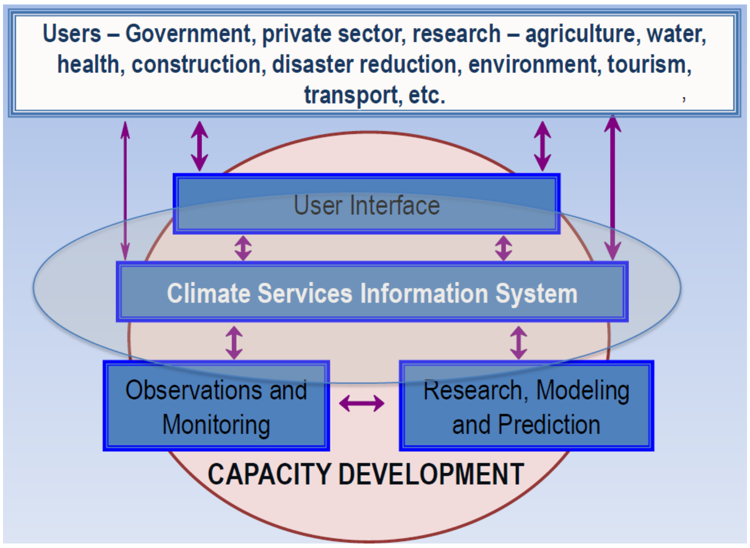
38. Mr. Kamga presented on **WMO global to regional climate services** for better climate change adaptation and risk management; and specific examples of climate services in Africa addressing support for policy makers.

39. Mr. Kamga highlighted the work of the **WMO Climate Service Information System** (CSIS),[26] which is the core of the Global Framework for Climate Services (figure 11).[27] The GFCS is in its second phase with the key objective and challenge to bring climate science to the policy interface at global, regional and national level.

40. An international coordination team[28] manages the CSIS to co-produce and deliver customised information about past, present and future climate for policy, decision making and practices. This includes: data management for data providers working within the WMO and those working externally; climate analysis, monitoring, assessment and attribution (particularly of high impact events); and climate predictions (from weeks to a decade) and projections (several decades to centuries).

[26] http://www.wmo.int/gfcs/CSIS.
[27] http://www.wmo.int/gfcs.
[28] https://www.wmo.int/pages/prog/wcp/ccl/opace/opace3/ET_CSIS_Opace3.php.

Figure 11
How the Global Framework for Climate Services operates

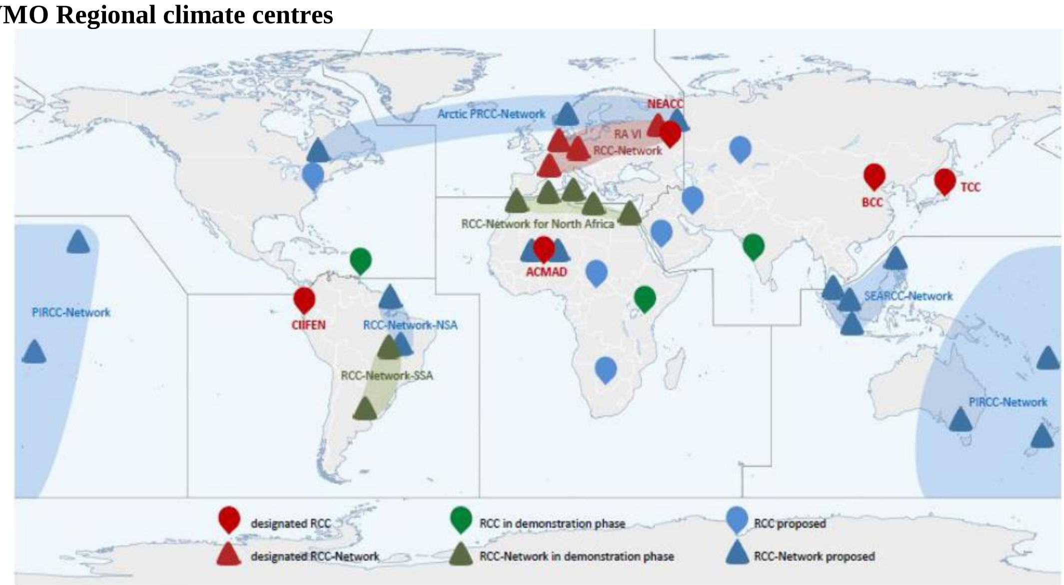


Source: Slide 5 of the presentation by Mr. Kamga.

41. Mr. Kamga explained how the CSIS provides support at three levels: national, regional and global, and at each level there are a range of users with climate centres providing support and advice to decision and policy makers. The national meteorological and hydrological services (NMHS) of individual countries are already the key element of national level climate support. The WMO is now promoting **regional climate centres** (RCCs) to be recognized as part of the system. The WMO also has **global producing centres** providing global scale information which in turn can be used by regional centres.[29]

42. RCCs are a new development for the WMO. They are r**ecognized centres of excellence** providing regional-scale climate functions including data services, training, monitoring, long range forecasting, climate prediction and projection, research and development and coordination of activities within their regions. The RCCs are existing centres which are nominated, at the request of the Members of the WMO Regional Associations, and offered accreditation by the WMO after a successful 2–4 years demonstration phase (figure 12).[30]

Figure 12
WMO Regional climate centres



Source: Slide 9 of the presentation by Mr. Kamga.

[29] http://www.wmo.int/pages/prog/wcp/wcasp/gpc/gpc.php.
[30] http://www.wmo.int/pages/prog/wcp/wcasp/rcc/rcc.php.

43. Mr. Kamga provided examples of the climate services that ACMAD have been developing in regards to disaster risk reduction, also presented in the ACMAD posters:[31]

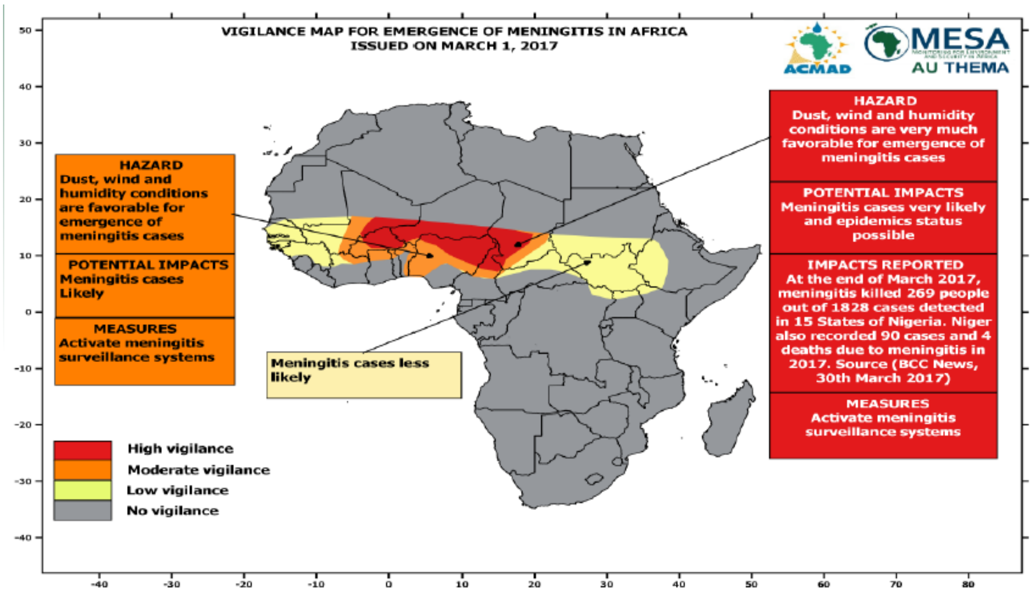
(a) ACMAD are using the **CORDEX for Africa database to analyse the hazards** that could be expected in the future and partaking in **participatory dialogue** with users to identify needs and produce effective services for decision making, including working with UNDESA to develop guidelines to mainstream climate information into strategic planning at the national level;

(b) In Niger, the ministry of health meet weekly to determine the vigilance level for meningitis in all districts and thus optimise meningitis vaccine distribution. As part of the implementation of the Sendai Framework for Disaster Risk Reduction, African countries in the meningitis belt are encouraged to consider **vigilance products** for optimal planning and distribution of vaccine following this best practice initiated in Niger (figure 13).

44. Mr. Kamga highlighted the **urgency to rehabilitate observing networks** to monitor warming and forecast heat waves in African countries with an emphasis on cities with millions of inhabitants, particularly as the warming rate in Africa is increasing from 2°C per century in 1950 to close to 4°C per century over the last 25 years.

45. Mr. Kamga concluded with identifying that information from **early warning systems** at national level is a challenge. There must be a focus on bringing together different sets of information at national level, including hazard outlook fora, and developing capacity and governance to support observations, research, modelling, prediction, information and use, in order to change from current post disaster management (reporting on the disaster by local offices after the event) to future disaster risk reduction management. The priority must be on **capacity development for integration of climate information into sustainable development** planning and budgeting processes (Agenda 2063 of the African Union).[32]

Figure 13
Climate services for meningitis epidemic surveillance and control in Africa in support of sustainable development goal 3: good health and well-being



Source: Slide 15 of the presentation by Mr. Kamga..

46. In addition to the posters presented by Mr. Kamga on behalf of the Africa regional centre (ACMAD), 5 further posters were presented on **the regional information provided and gaps identified by WMO regional centres**:

(a) Mr. Zhiqiang Gong presented the climate activities and services of the **Beijing Climate Center** (BCC).[33] The BCC runs the China Framework for Climate Service (CFCS), a user-oriented service platform acting on government's and customers' demands. A series of pilot projects relevant to agriculture and food security, disaster risk management, water resources, energy and urban areas have been launched.

[31] http://unfccc.int/files/adaptation/application/pdf/1.4_1.5_1.6_posters_wmo_acmad_rcc.pdf.
[32] http://www.un.org/en/africa/osaa/pdf/au/agenda2063.pdf.
[33] http://unfccc.int/files/adaptation/application/pdf/1.7_bcc_gong.pdf.

BCC has also established the East Asia Monsoon Monitoring System and the Climate Model system to underpin the implementation of the CFCS. Current gaps for climate services in East Asia are the lack of a regional platform and schemes for collecting observation data, distributing outlook products, and issuing warnings.

(b) Mr. Juan José Nieto, **Centro Internacional para la Investigación del Fenómeno de El Niño** (CIIFEN), presented the poster on climate research gaps and opportunities to support risk management and adaptation in Latin American countries.[34] Good climate knowledge is essential for developing communication strategy to inform and engage authorities and community leaders at local and national levels. Once decision makers are involved, and adaptation or resilience measures are defined, with the participation of the stakeholders, these can be implemented in the territory. CIIFEN have developed a geoportal on climate knowledge[35] and examples of community-based action.[36] Research gaps include improving the quality of databases; the need for higher resolution model outputs; understanding the climate system and its dynamic response to ENSO; the ENSO cycles and their relation to climate change; and better understanding ENSO impacts in different regions. The poster also shows lessons learned on climate risk management of El Niño 2015–2016 and identifies the need for improved monitoring, data and information provision, communication strategies at different levels, strengthening of the institutional framework, inter-agency coordination, and the need to harmonize the agendas of risk management and climate change.

(c) Mr. Stefan Rösner, **RA VI Regional Climate Centre Offenbach Node on Climate Monitoring**, presented on RA VI RCC Network (Europe) which supports a region from Greenland in the Northwest to Jordan in the Southeast and well into the western part of the Russian Federation. As with all RCCs this node is part of the CSIS and has three main functions: providing data sets; climate monitoring and watch information; and long-range forecasting products. Research challenges include merging of new data sources, filling of data gaps, data rescue, homogeneity, uncertainty estimation, new and improved climate monitoring products, attribution of trends, improved Climate Watch System, further development of long-range forecast modelling, verification and interpretation of model results, downscaling, and impact forecasts.[37]

(d) Mr. Atsuya Kinoshita, Japan, presented work by the **Tokyo Climate Center** (TCC) and the Meteorological Research Institute (MRI) of the Japan Meteorological Agency (JMA) on gap filling through collaborative research using a Non-Hydrostatic Regional Climate Model (NHRCM).[38] The TCC assists climate services of Asia-Pacific NHMSs as part of their regional cooperation activities, such as through annual training seminars and expert visits for effective technical transfer. TCC provides up to date climate information and gap filling to the region including two publications series, Global Warming Projection and the Climate Change Monitoring Report. The MRI has conducted international collaborative research with developing countries to produce detailed climate change projections in tropical and sub-tropical regions. Eighteen researchers have been trained in the last 5 years to use the NHRCM and calculate future climate projections data for their home countries, which has been analyzed in detail for adaptation measures. MRI will invite 4 researchers from Southeastern countries in this fiscal year.

(e) Mr. Gé Verver, **Royal Netherlands Meteorological Institute** (KNMI), presented on the Climate Risk and Early Warning (CREWS) initiative launched at the Paris climate conference in 2015.[39] CREWS aims to enhance the capacity in developing countries to put in place early warning systems. It should enable authorities to issue warnings to local governments and residents on extreme events and their potential impacts. The WMO RCCs structure contributes to the goals of CREWS by providing key data, such as regional climate outlooks, climate projections, and historical records of high-impact extremes. The poster also describes the **International Climate Assessment and Dataset** (ICA&D), which is the backbone of RCC-nodes on climate data in 3 different regions of the world: Europe, Southeast Asia and South America. It provides basic, regional, and climatic information for applications in sectors including water, health and agriculture. A new plan (which is yet to be approved) to implement ICA&D at ACMAD in West Africa is presented as part of a CREWS project, twinning the European and African RCC networks.

47. Information on **further regional climate services** was presented in four posters:

[34] http://unfccc.int/files/adaptation/application/pdf/1.8_ciifen_nieto.pdf.
[35] http://geoportal.ciifen.org/es/.
[36] http://cordilleracostera.org/portal/.
[37] http://unfccc.int/files/adaptation/application/pdf/1.9_ravi-rccroesner.pdf.
[38] http://unfccc.int/files/adaptation/application/pdf/1.18_japan_kinoshita.pdf.
[39] http://unfccc.int/files/adaptation/application/pdf/1.24_knmi_verver.pdf.

(a) Mr. Hugo Zunker, European Commission, presented on the **Copernicus Climate Change Service** - Developing drought, pest impact and phenological indicators for potential adaptation anywhere in the World.[40] Copernicus provides data and information to all types of research activities at global, regional or national level under a full, free and open data policy. A Sectoral Information System builds on these data providing value added products, by merging climate data with other sector specific data, to deliver on aspects such as infrastructure, population and economy. Downstream services, outside of the programme itself, can then further enrich and downscale this information to meet even more specific and local needs, which has included indicators for adaptation planning in the sectors of forestry, olive farming and vine cultures.

(b) Mr. Ulric Trotz, **Caribbean Community Climate Change Centre** (CCCCC), presented on decision making and adaptation planning decision support tools for the Caribbean.[41] The Caribbean, with support from the **Climate Development and Knowledge Network** (CDKN) and other partners, now possesses climate adaptation tools tailored for use in the region, and with the capacity for regional institutions to utilise and improve these tools. Key challenges have been accessing historical climate data necessary for establishing baselines against which to measure future changes; validation of the outputs of regional modeling and downscaling activities; and the absence in many instances of local meteorological observations, which was using a "gridded reanalysis dataset". Effort and resources are now being devoted to the dissemination of, and training on, the use and application of these tools to national and regional stakeholder groups, supported by USAID. This is facilitated by the fact, that, all the tools are now in the public domain and available on line.[42] This research complements the work of the WMO regional climate Centre, the Caribbean Institute of Meteorology and Hydrology (CIMH), which has been providing different sectors in the region with short term forecasts and engaging with different interest groups, to promote a community of intelligent users of climate information for decision making in the Caribbean.

(c) Ms Christiana Olusegun, Karlsruhe Institute of Technology (KIT), presented on the **West African Climate Service Center on Climate Change and Adapted Land Use** (WASCAL) Regional Climate and Land Surface Information and Services.[43] WASCAL provides a hydro-climate observation network across 10 member countries of WASCAL, with data access to the national weather services of these countries on request. It has developed science-based services for West Africa through partnership with local, national and international stakeholders. Selected WASCAL services include provision of the multi-model ensemble of high spatial and temporal resolution (12 km/ 3 hr) climate simulations over West Africa available for up to the end of the 21st century; land surface and land use data, as well as other derived products from remote sensing; bias corrected Africa CORDEX climate data and capacity building and training workshops.

(d) Mr. Espen Ronneberg, **Secretariat of the Pacific Regional Environment Programme** (SPREP), presented on Combining Traditional Knowledge and Meteorological Forecasts in the Pacific to Increase Community Resilience to Extreme Climatic Events.[44] The rapid disappearance of climate traditional knowledge in the Pacific is a concern. Pacific communities can access information provided by national meteorological services. However, there can be difficulties with accessing information and when this occurs, communities tend to refer to the climate traditional knowledge and practices they trust. In order to increase community resilience, SPREP and the Bureau of Meteorology (BoM) are working to transition the management of the Climate Traditional Knowledge project to assist Pacific Island Communities with the collection, storage and integration of climate traditional knowledge and contemporary forecasts, and share lessons learned across the wider Pacific Community.

48. The following 5 posters presented **observation and research information to support regional and national decision making and adaptation planning**.

(a) Mr. Simon Eggleston, GCOS, presented on **systematic observations: from global systems to local information**.[45] GCOS, through its 2016 implementation plan, supports high-quality, reliable and sustained observations from both a global and local perspective to support adaptation planning. GCOS in collaboration with the UNFCCC secretariat, IPCC and other partners, is planning to hold a series of regionally focused workshops to develop an understanding of the observations needed for different regions.

[40] http://unfccc.int/files/adaptation/application/pdf/1.13_ec_zunker.pdf.
[41] http://unfccc.int/files/adaptation/application/pdf/1.12_ccccc_trotz.pdf.
[42] All links provided in the poster.
[43] http://unfccc.int/files/adaptation/application/pdf/1.27_kit_dlr_olusegun_hirner.pdf.
[44] http://unfccc.int/files/adaptation/application/pdf/1.25_sprep_ronneberg.pdf.
[45] http://unfccc.int/files/adaptation/application/pdf/1.15_gcos_eggleston.pdf.

These workshops will prepare plans for improving the regional observational capacities. One important initial topic will be water: extreme rainfall, floods and droughts.

(b) Mr. Carlson, WCRP, presented an overview of the **WCRP Grand Challenge on Understanding and Predicting Weather and Climate Extremes** (GC-Extremes).[46] Its objective is to better identify the factors and mechanisms that determine the location, intensity, and frequency of heatwaves, droughts, heavy precipitation and storms, with information on other event types obtained indirectly from the research. Society depends increasingly upon the global climate research community; in the near-term (from a season to a year) to mitigate risks to society and ecosystems, and in the longer term (from a decade to centuries) for effective adaptation planning. The four over-arching themes of GC-Extremes are to document, understand, simulate, and attribute, with a focus on actionable information around key topics to facilitate science progress and overcome long-standing barriers. Progress on these topics is increasingly enabled by cross-disciplinary scientific advances. GC-Extremes is advancing its science agenda through engaging scientists across disciplines, working with a range of stakeholders, focused workshops, and emphasizing funding needs.

(c) Mr. Morten Skovgård Olsen, **Arctic Monitoring and Assessment Programme** (AMAP) presented the findings of the ***Snow, Water, Ice and Permafrost in the Arctic 2017 assessment*** (SWIPA 2017).[47] The Arctic is a regulator of global climate and warms more than twice as fast as the rest of the globe. Climate change is driving widespread changes in the Arctic. Results from SWIPA 2017 show: climate change is continuing in the Arctic at a rapid pace; the Arctic is shifting to a new state; substantial cuts in GHGs now can stabilize impacts by the end of the century; adaptation is needed as the Arctic will continue to change but regional and global consequences are not well quantified and reducing knowledge gaps and improving quantitative predictions will improve adaptive capacity. SWIPA 2017 adds two critical goals to the climate research agenda:

(i) Improve quantitative predictions for the timing of future Arctic change, including further understanding of cryospheric feedbacks that are consequential for amplification of Arctic warming.

(ii) Improve confidence in quantitative predictions of interactions between the Arctic and global system on a monthly to decadal scale.

(d) Mr. Thorsten Kiefer, **Future Earth**, presented on three aspects: **Regional effects of air pollution, disaster risk, and urban climate change**.[48] 1) The International Global Atmospheric Chemistry project is studying **air quality and climate** change which are inexorably linked from their emission sources to their impacts on climate, human health, and ecosystems. By taking into account the mix of emissions, lifetime, and benefits and trade-offs, more comprehensive sustainable policies can be developed to maximize the benefits for both air quality and climate change mitigation. 2) **A new regionalization scheme**, the Integrated Risk Governance Project,[49] using a combination of tendencies and fluctuation patterns of climate change, provides a scientific basis for countries and regions to develop adaptation and decision making, especially for managing climate-related disaster or environmental risks. 3) The **Cities and Climate Change conference** will be held in Edmonton, Canada, March 2018, co-sponsored by IPCC and co-arranged by Future Earth and several partners, to support the implementation of the Paris Agreement, the New Urban Agenda, and the Sustainable Development Goals.

(e) Mr. Rösner, on behalf of the **Group on Earth Observations**, presented on **open-access Earth observation** data for regional climate research, mitigation and adaptation decision making.[50] GEO is building regional initiatives, including AfriGEOSS (in Africa), AmeriGEOSS (in the Americas) and AOGEOSS (in Asia-Oceania), to support decision-making and regional sustainable development, and build institutional and individual capacity through engagement of experts, stakeholders and decision makers. For example, AfriGEOSS is leveraging the Africa Data Intensive Research Cloud (ADIRC), to provide researchers in African countries access to high performance computing (HPC) infrastructures, enabling them to take part in big data science projects and to build Earth observation data processing platforms. GEO engages providers and users of climate data resources through outreach, including targeted workshops and its annual international Plenary, to ensure a sustained dialogue around the information needs of those seeking to integrate climate products and services into adaptation processes and decisions.

[46] http://unfccc.int/files/adaptation/application/pdf/1.1_wcrp_carlson_gc-extremes.pdf.
[47] http://unfccc.int/files/adaptation/application/pdf/1.10_amap_olsen.pdf.
[48] http://unfccc.int/files/science/application/pdf/1.14_futureearth_kiefer.pdf.
[49] http://www.futureearth.org/projects/irg-integrated-risk-governance-project.
[50] http://unfccc.int/files/adaptation/application/pdf/1.17_geo_roesner.pdf.

49. A range of initiatives on **regional downscaling** were presented in 7 posters:

(a) Mr. Ralf Döscher, **Swedish Meteorological and Hydrological Institute** (SMHI) presented a summary on regional projections of global climate change for local adaptation response and the importance of resolution in climate models.[51] Regional features such as steep orography, varying soil and vegetation properties, and small-scale landscape heterogeneities strongly shape the climate signal, including climate events and probabilities of short-term extremes. **Regional climate models** (RCMs) are applied downstream of the global models with enhanced grid resolution allowing for a more realistic regional climate response. Improving regional climate models will be essential for: regional-to-local climate information; planning of adaptation measures; assessing local consequences of mitigation measures, such as land use change for negative emission technologies; and for establishing regional and national climate services. Challenges and gaps include the need for better and more complex process descriptions at high and very high resolution, as well as distillation of user-relevant information. The value of downscaling for impact applications generally increases with resolution. Increasing resolution would improve representation of precipitation. The CORDEX community is providing coordinated sets of downscaled climate projections at regional and national scale that clearly add value to underlying global climate projections. Downscaling is critical and will be the primary source for climate services on regional and local level, even in coming decades, and thus needs further attention.

(b) Mr. Carlson presented on the **EURO-CORDEX initiative**: A new generation of regional climate scenarios for Europe.[52] The current EURO-CORDEX regional simulations are based on CMIP5 global climate projections and representative concentration pathways (RCPs). A total of 37 simulations are available at 50 km resolution (EUR-44), and a further 31 simulations at 12.5 km resolution (EUR-11). The data is available via the Earth System Grid Federation (ESGF). Since the first EURO-CORDEX meeting in 2011, the initiative’s efforts have included hindcast simulations for evaluation as well as climate projections and their analyses. Recent activities involve high-resolution simulations and studies as well as contributions to the **CORDEX Flagship Pilot Studies** (FPS), in particular the FPS on “Convective phenomena at high resolution over Europe and the Mediterranean” and “LUCAS – Land Use & Climate Across Scales”. Through the FPS on Convective Phenomena, EURO-CORDEX members contribute to the next generation of convection-resolving climate models. The EURO-CORDEX initiative will utilize the upcoming CMIP6 GCM data as forcings for subsequent simulations.

(c) Mr. Carlson also presented on **regional climate downscaling through the Arctic-CORDEX**,[53] coordinated through the WCRP Climate and Cryosphere Project (CliC). Currently, the core of Arctic CORDEX consists of regional climate model simulations over the Arctic, with hindcast (ERA-Interim and GCM-driven historical simulations) and scenario (GCM-driven RCP4.5, RCP8.5) simulations. Arctic CORDEX runs are available from 11 atmosphere and 6 coupled atmosphere-ice-ocean RCMs for the ERA-Interim period. Some high-resolution simulations are available as well (15km pan-Arctic and 5km for Greenland). Arctic CORDEX simulations are also used to project temperature and precipitation change over the Svalbard area. Multi-model analyses of extreme temperature and cyclones have recently been completed. In October 2017, both components of **Polar CORDEX** (i.e., Arctic and Antarctic CORDEX) will hold a joint annual meeting (hosted by the British Antarctic Survey in Cambridge, UK) for the first time, strengthening further the interactions between the two communities.

(d) Mr. Dairaku, Japan, presented on the establishment of the **CORDEX Asia Empirical-Statistical Downscaling** (ESD) Group.[54] To meet with the needs of stakeholders such as local governments in Asia, the ESD Group was established in November 2016 to advance and coordinate, through partnerships, the science and application of regional CORDEX activities for Dynamical Downscaling (DDS) from CORDEX-East Asia, Southeast Asia, South Asia, and Central Asia. Through this work, the ESD provides regional climate information and services, which are required for risk assessment, on subnational scale for climate change adaptation and for the IPCC AR6. The main activities of the CORDEX Asia ESD group are in providing:

(i) Regional climate statistical downscaling information based on common protocols for a common benchmark for investigating the uncertainty of regional climate scenarios;

(ii) Case studies for developing and improving methods when sufficient observation is available (such as in cities, coastal areas and agricultural lands) and for obtaining best practices of co-production and coordination with the IAV community;

[51] http://unfccc.int/files/adaptation/application/pdf/1.26_smhi_doescher.pdf.
[52] http://unfccc.int/files/adaptation/application/pdf/1.3_wcrp_carlson_euro-cordex.pdf.
[53] http://unfccc.int/files/adaptation/application/pdf/1.2_wcrp_carlson_arcticcordex.pdf.
[54] http://unfccc.int/files/adaptation/application/pdf/1.19_japan_dairaku.pdf.

(iii) Reference data for improving ESD and DDS skills by collecting better observational data and updates;

(iv) Training workshops to share and exchange knowledge and techniques.

(e) Mr. Hans-Jurgen Panitz, KIT, presented on the added **value of regional downscaling with COSMO-CLM** (Consortium for Small-scale Modeling – Climate Limited-Area Modeling) in the context of CORDEX-Africa.[55] COSMO-CLM results are one example of a variety of RCMs results achieved within CORDEX. However, it is important that the knowledge from this information is presented effectively to support the data needs of stakeholders. As highlighted in paragraph 49(a), RCMs, such as COSMO-CLM, are better suited to assess climatology, extremes and climate indices than global models, and can thus help to identify the most vulnerable regions for more focused and better inform planning of adaptation and mitigation measures. They can provide very high resolution (< 10 km), physically consistent data needed by impact models. However, assessment of **robustness of results needs a multi-model ensemble approach and more long-term and reliable observations** for model evaluation and improvement. In terms of regional coverage, only a few long-term (> 30 years) climatological observations are available, mainly with low spatial and temporal resolution and diverging data. There is a need for other observations than near surface temperature and precipitation, including agriculture and energy related quantities: soil moisture, evapotranspiration, insolation, cloudiness, climate indices and extremes. In Africa, where observational networks must be improved, regional climate projections could help identify the most critical regions.

(f) Mr. Jacob Schewe, Potsdam Institute for Climate Impact Research (PIK) presented on ISIpedia - **the climate impacts encyclopedia**.[56] ISIpedia, based on results from the ISIMIP initiative, will make climate impacts research more accessible and applicable for scientific users, planners and practitioners around the world. The upcoming 3rd phase will develop an online platform that offers guided access to scientific model data, as well as region-specific assessments of climate impacts in multiple sectors, along with an assessment of data quality and data visualizations. Regional stakeholder workshops will be held in West Africa and Europe and a worldwide online survey will be conducted. In terms of gaps, the project is carried out by a large European research consortium, but its success could be further enhanced if more non-European scientists could contribute to the region-specific impacts assessments. Strengthening the international research architecture would help in this regard.

(g) Mr. Schewe also presented on **regional impacts of climate change on hydrology**: a model inter-comparison.[57] This is a large international modelling initiative, also part of ISIMIP, that has produced consistent projections of climate change impacts on the terrestrial water cycle in twelve major river basins around the world. For each of these basins, which include the Niger and the Ganges, simulation ensembles are now available to facilitate regional-scale research into future risks to water resources.

50. Five posters highlighted **capacity building to support decision making and adaptation planning**:

(a) Mr. Eggleston, presented on **capacity development through the GCOS Cooperation Mechanism**.[58] In 2003, Decision 11/CP.9 welcomed the establishment of the GCOS Cooperation Mechanism which was established by the sponsors of GCOS assisted by Parties to the Convention. It enables donor funds to be used to support continued operation of at-risk climatological stations. The Cooperation Mechanism now **needs to be reinvigorated** to avert decline in essential climate observations for the atmosphere, oceans and land and provide greater focus on sustainable, multi-purpose observations at the national level, covering all the Essential Climate Variables. Decision 19/CP.22 emphasizes the need to build capacity in developing countries through existing relevant mechanisms, including the GCOS Cooperation Mechanism.

(b) Mr. Andrew Matthews, Asia Pacific Network for Global Change Research (APN), presented on **Measure to Manage: A view from the Asia-Pacific**.[59] He highlighted the need for: commitment to long-term systematic observations; human as well as financial investment, ongoing calibration and maintenance; and interpreted satellite data which is expensive due to a heavy computing component. APN is undertaking ongoing capacity development including translation of information into local languages, training, data recovery and digitisation. Mr. Matthews highlighted the increasing pressure, which is counter-

[55] http://unfccc.int/files/adaptation/application/pdf/1.21_kit_panitz.pdf.
[56] http://unfccc.int/files/adaptation/application/pdf/1.22_pik_schewe.pdf.
[57] http://unfccc.int/files/adaptation/application/pdf/1.23_pik_schewe.pdf.
[58] http://unfccc.int/files/adaptation/application/pdf/1.16_gcos_eggleston.pdf.
[59] http://unfccc.int/files/adaptation/application/pdf/1.11_apn_matthews.pdf.

productive to needs, to reduce costs by reducing measuring sites, to calls that 'all the information is on the internet' or the call to 'just Google it!'.

(c) Ms. Sara Purca, Inter-American Institute for Global Change Research (IAI), presented a case study on **the impact of 2015–2017 El Niño on the regional ocean variability off Peru**.[60] Through international coordination and cooperation, the research is providing a regional focus and cooperation. It uses elephant seals to collect temperature and salinity observations at unprecedented spatial and temporal resolutions compared to other ship-based or autonomous platforms. The project is building a full picture from the ocean surface to the sea bed of ocean variability and the impact of climate change on the ecosystems and feedbacks. Project tools will enable better mapping of the relationship between ocean variability, from primary production to fisheries in the Humboldt Large Marine Ecosystem following the 2015–2017 El Niño impacts.

(d) Mr. Stuart Goldstraw, UK MetOffice, presented on **Long-Term Observing Stations** as a critical part of the climate puzzle.[61] Long-term observations are important for preserving mankind's scientific and cultural heritage as they are, and will continue to be, unique sources of past, present and future information about our atmosphere. Therefore, they act as references for assessing climate variability and change. They are also important for the improved understanding and prediction of our future climate. The WMO Mechanism for the Recognition of Long-term Observing Stations is aimed at highlighting the importance of long-term observations, as well as promoting sustainable observing standards and best practices that enable the continued generation of high-quality time series data now and for the future.[62]

(e) Mr. Joachim Post, UN Space-based information for emergency and disaster response (UN-SPIDER), presented on UNISPACE+50 and its Thematic Priority "**International Cooperation Towards Low-emission and Resilient Societies**."[63] The UN-SPIDER approach to this priority is through facilitation of synergistic uses of space-based applications and information to contribute to the 2030 Development Agenda and the incorporation of scientific and technological knowledge into uses, especially in developing countries. It is also enabling access to space-based data and information, building capacities in value-added methods and advising on implementation at the national level.

51. Mr. Adao Barbosa, LEG, gave a response on theme 1 identifying **gaps and needs for the LDCs for the process to formulate and implement NAPs**.[64] He highlighted that the LEG is strengthening its relationship with stakeholders to help the implementation of NAPs including through collaboration with the WMO and Green Climate Fund (GCF). He identified the importance of early warning systems and linking the scientific and policy making processes. He further identified that the LEG is promoting the engagement of scientific institutions with decision makers so as to help them use climate information and research. He encouraged participants to engage with the regional NAP workshops which provide opportunities for the scientific community to work directly with country NAP teams.

C. Theme 2: Science to take stock and assess progress on mitigation

52. This section provides a brief summary of information presented and discussed on theme 2, including: the introductory presentation by Mr. Jim Skea, Working Group III (WG III) of the IPCC and the posters provided by experts. There were 14 posters presented at RD9 on theme 2.

53. Mr. Skea outlined the focus of the IPCC sixth assessment cycle and the actions that the IPCC can contribute towards the global stocktake in AR6. He reported on outcomes from the IPCC scoping meeting in Addis Abeba and emphasized the large number of scientists, over 200, working together across the 3 working groups to scope the new reports. The scoping meeting had been preceded by a WG III expert meeting on Mitigation, Sustainability and Climate Stabilization Scenarios.[65] Mr. Skea explained that this expert meeting was useful in shaping the conclusions of the scoping meeting, in particular to address previous feedback on the use of scenarios in AR5 relating to feasibility, sustainability implications and transparency of modelling and scenario approaches.

54. Mr. Skea displayed the **proposed outline for WG III contribution to AR6** (figure 15) which, since RD9, has been confirmed along with the outlines for WG I and II at the forty-sixth session of the IPCC,

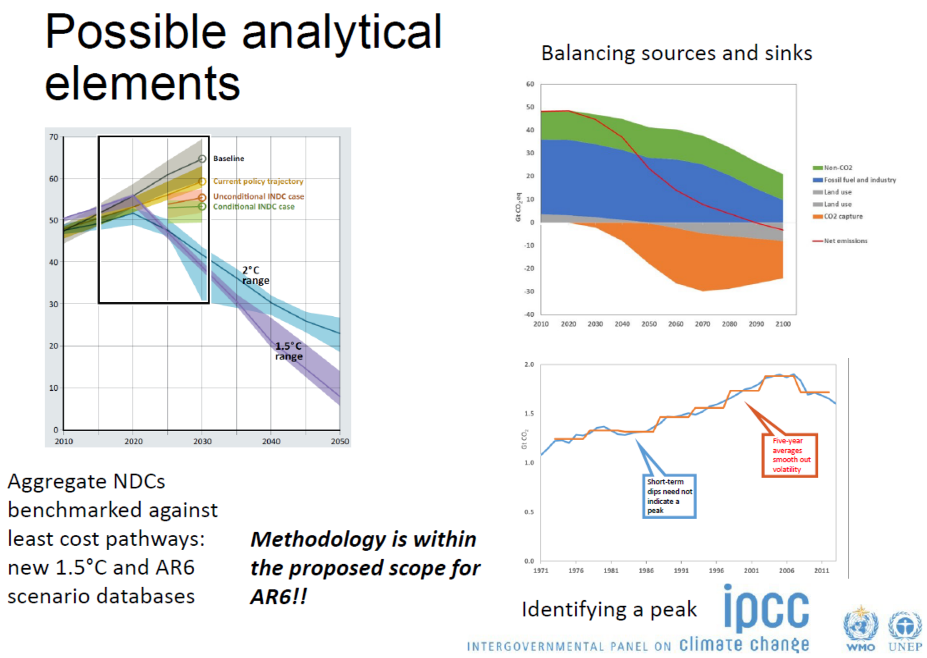
[60] http://unfccc.int/files/adaptation/application/pdf/1.20_iai_purca.pdf.
[61] http://unfccc.int/files/adaptation/application/pdf/1.28_wmo_goldstraw.pdf.
[62] https://public.wmo.int/en/our-mandate/what-we-do/observations/long-term-observing-stations.
[63] http://unfccc.int/files/science/application/pdf/1.29_unoosa_post.pdf.
[64] http://unfccc.int/files/science/application/pdf/leg_sbsta_research_dialogue_10may2017.pdf.
[65] http://www.ipcc.ch/meeting_documentation/meeting_documentation_ipcc_workshops_and_expert_meetings.shtml.

Montreal, 6–10 September 2017.[66] He explained that **sectors remain the core** of the WG III report, which helps map the information onto emission inventories as reported by Parties to the UNFCCC. As well as the key chapters on emissions sections, the WG III report will **provide assessment of: information that could be used for the global stocktake** (chapters 2–4); a greater f**ocus on cities** (chapter 8); a general look at how to **orient the sectors to meet human needs** (chapter 5); the mobilization of financial flows and technology development and transfer (chapters 15 and 16); and link to sustainable development and sustainable development goals (chapters 1 and 17).

55. Mr. Skea explained that the information in chapters 2–4, for use in the global stocktake, will have chapter 2 assessing drivers and trends, chapter 3 assessing mitigation pathways compatible with long-term goals, and chapter 4 focusing its assessment more on near and medium term scenarios and the collective impact of NDCs, emissions peaking and mid-century and end of century carbon development strategies.

56. He encouraged Parties to **continue dialogue with scientists and the IPCC to better define the science needed to support the global stocktake**. Mr. Skea showed some possible analytical elements that could be used (figure 14). He also explained that, under AR6, IPCC is establishing new databases for the scenarios, including a 1.5°C database. The databases are produced through collaboration between IPCC, IAMC and IIASA, which will host the database, and will contain the AR5 scenarios, and in due course the scenarios from AR6. It may be possible, with agreement from scenario authors, to also provide information from the database to support the facilitative dialogue in 2018.

Figure 14
Some of the possible analytical elements that the IPCC can provide to support the global stocktake



Source: Slide 5 of the presentation by Mr. Jim Skea.
Notes: *LHS* – Diagram taken from UNEP Gap Report[67] balancing NDCs against least cost emissions pathways.
RHS top – Balancing sinks and sources and long - term low greenhouse gas emission development strategies. Derived from the Fifth Assessment Report database. The figure illustrates how the net emissions are associated with the balance (or lack thereof) between emissions (fossil fuels and industry, land use and non-carbon dioxide emissions) above the zero line, and sinks (carbon dioxide capture and land use) below the zero line.
RHS bottom – Aggregate fossil fuel CO_2 emissions of twelve countries whose emissions peaked in the period 2001–2010.[68] International Energy Agency data. The figure illustrates that averaging aggregate emissions over five year periods helps to smooth out volatility. The blue line depicts annual emissions, showing variability due to climate and fluctuations in economic activities. The red line refers to five-year averages.

[66] http://www.ipcc.ch/activities/activities.shtml.
[67] http://www.unep.org/emissionsgap.
[68] For further information see Summary report on the SBSTA–IPCC special event on advice on how the assessments of the IPCC can inform the global stocktake http://unfccc.int/files/adaptation/application/pdf/specialevent_summaryreport_online.pdf.

57. Mr Skea ended with outlining the possible elements that could be included in the AR6 synthesis report, as discussed at the scoping meeting:

(a) Global stocktake;

(b) Interaction among emissions, climate, risks and development pathways;

(c) Economic and social costs and benefits of mitigation and adaptation in the context of development pathways;

(d) Adaptation and mitigation actions in the context of sustainable development;

(e) Finance and means of support.

58. Four posters highlighted **advances in climate modelling and future projections**:

(a) Mr. Carlson presented on **updated scenario planning and current schedules for CMIP6**.[69] The poster shows the latest CMIP6 scenario matrix, the timeline for the CMIP6 DECK, historical, and MIP simulations as well as their analysis. In designing CMIP6, the CMIP Panel, an oversight group of international scientists, undertook a rigorous assessment of past performance and future needs. For CMIP6, the Panel defined five key design goals: ensuring consistency across CMIP phases; science-based priority outlines; supporting self-determined schedules by modeling groups; strengthening a coherent scientific framework; and maintaining an open and inclusive process.

(b) Mr. Matthias Tuma, WCRP, presented on WCRP activities on **decadal climate prediction**.[70] Modeling and predictions at decadal time ranges must take into account current and projected anthropogenic forcing (centennial projections), as well as starting from the present, observed state of the coupled system. Such initialized climate predictions were, for example, produced as an outgrowth of CMIP5 and are being continued through a range of dedicated, systematic activities including under CMIP6. WCRP activities on decadal climate prediction are, among others, carried out by the Decadal Climate Prediction Project (DCPP) and the WCRP Grand Challenge on Near-Term Climate Prediction (GC-NTCP). They aim to advance scientific understanding of all aspects of decadal predictability and prediction; carry out, support, and contribute to the ongoing production of decadal climate predictions in support of societal needs; provide and inform operational standards, methods and guidance for routine decadal predictions, in close collaboration with activities on operational decadal prediction by the WMO; and initiate and issue a real-time "**Global Annual to Decadal Climate Update" each year** (2017 onwards, with 2 years of initial dry runs). Climate information from these themes will support the Global Framework for Climate Services (GFCS). The WCRP decadal prediction science community is currently coordinating its suggestions for its input to the IPCC Special Report on 1.5 °C as well as to the global stocktake.

(c) Mr. Joeri Rogelj, International Institute for Applied Systems Analysis (IIASA), presented an **update on the process of creating a very low emission scenario for climate change research**.[71] An international consortium of six global modelling teams has developed a set of scenarios that limit end-of-century radiative forcing to 1.9 Watt per square meter (RCP1.9), keeping warming in 2100 below 1.5°C with approximately 66% probability, although peak warming is often higher than 1.5°C. One scenario out of this diverse set has been selected for further analysis as part of CMIP6. The new scenarios provide a wealth of information that can be of interest to the facilitative dialogue and the global stocktake. They provide **sectoral detail on how a transformation to a 1.5°C world can be achieved**, and provide important insights to understand the consequences of lower or higher emissions in 2030 in the context of pursuing 1.5°C. For example, peak temperatures are about 0.2°C higher if emissions in 2030 are at the high (>45 GtCO2-eq yr^{-1}) instead of the low (<30 GtCO2-eq yr^{-1}) end of the available range. Furthermore, being at the high end of this range would roughly halve the probability of limiting peak warming below 1.5°C over the coming decades. A trade-off was also found for the timing of achieving global zero emissions. In the 1.5°C scenarios, net zero GHG emissions are achieved between 2050 and 2075, but if emissions in 2030 are higher than 40 GtCO2-eq yr^{-1} zero emissions have to be reached before 2060. Scenario analysis and data will be made available online.

(d) Mr. Tomohiro Hajima, Japan, presented on, **Earth system modeling to contribute to the Paris Agreement** as part of the Integrated Research Program for Advancing Climate Models.[72] Recently launched by the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT), this integrated research program aims to conduct more accurate climate change projection from global to local

[69] http://unfccc.int/files/adaptation/application/pdf/2.1_wcrp_carlson_scenarios.pdf.
[70] http://unfccc.int/files/adaptation/application/pdf/2.2_wcrp_tuma_decadalactivities.pdf.
[71] http://unfccc.int/files/adaptation/application/pdf/2.9_iiasa_rogelj.pdf.
[72] http://unfccc.int/files/adaptation/application/pdf/2.12_japan_hajima.pdf.

scales, and from international to domestic level, and clarify the mechanisms applicable to climate change measures. It has four main areas: global climate change projection and model development; clarification of the carbon cycle mechanism, climate sensitivity and tipping points; integrated regional climate change projection in Asia-Pacific regions; and integrated regional hazard projection. In regards to the clarification of the carbon cycle mechanism, climate sensitivity and tipping points, this work aims to reduce the uncertainty of the projection of future global warming and the carbon budget, increasingly important for the Paris Agreement. MEXT will be upgrading their climate change research support and will endeavour to provide cutting-edge scientific knowledge that contributes to climate change actions through proactive contribution to the IPCC AR6.

59. Three posters provided information on **indicators and/or indices to measure progress under the Paris Agreement**:

(a) Mr. Glen Peters, Center for International Climate Research (CICERO), presented a **framework for key indicators to track current progress and future ambition of the Paris Agreement**.[73] The research posed the question “we have had three years with virtually no growth in carbon dioxide emissions from fossil fuels and industry - what has caused the slowdown and does this put us on a path “well below 2°C”? The framework helps to track progress towards the Paris goal, inform the global stocktake and increase the ambition of the NDCs through a nested structure of key indicators selected to map the most important drivers of emission changes, key components of the NDCs, and key characteristics of 1.5°C and 2°C emission scenarios. As the framework is nested, it first focuses on simple and overarching indicators, and then later zooms in to analyze more detailed and relevant analysis. The research shows that China, the US, and the European Union have all seen emission reductions recently. These countries are affected by lower than expected economic growth since the Global Financial Crisis in 2008/2009, but there is an emerging trend due to the shift from coal to gas and the rapid growth in solar and wind. However, the research highlights that to keep options open to stay below 2°C, it is necessary to have a globally-coordinated effort on the development and deployment of large-scale carbon capture and storage.

(b) Mr. Amir Delju, WMO, presented on **understanding changes in climate in support of the global stocktake**.[74] The poster identifies that long-term climate observations over a century can provide reliable quantified indicators that show the historic physical state of the climate and are the basis of future projections. Indicators can contribute to the global stocktake and need to be recognized as scientific heritage for all. As mentioned by Mr. Rapley, WMO is supporting the scientific community to identify a set of essential climate indicators. Surface temperature is not the best indicator of climate change as it is a poor overall thermodynamic descriptor of the Earth’s energy balance and a broader set of indicators would better describe and communicate the full range of physical climate change over the last 150 years. Indicators as a package should provide a representative picture of changes to the earth system related to climate change, come from an official source and be useful, actionable, reliable, robust, verifiable and forecastable.

(c) Mr. Richard Millar, University of Exeter and Environmental Change Institute, University of Oxford, presented on **human-induced warming to date and implications for outstanding carbon budgets for 1.5°C**.[75] Human-induced warming can be robustly calculated using observations and simple climate modelling tools to give an up-to-date assessment of its present-day magnitude. **Human induced warming is currently at about 1ºC above an 1861–1880 pre-industrial baseline** and is increasing by about 0.15ºC per decade. An **index of human-induced warming** can be maintained and continually updated based on the latest observations of the climate and improvements in the understanding of climate forcing agents. This index could be used to provide a reliable measure of current human influence on the climate to the UNFCCC process in between the IPCC assessment reports. Such an index of human-induced warming can also help understand the required level of future mitigation ambition needed to limit warming to the Paris Agreement’s long-term goals. In order to meet a long-term temperature limit of well below 2ºC, emissions must reduce by, on average, 10% for every additional 0.1ºC increase in human-induced warming For a 1.5ºC limit, emissions must fall by on average 20% per additional 0.1ºC of human-induced warming.

60. Three posters provided information on **measuring emissions and/ or GHG concentrations:**

(a) Mr. Thorsten Kiefer, Future Earth, presented on three aspects: **carbon budgets, historic baselines, and agricultural contribution to climate mitigation**.[76] 1) The Global Carbon project has determined that carbon dioxide emissions have been almost flat for 3 years despite large economic growth in parts of the globe, mostly due to decreased use of coal in China. However atmospheric methane

[73] http://unfccc.int/files/adaptation/application/pdf/2.4_cicero_peters.pdf.
[74] http://unfccc.int/files/adaptation/application/pdf/2.15_wmo_delju.pdf.
[75] http://unfccc.int/files/science/application/pdf/2.6_unioxford_millar.pdf.
[76] http://unfccc.int/files/science/application/pdf/2.7_futureearth_kiefer.pdf.

concentrations are rising faster than at any time in the past two decades. 2) Natural recorders of Earth's climate, such as corals, tree-rings and ice cores, reveal that human-induced climate warming commenced in many parts of the world as early as the 1830s. The rapid response of the Earth's climate system to even small increases in atmospheric greenhouse gas levels during the early parts of the Industrial Revolution suggest a baseline for human-driven climate change before that warming onset. 3) To achieve the below 2 degrees limit, agriculture must reduce emissions of nitrous oxide and methane by 1 Gt by 2030, requiring the rapid development of more transformative technical and policy options.

(b) Ms. Rosa Maria Roman Cuesta, Center for International Forestry Research (CIFOR), presented on **Identifying AFOLU emission hotspots in the tropics: where are they, how uncertain are they, and what can be done about it?**[77] The research shows that provision of data on the location of emission hotspots for the land use sector (AFOLU) can help build trust and improve the transparency, comparability and completeness of country emission reports. Spatially explicit independent emissions data helps fill country data gaps and compare current estimates; offers much needed estimates of uncertainty; and supports the development of mitigation activities and the tracking of emission drivers. Thus information on emission hotspots could help the global stocktake by offering a benchmark (2000–2005) against which countries can contrast their present and future emission performances, navigate and prioritize mitigation actions at subnational scale, and support policy makers and donors on their decision making processes on where and why to take action. Disaggregated emissions of CO_2 versus non-CO_2 (N_2O, CH_4) could be used as mitigation indicators. Although there are still large uncertainties in the AFOLU emissions, with a clear bias towards the forest sector (i.e. forest degradation and deforestation) and new research suggesting even larger uncertainties for afforestation emissions (i.e. restoration challenges), non-forest (non-CO2 emissions) can play a part in the discussion of mitigation potentials due to their lower uncertainties. More dynamic, multitemporal emission estimates at a global scale will help to support the independent tracking of emission trends and associated stocktaking processes.

(c) Mr. Shamil Maksyutov, Japan, presented on their **Contribution to the Paris Agreement using space-based GHG monitoring**.[78] Since 2009, the Ministry of the Environment of Japan, the Japan Aerospace Exploration Agency, and National Institute for Environmental Studies jointly developed and are operating, the GHG observing satellite, GOSAT, which globally measures the column concentrations of carbon dioxide and methane, from an altitude of 666 km. To maintain the data continuity, Japan will launch GOSAT's successor, GOSAT-2, in 2018. GOSAT data can be used to map the enhancements of GHG concentrations due to anthropogenic emissions from large cities, industrial areas, mining areas, and other emission sources. Such enhancements can be quantitatively compared to those derived from GHG emission inventories and atmospheric transport models. Space-based GHG monitoring such as GOSAT has the potential to be a new tool for independent and transparent support of national GHG inventories and a useful contribution to the implementation of the Paris Agreement. The project is willing to work together with scientists and inventory compilers in developed and developing countries to establish methodologies for such satellite data applications in the near future.

61. Future pathways to decarbonization and sustainable development depend on a number of factors, especially deep emissions cuts. Four posters elaborated on **research looking at future pathways**.

(a) Mr. Henri Waisman, Institute for Sustainable Development and International Relations (IDDRI), presented on **country-driven mid-century low-emission development strategies – methods and insights from the Deep Decarbonization Pathways Project** (DDPP).[79] The DDPP is a global collaborative research initiative that actualizes the process of designing long-term pathways that reflect national circumstances. It is engaging with the 2050 Pathways Platform, directed by Laurence Tubiana, and plans in the future to share lessons learnt with new countries requiring technical support, notably in developing countries. The project gives a proof of concept for 6 key domestic benefits:

(i) Building emission pathways that are consistent with national circumstances and global climate constraints, thanks to collective benchmarks guiding the country-driven assumptions;

(ii) Selecting the short-term actions needed to follow transformative pathways in the long term, by starting with the definition of a desirable future and backcasting to it from the present;

[77] http://unfccc.int/files/adaptation/application/pdf/2.5_cifor_roman-cuesta.pdf.
[78] http://unfccc.int/files/adaptation/application/pdf/2.13_japan_maksyutov.pdf.
[79] http://unfccc.int/files/adaptation/application/pdf/2.8_iddri_waisman.pdf.

(iii) Ensuring that low-emission transformations are consistent with the satisfaction of domestic development priorities;

(iv) Supporting the identification of tangible country-specific actions towards low-emission futures, by using transparent and sectorally detailed metrics;

(v) Informing the regular revisions of domestic transformations in a context of uncertainties, by making explicit the challenges associated to different possible pathways, at different time horizons;

(vi) Revealing the domestic requirements from international cooperation to serve as inputs for the global stocktake, by identifying the enabling conditions of domestic transformations that depend upon the support from the international community.

(b) Mr. Rogelj, IIASA, presented on **understanding the origin of Paris Agreement emission uncertainties**.[80] Taking stock and assessing progress towards the achievement of the Paris Agreement long-term mitigation goal requires information on many aspects related to current and future emissions. One of the key questions in this context is: **what are the emissions levels implied by the NDCs in 2030?** A new study from IIASA[81] shows how the ambiguity in the NDC targets translates to a potential range of 47 to 63 gigatons of CO_2 equivalent emissions in 2030, with a **median estimate of 52 gigatons**. Thus global emissions in 2030 could be higher, equal or lower than today's level (-10% to +20%), while at the same time complying with the NDCs. The study examined this uncertainty range, and whether it can be reduced. With important variations across regions, the main uncertainties are: socioeconomic baseline variation (ca. 15–20%); alternative energy accounting methods (ca. 0–10%); uncertainty due to conditionality of NDCs (ca. 0–5%); range specifications of targets (ca. 0–5%); attribution of non-commercial biomass (<2%); and uncertainty in historical emission inventories (<2%). The overall uncertainty range can be reduced by about 10% through simple, technical clarifications of how renewable energy is accounted for in NDCs or which historical emission inventory is used. Remaining uncertainties depend to a large extent on political choices about how NDCs are expressed. This allows socioeconomic developments to have an important influence on the emissions outcome. For example, as it is uncertain how the economy will develop up to 2030, uncertainties appear mostly irreducible when actions are expressed as intensity improvements. Uncertainty due to the conditions attached to particular NDC actions can be reduced by improving the clarity of whether and when conditions are met and providing greater clarity about the future availability of funding and other types of support by developed countries. The wide range of irreducible uncertainties highlights that a thorough and robust process that keeps track of emissions trajectories is of utmost importance.

(c) Mr. Volker Krey, IIASA, presented an overview of new work on **climate and development linkages from the CD-LINKS project**.[82] CD-LINKS brings together a consortium of nineteen leading research organizations from around the globe to maximize synergies and explore national and global climate transformation strategies and their linkages to a range of SDGs. Based on an analysis of the NDCs and pathways to achieve the 1.5 and 2°C targets, the project assesses implications for achieving the SDGs and analyzes how more stringent climate action could foster a transformation with positive feedbacks with regards to the SDGs. The current analysis, that **aims to inform the 2018 facilitative dialogue** under the Paris Agreement, indicates that:

(i) Climate change mitigation generates significant synergies with air quality improvements, thus reducing negative health impacts of air pollution (SDG 3);

(ii) Inclusive development and climate policies are key to reduce risk of hunger for simultaneous achievement of SDG 2 (Zero Hunger) and SDG 13 (Climate Action);

(iii) Options are available to pursue stringent climate mitigation without increasing water demand (SDG 6), e.g. through water-efficient cooling technologies or structural change in power generation, or by reducing energy demand;

(iv) Inclusive policies which combine target emission reductions while also supporting low income households, allow stringent climate protection without deteriorating access to clean energy services (SDG 7).

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[80] http://unfccc.int/files/adaptation/application/pdf/2.10_iiasa_rogelj.pdf.

[81] Rogelj, J., A. Fricko, M. Meinshausen, V. Krey, J.J.J. Zilliacus & K. Riahi (2017). "Understanding the origin of Paris Agreement emission uncertainties", Nature Communications.

[82] http://unfccc.int/files/adaptation/application/pdf/2.11_iiasa_krey_cd-links.pdf.

(d) Mr. Tommi Ekholm, VTT Technical Research Centre of Finland, presented on **mitigation strategy under uncertainty and learning on climate sensitivity and damages**.[83] Cost-benefit analyses on climate change mitigation have faced considerable difficulties, particularly due to uncertainties in climate sensitivity, valuation of climatic impacts and future mitigation costs, and also the inconclusiveness on how future costs and benefits should be discounted. This research maps optimal emission pathways under a wide range of plausible assumptions on these uncertain factors under a cost-benefit framework. With most of the calculated cases, the optimal emission pathways fall between corresponding 1.5°C and 2°C pathways. Emissions above the 2°C pathway are supported only if future mitigation is deemed to be expensive and discount rate is above 3%; while aiming below the 1.5°C pathway would be optimal with low mitigation costs and 1% discount rate. The results suggest that the **1.5–2°C target range of the Paris Agreement provides a robust policy guidance for the next decades'** mitigation action under a wide range of plausible parameter choices. The range of optimal emissions by 2030 is very wide: from 23 to 53 Gt CO2-eq, with a median at 40 Gt CO2-eq. This range implies a notable emission gap relative to Parties' current NDC targets.

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[83] http://unfccc.int/files/adaptation/application/pdf/2.14_vtt_ekholm.pdf.