GCOS Joint Panels Meeting Report

Marrakesh, Morocco, 18-22 March 2019

24th Session of the Atmospheric Observation Panel for Climate (AOPC-24)

22nd Session of the Ocean Observations Panel for Physics and Climate (OOPC-22)

21st Session of the Terrestrial Observation Panel for Climate (TOPC-21)

8th Session of the WCRP Data Advisory Council (WDAC-8)

10th Session of the Joint CEOS-CGMS Working Group on Climate (WGClimate-10)

GCOS-228 WCRP-10 GOOS-235

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Background Information on the Reason for a Joint Panels Meeting

At the 25th session of the GCOS Steering Committee in October 2017, in Hangzhou, China, one of the dominant discussion items was that the panels should not work separately and that cross links between panels are increasingly important, for instance around the topics of coastal zones (OOPC and TOPC), ocean heat fluxes (OOPC, AOPC), GCOS Surface reference network (AOPC, TOPC), and Essential Climate Variables (ECV) requirements and review.

Key activities planned for 2018 from that session included inter alia, providing expertise with respect to cross-panel activities and cross-calibration issues, complementing ECV product requirements, and identifying observation requirements for adaptation needs.

Consequently, the GCOS secretariat proposed to all GCOS panel chairpersons to discuss at their upcoming meetings in the first quarter of 2018 an "all panel" meeting in March 2019 as a possible mechanism. This joint meeting should be focusing on panel work plans until 2023 including a possible conference on climate observations, the update of the 2015 Status Report and of the 2016 Implementation Plan, activities to support climate services and improving monitoring of the Earth cycles (Energy, Water, Carbon); observations in support of adaptation; and interface issues, such as air sea fluxes and land-ocean fluxes. The underlying overall aim of this joint meeting should be to agree on consistent approaches to panel activities including review of ECV requirements, monitoring how well ECVs are being observed and reviewing implementation plan actions, and to start inter-panel discussions on cross-cutting issues. Chairpersons and members of the AOPC, TOPC and OOPC, were favourable to this idea.

In addition, the need for looking into more economic ways to meet, fostered the idea of "all" meeting only "once". As the decision to have all GCOS panels meeting together had been communicated to internal WMO line management and to WCRP and space agency partners, eventually, WCRP WDAC and the WGClimate decided to join and to meet in parallel in 2019.

The 26th session of the GCOS Steering Committee in October 2018, in Helsinki, Finland, further discussed how to best organize the GCOS Joint Panels Meeting in collaboration with WCRP and WGClimate, and to address the important issues of interest to GCOS. The Steering Committee recommended, that the GCOS Joint Panels Meeting should be framed around the GCOS draft strategy and should serve as a platform for the panels to work together on scientific and on cross-panel topics.

The GCOS panel chairpersons together worked on an agenda, convened experts and discussed how to include the multidisciplinary climate issues. In the months preceding the GCOS Joint Panel Meeting, the chairs of the respective groups (AOPC, TOPC, OOPC, WDAC and WG Climate), together with the GCOS and WCRP Secretariat, held several video and teleconferences to finalize the draft agenda.

Marrakesh, Morocco had been chosen based on the fact that this has been the venue of the UNFCCC Climate Conference in 2016, that it provided options for meeting at a venue guided by a "green" policy, and that it represented a region in dire need to adapt to a changing climate and an opportunity for GCOS regional outreach. The meeting venue had been chosen through the WMO procurement process, and the meeting form had been formally approved by WMO.

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A. JOINT SESSIONS

1. Opening

1.1 Welcome

Speakers: Carolin Richter, Director Global Climate Observing System; Omar Chafki, Director of National Meteorology of Morocco

More than 80 experts (Annex 2: List of Participants) from the Global Climate Observing System (GCOS), the World Climate Research Programme (WCRP) and the space agencies came together in a series of interlinked meetings from 18 to 22 March 2019, at the Es Saadi Hotel Resort, in Marrakesh, Morocco. The overall aim was to achieve a common understanding of the needs of stakeholders for climate observations and of how GCOS and WCRP should achieve their strategic goals.

The Director of the GCOS Secretariat, Carolin Richter, welcomed all participants to the first-ever meeting of all three GCOS panels together, organised in partnership with WCRP and its Data Advisory Council (WDAC) and the joint Working Group on Climate (WGClimate) of the Committee of Earth Observation Satellites and the Coordination Group for Meteorological Satellites, CEOS and CGMS.

She referred to the dedicated web page for this joint panels meeting[1] which holds supporting documents, presentations, posters on exhibition at the back of the conference room. The site also holds the agenda for the joint panels meeting (Annex 1: Agenda), as well as the agendas for the three individual GCOS/WCRP panels Atmospheric Observation Panel for Climate (AOPC), Terrestrial Observation Panel for Climate (TOPC), Ocean Observations Panel for Physics and Climate (OOPC), and for WDAC and for WGClimate. During the week, at different times the three panels (AOPC, OOPC, TOPC) met individually, as a group of all three panels together, and as a single meeting with both the WDAC and WGClimate.

The first day was held in plenary and focussed on the need to know where observations contribute to the key areas of the IPCC special reports and IPCC 6th assessment report and its relevant chapters, and to identify the knowledge gaps. The first session was complemented by the view of the UN Framework Convention on Climate Change (UNFCCC) secretariat on how Earth observations could support the UNFCCC and the Paris Agreement, and a presentation about observational needs for the national Greenhouse Gas inventories. The next two days were spent discussing how climate observations could be enhanced and continued into the future in order comprehensively to monitor the Earth's water and carbon cycles, the global energy budget and how best to address changes in biodiversity and ecosystems, which for better understanding was later introduced as a fourth "life" cycle. The experts focussed also on specific cross-cutting concerns of the GCOS panels, for example, air-sea-fluxes, coastal land-ocean fluxes and extreme events. The last two days were dedicated to the individual GCOS panel meetings (Annex B-AOPC,C-OOPC, Annex D-TOPC reports). The WGClimate started its individual meeting already in the afternoon of the second day, but assigned some of its experts to stay in the plenary session to contribute to the discussions on the Earth cycles. To complete the suite of meetings, WDAC began its session in the morning of the third day.

After some short remarks on the logistical arrangements, Carolin Richter invited the representative of the Moroccan Meteorological Service, Said El Khatri, Director of the National Climate Centre, to deliver his welcoming remarks, on behalf of the Director of the Moroccan

[1] https://gcos.wmo.int/en/gcos-joint-panels-meeting

Meteorological Service (DMN), Omar Chafki, who sent his regrets due an unforeseen mission to Geneva:

"Ladies and Gentlemen, it is a real honour and a great pleasure to address you today for the opening of the Joint Expert Working Group Meeting of the Global Climate Observing System.

I congratulate you for having chosen the city of Marrakesh as your meeting venue, the ochre imperial city is famous for its pleasant climate, its beautiful landscapes, the hospitality of the Marrakesh is but also deemed to have hosted two COPs[2]: the COP 7 in 2001 and COP 22 in 2016.

Ladies and Gentlemen, I would like to commend your efforts in terms of regular assessment of global climate observations state on the atmosphere, land and oceans and also in terms of guidance for improvement. No one can deny the crucial importance of this component in observing climate change, leading scientific research and also providing climate services for different socio-economic sectors.

In this regard, I would like to point out that the DMN is ensuring the maintaining and strengthening of its terrestrial weather observation network composed of 44 synoptic stations, 156 automatic stations, 5 marine stations, 7 meteorological radars and 8 lightning sensors. The management of this network is being performed according to the quality standards which require the availability, the control, the transmission, the safeguarding and the exploitation of meteorological data.

The DMN provides users with climate information both in raw format and appraised value-added format. At the national level, the DMN is considered as a key partner in several climate-related scientific research projects thanks to its expertise and know-how in the field.

At the regional level, we are sparing no effort to succeed in multi-stakeholder actions: I quote, without being exhaustive, that the DMN is the coordinator of the RCC-NA and hosts its web platform. It is also a member of the regional expert group of EUMETSAT and WMO, in charge of the development and use of satellite products in Africa. In the same vein, the DMN is a virtual laboratory of EUMETSAT for training on the use of satellite products in meteorology (via Casablanca). Moreover, bilateral relations are established between the DMN and other NMHs in order to share and exchange expertise, particularly with regard to climate observation systems.

At the international level, I would like to emphasize that the DMN is a Global Information System Center (GISC) that plays an important role in the dissemination of weather and climate information.

On the other hand, the DMN participates actively, through its experts, in various commissions belonging to WMO, IPCC and other organizations interested in climate themes.

In short, it is a work energy whose main objective is the improvement of climate and weather services from local to global scales.

Finally, I wish you every success in your work and welcome to your second country: Morocco."

1.2 Introduction – GCOS

Speaker: Stephen Briggs, GCOS Steering Committee Chair

On behalf of the GCOS Steering Committee, the Chairperson, Stephen Briggs, welcomed all members and invited experts of these five important groups and emphasised the importance of this joint panels meeting as the first of its kind, bringing together all elements of climate

[2] Conference of the Parties to UNFCCC

information delivery. He expected from this meeting, that the groups could help consolidate user needs for observations in support of modelling, prediction and adaptation and mitigation to support climate change and sustainable development, the requirements of the UNFCCC and other multilateral environmental agreements.

1.3 Introduction – WMO

Speaker: Pavel Kabat, WMO Chief Scientist

The Chief Scientist and Director of Research of the World Meteorological Organization (WMO), Pavel Kabat, welcomed the participants and pointed out that GCOS and WCRP are both WMO-led co-sponsored programmes, and fundamental players in climate monitoring and Earth system science. From his perspective, the GCOS programme is providing data to three customers: climate science, climate system monitoring and monitoring of adaptation and mitigation. He considered in particular climate science as a key future customer. Regarding climate system monitoring, he found that it is of great importance that research and observations related to land and to oceans collaborate.

He also informed the meeting about the current plans for a major reform at WMO. Instead of the former eight technical commissions, there will be a proposal to the upcoming WMO Congress in June 2019 to establish only two technical commissions; one on infrastructure, i.e., observations, networks and information systems, and the second one on services, i.e., forecasts, warnings, marine, and aeronautical meteorological applications, etc. These two new commissions will be complemented by a science board which will bring a strengthened focus on seamless Earth system sciences to support weather, climate, water and the societal aspects of all three topics. The Chief Scientist was confident that the GCOS programme should be an important player within this new structure.

Pavel Kabat informed about the UN Climate Summit[3] , which will take place on 23 September 2019, in New York. WMO Secretary-General Petteri Taalas chairs the Climate Science Advisory Group of the UN Climate Summit and is a member of the Summit Steering Committee, chaired by UN Deputy Secretary-General Amina Mohammed. WMO Secretary-General is also a member of the Core Climate Group of principals advising the UN Secretary-General and UN Deputy Secretary-General. The Chief Scientist motivated the experts present to keep in mind during their discussions the five major improvements for each of the observation domains, the WMO Secretary-General could bring to the Climate Summit.

2. Climate Monitoring & adaptation success in Morocco

Speaker: Said El Khatri, Director of the Meteorological Service Morocco

Presentation link

Morocco has an observational network of 44 synoptic stations, 156 automatic weather stations, 5 marine stations, 7 atmospheric stations, 7 weather radar and 3 agro-meteorological stations, which are concentrated in north and central parts of the country. Many of these stations have been operating for a long time with two qualifying as WMO Centennial Stations and 20 stations have more than 50 years of records. However, many of these records are on paper.

Morocco creates gridded climate data, preparing spatial data for climate parameters, such as precipitation and temperature, for regions at various spatial and temporal scales. They use agricultural maps as spatial masks to provide specific information. They also produce snow

[3] https://www.un.org/en/climatechange/un-climate-summit-2019.shtml

maps, a drought index showing 33% of precipitation compared to normal, and also a range of indices of extremes.

Generally, there has been a decrease of convective precipitation in south, in north a general decrease, and a temperature increase in many regions

3. IPCC Reports

3.1 Knowledge gaps related to observation systems

Speaker: Peter Thorne, CLA Chapter 2, WGI, AR6

Presentation link

The presentation stressed the importance of observations for the IPCC assessments. It is important to have:

- Long term datasets of key indicators;
- Globally comprehensive datasets;
- Physical consistency of products across ECVs;
- Regional detail;
- Information on extremes as well as mean state change.

The 6th Assessment Report of the IPCC (AR6) can only use data submitted for publication before 31 December 2019.

One issue that needs to be clarified is the use of global mean surface temperature (global average of near-surface air temperatures over land and sea-ice, and sea surface temperatures over ice-free ocean regions) and the global mean surface air temperature (global average of near-surface air temperatures over land and oceans).

Understanding the carbon and water cycles and energy requires all components to be adequately sampled. Even the smaller components (e.g. sparsity of borehole temperature measurements) are an issue for energy budget closure.

Many observations are not exploited because, they are:

- in hard copy or image format only;
- not shared owing to intellectual property rights restrictions;
- in arcane formats.

3.2 Observational gaps in the ocean and cryosphere

Speaker: Michael P. Meredith, British Antarctic Survey, Cambridge, UK; Scottish Association from Marine Science, Oban, UK, CLA Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC)

Presentation link

The oceans connect all regions of the Earth. Ocean circulation is (comparatively) well measured at the surface and arguably at 1000m depth, plus some key chokepoints (RAPID, SAMOC, etc.). However, the polar regions (and also boundary currents) are under sampled. Coverage is especially poor in seasonally and perennially ice-covered regions, although these are some of the key areas (e.g. for deep ocean ventilation).

While there are various techniques available or being developed to address these gaps, the key issue is making these observations sustainable.

3.3 Knowledge gaps in climate change and land

Speaker: María José Sanz Sánchez, Scientific Director of the Basque Centre for Climate Change (BC3), Bilbao, Spain, CLA 2019 Refinement of the 2006 IPCC Guidelines for GHG Inventories

Presentation link

Land can contribute to mitigation, and many future pathways largely rely on these sinks. However, these sinks are very vulnerable to climate change impacts and adaptation is therefore key. The IPCC is producing refined guidelines for estimating greenhouse gas emissions.

Forests are vulnerable to climate change. The impacts of disturbances are increasing (i.e. diseases and pests, fires, windthrows, unexplained decays, etc.), and their effects on carbon dynamics, are generally poorly monitored and therefore ignored in modelling analyses and mitigation scenarios.

Earth observation therefore becomes critical for:

- Monitoring the natural variability of ecosystems and their response to climate change and human management, understanding the processes behind;
- Establishing early warning systems for disturbance and damage early detection and assessment;
- Establishing relations between the above and the land planning and practices to address climate change (Adaptation and Mitigation) and the provision of other services.

3.4 Climate extremes: knowledge gaps and observational uncertainties

Speaker: Wafae Badi, Moroccan Meteorological Service, LA Chapter 11, Extremes, AR6

Presentation link

Many of the critical impacts of climate changes are due to extreme events, heat waves, heavy precipitation, drought etc.

Observational data has many sources of uncertainty from transcription errors to changes in the location of monitoring stations. Preparing the data to be used can introduce additional errors: insufficient monitoring sites can lead to errors in mapped data sets – decreasing the spatial resolution of these products decreases their error but also decreases their ability to detect extreme events that vary across short distances.

Many of the datasets available have large errors in parts of Africa, South America and the tropics.

4. Earth observations in support of the UNFCCC and its Paris Agreement

Speaker: Joanna Post, UNFCCC Secretariat

Presentation link

GCOS, the IPCC and the space agencies through the joint CEOS/CGMS WGClimate have a long history of supporting the UNFCCC, starting for GCOS in 1992.

The Paris Agreement brought a new paradigm for the science community and with it the emphasis for "science driving policy" and "policy driving science". The Paris Agreement is

based around an Ambition Cycle: Parties identify their contributions through Nationally determined contributions (NDCs) and National Adaptation Communications, actions (including on mitigation and adaptation) will be reported through the Enhanced Transparency Framework, and assessed in the Global Stocktake (GST) every five years, leading to increased ambition, based on the best available science

The first global stocktake will be in 2023. The first Enhanced Transparency reports will be submitted in 2024, so the enhanced transparency reports will not be available for the first GST.

The global stocktake is mandated to use a range of sources of input and will have 3 phases: information collection and preparation, technical assessment, and consideration of outputs (Decision 19/CMA.1).

Observations of ECVs can, among other things:

- Provide information on GHG concentrations to support countries in measuring progress on mitigation measures (Paris Agreement Article 4);
- Assist countries in planning and tracking adaptation (Paris Agreement Article 7);
- Assist countries through support on loss and damage information (Paris Agreement Article 8);
- Support the global stocktake (Article 14) including through providing:
    - Information on GHG concentrations, global warming, vital signs / climate indicators, ecosystems
    - Consistency in base lines / methodologies;
    - Assessment of progress towards the long-term goals.

Earth observations, satellite and in situ, are fundamental for decision making on mitigation and adaptation and for ensuring the success of the Paris Agreement.

5. Observational needs for the national inventories

Speaker: Simon Eggleston, GCOS Secretariat, IPCC Task Force on inventories

Presentation link

Countries have to report their greenhouse gas emissions to the UNFCCC with differing requirements: annex A parties (essentially developed countries) have to report annually, other countries have less strict requirements.

In reporting these emissions and removals countries must follow the IPCC Guidelines for National Greenhouse Gas Emission Inventories (2006) which are currently being refined.

It is important to note that the inventories have clearly defined boundaries, particular the definition of anthropogenic emissions and removal: the estimates do not aim to estimate all emissions and removals in a country but reflect those that a country can influence.

The inventories are based on data about activities in a country, from census and survey data, tax information, traffic counts to industrial production and most importantly fuel use. Earth observations are important to measure changes in land use. Measurement programmes measure emission and removal rates for relevant activities and processes so that the national emissions and removals can be estimated.

A very important part of any inventory are the processes and system put into place to ensure and check inventory quality through suitable QA/QC, review and appropriate choice of methods.

6. Panel Discussion

Moderator: GCOS SC Chairman; Panel: Chairs AOPC, OOPC, TOPC, WDAC, WGClimate, WMO Chief Scientist, Director GCOS, GOOS Co-Chair

The panel reflected on the presentations about the IPCC and UNFCCC needs (sections 3, 4 and 5 above) and identified the following issues that need to be addressed in the upcoming revisions to the GCOS Status Report and Implementation Plan:

- Quality, traceability and consistency of observations.
  - Traceability is increasingly important, both for the observations themselves and for derived information. It is important to ensure high quality observations for climate change detection, projection and services.
  - Observations of different ECV need to be consistent with each other. For some observations, consistency is a long way away: GCOS should be voice demanding consistency.
  - In situ and satellite observations should be complementary: they support each other. Need a platform to bring observations together and bridge between satellites (e.g. optical and radar) and in situ.
  - The terrestrial area is complex and least organised – a organizing agency is needed.
  - There needs to be a unified approach to uncertainty based on international standards.
- Sustainable Observing Systems
  - Sustained observing systems are needed to ensure long-term climate records and support climate change detection. Funding should support observations, data archiving and distribution.
  - In particular, sustained funding is needed for reference networks.
  - The scientific basis of some observations (e.g. oceans) poses difficulties through staff turnover, limited period funding etc. so global climate observations need to move away from science-based observations. These observations are not just to meet a scientific need; operational observing systems are needed for the long-term.
- Open Data
  - Open data access is important, especially for the UNFCCC. The Paris Agreement implies that net emissions go to zero by 2050 so observations in the future should support that ambition. Open data are also needed for climate services and to meet the demands of Small Island Developing States (SIDS) and (Least Developed Countries), LDCs.
  - There is a need to develop organised access to the large number of datasets. This is already being done by COPERNICUS (organizing data and its QA/QC for Europe) and the ECV Inventory for satellite data.
  - Free and open data is also needed for services. GCOS may need to distinguish between the downstream data that may be more commercial and the core datasets with open access.

- Improvements
  - GCOS needs to ensure that in improving the observing system, it considers the needs of UNFCCC parties, and the views of WCRP and its panels and working groups. As GCOS is used by space agencies for developing plans for climate monitoring it needs to be as complete as possible, with requirements clearly traceable to specific needs. GCOS needs to think how the requirements should evolve, remembering the long times satellites need to be implemented (i.e. what do we need in 2040?).
  - Links across the GCOS panels need to be improved.
  - GCOS needs to serve the Earth System modelling approach that is increasingly being adopted.

The Chair of the GCOS Steering Committee, Stephen Briggs, summarised that three overarching topics arose from the presentations and discussions, in addition to individual gaps and developments: Traceability, Sustainability and Open Access. A Conference on Observations for Climate was proposed to review the state of the art of observations, addressing these topics, in advance of the revisions to the GCOS Status Report and Implementation Plan. This would be held in partnership between GCOS, GOOS, Copernicus and the joint CEOS/CGMS WGClimate.

N°	Action	Responsibility	Deadline
G1	**GCOS Climate Observation Conference** Plan a GCOS Climate Observation Conference, present plan to Steering Committee.	GCOS Secretariat to prepare plan with ideas from GCOS Panels; All to consider and propose support for such a conference	Initial report on progress for Steering Committee in 2019 Conference in 2021
G2	**Traceability, Sustainability and Open Data** Consider Traceability, Sustainability and Open Data and ensure these are addressed in upcoming updates to the Status Report and Implementation Plan, considering WMO, IOC and UNFCCC regulations and decisions.	Panel Members to ensure these are considered in updates to the Status Report and Implementation Plan; Steering Committee to ensure cross-GCOS consistency in addressing these issues	Update of GCOS Implementation Plan in 2022

7. Earth System Cycles

7.1 Introduction to GCOS IP and WCRP targets for Earth System cycles

Speakers: Carolin Richter, GCOS Director; Pavel Kabat, WMO Chief Scientist

Presentation Richter; Presentation Kabat

Carolin Richter recalled that the GCOS Implementation Plan (IP) is presenting four targets for overall closing of the cycles and budgets based on observations. These targets may not be met immediately, but they provide an assessment of how good the overall observations should be and should lead to improvements in individual ECV observations. These targets will eventually be met by achieving the individual ECV requirements. Break-out groups in the afternoon of

the second day, are supposed to discuss how well the observations meet the targets (Box 4,5,6,7, pp. 37-38, GCOS IP), and whether the ocean, atmosphere and terrestrial requirements are consistent to meet the targets. The leaders of the break-out groups were for;

Water: Stephan Dietrich

Energy: Karina von Schuckmann

Carbon: Han Dolman

Biosphere: Nadine Gobron

Pavel Kabat gave an overview of the state of the global climate and the role of WMO. In particular, he stressed the role of WMO in climate research since the GARP (Global Atmospheric Research Programme) established by WMO in 1967, and the instigation of WCRP in 1985. He also preferred to take a holistic view of the Earth System when it comes to climate, and noted that today there are new tools in the toolbox: i.e., seamless prediction across timescales. The Earth cycles going to be discussed by the GCOS experts cannot be closed without WCRP initiatives like the Global Energy and Water Exchange (GEWEX) project and careful data analyses and reanalyses. Pavel closed in pointing to one of the recommendations coming out of the WCRP review which commends that WCRP should seek to develop strategic and strong partnerships with other WMO research programmes (specifically WWRP and the Global Atmosphere Watch), with GCOS, and with Future Earth. WCRP and GCOS are equally important in the discussions on closing the Earth cycles.

7.2 Carbon

Speaker: Han Dolman

Scoping paper

Presentation link

Breakout group results

Global temperatures are steadily increasing driven, primarily, by emissions of carbon dioxide which are projected to increase by 2.8% between 2017 and 2018. The IPCC's 1.5C report highlights the urgency to reduce these emissions to a net zero (emissions – removals) by 2045-2055. The fossil fuel emissions overlie and interact with highly dynamic natural carbon cycle that itself is sensitive to climate. The carbon sinks have continued to grow with increasing emissions, but climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO_2 in the atmosphere. From measurements and model results, there remains a large and unexplained variability in the global carbon balance caused by uncertainty and understanding hinder independent verification of reported CO_2 emissions of about 0.5 Gt/year. Errors in the land and ocean sinks are likely to be the main cause for this budget imbalance. Lateral transport between land, ocean and atmosphere likely has implications for estimates of the land budget. In the oceans, the global circulation is important.

New satellites (GOSAT, OCO-2) and new in situ infrastructure combined with an interest by emission inventory agencies in using concentration measurements to check emission estimates will lead to improved observations of the carbon cycle.

Discussion

The discussions in the breakout group identified two reasons to observe the carbon cycle: diagnostic –to monitor how well/badly we are doing and prognostic – understand and predict how the cycle will change.

There are large gaps in ocean observations with poor spatial and temporal resolution of stocks and fluxes. Other parameters are needed to drive models such as surface properties and a good transport model to link fluxes and stocks. More regional understanding is needed.

There is poor information about carbon stocks: almost none on soil carbon. We do not understand very well how these soil carbon stocks will change. Such changes have been estimated but difficult validate with a reliance on models. While it is difficult to validate a flux, the summation of instantaneous fluxes should equal stock changes. For oceans – the measured pCO_2 at the surface is difficult to relate to carbon stocks. In the oceans, stock changes stock changes rather than stocks themselves. The riverine flux of carbon into the oceans is large and uncertain. As the dynamics of carbon cycle are not well understood, fluxes into the atmosphere to alone are not enough to improve projections.

Measurements need to be more accurate with a higher resolution to monitor changes. In the future isotopes of Carbon will be important but this is still a research activity rather than operational observation. GCOS should recommend and promote novel techniques to cover gaps e.g. aircraft/ocean measurements of CO_2 and CH_4 to cover gaps in the satellite observations. Other areas for improvement are particulate carbon and fluxes in the Oceans, biosphere fluxes on land and in the oceans, impact of UV radiation and the CH_4 sink mechanism.

Observational issues GCOS should address include collection of river discharge of carbon (to understand how this change with climate change); revised atmospheric CO2 composition requirements; consider if terrestrial CO_2 Flux measurements (e.g. FLUXNET) should become an ECV in the future; and ocean dissolved organic carbon which can now be measured.

Following the breakout group discussion, the issues arising will be discussed by the panels separately (see below):

- AOPC – revisions to atmospheric composition requirements;
- OOPC – measurements need to improve understanding of carbon uptake and stocks;
- TOPC – River discharge – water volume and carbon content; soil carbon.

RECOMMENDATION 1: It is recommended that WCRP considers the regional and temporal resolutions needed to improve the understanding of the carbon cycle. WCRP should also look at how information about carbon isotopes can be used and what is needed to improve monitoring of the carbon cycle.

7.3 Water

Speaker: Stephan Dietrich

Scoping paper

Presentation link

Breakout group results

Closing the global water cycle within 5% on annual timescales is one target of GCOS' Implementation Plan. In order to take stock on this task and assess in general the current capabilities of the observing system for water and identify gaps, experts from different communities and domains working on the Earth's water cycle prepared a scoping document for this session. The results were presented by Stephan Dietrich, who coordinated the paper and led the discussion during the breakout session.

It was highlighted that global climate change puts a particular pressure on water resources whilst the Earth's population is increasing strongly. Therefore it is important to understand the impacts of climate change on the water cycle better. This implies an integrated approach since water fluxes across all domains. Processes like evaporation, transport of water vapour, precipitation, storage on land as well as river and groundwater discharge to the ocean need to be addressed from different perspectives to understand the water cycle. In general, scientists expect an increase of 2-3% of precipitation per degree warming. The increase of evapotranspiration excels this rate on a global average which will lead to general changes of precipitation-evaporation patterns and intensify inequalities in the global water supply. This is, however, related to large uncertainties, both in observations and model projections on a global level and regionally even more. In general the observed residuals are smaller than the expected errors, which are currently estimated to be smaller than 10% of the water budgets (Residual being forced towards zero; land: 7.2%, ocean: 7.8%%, atmosphere: 7.5%).

In order to improve the understanding and close the budget as envisaged, data availability of all relevant ECVs is key. The Global Terrestrial Network-Hydrology (GTN-H) provides a framework for operational data centres that collect and provide data for the water cycle. These data centres cover already most of the relevant ECVs but some like surface water vapour are still missing. However, even crucial ECVs like precipitation, which is covered by the Global Precipitation Climatology Centre (GPCC), have limitations in time and space and issues with spatial representativeness of point measurements in many regions of the world. Other constraints include scaling issues between observations and models, uncertainties in variable estimates from satellite retrievals and numerical modelling and even basic definitions for extremes are not uniformly defined.

A couple of next steps were proposed in the paper to advance the observation system for precipitation, snow water equivalent, ground water, river discharge, snow and ice inventories, sea surface salinity as well as water use.

Discussion

Participants from all three GCOS panels attended the discussion, which focussed on observations of precipitation of oceans and water fluxes between domains in general.

Several measurements like lightning and sea surface salinity were suggested as proxy measurements to quantify precipitation over oceans better, but currently the products seem not to be mature or exact enough. In addition, several satellite measurements can contribute, e.g. several Space Agencies are now implementing lightning mappers on their meteorological satellites and the group welcomed the ESA initiative to include ocean salinity missions in the Copernicus framework to make them sustained. It was also noted that currently no reference network covers precipitation over the ocean which hinders calibration and validation of satellite products.

More general, the participants identified the relevant fluxes between domains on which the panels need to collaborate:

Atmosphere-Land:

- Evapotranspiration
- Root zone moisture measurements important for ET, currently gap
- Groundwater Recharge

Atmosphere-Ocean:

- Over oceans measurements for rainfall

- Measurements of evaporation requires innovation

Land-Ocean:

- Ice-Sheets
- Groundwater inflow

Atmosphere- Ocean-land:

- Sea level measurements can contribute to solve other water related questions (global, annual to decadal timescale)

As next steps, the participants agreed to work further on the paper and try to submit it before end 2019 so it might go into the AR6. An open question is, if data availability should be covered as well by the paper.

N°	Action	Responsibility	Deadline
G3	**Water Cycle** Continue work on scoping paper with goal of publication.	Stephan Dietrich as lead and other authors to contribute, GCOS secretariat to facilitate	December 2019

7.4 Energy

Speaker: Karina von Schuckmann

Scoping paper

Presentation link

Breakout group results

In preparation for this discussion, a scoping document was made available to the meeting. This document, proposed approaching the observational targets for the Earth's energy budget through two topics: the top-of the atmosphere Earth's Energy Imbalance (EEI) and the surface energy budget. Following this approach, the discussion started by formulating the two main questions:

Question 1. What is the accuracy needed to measure the earth surface budget and the EEI (both of which are approximately equal to changes in the total ocean heat storage)?

Question 2. What are the implications of changes in storage or fluxes: do small changes have big implications?

In the GCOS IP, the target for closing the energy budget is 0.1 W/m2 on annual timescales. This target is reasonable as it enables us to resolve the radiation forcing. However, further investigation will be required in order to establish if more detailed spacial and temporal requirements are needed for assessing the total-energy budget, given the importance of flows of energy within the Earth's systems.

The energy budget cannot be closed within this target (0.1 W/m2 on annual timescales) by observations of energy fluxes alone and techniques such as optimisation and reanalysis are needed to improve the accuracy and reduce the uncertainty. Approaches such as Numerical Weather Prediction model and reanalysis can also help identify the observational requirements needed to meet this target. Therefore, it is suggested that the Ocean Reanalysis Intercomparison Project (ORA-IP) is continued and includes the atmospheric interactions.

The main ECVs needed to be observed for the EEI and the surface energy budget are the earth radiation budget and subsurface ocean temperature. Other significant ECV from the atmosphere, cryosphere and land, still need to be identified.

An OOPC task team on air-sea flux is already working on defining the observational requirements based on the practicality of remotely sensed observations together with in-situ observations for calibration and measurements. A summary of their meeting and proposed actions can be found in section 9.1 of this report.

It was also noted that an earth system approach should be adopted as other climate cycles are also intimately linked to the energy balance.

From the discussion and its conclusions, it appears that the scientific understanding of the processes involved is too immature to be able to formulate requirements for the observing system, see Question 1 above. It was also not possible to address Question 2: impacts of changes in energy storage and fluxes. This implies that work by WCRP is necessary to first assess how to capture these processes and what is the required accuracy. Then GCOS can consider the practicality to improve observations. This should be followed by a gap analysis to assess what is currently available in terms of observations which will then permit GCOS to establish where and how the observations can be improved and also the feasibility of reaching the target.

It is suggested that:

1) WCRP should be asked how to capture these processes observationally and what is the required accuracy of these observations to close the Energy balance sufficiently to resolve the radiative forcing;

2) Following this, a task team should be formed that will develop practical requirements and actions that would lead to the implementation of such a system, listing the observations and the requirements (e.g., vertical profile of humidity and temperatures with minimum required vertical resolution and uncertainty);

3) This will then be analysed by the GCOS panels with the involvement of the broader community, and recommendations on the development of the observing system will be formulated for a future update of the GCOS Implementation Plan.

The following specific recommendations were agreed as part of an integrated way forward:

RECOMMENDATION 2: Ask WCRP to work with modelling and observational communities to establish a scientific basis for improving observations, (i.e. how to capture the Earth's energy balance observationally and what is the required accuracy of these observations to close the Energy balance sufficiently to resolve the radiative forcing), including:

- **Provide contribution of surface flux work as done under OceanObs / GCOS.**
- **Recommend and support that the community should submit a 'proposition of continuation' of CONCEPT-HEAT (Consistency between planetary heat balance and ocean heat storage).**
- **Encourage and support contributions to other scientific papers, for example on the EEI inventory (e.g. added expertise from observations on atmospheric, land and cryosphere storage)**

- **Building on a previous workshop [4], improve links between model and observational communities.**
- **Recommend and support the continuation of ORA-IP. Support related reanalysis inter-comparison projects.**
- **Determine the time-scales needed to understand the global energy balance.**
- **Identify the regional scale that needs to be considered (e.g. including heat re-distribution: transport in the atmosphere and ocean, and regional budgets)**
- **Continue to increase scientific understanding, knowledge and tools through the physical budget constraint approach, and address implications of changes in the energy budget**

When the science is clearer GCOS panels should:

- Help identify and analyse the core ECVs for the atmosphere, land and cryosphere needed for the Earth's energy budget.
- Provide a gap analysis.
- Provide recommendations implementation by observing systems

N°	Action	Responsibility	Deadline
G4	**Energy Cycle** OOPC to consider a workshop on heat and freshwater. GCOS panel members were encouraged to provide input to WCRP activities and to the scoping paper on energy.	GCOS and GOOS Secretariat	June2019

7.5 Biosphere

Speaker: Nadine Gobron

Scoping paper

Presentation link

Breakout group results

The GCOS mandate is to "... ensure data needs are met for climate system modelling, for assessing the impacts of climate change and variability and applications to national economic development, as well as research leading to improved understanding, modelling and prediction of the climate system …". Therefore GCOS needs to consider how the impacts of climate change on the biosphere and its human use can be monitored.

The importance of climate change impacts on the biosphere and its fundamental role in the carbon cycle has long been recognized. The IPCC has reported on terrestrial and oceanic ecosystems since their first assessment report in 1990. The UNFCCC has asked for reporting on emissions and removals of greenhouse gases including changes to terrestrial ecosystems, initially based on the 1996 revised IPCC Guidelines for National Greenhouse Gas Inventories. However, to date, there are no agreed global indicators of changes to the biosphere.

[4] 2018 WCRP workshop: The Earth's Energy Imbalance and its implications (EEI) November 13-16, 2018, Toulouse, France

The group noted that several of the current ECV are relevant for the biosphere. In the ocean, these are Plankton (both phytoplankton and zooplankton) and Marine Habitat Properties (comprising Coral Cover, Mangroves, Seagrasses and Macro Algae). Relevant terrestrial ECVs include: Landcover, Above-ground biomass, Leaf Area Index, Fraction of Absorbed Photosynthetic Active Radiation (FAPAR), Fire Disturbance. The group also noted the Essential Ocean Variables, (EOVs), and the process that led to their development (EOVs have been grouped to form ECVs), and also the Essential Biodiversity Variables, which include Net Primary Production (NPP), etc.

Land and ocean biosphere ECVs currently very different. Ocean ECVs are typically species-based. Land-based ECVs are satellite-based observations of vegetation cover and are more consistent with Essential Biosphere Variables (EBVs).

The group discussion identified 3 potential indicators of change in the biosphere (based on indicators in the 4th Assessment report of IPCC (AR4), and EBVs), which could span ocean and terrestrial systems:

a. Phenology

b. Distribution

c. Productivity

It was noted that terrestrial ECVs generally contain the information needed (e.g. distribution can be derived from Land Cover). The group agreed it was timely for a review of these variables considering, how the existing ECV can be used to derive these indicators, if the ECV products and their requirements are sufficient and if the data can be combined across the land and oceans.

For phenology and distribution, there are good example assessments in the literature, and they are much more easily measured than abundance measures. For terrestrial ecosystems, land cover and other ECV can be used to look at phenology, productivity and distribution changes of plants. For animals, indicator species (such as species of birds) could be used to look at phenology and distribution changes although attribution may be difficult. In the ocean, significant work is also being done looking at distribution and phenology changes.

Relevant data are often captured by community groups. It may mean citizen science projects are needed to gather information into a common format for meta-analysis. However, there are significant issues around coverage, completeness and bias. This would be a great way to engage the broader community in GCOS. Potential funding could be sought from e.g. Future Earth. The changes people see in their environment are more tangible to most also than a temperature graph showing incremental change.

Although the NPP occurs in the surface and near surface layers there are difficulties relating ocean colour (a measure of chlorophyll) to NPP in the oceans,

There are also short-term changes that may need to be monitored such as mass mortalities (e.g. coral reef bleaching, mangrove die off, and insect infestations in forests). These are related to monitoring of heat waves (terrestrial, marine), droughts, floods etc., and their impacts on ecosystems. An understanding of the relationship between these short-term events and their impacts on the biosphere would support adaptation and mitigation and the UNFCCC.

N°	Action	Responsibility	Deadline
G5	**Biodiversity** Organize a joint workshop between terrestrial and ocean researchers on identifying global methods of monitoring productivity, phenology and distribution. Workshop topics and outcomes should include: • Consideration whether biosphere indicators (productivity, phenology and distribution) may in the short-term be better serviced by synthesizing existing data from mixed sources (including citizen science) than new observations. • Determination whether the existing ECVs for marine biosphere need to be reconsidered in light of IPCC AR6 • Consideration of the potential for mining paleodata. • Exploration of interest of Future Earth (Lead: Nic Bax).	GCOS and GOOS Secretariat	March 2020

7.6 Discussion (Agenda Items 7.6 and 7.7)

The discussions as well as the results from the breakout groups are merged with the overall reports from the respective cycles.

N°	Action	Responsibility	Deadline
G6	Convey recommendations related to carbon and energy cycles to WCRP Ask WCRP the questions expressed in the recommendations 1 and 2 regarding observational needs for monitoring the global carbon cycle and the Earth's energy balance Report on progress to the steering committee and panels.	GCOS Chair and secretariat	Dec 2019

8. Preparing for the 2022 GCOS IP update

Speaker: Simon Eggleston

Presentation link

GCOS plans to update the Status Report reviewing the global climate observing system in 2021 and the Implementation Plan in 2022. This is in order to fit the UNFCCC Global Stocktake and ambition cycle. One change will be to ask panels to provide at least 2 values: "threshold" and "goal" similar to WMO OSCAR[5] requirements database. The Threshold is the minimum requirements for useful data and the Goal is the maximum beyond which there is no need to go. Panels can also supply "breakthrough" values as in OSCAR, if they wish and are able. It is difficult to assess where the optimum cost-benefit requirement would lie.

The mandate of GCOS is to "… ensure the data needs are met for climate system monitoring, for assessing the impacts of climate variability and change and applications to national

[5] Observation Systems Capability Analysis and Review Tool (OSCAR)

economic development, as well as research leading to improved understanding, modelling and prediction of the climate system."

The specification of the requirements follows previous GCOS requirements with a few additions to improve clarity. Each requirement should include:

- Definitions
  - Name of ECV;
  - Name of Products: these are the data to be delivered to users: They are what is actually measured or derived from measurements. This can mean directly measured (e.g. permafrost active layer thickness) but can also include derived from measurements (e.g. above ground biomass) models or reanalysis based on observations (e.g. maps of evaporation). These are what is needed by users;
  - Definition: A precise, complete definition of the product;
  - The measurement units in SI units (common units can be given in addition if appropriate).
- Resolution
  - Temporal sampling needed by users. The minimum temporal resolution of the ECV product dataset;
  - Horizontal and vertical resolution needed by users. Minimum horizontal and vertical resolutions of the data set to be provided to users;
  - Timeliness needed by users. The maximum time lag between observations and the data being freely distributed. (An addition since GCOS-200, to account for use of data in models and reanalysis etc. and for reporting the state if the climate system in a timely manner.).
- Uncertainty
  - Required Measurement uncertainty for users. The required measurement Uncertainty includes both random and systematic components. (see "International Vocabulary of Metrology – Basic and General Concepts and Associated Terms" (VIM) of the International Bureau of Weights and Measures (BIPM) and "Guide to the expression of uncertainty in measurement" (GUM) of the Joint Committee for Guides in Metrology (JCGM)). Uncertainty should be expressed in units of 2 standard deviations. Three items are needed: the uncertainty metric, the units and the value itself;
  - Stability for users. The maximum permissible cumulative effect of systematic changes of the measurement system per decade to allow long-term climate records compiled from assorted measurement systems/satellites etc. Uncertainty should be expressed in units of 2 standard deviations. Three items are needed: the metric used to measure change, the units and the value itself.
- References and Notes
  - References and Standards. Any recognized standards and methodological references for the ECV product and uncertainty;
  - Notes. Additional information to explain the choice of requirement. Each number should be explained. May include links to other documents.

N°	Action	Responsibility	Deadline
G7	Update ECV Requirements for 2022 update of the Implementation Plan Ensure the updated ECV requirements are specified as shown above, with a threshold and goal value as a minimum, and all the fields listed above completed.	Panel Members to update requirements; GCOS Secretariat to ensure consistency across all panels	Update of GCOS Implementation Plan in 2022

9. Cross-panel discussions

n.b. Agenda item 9.4, Reports from the Breakout Groups, is included in the individual breakout group reports below.

9.1 Energy Fluxes

Discussion Leaders: Meghan Cronin; Bob Weller; Elizabeth Kent

Rapporteur: Caterina Tassone

Presentation link

Scoping paper

In preparation of the discussion, a scoping document, based on the white paper by Cronin et al., 2019, was made available to the meeting .

Surface fluxes are an essential part of the Earth's energy budget. They are needed to understand the ocean influence on weather and climate and can lead to improved predictions on time scales of hurricanes, El Nino and decadal oscillations, as well as improved climate projections and their impacts.

ECVs related to surface fluxes are distributed across every GCOS panel and include:

- For the atmospheric domain: precipitation, pressure (surface), radiation budget, temperature (surface), water vapour (surface), wind speed and direction (surface), aerosols and cloud properties.
- For the terrestrial domain: albedo, evaporation from land, land surface temperature and soil moisture.
- For the ocean domain: ocean surface heat flux, sea ice, sea state, sea surface currents, sea surface salinity, sea surface currents, sea surface temperature.
- Global estimates of surface energy fluxes are not directly constrained by the direct observations of turbulent fluxes (sensible, latent, stress) nor are the direct turbulent flux measurements assimilated into Numerical Weather Prediction systems or in the reanalysis. Global flux fields are therefore derived from parameterisations based on observations or model estimates of mean state variables using parameterisations. This underlines the importance of process studies to improve the physical parameterization of surface fluxes, including in models.
- Therefore, the elements of an air-surface energy exchange observing system are:
- Direct measurements of fluxes at selected sites, including high-frequency measurements of turbulent fluxes and long and shortwave radiation.

- Collocated measurement of fluxes with state variables, such as SST, air temperature, humidity, wind speed and direction, pressure, waves, currents, clouds, which allow parameterisations to be developed.
- Global observations of the state variables noted above that will allow global flux estimates to be developed from the parametrisations.

Thus, requirements need to be established not only for the fluxes, but also for the state variables used for computing the fluxes with parameterizations, ensuring where possible, the consistency of requirements across ocean, land and ice-covered regions.

The group agreed to choose surface radiation as the focus of a first workshop, with the objective to ensure consistency for the radiation products between ocean and land. The workshop will bring together the Basic Surface Radiation Network (BSRN) and the ocean community and will concentrate on the global, ocean and land-based, radiation network, with the ultimate goal to develop best practice for surface radiation.

The group discussed the timeline on the adequacy of the ECV observations needed to obtain the desired uncertainty for air-sea fluxes. High resolution vertical profile of temperature and humidity are needed but the technology for producing these observations from satellite is still not developed, implying that the products will not be available at least for the next 30 years. It was agreed to ask the AOPC satellite experts to discuss within their community the feasibility of remotely-sensed humidity and temperature profiles, optimized for surface boundary layer (See Section B-2).

Developing and implementing strategies to produce high quality, high resolution global fields of surface state variables and fluxes, requires the engagement of a wide range of specialists and stakeholders, such as the modelling community, air-sea interaction researchers, satellite experts and developers of new technology. Members of this group are asked to liaise with WCRP, BSRN, the Working Group on Numerical Experimentation (WGNE), and the WCRP Working group on Coupled Modelling (WGCM) to ensure adequate collaboration through their work.

A vision paper directed on near-term goals and for the broader community will be coordinated by this group. A proposal for a Scientific Committee on Ocean Research (SCOR) Working Group aimed at organizing and implementing the near-term goals should also be considered.

The team suggested the following recommendations:

AOPC

- AOPC with CGMS and CEOS to report on the feasibility of remotely-sensed humidity & temperature profiles, optimized for surface boundary layer. Elizabeth Kent (AOPC) and Rainer Hollman (AOPC) (see related AOPC Action).

OOPC (see section OOPC)

- Coordinate a vision paper for the broader community, beyond OceanObs19. Meghan Cronin;
- Prepare a proposal for a SCOR Working Group. Meghan Cronin, Elizabeth Kent, Bob Weller.

N°	Action	Responsibility	Deadline
G8	Radiation Workshop Hold a workshop on a global (ocean & land-based) radiation network and develop best practices for surface radiation. Bob Weller (OOPC), Christian Lanconelli (BSRN).	OOPC, AOPC, TOPC and BSRN	Dec 2020
G9	Ocean & land-based flux groups Report on existing WCRP ocean & land-based flux groups such as WDAC, Surflux Task Team, GEWEX, and SOLAS. Caterina Tassone (GCOS) Report on relevant activities by WMO/WGNE & WCRP/WGCM. Matt Palmer (OOPC).	Caterina Tassone (GCOS) Matt Palmer (OOPC)	Next panel meetings

9.2 Coastal Land-Ocean Water Fluxes

Discussion leader: Stephan Dietrich

Rapporteurs: Katy Hill, Simon Eggleston

Presentation link

Background

Around 70% of economic activity globally, including most major cities, is in the coastal zone which is exposed to the changing climate through sea level rise and extreme events.

As global models move to higher and higher resolution and coastal hydrodynamic models for regional management are developed, there is an increased demand for relevant observations. Earth system modelling requires a wide range of ocean, atmosphere, cryosphere, terrestrial and biosphere observations.

The key observation needs identified were Land-ocean fluxes of freshwater; carbon and nutrients; and regional and local sea level rise.

Initially consideration should be given to globally significant issues and the regional information needed to understand them.

Land-ocean fluxes of freshwater, carbon and nutrients.

River flow and runoff have a number of impacts on coastal waters. Freshwater is generally buoyant relative to seawater and has significant impacts on global ocean circulation.

Carbon carried in rivers is a significant part of the carbon cycle that is not currently monitored: there are few data on carbon contents in global data centres (both organic and inorganic carbon).

The transport of nutrients into the oceans impacts coastal productivity, eutrophication, and coastal water quality.

The increased resolution of models allows the coastal zone to be resolved, and this emerging coastal hydrodynamic modelling can be used for management. The group noted the need for

coastal exemplars of where these issues come together and for more validation data to support modelling at finer scales. There are also particular issues in the Arctic.

Mean Sea Level Change

Globally, mean sea level is monitored through satellite-based altimetry combined with a network of tide gauges (GLOSS). However, attributing sea level changes requires a broader range of information, for example, changes in ocean heat content, ice melt, groundwater depletion and water storage on land.

Regional Sea Level Variability and Coastal Impacts.

Impacts of climate variability through coupled climate modes, for example, ENSO and the Indian Ocean Dipole. Variability on shorter timescales such as storms and cyclones with associated storm surges also need to be considered. Local gravitational effects are an emerging area of research. The WCRP Grand Challenge on Sea Level Rise and Coastal Impacts and ESA's CCI regional sea level closure project may provide useful information on observational needs, including on any data gaps. The Grand Challenge will hold a workshop on Coastal Services in November 2019. OOPC representatives will participate to discuss how such efforts can provide feedback on observation requirements.

Coastal infrastructure impacts

The main impact of the oceans on coastal infrastructure is through flooding and storms. The impact is a combination of sea level change, storm surges and river and surface floods. Thus, a combination of data from disparate sources is needed to understand and project coastal infrastructure impacts.

Data Availability

While sea level changes are well monitored globally, through a combination of altimeter and a global network of 300 tide gauges, the observing system does not meet the needs for tracking coastal sea level changes and impacts. Work is underway through the WCRP Grand Challenge on regional sea level rise and coastal impacts as well as the Tide Gauge Network, GLOSS to articulate requirements and refine the global observing network design, recognising there are a broader range of tide gauges installed for a range of applications e.g. local port operations. An assessment of the requirements, network missions and targets for tide gauges is underway, including identification of gaps (including consideration of the upcoming satellite swath altimeter capability).

Much river discharge data is not exchanged despite WMO regulations requiring this. Some of this information is available to researchers in response to specific requests, other data is not. In many cases there are no observations. When there are measurements, often only river discharge is measured not carbon or nutrient concentrations. For large rivers, ocean salinity and colour can be used to estimate discharges. One way to address this lack of observations is through data assimilation and reanalysis, integrating the available river observations, modelled river flows and oceanic data.

High resolution coastal modelling and data assimilation requires coastal wind data. While there are some observations on the coastal zone (e.g. from Metocean moorings coordinated through the Data Buoy Cooperation panel, and High Frequency Radar), this data is not always quality controlled or made available. Scatterometer data is of limited use within 12kms of the coast. Wind and wind stress data in the coastal zone should be made available, and the JCOMM/GOOS Observation Coordination Group is a forum to raise these issues with the relevant observing networks.

Groundwater discharge is a significant source of water and nutrients into the oceans and currently is not monitored beyond a few research activities and it is unlikely this will change in the near future.

Other data that are of interest include ocean circulation, wave height, salinity, precipitation (esp. extremes), glaciers, ice sheets/shelves, permafrost and landcover. Tracking relevant coastal changes could potentially be done through IPCC Landcover classifications. The IPCC classifications should track changes in agricultural land to saltmarsh, reclamation of land, and changes to mangroves (under the IPCC forest category), sea grasses, saltmarshes. Implicitly, but perhaps not explicitly, erosion on the coast is also part of landcover.

Initial steps

Following the breakout group discussion, the issues arising were discussed by the panels separately (see below):

TOPC:

- Encourage free sharing of river gauge data e.g. water volume and quality.
- Groundwater discharge is not available – consider if this can this be addressed?
- Determine if landcover products are suitable for coastal applications (including coastal erosion).

OOPC:

- Work with the JCOMM/GOOS Observations Coordination Group to advocate for improved accessibility and QA/QC of archived in situ coastal wind data.
- Connect with WCRP Grand Challenge on Sea Level Rise and Coastal Impacts regarding articulation of applications, observation needs (the Grand Challenge is hosting a Workshop on Coastal Climate Services being held in November 2019).
- Review CCI regional sea level closure project for identified gaps.
- Promote coastal assimilation systems to integrate coastal observations; identify existing examples.

9.3 Extremes

Discussion leader: Bernadette Sloyan

Rapporteurs: Valentin Aich, Tim Oakley

Presentation link

The breakout group on biosphere under item 0o proposed to discuss extreme events during the cross-panel session. Bernadette Sloyan led the discussion. It was agreed that there is a role for GCOS in monitoring frequency and intensity of extremes, but currently this is not done systematically across ECVs and former GCOS reports like the 2015 status report did not consider the capacity of the global climate observing system to monitor extremes. During the discussion it became clear, that almost all kinds of extreme events are cross-domain events, and, including causes and impacts, they cannot be monitored using ECVs from one domain only. Mentioned examples were:

- Mangrove die-offs (compound event)
- Urban heat waves
- Monsoon onset

- Hurricanes
- Flooding (different causalities)
- Drought
- Vector-borne diseases and other health impacts
- Marine heat waves

This implies, that a close collaboration of the panels is needed in order to improve the capacity of the global climate observing system to provide needed information about extreme events. GCOS should be able to provide information to assess regional changes in extremes.

Traditional climate monitoring focused in general on long term trends not extremes, and therefore current monitoring system are often not adequate for extremes. One mentioned example were atmospheric temperature measurements, which are rarely done within cities were heatwaves are most severe for the population but in pristine areas with the premise to have as little anthropogenic influence as possible. This hinders the need to understand, mitigate and project heatwaves. It was also noted that the discussion about observing extremes is closely related to the discussion on observations for/of adaptation since adaption includes coping with climate extremes. In order to respond to this need and inform adaptation, intensities and frequencies of extremes are important. In addition, observations are needed to improve the model skills so they can be used to predict extremes. In order to follow up on this, the following Actions were suggested to the plenary and accepted:

N°	Action	Responsibility	Deadline
G10	Next status report to cover extremes Include reports about the capability of current observing systems for extreme events explicitly in next status report.	Panel Members to ensure these are considered in updates to the Status Report; Steering Committee to ensure cross-GCOS consistency in addressing these issues.	Update of GCOS Status Report in 2021
G11	Identify of relevant ECVs for extremes Discuss which ECVs are relevant and are the requirements fit to monitor, understand and predict extremes.	GCOS Panels	For update of ECV requirements for Update of GCOS Implementation Plan in 2022
G12	Review of AR6 chapter on extremes Make sure that chapter on extremes of the 6th Assessment report of IPCC covers all relevant observations for extremes including oceans.	Panel Members to register and review draft AR6 reports GCOS Secretariat to inform panel members and ECV Stewards	During AR6 review

10. GCOS' Role in climate adaptation

Since its inception, a key role for GCOS has been to regularly report to the UNFCCC on the adequacy of the current climate observing system and to support the activities of the various working groups of the IPCC. Until COP22 the focus had been on supporting the work of IPCC Working Group 1, but since then imperatives have changed, with a new focus to include what can be done to support Working Group 2, especially in the area of adaptation. The Paris Agreement (2015 COP21) established the Global Stocktake as a tool to track global efforts, including adaptation. The GCOS response to the call from COP22 included two adaptation-relevant actions in its 2016 Implementation Plan; Action G1 to produce guidance and best practice for adaptation observations, and Action G4 to identify indicators for adaptation and risk.

TOPC formed a Scoping Group on Observations for Adaptation, a small group of invited experts on adaptation to help develop a way forward, including identification of how current ECVs could be used or adapted to inform the adaptation community that met for the first time in Geneva from 19-21 February 2019. The GCOS Steering Committee (GCOS SC) has also formed a sub-group to oversee the development of the GCOS adaptation response. Brief reports and associated discussions from these two groups follow below.

10.1 TOPC Scoping Group on observations for adaptation

Speaker: Nigel Tapper

Presentation link

Nigel Tapper reported on key outcomes from the TOPC Adaptation Scoping Group Meeting. The group identified some clear opportunities to contribute to the Global Stocktake in the area of adaptation, even from the current ECVs. For example, GCOS can provide clear information to inform adaptation (these might be called observations for adaptation) *e.g. key information about hazards and the links to exposure/risk*.

An example would be improved understanding of climate change impacts and adaptation imperatives through provision of geospatial data inputs relevant to bio-geophysical modelling (e.g. ECV input to flood risk modelling). A further example would be improved understanding of climate change impacts and adaptation imperatives through provision of geospatial data inputs relevant to assessment of climate-related risk (e.g. ECV input on land cover subject to certain climate hazards).

GCOS also has the possibility, through some ECVs, to directly observe adaptation (indicators of adaptation). Use of existing ECVs (possibly enhanced) to extract information on the spatiotemporal development of adaptation for some limited examples (e.g. shifts in patterns of land cover or changes in land cover type {urban vegetation} reflecting climate adaptation). Less likely would be the development of entirely new ECVs to represent adaptation.

There was also discussion of the (in)adequacy of existing data for the purpose, a topic that carried through to the post-presentation discussion. Panels were encouraged to review if their ECVs were fit for purpose of contributing to adaptation monitoring. Concerns were expressed about the expertise of Panels in the adaptation area.

10.2 GCOS SC Subgroup on a draft for observations in support of adaptation

Speaker: Han Dolman

Presentation link

In his presentation Han Dolman confirmed the commitment of the GCOS SC to supporting adaptation and the need for developing observational requirements accordingly. The need to identify opportunities and user needs through consultation and workshops with adaptation experts such as the TOPC Scoping Group as well as with potential data users/providers was also confirmed. A review of National Adaptation Plans was identified as a key task for GCOS moving forward. Discussion continued about the adequacy of the existing ECVs for adaptation, the need for cross-Panel discussions, and the need for an audit/checklist for all GCOS Panels of adaptation relevant ECVs. It is anticipated that the final report from the Scoping Group on Observations for Adaptation, due mid-year, would provide GCOS SC with a framework within which to proceed.

N°	Action	Responsibility	Deadline
G13	Review of National Adaptation Plans Review available National Adaptation Plans to identify observation needs.	TOPC Scoping Group on observations for adaptation	GCOS SC meeting 2019

11. Discussion: How to strengthen the collaboration between the panels?

This discussion was merged with the following on GCOS Goes Green since this effort has direct implications on the way the panels work.

12. GCOS Goes Green

Speaker: Stephen Briggs

Presentation link

The discussion on how to strengthen the collaboration between panels and a proposal for a "green" strategy had been handled together. Stephen Briggs led the discussion of this topic which had been introduced at the 26th session of the GCOS Steering Committee October 2018, by the Steering Committee member Michael Zemp. The overarching question was about "What can GCOS contribute to achieve the Paris Agreement?", but the subtitle is actually "How to reduce the carbon footprint of GCOS?" There is a list of actions which can be put into practise and have been tested already at the University of Zurich:

- Start monitoring
- Set reduction goals
- Take reduction measures
- Implement 2000-watt office
- Reduce air miles
- Develop new meeting culture
- Offset baseline emissions
- Communicate good examples

Something which the GCOS secretariat should consider in organizing its work plan and future meetings is to assess whether it should rather focus on regional issues and hence regional meetings, which could lead to potential air miles reduction, without changing the allotted budget. It was also recommend to review existing travel policies, and to rather consider environmental criteria instead of choosing presumably most economic airfare options.

Wolfgang Wagner suggested that the online forum used by the TOPC is also an excellent tool to facilitate working together, and that the other panels should consider introducing such online communication platforms.

Some of the participants concluded that though it is important to have face to face meetings, remote facilities should be used if suitable and possible, but that a combination of both would the most helpful way to work together.

Stephen Briggs closed with the note that a group led by GCOS Secretariat agreed to review the arrangements of future meetings and will produce a paper on how best to change the meeting format for future meetings, taking as example the Steering Committee meetings.

N°	Action	Responsibility	Deadline
G14	GCOS Goes Green Strategy Prepare a document that summarizes GCOS goals and strategy on how to reduce its carbon and ecological footprint.	GCOS Secretariat	GCOS SC meeting 2019

Annex 1: Agenda

Monday 18th March 2019 - Day 1 Plenary all day					
N°	**Item**	**Presenter**	**Targeted outcome/note**	**WDAC**	**WGClimate**
	Registration		Opportunity for panel pre-meetings	Joint in plenary	Joint in plenary
1.1	Brief Welcome	**Omar Chafki** Permanent Representative to WMO of Morocco & Director of the Meteorological Service Morocco	GCOS Director, Carolin Richter Introducing the speakers		
1.2 1.3	Introductions – why are we here, expectations	**Stephen Briggs** GCOS Steering Committee Chair **Pavel Kabat** WMO Chief Scientist	A common understanding on the needs of stakeholders and on the approach for: a) GCOS to achieve its strategic goals nr. 1 and 3 (document): *1 - Identify user needs. …the needs of adaptation and mitigation to climate change, support sustainable development, the requirements of the UNFCCC and other multilateral environmental agreements.* *3- Advocate for free and open access to relevant data.*		
2.	Climate Monitoring & adaptation success in Morocco	**Omar Chafki** *Director of the Meteorological Service Morocco*			
3.1	IPCC reports[6] and implication for observations:	*Where do observations contribute to these key areas? What observations are being done?*			
3.2	*Knowledge gaps related to observation systems:* IPCC SR1.5	**Peter Thorne** *CLA Chapter 2 (observations chapter), WGI*			

[6] Special Report on Global warming of 1.5°C (SR15); Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC); Special Report on Climate Change and Land (SRCCL); 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (2019 Refinement); and the IPCC Sixth Assessment Report (AR6)

Monday 18th March 2019 - Day 1 Plenary all day					
N°	**Item**	**Presenter**	**Targeted outcome/note**	**WDAC**	**WGClimate**
3.3	Observational gaps in the ocean and cryosphere	**Michael P. Meredith** British Antarctic Survey, Cambridge, UK; Scottish Association from Marine Science, Oban, UK, CLA Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC)	b) the Implementation of the WCRP Strategy 1- Fundamental understanding of the climate system 2- Prediction of the near-term evolution of the climate system 3- Future evolution of the climate system 4- Bridging climate science and society Supported by critical infrastructure: Observations for process understanding and Sustained reference data		
3.4	Knowledge gaps in climate change and land	**María José Sanz Sánchez** Scientific Director of the Basque Centre for Climate Change (BC3), Bilbao, Spain CLA 2019 Refinement of the 2006 IPCC Guidelines for GHG Inventories		Joint in plenary	Joint in plenary
3.5	Climate extremes: knowledge gaps and observational uncertainties	**Wafae Badi** Moroccan Meteorological Service LA Chapter 11, Extremes, AR6			
4.	Earth observations in support of the UNFCCC and its Paris Agreement	**Joanna Post** UNFCCC Secretariat			
5.	Observational needs for the national inventories	**Simon Eggleston** GCOS Secretariat, IPCC Task Force on inventories			

Monday 18th March 2019 - Day 1 Plenary all day					
N°	**Item**	**Presenter**	**Targeted outcome/note**	**WDAC**	**WGClimate**
6.	Panel Discussion Moderator: GCOS SC Chairman *Chairs AOPC, OOPC, TOPC, WDAC, WGClimate, WMO Chief Scientist, Director GCOS, GOOS Co-Chair* Observation and science priorities to inform the GCOS Strategy and WCRP Implementation				

Tuesday 19th March 2019 - DAY 2 – Plenary (am) and Breakout Groups (pm)					
N°	**Item**	**Presenter**	**Targeted outcome/note**	**WDAC**	**WGClimate**
7.1	Introduction to GCOS IP and WCRP targets for Earth System cycles. (IP section)	**Carolin Richter** GCOS Director **Pavel Kabat** WMO Chief Scientist	A summary of the current status and identification of where work is needed	Joint in Plenary	Joint in Plenary
7.2	Carbon (document)	**Han Dolman**			
7.3	Water (document)	**Stephan Dietrich**			
7.4	Energy (document)	**Karina von Schuckmann**			
7.5	Biosphere (document)	**Nadine Gobron**			
7.6	Discussion				
	Afternoon – Break-out groups (1) Carbon (2) Water (3) Energy (4) Biology/ ecosystem/	Moderators: (1): Han Dolman (2): Stephan Dietrich (3): Karina von Schuckmann (4): Nadine Gobron	A common understanding on the needs of stakeholders and on the approach for GCOS to achieve its strategic goals Nr. 2 and 3: *2- Ensure that climate observations are enhanced and*	Joint with GCOS in Break-out groups	**10th Session of WGClimate** Agenda

	biodiversity Discussion on: How well do the observations meet the GCOS IP targets (Box 4-5-6-7, page 37-38)? Are ocean, atmosphere and terrestrial requirements consistent to meet the GCOS IP targets (Box 4-5-6-7)?	Rapporteurs: (1): Simon Eggleston (2): Valentin Aich (3): Caterina Tassone/ Tim Oakley (4): Carolin Richter/ Katy Hill	*continued into the future to, in order to fully monitor the Earth's water and carbon cycles and energy.* *3- Advocate for free and open access to relevant data.* WCRP to achieve its four Overarching Objectives Agree 1-2 page summary of status and next steps		
7.7	Progress review from break-out groups				
	Outlook for Wednesday parallel session on cross-panels discussion	**Carolin Richter**			
8.	Preparing for the 2022 GCOS IP update	**Simon Eggleston**			

Wednesday 20th March 2019 - DAY 3 All Day - parallel sessions					
N°	**Item**	**Presenter**	**Targeted outcome/note**	**WDAC**	**WGClimate**
9.	Cross-panel discussions	Focus on specific areas of concern between panels identified before the meeting.	**Discussion and agree cross-panel needs and activities**	**WCRP Data Advisory Council 8th Session** Agenda	
9.1	Discussion session on Energy Fluxes (document)	Discussion leaders: **Meghan Cronin** **Bob Weller** **Elizabeth Kent** Rapporteur: Caterina Tassone			

9.2	Discussion session on Coastal-Land-Ocean-Water Fluxes	Discussion leader: **Stephan Dietrich** Rapporteurs: Katy Hill, Simon Eggleston			
9.3	Discussion on Extremes	Bernadette Sloyan Rapporteurs: Tim Oakley, Valentin Aich			
Start with individual GCOS panel meetings					

Thursday 21st March 2019 - Day 4 Plenary (am) – Separate Panel Meetings (pm)					
N°	**Item**	**Presenter**	**Targeted outcome/note**	**WDAC**	**WGClimate**
	Plenary		agree 1-2 page summary of status and next steps Development of strategic guidance on how to be more relevant and key requirements from regions.		Joint WDAC and WGClimate
10.1	TOPC Scoping Group on observations for adaptation	**Nigel Tapper**			
10.2	GCOS SC Subgroup on a draft for observations in support of adaptation	**Han Dolman**			
9.4	Reports from previous day cross-panel discussion (10' each)				
11.	Discussion: How to strengthen the collaboration between the panels?				
12.	GCOS goes green	**Stephen Briggs**			
Individual Panel Meetings: AOPC-OOPC-TOPC					

Friday 22nd March 2019 - Day 5 Individual Panel Meetings	
Item	**WGClimate**
Individual Panel Meetings: AOPC, OOPC, TOPC	

Annex 2: List of Participants

24th session of the Atmospheric Observation Panel for Climate

Ms Imke Durre Center for Weather and Climate NOAA's National Centers for Environmental Information (NCEI) Asheville, NC, United States	**Mr Rainer Hollmann** Deutscher Wetterdienst Offenbach, Germany
Mr Kenneth Holmlund European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Darmstadt, Germany	**Mr Robert H. Holzworth** University of Washington Seattle, WA, United States
Mr Dale F. Hurst NOAA Earth System Research Laboratory Boulder, CO, United States	**Ms Elizabeth Kent** National Oceanography Centre Southampton, United Kingdom
Mr Shinya Kobayashi Japan Meteorological Agency Tokyo, Japan	**Mr Paolo Laj** Université Grenoble Alpes Saint-Martin-d'Hères, France
Mr Christian Lanconelli European Commission, Joint Research Centre Ispra, Italy	**Ms Johanna Tamminen** Finnish Meteorological Institute Helsinki, Finland
Mr Peter Thorne National University of Ireland Maynooth Maynooth, Ireland	**Mr Peng Zhang** China Meteorological Administration National Satellite Meteorological Center Beijing, China

22nd session of the Ocean Observations Panel for Physics and Climate

Mr Nic Bax CSIRO Oceans and Atmosphere Hobart, Australia	**Ms Maria Paz Chidichimo** Universidad de Buenos Aires Buenos Aires, Argentina
Ms Meghan Cronin National Oceanic and Atmospheric Administration Seattle, WA, United States	**Mr Masao Ishi** Japan Meteorological Agency Meteorological Research Institute Tsukuba, Japan

Mr Johannes Karstensen GEOMAR Helmholtz Center for Ocean Research Kiel, Germany	**Ms Marjolaine Krug** Council for Scientific and Industrial Research (CSIR) Stellenbosch, South Africa
Mr Tony Lee NASA Jet Propulsion Laboratory Pasadena, CA, United States	**Mr David Legler** National Oceanic and Atmospheric Administration / Office of Oceanic and Atmospheric Research Silver Spring, MD, United States
Mr Eitarou Oka The University of Tokyo Kashiwa Chiba, Japan	**Mr Matthew Palmer** Met Office Exeter, United Kingdom
Ms Bernadette Sloyan CSIRO Marine and Atmospheric Flagship Hobart, Australia	**Ms Sabrina Speich** Ecole Normale Supérieure (Paris), Laboratoire de Météorologie Paris, France
Mr Toste Tanhua GEOMAR Kiel, Germany	**Mr Maciej Telszewski** International Ocean Carbon Coordination Project Sopot, Poland
Ms Karina von Schuckman Mercator Ocean International Ramonville Saint-Agne, France	**Mr Robert Weller** Woods Hole Oceanographic Institution (WHOI) Woods Hole, MA, United States
Mr Weidong Yu National Marine Environmental Forecasting Center Beijing, China	

21st session of the Terrestrial Observation Panel for Climate

Ms Sarah Carter GOFC-GOLD. Wageningen University Wageningen, The Netherlands	**Mr Stephan Dietrich** International Centre for Water Resources and Global Change (ICWRGC), Federal Institute of Hydrology) Koblenz, Germany
Mr Hiroyuki Enomoto National Institute of Polar Research (NIPR) Tokyo, Japan	**Mr Darren John Ghent** University of Leicester National Centre for Earth Observation (NCEO) Leicester, United Kingdom

Ms Nadine Gobron European Commission Joint Research Centre Ispra, Italy	**Mr Werner Kutsch** Integrated Carbon Observation System (ICOS ERIC) Helsinki, Finland
Ms Huilin Li Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences (CAREERI/CAS) Beijing, China	**Ms Claudia Ruz Vargas** International Groundwater Assessment Centre (IGRAC) Delft, The Netherlands
Mr Philippe Schoeneich Institut de Géographie Alpine Grenoble, France	**Mr Nigel Tapper** Monash University Clayton, VIC, Australia
Mr Wolfgang Wagner Vienna University of Technology Vienna, Austria	

GCOS Joint Panels Meeting

Mr Stephen Briggs GCOS Steering Committee Chairperson Cambridge, United Kingdom	**Mr Omar Chafki** Permanent Representative of Morocco with WMO
Mr Albertus Johannes Han Dolman VU University Amsterdam Amsterdam, The Netherlands	**Mr Johnny Johannessen** Nansen Environmental and Remote Sensing Center Bergen, Norway
Ms Joanna Post United Nations Framework Convention on Climate Change (UNFCCC) Bonn, Germany	**Ms Wafae Badi** Direction de la Météorologie Nationale Casablanca, Morocco
Mr Michael P. Meredith British Antarctic Survey Cambridge, UK	**Ms María José Sanz** Scientific Campus of the University of the Basque Country Leioa, Bizkaia, Spain

8th Session of the WCRP Data Advisory Council

Ms Dorothea Bakker University of East Anglia (UEA) Norwich, United Kingdom	**Mr Pavel Kabat** World Meteorological Organization (WMO) Geneva, Switzerland
Mr Christian Kummerow Colorado State University Fort Collins, CO, United States	**Mr Michel Rixen** World Meteorological Organization (WMO) Geneva, Switzerland
Ms Anna Rutgersson University of Uppsala Uppsala, Sweden	**Mr Andrea Storto** Centre for Maritime Research and Experimentation (CMRE La Spezia, Italy
Ms Susann Tegtmeier Leibniz Institute of Marine Sciences Kiel, Germany	**Mr Jean-Noel Thépaut** European Centre for Medium-Range Weather Forecasts (ECMWF) Reading, United Kingdom

10th session of the Joint CEOS-CGMS Working Group on Climate

Mr Werner Balogh World Meteorological Organization (WMO) Geneva, Switzerland	**Mr Bojan Bojkov** European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Darmstadt, Germany
Ms Selma Cherchali Centre National d'Études Spatiales (CNES) Toulouse, France	**Mr David Crisp** NASA Jet Propulsion Laboratory Pasadena, CA, United States
Mr Mark Dowell European Commission Joint Research Centre Ispra, Italy	**Mr Steven Hosford** European Space Agency (ESA) / Centre National d'Études Spatiales (CNES) Frascati, Italy
Mr Robert Husband European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Darmstadt, Germany	**Mr Toshiyuki Kurino** World Meteorological Organization (WMO) Geneva, Switzerland

Mr Akihiko Kuze Japan Aerospace Exploration Agency (JAXA) Tsukuba, Japan	**Mr Pascal Lecomte** European Space Agency (ESA)/ECSAT Oxfordshire, United Kingdom
Mr Chris Merchant UK Space Agency (UKSA) Reading, United Kingdom	**Ms Alexandra Nunes** Hamtec Consulting Ltd. c/o EUMETSAT Darmstadt, Germany
Mr Simon Pinnock European Space Agency (ESA)/ECSAT Oxfordshire, United Kingdom	**Mr Jeff Privette** Center for Weather and Climate (CWC) NOAA's National Centers for Environmental Information (NCEI) Asheville, NC, United States
Mr Joachim Saalmüller European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Darmstadt, Germany	**Mr Joerg Schulz** European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Darmstadt, Germany
Ms Eunha Sohn Korea Meteorological Administration (KMA) Jincheon-gun, Republic of Korea	**Ms Wenying Su** NASA Langley Research Center Hampton, VA, United States
Mr Ben Veihelmann European Space Agency (ESA)/ESTEC Noordwijk, The Netherlands	**Mr Albrecht von Bargen** German Aerospace Center (DLR) Bonn, Germany

GCOS Secretariat

Mr Valentin Aich World Meteorological Organization (WMO) Geneva, Switzerland	**Mr Simon Eggleston** World Meteorological Organization (WMO) Geneva, Switzerland
Ms Katy Hill World Meteorological Organization (WMO) Geneva, Switzerland	**Mr Tim Oakley** World Meteorological Organization (WMO) Geneva, Switzerland
Ms Carolin Richter World Meteorological Organization (WMO) Geneva, Switzerland	**Ms Caterina Tassone** World Meteorological Organization (WMO) Geneva, Switzerland

Annex 3: General Actions and Recommendations

N°	Action	Responsibility	Deadline
G1	GCOS Climate Observation Conference Plan a GCOS Climate Observation Conference, present plan to Steering Committee.	GCOS Secretariat to prepare plan with ideas from GCOS Panels; All to consider and propose support for such a conference	Initial report on progress for Steering Committee in 2019 Conference in 2021
G2	Traceability, Sustainability and Open Data Consider Traceability, Sustainability and Open Data and ensure these are addressed in upcoming updates to the Status Report and Implementation Plan, considering WMO, IOC and UNFCCC regulations and decisions.	Panel Members to ensure these are considered in updates to the Status Report and Implementation Plan; Steering Committee to ensure cross-GCOS consistency in addressing these issues	Update of GCOS Implementation Plan in 2022
G3	Water Cycle Continue work on scoping paper with goal of publication.	Stephan Dietrich as lead and other authors to contribute, GCOS secretariat to facilitate	December 2019
G4	Energy Cycle OOPC to consider a workshop on heat and freshwater. GCOS panel members were encouraged to provide input to WCRP activities and to the scoping paper on energy.	GCOS and GOOS Secretariat	June2019
G5	Biodiversity Organize a joint workshop between terrestrial and ocean researchers on identifying global methods of monitoring productivity, phenology and distribution. Workshop topics and outcomes should include: • Consideration whether biosphere indicators (productivity, phenology and distribution) may in the short-term be better serviced by synthesizing existing data from mixed sources (including citizen science) than new	GCOS and GOOS Secretariat; Nic Bax	March 2020

	observations. • Determination whether the existing ECVs for marine biosphere need to be reconsidered in light of IPCC AR6 • Consideration of the potential for mining paleodata • Exploration of interest of Future Earth (Lead: Nic Bax).		
G6	Convey recommendations related to carbon and energy cycles to WCRP Ask WCRP the questions expressed in the recommendations 1 and 2 regarding observational needs for monitoring the global carbon cycle and the Earth's energy balance Report on progress to the steering committee and panels.	GCOS Chair and secretariat	Dec 2019
G7	Update ECV Requirements for 2022 update of the Implementation Plan Ensure the updated ECV requirements are specified as shown above, with a threshold and goal value as a minimum, and all the fields listed above completed.	Panel Members to update requirements; GCOS Secretariat to ensure consistency across all panels	Update of GCOS Implementation Plan in 2022
G8	Radiation Workshop Hold a workshop on a global (ocean & land-based) radiation network and develop best practices for surface radiation. Bob Weller (OOPC), Christian Lanconelli (BSRN).	OOPC, AOPC, TOPC and BSRN	Dec 2020
G9	Ocean & land-based flux groups Report on existing WCRP ocean & land-based flux groups such as WDAC, Surflux Task Team, GEWEX, and SOLAS. Caterina Tassone (GCOS) Report on relevant activities by WMO/WGNE & WCRP/WGCM. Matt Palmer (OOPC).	Caterina Tassone (GCOS) Matt Palmer (OOPC)	Next panel meetings
G10	Next status report to cover extremes Include reports about the capability of current observing systems for extreme events explicitly in next	Panel Members to ensure these are considered in updates to the Status Report; Steering Committee to	Update of GCOS Status Report in 2021

	status report.	ensure cross-GCOS consistency in addressing these issues.	
G11	Identification of relevant ECVs for extremes Discuss which ECVs are relevant and whether the requirements are fit to monitor, understand and predict extremes.	GCOS Panels	For update of ECV requirements for Update of GCOS Implementation Plan in 2022
G12	Review of AR6 chapter on extremes Make sure that chapter on extremes covers of the 6th Assessment report of IPCC all relevant observations for extremes including oceans.	Panel Members to register and review draft AR6 reports GCOS Secretariat to inform panel members and ECV Stewards	During AR6 review
G13	Review of National Adaptation Plans Review available National Adaptation Plans to identify observation needs.	TOPC Scoping Group on observations for adaptation	GCOS SC meeting 2019
G14	GCOS Goes Green Strategy Prepare a document that summarizes GCOS goals and strategy on how to reduce its carbon and ecological footprint.	GCOS Secretariat	GCOS SC meeting 2019

Recommendations for WCRP (related to Action G6) :

RECOMMENDATION 1: It is recommended that WCRP consider the regional and temporal resolutions needed to improve the understanding of the carbon cycle. WCRP should also look at how information about carbon isotopes can be used and what is needed to improve monitoring of the carbon cycle.

RECOMMENDATION 2: Ask WCRP to work with modelling and observational communities to establish a scientific basis for improving observations, (i.e. how to capture the Earth's energy balance observationally and what is the needed accuracy of these observations to close the Energy balance sufficiently to resolve the radiative forcing), including:

- **Provide contribution of surface flux work as done under OceanObs / GCOS;**
- **Recommend and support that the community should submit a 'proposition of continuation' of CONCEPT-HEAT (Consistency between planetary heat balance and ocean heat storage);**
- **Encourage and support contributions to other scientific papers, for example on the EEI inventory (e.g. added expertise from observations on atmospheric, land and cryosphere storage);**

- **Building on a previous workshop [7], improve links between model and observational communities;**
- **Recommend and support the continuation of ORA-IP. Support related reanalysis inter-comparison projects.;**
- **Determine the time-scales needed to understand the global energy balance;**
- **Identify the regional scale that needs to be considered (e.g. including heat re-distribution: transport in the atmosphere and ocean, and regional budgets);**
- **Continue to increase scientific understanding, knowledge and tools through the physical budget constraint approach, and address implications of changes in the energy budget.**

[7] 2018 WCRP workshop: The Earth's Energy Imbalance and its implications (EEI) November 13-16, 2018, Toulouse, France

INDIVIDUAL PANEL MEETING REPORTS

B. AOPC

24th Session of the Atmospheric Observation Panel for Climate (AOPC-24)

1. ECV

1.1 OSCAR requirements

Speaker: Caterina Tassone

Presentation link

Ken Holmlund introduced the subject by asking the panel to consider whether requirements should be established only for the climate application 'Climate Monitoring', or whether there is a concrete need to establish requirements for other application areas, such as regional, process studies, modelling and extremes. The AOPC agreed to look at a set of additional application areas (Action A1) and the ECV stewards were asked to consider whether the current requirements are adequate also for other application areas, including adaptation and mitigation (Action A2).

Caterina Tassone updated the panel on the status of the atmospheric ECV products and definition mapping into the OSCAR requirements database. During an Inter-Programme Expert Team on the Observing System Design and Evolution (IPET-OSDE) workshop on OSCAR/Requirements, held in Geneva, Switzerland, 3-4 December 2018 (http://www.wmo.int/pages/prog/www/OSY/Reports/IPET-OSDE-Workshop-OSCAR-Req-Report-Final.pdf), input from AOPC to the definition of variables for the Climate Monitoring application area was integrated in the OSCAR/requirements tables. However, agreement was not reached for the ECV precipitation and for the ECV cloud properties products: cloud liquid water path, cloud ice water path (different names for the OSCAR variables) and cloud drop effective radius (different definitions). AOPC decided that for precipitation one single product will be defined, accumulated precipitation, defined as 'integration of solid and liquid precipitation rate reaching the ground over a time period defined in the metadata'. Rainer Hollmann reported that the co-chairs of the International Cloud Working Group of CMGS support the scientific community accepted terminology cloud liquid water path/cloud ice water path and the definition of effective radius as 'ratio of integral of water droplets size distribution in volume divided by integral in area (μm)'. Caterina will communicate these decisions to IPET-OSDE (Action A3). For the aerosols, the process of mapping the existing ECV products with the OSCAR variables names and definitions will be done by the GAW representative, Paolo Laj (Action A4). With this last step, the process of mapping ECV products with OSCAR variables is completed.

N°	Action	Responsibility	Deadline
A1	AOPC to agree on a set of application areas to be considered.	AOPC Chair, GCOS Sec AOPC	AOPC-25
A2	AOPC to consider the applicability of the current requirement to additional climate application areas, including adaptation and mitigation (in addition to Global Climate Monitoring).	AOPC	AOPC-25
A3	Communicate to IPET-OSDE chair, names and definitions for the following ECVs: precipitation, clouds and aerosols.	GCOS Secretariat	June 2019
A4	Complete mapping of ECV products to OSCAR variables for the ECV aerosols properties.	GAW representative	June 2019

1.2 Update of requirements for ECV products

Speaker: Caterina Tassone

Next step is to review and update the requirements for the ECV products. The definitions for the requirements, such as temporal sampling, horizontal and vertical resolution, timeliness, uncertainty and stability, as presented during plenary (Section 8) were reviewed and agreed upon. It is requested that each requirement is clearly documented and traceable.

1.3 Break-out groups

The AOPC members met in break out groups to start the process of updating the requirements. The ECV stewards will continue the work started during the break out group and GCOS secretariat will organize teleconferences within 3 months to check on progress (Action A5). The draft of tables containing requirements for the ECV products are expected to be ready by the end of December (Action A6).

N°	Action	Responsibility	Deadline
A5	AOPC to consolidate a first draft of the requirement for Climate Monitoring and document the requirements.	AOPC and GCOS Secretariat	End of June 2019
A6	Complete draft of requirements for OSCAR tables.	AOPC and GCOS Secretariat	End of December 2019

2. Output from Joint Panel Meeting

The discussion on the output from the previous sessions and the cross-panel activities focused mainly on the topic of observations in support for adaptation (section 10), and on the outcome of the discussions at the air-sea flux task team (section 9.1) and at the session on extremes (section 9.3).

AOPC agreed to make a request to the TOPC Task Team on observation for adaptation to identify which of the ECVs are relevant in support to adaptation (Action A7). AOPC will then look at the requirements for these ECVs to see whether they are adequate for adaptation.

The air-sea flux group asked AOPC to prepare a report about the feasibility of satellite measurements of vertical profile of temperature and humidity in the Planetary Boundary Layer. AOPC agreed that such measurements are not possible at the moment, and that right now demonstration capabilities are not available. However, AOPC will prepare a report that will also include the expected timescale in case this becomes feasible (Action A8).

AOPC recognized that there is a lack of expertise in extremes within the current AOPC members, and that the topic of extremes is very relevant to adaptation. It was agreed to invite an expert on extremes to the next AOPC meeting (Action A9).

Regarding the measures to be implemented by AOPC to reduce its carbon footprint, there was consensus that face-to-face meetings once a year are important to progress with AOPC work. Suggestions included eventually organizing back to back meetings, for example with the Implementation Coordination Meeting of the GCOS Reference Upper Air Network (GRUAN), or to choose a location that minimizes the total air miles. AOPC chair and GCOS secretariat will consider the different options to be discussed with the 'GCOS Goes Green' team (Action A10).

N°	Action	Responsibility	Deadline
A7	AOPC to request the TOPC Task Team on observations for adaptation to identify which ECVs are relevant to climate adaptation activities.	AOPC chair and GCOS Secretariat	AOPC-25
A8	AOPC to explore the future capabilities to derive PBL temperature and humidity profiles using satellite data.	AOPC chair, Rainer, Peng.	December 2019
A9	Invite an expert on extremes to next AOPC.	Imke Durre	January 2020
A10	AOPC to consider with GCOS Sec its organization of future meetings in terms of going green.	AOPC chair	AOPC-25

3. Networks

3.1 GBON

Speaker: Tim Oakley

Presentation link

Tim Oakley gave a presentation on the WMO Integrated Global Observing System (WIGOS) proposal for a Global Basic Observation Network (GBON) which will be submitted for approval at the upcoming WMO Congress in June 2019. The GBON defines a minimum requirement for in-situ observations, primarily land surface and upper-air measurement, and the expectations on WMO Members for the international exchange of mandatory (shall) and recommended (should) observations. The key components of the text that has been drafted for the WMO Congress meeting (i.e. upper-air observations twice per day at a global resolution of 500km and land-surface observations hourly) was shown to and discussed by the panel experts.

There were some concerns expressed about the focus of the GBON on specific observations which might suggest to WMO Members that this is all that is required for Global NWP and Climate Monitoring (through reanalysis) but it was expressed that there was further text which covered the other observing system components, albeit a should rather than a shall, with the expectation that the GBON would expand to other observing systems, and be enhanced by additional measurements, once the concept had been adopted by WMO Members. AOPC decided to support the GBON proposal, and that assuming that the GBON concept was adopted by WMO Congress, AOPC will work with WIGOS to expand and enhance GBON in the future (Action A11).

N°	Action	Responsibility	Deadline
A11	GBON: AOPC supports the implementation of GBON and if adopted will consider the implications for GUAN, GSN and observations in the atmosphere over the ocean. If GBON is approved in Congress, AOPC to ensure that relevant experts are included in the implementation team.	Peter Thorne, Elizabeth Kent and GCOS network manager	Ongoing

3.2 GUAN-GSN

Speaker: Tim Oakley

Presentation link

Tim Oakley provided a short summary of his annual report on the performance of the GCOS Upper-Air Network (GUAN) and GCOS Surface Network (GSN) in 2018. The key points that required feedback from the meeting were:

- The approval of the station list update for GUAN and GSN (2019);
- Noting that at best the networks performance was stable but for some regions, notably RA-I (Africa), the annual performance was further deteriorating.

AOPC approved the 2019 update to the GUAN and GSN station list.

3.3 BSRN

Christian Lanconelli, project manager of the Baseline Surface Radiation Network (BSRN), gave an update on the BSRN. There are at the moment 58 stations, including 8 candidates, ensuring partial global coverage. Some of these stations are supersites, measuring also various atmospheric variables. All the stations measure shortwave and longwave radiation, have secondary standard instruments and high frequency sampling. In his final remarks, the BSRN project manager underlined the need for a better coverage in present geographical gaps of the network, including a plan for economical support, and the importance of promoting community joint scientific and best practice publication in collaboration with the Commission for Instruments and Methods of Observation (CIMO) and GCOS.

3.4 GRUAN

Peter Thorne updated on progress for GRUAN. He reported progress on the efforts within the GRUAN community to address the upcoming likely phase-out of the cryogen used in both Frost Point Hygrometer and Cryogenic Frost Point Hygrometer. He asked AOPC to note an increase in momentum within GRUAN due to a new dedicated staff, supported by use of his overhead at Maynooth University and closely working with the co-chairs and the Lead Centre.

4. IP Actions

4.1 Break-out groups

Merged with 4.2

4.2 Presentations from break-out groups

Actions from the GCOS IP were briefly discussed and where necessary new rapporteurs were assigned. AOPC noted that Action A20 from the GCOS IP on the increase of the coverage of aircraft observations has not been started yet and suggested to invite a commercial aircraft observations expert to the next AOPC meeting to contribute addressing this action (Action A12).

Further discussion was postponed to next AOPC teleconference.

N°	Action	Responsibility	Deadline
A12	AOPC to invite a commercial aircraft observations expert to next AOPC meeting.	AOPC Chair and GCOS Secretariat	January 2020

5. Task Teams

5.1 GSRN

Speaker: Peter Thorne

Peter Thorne presented the progress done by the GCOS Surface Reference Network (GSRN) team. The report defining the concept for the establishment of a GSRN (GCOS-226) has been completed and was adopted by AOPC. A presentation on the proposed future of the GSRN was given at the CIMO-TECO (Amsterdam, October 2018). As outlined in the report, to proceed to the implementation phase, the following are required: approval of the proposed GSRN by relevant WMO programmes, the GCOS programme and other sponsors, leading to the adoption of an agreed governance structure; an offer to host and staff appropriately a Lead Centre; offers of suitable sites for an initial GSRN. AOPC agreed that the GCOS Secretariat will work towards identifying a Lead Centre for the GSRN (Action A13). AOPC decided to keep the task team opened for two additional years to contribute input to the WMO Executive Council in 2020 and identifying a Lead Centre. GCOS Secretariat will communicate this decision to the GSRN task team and congratulate them for the report.

N°	Action	Responsibility	Deadline
A13	Identify one or more Lead Centres for GSRN.	GCOS Secretariat	AOPC-25

5.2 Lightning

Speaker: Robert Holzworth

Presentation link

Robert Holzworth presented the output from the Lightning Task Team (TTLOCA). The report is now completed and was adopted by AOPC. The task team has specified the requirements with a minimum goal for climate of 10km horizontal resolution, as a target daily points as aggregated in a grid of 10km. There are now more than ten years of lightning data available, but it is possible to extend the data record back by using thunder data. Therefore, the task team asked AOPC to recommend to NCEI to include the thunder observations in the NCEI and Copernicus data sets. The task team also requested AOPC to continue to support the collaboration between the TTLOCA and GRUAN on the Global Electric Circuit. AOPC agreed to keep the task team opened for one additional year with the specific action to complete the requirements table and to give a plan on how to move forward. One proposed action is to engage CIMO and the expert team on Surface Based Observations (ET-SBO) and form a joint task team. GCOS Secretariat will congratulate the members of the task team TTLOCA on their contribution and on the final report. GCOS Steering Committee and GCOS Secretariat, together with AOPC chair, will consider the potential need for an expert on lightning either as a member of the AOPC panel or as an invited expert at next AOPC meeting.

N°	Action	Responsibility	Deadline
A14	AOPC to recommend to NCEI to include thunder observations in the NCEI and Copernicus to their data sets.	GCOS Secretariat on behalf of AOPC	January 2020
A15	Consider the potential need for an expert on lightning as an AOPC member or as an invited expert at AOPC-25.	AOPC chair, GCOS Steering Committee and GCOS Secretariat	January 2020

5.3 Radar

Speaker: Rainer Hollmann

Presentation link

Rainer Hollmann presented the output of the task team on the use of weather radar for climate studies. The task team concluded its work and produced a report (GCOS-223) that summarizes its primary recommendations. An article on 'Radars ready for Climate' has been submitted to BAMS. The report was adopted by AOPC. AOPC was invited to discuss the recommendations and decide on a way forward. In particular, the task team recommended to establish an international portal to allow harmonized access to radar data, metadata and documentation. The task team will work together with the GCOS Secretariat to formulate the correct terms for this recommendation that will then be submitted to WMO and worked together with the (CIMO) Inter-Programme Expert Team on Operational Weather Radars (IPET-OWR) (Action A16). GCOS Secretariat will congratulate the members of the task team for their contribution and on the final report.

N°	Action	Responsibility	Deadline
A16	Write formal recommendation to WMO on next steps.	Radar TT and GCOS Secretariat	September 2019

5.4 GUAN

Speaker: Tim Oakley

Tim Oakley reported that there had been little progress on the work-plan of this task-team agreed at the previous AOPC meeting, except the approval of the meeting report from the Lindenberg meeting in December 2017 and a presentation on the proposed future of the GUAN given at the CIMO-TECO (Amsterdam, October 2018).

It was agreed that a future GUAN proposal was very much linked to the GBON proposal discussed under agenda item 3a, and if the GBON concept was adopted by WMO, then a future GUAN should either be a baseline component of the GBON (upper-air stations) or it should be replaced with the GBON.

N°	Action	Responsibility	Deadline
A17	Report on GBON and the role of GUAN at next AOPC.	GCOS Network Manager	AOPC-25

6. Conclusions

6.1 Actions from AOPC-23

Actions from AOPC-23 were reviewed. All actions were completed and closed.

6.2 Actions

Actions from AOPC-24 were reviewed and agreed upon. They can be found in Annex 2

It was agreed that quarterly teleconferences with all the panel members will be continued to promote collaboration within the panel in between panel's meetings. Date and location of next AOPC meeting will be discussed within the next months. Ken Holmlund thanked all the participants and the meeting closed at 12pm on Friday.

Annex A1 : Agenda

n.	Item	Presenter	Envisaged Outcome
1.	ECV		
1a.	OSCAR/requirements (presentation)	Caterina	Information Discussion on how to complete OSCAR database for AOPC ECV products
1b.	Update of requirements for ECV products	Caterina	Agreement on how to update requirements for AOPC ECV products (based on presentation on Tuesday)
1c.	Break-out groups		Start reviewing requirements for AOPC ECV products
2	Output from JPM.		
2a.	Discussion	Ken+all	AOPC workplan
3.	Networks		
3a.	GBON (presentation)	Tim	Information
3b.	GUAN-GSN (report)	Tim	Information
3c.	BSRN	Christian	Information
3d.	GRUAN	Peter	Information/discussion
4.	IP actions (list)		
4. a	Break-out groups		IP actions update
4. b	Presentation from BoG		
5.	Task Teams		
5a.	GSRN (draft report)	Peter	Presentation of outcome of TT Decision on following step
5b.	Lightning (draft report, presentation)	Bob H.	Presentation of outcome of TT Decision on following step
5c.	Radar (draft report)	Rainer	Presentation of outcome of TT Decision on following step
5d.	GUAN	Tim	Presentation of outcome of TT Decision on following step
6.	Conclusion		
6. a	Actions from AOPC-23 (list)	Caterina	Closing/reviewing open actions
6. a	Actions	Ken	AOPC workplan
6. b	AOB and next year meeting	Ken	

Annex A2 : Actions

N°	Action	Responsibility	Deadline
A1	AOPC to agree on a set of application areas to be considered.	AOPC Chair, GCOS Sec AOPC	AOPC-25
A2	AOPC to consider the applicability of the current requirement to additional climate application areas, including adaptation and mitigation (in addition to Global Climate Monitoring).	AOPC	AOPC-25
A3	Communicate to IPET-OSDE chair, names and definitions for the following ECVs: precipitation, clouds and aerosols.	GCOS Secretariat	June 2019
A4	Complete mapping of ECV products to OSCAR variables for the ECV aerosols properties.	GAW representative	June 2019
A5	AOPC to consolidate a first draft of the requirement for Climate Monitoring and document the requirements.	AOPC and GCOS Secretariat	End of June 2019
A6	Complete draft of requirements for OSCAR tables.	AOPC and GCOS Secretariat	End of December 2019
A7	AOPC to request the TOPC Task Team on observations for adaptation to identify which ECVs are relevant to climate adaptation activities.	AOPC chair and GCOS Secretariat	AOPC-25
A8	AOPC to explore the future capabilities to derive PBL temperature and humidity profiles using satellite data.	AOPC chair, Rainer, Peng.	December 2019
A9	Invite an expert on extremes to next AOPC.	Imke Durre	January 2020
A10	AOPC to consider with GCOS Sec its organization of future meetings in terms of going green.	AOPC chair	AOPC-25
A11	GBON: AOPC supports the implementation of GBON and if adopted will consider the implications for GUAN, GSN and observations in the atmosphere over the ocean. If GBON is approved in Congress, AOPC to ensure that relevant experts are included in the implementation team.	Peter Thorne, Elizabeth Kent and GCOS network manager	Ongoing
A12	AOPC to invite a commercial aircraft observations expert to next AOPC meeting.	AOPC Chair and GCOS Secretariat	January 2020
A13	Identify one or more Lead Centres for GSRN.	GCOS Secretariat	AOPC-25
A14	AOPC to recommend to NCEI to include thunder observations in the NCEI and Copernicus data sets.	GCOS Secretariat on behalf of AOPC	January 2020

A15	Consider the potential need for an expert on lightning as an AOPC member or as an invited expert at AOPC-25.	AOPC chair, GCOS Steering Committee and GCOS Secretariat	January 2020
A16	Write formal recommendation to WMO on next steps.	Radar TT and GCOS Secretariat	September 2019
A17	Report on GBON and the role of GUAN at next AOPC.	GCOS Network Manager	AOPC-25

C. OOPC

22nd Session of the Ocean Observations Panel for Physics and Climate (OOPC-22)

1. Introduction

The OOPC-22 Session was held in Marrakesh, Morocco, at the El Saadi resort as part of a GCOS Joint Panels meeting to enable the GCOS expert panels (for Atmosphere, Land and Ocean) to discuss cross cutting issues, including the observations required across the domains to track the global climate cycles. The Panel discussed the outcomes of these sessions and implications for the OOPC work plan. The Panel then focussed on discussing OOPC's role and priorities going forward, and had the opportunity to discuss joint efforts with GOOS Biogeochemistry and Biology panels given the GOOS Biogeochemistry Co-Chair and Secretariat, as well as the Biology and Ecosystems Chair were in attendance.

2. Outcomes for OOPC from cross cutting breakout sessions

2.1 Carbon Cycle

The carbon cycle breakout session discussed available observations across the 3 domains and their status and gaps. Full details of the discussion can be found in section A.7.2. River flux was highlighted as a key uncertainty. For the ocean, pCO2 and methane observations need to extend into the coast, and the need to improve coverage in the southern hemisphere was discussed. Biogeochemical Argo shows promise for inferring broad scale changes, but the scales of observations need to be considered in the context of the scales of variability. Satellite observations, such as the OCO satellite sensor show promise for surface ocean carbon observations. A coordination group has been established for the carbon cycle in the coastal zone. The breakout group mostly focussed on surface fluxes, and less about the interior ocean.

2.2 Water Cycle

The water cycle breakout session discussed the observational gaps for water cycle studies. Full details of the discussion can be found in section A.7.3. The need for continuity of instruments that measure exchange across systems was particularly highlighted. This included Evaporation-Precipitation (E-P), Evapotranspiration, and changes in land/sea fluxes (riverflow, runoff, ice melt). On large spatial scales, there is a useful relationship between salinity and E-P.

To track changes in the Hydrological Cycle, a complementary observing system across ocean, atmosphere and land is critical. Including consistency in observations across the land and ocean such as precipitation, soil moisture and salinity (measured using common satellite sensors) and gravity. It was suggested that perhaps OOPC, TPOS 2020 should consider advocating for upwards looking radars on ocean platforms for measuring precipitation.

A key link for OOPC is sea level changes, which span a broad range of space and timescales, and very much links to the coastal discussions (see section 2.5).

2.3 Energy Budget

The Energy budget breakout session on day 2 was led by Karina von Schuckmann, with several OOPC members in attendance (M. Palmer, M. P. Chidichimo, M. Cronin, R. Weller) along with key members of the AOPC and TOPC. K. von Schuckmann described progress made through the WCRP research focus CONCEPT HEAT and their recommendations for moving forward. Two aspects of the challenge of closing the global energy budget were highlighted: the inventory problem (how and where energy is stored), and the fluxes problem, which also flowed into the

Energy Fluxes breakout discussion the following day (see section 2.6) that was led by L. Kent, B. Weller and M. Cronin. Full details of the discussion can be found in section A.7.4.

One of the key aspects of the discussion was how to capitalize on the momentum and cross-disciplinary engagement that has been built under the WCRP CONCEPT-HEAT project, which had its final meeting during November 2018 in Toulouse. A strong partnership with WCRP is needed to guide the development of observation requirements to close the energy budget. OOPC is well placed to foster ongoing research efforts developed under CONCEPT-HEAT, while WCRP reorganizes. An example of this is the Heat and Freshwater Content paper submitted to Ocean Obs'19 and the associated workshop that will take place at the UK Met Office in 2020. The UN Decade of Ocean science for sustainable development was also highlighted as an opportunity to propose some ambitious plans, which would bring enhanced observations and models together to address key knowledge gaps. The panel discussed assessments of ocean heat content; particularly priority gaps to be addressed in order to close the sea level budget. Gaps include the deep ocean, marginal seas and the ice covered ocean. The panel noted that while the inventory is important, an understanding of mechanisms was also needed. Ocean reanalyses can be particularly useful for evaluating horizontal transports, however there may be a need to re-engage and seek to re-energize the ocean reanalysis community.

N°	Action	Responsibility
O1	Consult with CLIVAR-GSOP to re-energise the global ocean reanalysis effort and entrain them into ongoing OOPC-led assessments of the observing system.	Matt Palmer, Tony Lee

2.4 Biosphere Observations.

The GOOS Bio-Eco Co-Chair Nic Bax co-led a discussion on the biosphere observations for climate. Full details of the breakout discussion can be found in part section A.7.5. Usefully, the breakout session included Joanna Post from the UN Framework Convention on Climate Change, and Peter Thorne, Coordinating Lead author for the Intergovernmental Panel on Climate Change (IPCC) 6th Assessment report (AR6). Katy Hill, Bernadette Sloyan and Johannes Karstensen (OOPC) also participated.

The group questioned what the drivers for including biosphere observations in GCOS. How far down the adaptation and mitigation pathway is GCOS interested in proceeding. Is the biosphere only there to balance the carbon cycle or is GCOS also interested in impacts of change on the biosphere and its human use? Guidance is needed from GCOS on the drivers for including biosphere observations.

The ocean and land biosphere ECVs currently very different: Ocean ECVs are typically species-based and land-based ECVs are more process-based and more consistent with Essential Biosphere Variables (EBVs). Discussion focussed on 3 potential ECVs (based on indicators in IPCC AR4, and EBVs), which could span ocean and terrestrial systems:

a. Phenology;

b. Distribution;

c. Productivity.

The Group agreed to ensure marine information for phenology and distribution was provided to for AR6 Chapter 2 (Peter Thorne, Nic Bax).

There are good examples of this in the literature, synoptic coverage is not necessary, and they are much more easily measured than abundance/productivity measures. Ocean productivity seen as too complicated to achieve in the short-term, especially as this would require a more synoptic set of monitoring, including sub-surface production which may not be well-represented by satellite-based surface ocean colour.

The Group agreed to investigate joint workshop between terrestrial and ocean researchers on phenology and distribution observations/datasets to improve consistency and value of phenology and distribution – including potential for mining paleodata. Explore interest of Future Earth.

Implications for OOPC and GOOS Panels:

- Existing ECVs for marine biosphere may not be the key ones used in IPCC AR6.
- Biosphere impacts (phenology and distribution) may in the short-term be better serviced by synthesizing existing data from mixed sources (including citizen science) than new observations.
- Extent of GCOS interest in including biosphere (beyond carbon function and towards impacts, adaptation, restoration) needs to be established.

In the discussions that followed, the group asked if while we can't measure productivity in absolute terms, can we monitor (relative) productivity changes. Nic Bax noted that the ocean bio/ecosystem panel was challenged by the different needs of communities when identifying EOVs (e.g. food security or ocean health). The panel also discussed if there were biological observing needs which could be easily met, leveraging existing platforms, e.g. sensors on moorings, or doppler profilers for biomass estimates, passive acoustics. A new emerging EOV for Ocean Sound has been identified, supported by the International Quiet Ocean Experiment. The links to the Carbon cycle discussions were also noted.

N°	Action	Responsibility
O2	Seek clarity from GOOS SC regarding extent of interest in including Biosphere in the next GCOS IP.	Bernadette Sloyan, Nic Bax

2.5 Intersections between climate cycles discussions

Many links were highlighted between the Energy Budget and Water Cycle discussion; in addition the group noted the links between the biosphere, carbon and energy discussions. Measuring changes to ocean carbon is challenging as trying to capture a small perturbation of a big flux and a really big stock of carbon in the ocean. This makes the observation of carbon cycle difficult, and highlights the importance of engaging Biogeochemical modellers. In the GOOS Biogeochemistry discussions, it was the modellers who advocated for flux of particles for BGC modelling (particulate organic carbon, POC) to be an ECV. The discussions highlighted the importance of engaging the modellers. Links between the group discussions will influence where the emphasis will go for collecting new biosphere data; for the carbon cycle, observations plankton size/functional types are needed whereas for distribution species level data are needed.

2.6 Global Energy Fluxes

On day 3, the first parallel breakout discussion focussed on the details of the surface Energy fluxes at the air-sea and air-land interfaces, while the second parallel session focused on land-ocean interactions, and the third parallel session focused on extremes and the biosphere.

Bob Weller, Liz Kent, and Meghan Cronin led the breakout discussion on the surface energy fluxes, which drew from the OceanObs'19 Whitepaper (Cronin et al, 2019), a "building blocks" document prepared by them prior to the meeting, and discussions between OOPC and AOPC, the TPOS 2020 Planetary Boundary Layer Task Team, and the WCRP WDAC flux working group. A 10-year roadmap was laid out in the OceanObs19 Cronin et al. (2019) paper that would lead to a goal of having a gridded air-sea heat flux product with 25 km resolution at 3 hourly time steps (and an aspirational goal of 10 km at hourly resolution) that had an ambitious 1-day random uncertainty of 15 W/m2 (5%) and biases less than 5 W/m2. Likewise for wind stress, the product would have a 1-day random uncertainty of 0.1 N/m2 (5%) and biases less than 0.005 N/m2. The roadmap is based upon two major recommendations:

#1 Optimize satellite-based retrievals for boundary layer measurements of air temperature and humidity, sea surface temperature, and ocean wind stress.

#2 Create a global in situ array of flux observing platforms, built around an expanded OceanSITES network of time series reference station moorings.

Near-term steps were laid out in the "building blocks" background document, submitted ahead of the meeting. In particular, these air-sea flux team proposed the following next steps:

- Set up a working group across panels including AOPC, OOPC, and TOPC, plus carbon experts, considering engaging modellers and other expertise also. The group will mainly be supported by Caterina Tassone.
- Coordinate land surface radiation observing, including the Baseline Surface Radiation Network (BSRN), with the ocean-based surface radiation observing networks (e.g., OceanSITES). As a first step, it was a workshop on Radiation observations across land and ocean would be held to share best practices, decide how best to establish the provenance and quality of surface radiation observations, and make surface radiation observations across the globe accessible.
- Engage the Working Group on Numerical Experimentation (WGNE) and Working Group on Coupled Modelling (WGCM).
- Engage the WDAC Fluxes group on coordination of the forward path for global surface fluxes and the plans for ocean surface fluxes.

As the GOOS Biogeochemistry co-Chair and secretariat were in attendance, the panel discussed the synergies between the goals for air-sea heat and momentum fluxes with those for the carbon fluxes, and how the efforts should be connected. The panel noted the similarities with the measurement types and scales of interest, including the need for accurate, co-located wind measurements. Many ocean platforms that measure air-sea heat fluxes could likely be used to also measure carbon fluxes, and vice versa. While carbon fluxes are currently measured indirectly through bulk formulae (pC02 observations), it is expected that direct carbon flux measurements are possible. The biogeochemistry representatives noted that Carbon flux observations would always use model winds because of the need to extrapolate; assumptions have to be made regarding for instance a constant atmosphere. The panel noted that for air-sea heat fluxes, these assumptions can't be relied on, so will definitely have co-located measurements, and there are possibilities for the platforms to be leveraged for carbon and other fluxes. It was also noted that high winds and waves breaking were responsible for approximately a 30% uncertainty in carbon fluxes and highlights that in addition to recent focus on ocean surface stress, the Sea State ECV needs attention. This raises further the importance of seeking support for satellite winds. Particularly L-band satellites as they are more effective at seeing through stormy/cloudy conditions than KU-band winds. The group

suggested it might be useful to highlight this additional need when advocating for the continuance of ocean vector wind satellite missions.

It was agreed that it would be important to engage the surface CO2 representative on the GOOS Biogeochemistry panel, as well as the Surface Ocean Lower Atmosphere Study (SOLAS) project and the IOC Ocean Sciences Division Carbon group.

N°	Action	Responsibility
O3	GOOS Biogeochemistry Panel to identify carbon fluxes expertise to join the Air Sea Fluxes Task Team.	Masao Ishii, Maciej Telszewski, Meghan Cronin, Bob Weller
O4	Consider raising specific needs for ocean surface stress ECV/EOV Data for Carbon applications.	OOPC Chair, Secretariat
O5	Raise OOPC engagement with WGNE and WGCM Chair/Secretariat.	Matt Palmer, OOPC Secretariat

2.7 Extremes

The breakout group on extremes was proposed by the preceding Biosphere breakout, which noted in discussions with IPCC on the first day of the Joint Panels meeting, that 'marine extremes' were not considered in the 6th assessment report chapter on extremes. The breakout session discussed large scale extremes, and connections across the 3 domains; and considered whether the ECVs and their requirements were sufficient to enable GCOS to characterise extremes, particularly the time resolution required. The group noted that there is only one observing system, which needs to measure all the required space and timescales, beyond those needed for climate. The group also discussed the potential for 'categories' of extreme events, akin to Hurricane categories.

The breakout also discussed capacity to improve predictions of extreme events through e.g. coupled forecasting developments, and what this might mean for observation requirements. The challenge posed by the scales of extremes were discussed. Characterisation of terrestrial extremes are challenged by the local effects in built up communities; whereas in the ocean, the observing system is probably capable of measuring these events. There are some examples of small scale events such as oxygen minimums in eddies; and some research that suggests that the ocean is becoming more baroclinic. It was agreed that considering extreme events in the context of GOOS would be better, given GOOS covers applications across all time scales, and not just extreme events in the context of climate.

2.8 Land-Ocean interactions

The breakout largely focussed on two areas. River discharge as a key observation for many applications, and regional sea level rise and coastal impacts.

As global models move to higher resolution and regional hydrodynamic model are developed across the land-sea interface for a range of applications, there is an increased need for accurate and timely riverflow and runoff data. River fluxes were also identified as a key uncertainty in closing the Carbon Cycle. Coastal hydrodynamic modelling also demand improved coastal wind data. The challenge with river discharge observations are that many different groups collect the data, and there is a reluctance to share it. Developments in hydrodynamic modelling and forecasting and reanalyses are helpful in integrating the disparate datasets, as well as making the case that when the data is shared and included in regional products and forecasts, they are much more useful. Hence the group discussed whether the

development of regional hydrodynamic modelling capabilities could be used as a motivator for data sharing in the coastal and catchment regions. The upcoming launch of Swath Altimetry (SWOT) could also be a useful motivator to discuss in situ calibration/validation needs.

Wind data is also a key requirement for regional hydrodynamic modelling, particularly as Scatterometer wind data is not available within 12 km of the coast. The group discussed how existing observations could be leveraged; e.g. the quality control and curation of wind data from operational metocean moored buoys under the auspices of the Data Buoy Cooperation Panel, and the addition of doppler scanners on HF Radar networks.

OOPC needs to consider broader coastal applications than those for GCOS, and focus on targeted needs where progress can be made. It would be useful to identify and engage groups working on coastal environmental prediction systems development (e.g. the UK Met Office, the Australian e-Reefs project, etc) within the Boundary Systems task team.

N°	Action	Responsibility
O6	Initiate discussions with TOPC Hydrology representatives on applications, in preparation for the launch of Swath Altimetry (SWOT) for tracking mass changes/transport changes across the planetary surface.	Tony Lee, TOPC
O7	Work with the JCOMM/GOOS Observations coordination Group to advocate for improved accessibility and QA/QC of archived in situ coastal wind data.	Tony Lee, John Wilkin, OOPC Secretariat
O8	Connect with WCRP Grand Challenge on Sea Level Rise and Coastal Impacts re. articulation of applications, observation needs (inc. Workshop on Coastal Climate Services in November 2019).	OOPC Secretariat; Matt Palmer to attend workshop

2.9 Discussion: Utility of Cross Panel discussion

The attendees discussed the utility of cross panel discussions, and particularly discussions on Adaptation needs, and the link to climate services, potential for adaptation/response ECVs and indicators to inform adaptation, of adaptation. It was suggested that the EOV specification sheets could be given to groups working on adaptation to see if there are any gaps in the requirements. It was agreed that more guidance was needed specifically on what the GCOS panels were being asked to do, and agreed to write a letter to GCOS outlining:

- OOPC focusses on observations to improve understanding and prediction of the ocean component of the earth system, to improve the delivery of forecasts required across the timescales required for adaptation decision making (e.g. TPOS 2020).
- Specific stakeholder needs will be considered in developing work plan activities
- Recommend the GCOS SC task team on Adaptation Strategy develop an engagement strategy for discussions with Adaptation groups and activities (for instance, Climate Services programmes, the WCRP Workshop on Sea Level Rise, Coastal Climate Services).
- Recommend GCOS SC task team on Adaptation Strategy provide guidance to panels on what additional effort is required in this space.

N°	Action	Responsibility
O9	OOPC to draft a letter to the GCOS SC highlighting activities in support of Adaptation, recommendations for where effort, guidance is needed from the SC task team on Adaptation Strategy.	Bernadette Sloyan, Matt Palmer, OOPC Secretariat

3. OOPC Meeting

3.1 GOOS 2030 Strategy and Guidance to OOPC

GOOS Co-Chair Toste Tanhua gave an overview of the GOOS Strategy, including the vision, mission and strategic goals. He then gave an overview of the GOOS Structure, acknowledging the dual role of OOPC, and the OOPC's role in the 'feedback loop' in ensuring the observing system evolves to meet the diverse range of user requirements across Climate, Operational Services and Ocean Health. In this context GCOS represents a pathway for delivery to one of these user communities, with associated partnerships with Research (WCRP), Assessments (IPCC) and Policy (UNFCCC). The panel discussed whether similar partnerships with research, assessments and policy could be fostered for other panels and application areas. The governance of the Global Ocean Observing System, and how it needs to evolve to meet future needs will be the focus of discussion over the coming months and during OceanObs'19.

3.2 Role of OOPC

Given the complex and evolving demands on OOPC, particularly the dual role in plays for GCOS and GOOS, the panel took a step back to consider the unique role of the panel, and where it should focus its efforts to advance the observing system. The panel discussed where it felt it put effort against the GOOS Strategic Priorities and agreed to provide this input to the GOOS Steering Committee at their upcoming meeting in Kiel, Germany 1-3 May 2019.

3.3 Panel member perspectives.

Panel members were asked why they were on the panel and came up with a number of motivations, including:

- Oversight of the observing system and the need to 'broker' its evolution;
- A platform for connecting the big issues such as air sea fluxes, too big for a SCOR working group, and beyond one satellite, one network;
- Leadership of community efforts to develop fit for purpose observing systems;
- The observing system needs international coordination and oversight, bringing user communities together, sharing knowledge;
- Integration of satellite/in situ systems and assessment of observing system impact. Connection to observing system design and assessment, OSSE community;
- As a platform to put personal research, regional issues into a global perspective and bring that back to national community, strengthening impact on a global scale;
- Integration of regional observing systems into the international context for e.g. addressing global questions;

- Promoting the exchange of information between observations and modelling communities for the benefit of both, interest in improving predictions and projections on all timescales to inform international adaptation planning and underpin climate services;
- Key focus is on evolution (of requirements and of the observing system), which brings new opportunities. For new partners in the observing system, there is an opportunity to 'get onboard' a running train, and hence expand participation in the observing system;
- From a services point of view, feeding back guidance on observing system gaps and improvements across the range of applications;
- Recognition OOPC is a small group, given its historical impact and ambitious mandate.

As summary of the panel members response, is that OOPC key role is to provide authoritative guidance towards building an integrated, and consistent observing system, and to advocate for a sustained ocean observations.

Key activities are

- Assessment of ocean observing system with a global perspective - global integration of basin, topic and observing platform activities for a consistent observing system;
- Identify gaps in the observing system based on user requirements;
- Guidance and prioritized recommendation for future observing requirements;
- Advocate for the ocean observing system.

3.4 Relationship with the JCOMM-GOOS Observations Coordination Group

Chair of the Observations Coordination Group, David Legler, outlined the OCG role, membership and work plan and where guidance was needed from OOPC. The panel discussed potential areas of joint activity between OOPC and OCG. These included:

- Design and/or integration of observing to address gaps/take advantage of new capabilities
  - Pick a few foci; e.g. Boundary Current regions, air-sea fluxes, heat and freshwater content; and move forward.
  - JCOMM priority areas; tropical forecasting, midlatitude storm forecasts (adaptive sampling), wave forecasting.
- Monitoring/tracking observing system performance and effectiveness of meeting implementation targets, addressing requirements
  - Develop appropriate metrics along value chain.
- Assessment/Evaluation of Observing System at critical junctions.
  - Decadal review? Consideration/incorporation of new platform and sensor technologies (separate OOPC agenda discussion).
- Engagement discussion: stakeholders, end users.
- OCG Monitors Observing System Implementation, Data Delivery.
  - How do we monitor performance by variable, use/impact by application?
  - How do you connect the whole value chain in terms of metrics?

In the discussion that followed, it was agreed that joint activities between OOPC and OCG are central to taking forward an integrated ocean observing effort. We need to be able to monitor and evaluate the observing system in terms of metrics for:

- Implementation (by network, by variable);
- Data Delivery (by network, by variable)K;
- Performance (by application, phenomenon);
- Impact.

3.5 Revisiting the role of OOPC (I)

While OCG can evaluate implementation and data delivery, the design criteria/requirements are provided by OOPC; OOPC will need to take the lead on evaluations of performance and impact. The discussion helped crystalize the role OOPC plays going forward in the design and advocacy of the observing system to ensure delivery and impact. This includes brokering network design, in the context of the broader observing system capabilities. The networks may have ambitious forward plans, e.g. the Argo 2025 vision, or plans for OceanSITES; but it is up to OOPC take the systems perspective; to advise how network capabilities fit together to deliver an integrated observing system. OOPC also has the responsibility to look across regional projects and developments, and fit them into the global view. For instance, recent regional reviews, The Tropical Pacific Observing System (TPOS 2020), Tropical Atlantic Observing System (TAOS), and the Indian Ocean Observing System (IndOOS). OOPC also needs a strong connection with research programmes (such as WCRP-CLIVAR), particularly given most observations are research funded. OOPC must be a strong advocate for sustaining the observing system at the international and national funding level, and also for process studies leverage, advance the observing system. However, we also need to be cognizant that there are broader users and uses of the observing system than science, and we need to find ways of representing the needs of these broader users and increasing their support/advocacy of the observing system.

Hence, OOPC agreed that the panel is focussed on:

- Global Design, adequacy and assessment (e.g. observing system reviews);
- Regional - global design, across regional observing activities to advance the global effort (e.g. TPOS 2020, IndOOS, TAOS);
- Assessment of the observing system engaging operational agencies (need the weight of international community consensus to request assessments, feedback from e.g. ECMWF, JMA).

Based on the discussions, the panel reviewed whether effort was focussed in the right places. The current review focii provide a holistic review of the whole system including the Ocean Interior (Ocean Heat and Freshwater Storage), the boundary with the atmosphere (Air Sea Fluxes), and the boundary with the coast (boundary systems). The panel needs to be proactive in reviewing developments in the regional observing systems and reviews, and particularly how we learn from these efforts to guide the review of the observing system going forward. It was noted that the OOPC focii are currently largely driven by science and perhaps less by stakeholder needs; for instance, perhaps the panel should strengthen focus on coastal issues.

It was agreed that the panel needed to be more proactive at communicating its role and activities. The OOPC secretariat will continue to provide updates to the OOPC slide deck, and also develop the OOPC web presence to include pages for each of the key activities areas.

N°	Action	Responsibility
O10	Task leads to work with Katy to develop the webpages to outline current activities, contact points, etc.	Meghan/Bob, Matt/Paul, Marjolaine/Maria Paz

4. OceanObs'19

Sabrina Speich presented an overview of the planning for the OceanObs'19 Conference. Preparations so far represent a huge community effort, with 131 whitepapers submitted comprising 2000 unique authors from around the world. The Programme Committee and Sponsors Committee were now working on finalizing the programme, including afternoon breakout sessions (proposals for which were also submitted). The panel noted that important achievements came out of OceanObs99 and 09, and in general, this was known before. The OceanObs'19 leadership has been discussing the proposed outcomes but the ideas need further refinement. Some noted that there is a strong emphasis on delivering to industry in the proposed themes, verses benefits to society more broadly i.e. sustainable development goals. The UN Decade of Ocean Science for Sustainable Development, 2021-2030 is seen as a significant opportunity for advancing ocean observing; and potentially many of the outcomes of OceanObs (particularly for scientific and technological development) could be take up through the Ocean Decade agenda.

The panel noted that the whitepapers represented a massive amount of work from the community. It was an effective way to ensure good ideas bubble up to the surface, but questioned if the conference was the forum to decide which ideas gain traction; and to what extent the panel needed to play this role. It was agreed that the panel should be proactive in engaging in breakout sessions to ensure we get the best out of these fora in taking forward the OOPC work plan.

N°	Action	Responsibility
O11	OOPC review breakout sessions, and decide where OOPC needs to engage and who will represent the panel. (breakout sessions released late April, OOPC to discuss on teleconference in mid May).	OOPC

5. 10 year vision for OOPC

OOPC has an opportunity to consider a decadal vision for its activities, and in particular what the panel hopes to achieve on a decadal timeline, building on the planning for the OceanObs'19 decadal conference, and the UN Ocean Decade of Ocean Science for Sustainable Development. Perspectives included:

- Over the 10 years' time, it is hoped that OOPC would be able to identify, based on an assessment of the Observing System, where the gaps and opportunities are.
- While OOPC doesn't need to do all the work, it does need to provide guidelines, charge groups, and show leadership.
- In terms of OOPC's role in guiding assessments, the panel should consider keeping pace with the decadal planning schedule of OceanObs conferences.

- The panel needs to be working across all relevant timescales; for instance, atmosphere-ocean interactions need focus on shorter timescales, particularly given the development of coupled NWP. Hence, OOPC will need to consider forging links with groups beyond GCOS and WCRP working on the research and observations of shorter timescales.
- The panel also needs to consider multidisciplinary thematic focii which require cross GOOS panel effort. The panel, in consultation with other GOOS panels, could charge or guide workshops which would inform multidisciplinary observing system development, engaging e.g. WCRP-CLIVAR as now, but also WWRP, Future Earth, IOC Ocean Sciences programmes.

6. Revisiting the role of OOPC (II)

Given the discussions so far, the panel discussed the skills required to meet the evolving panel role, and potential membership gaps. Particular gaps highlighted include links to modelling areas; reanalysis, operational forecasting development, Ocean Forecasting (OceanPredict), Seasonal, Decadal Prediction; and coastal, near shore applications and expertise, and wave/sea state expertise.

N°	Action	Responsibility
O12	Refine Terms of reference for OOPC	Bernadette Sloyan, OOPC Secretariat
O13	Review OOPC membership, skills mapping and identify gaps	Bernadette Sloyan, OOPC Secretariat

7. OOPC Workplan

7.1 Air-Sea Fluxes

OOPC's task on air sea fluxes, led by Meghan Cronin and Bob Weller (with Liz Kent from AOPC) is gaining momentum, through the OceanObs'19 whitepaper led by Meghan (in press) and the discussions with AOPC, and the 'building blocks' document, with a list of specific actions coming out of the energy fluxes breakout. The aim now is to form a Joint Panel flux team, encompassing air- ocean and land fluxes. Caterina Tassone (AOPC staffer) has offered to provide some support to this effort. Proposed membership, rationale, and outcomes are being drafted, which will be separate but connected to the WDAC Air Sea Fluxes group. The aim is to take some tangible steps forward, building on the approaches outlined in the 'building blocks' document. There is also a recognized need to connect to work on fluxes of carbon dioxide, etc. with the GOOS biogeochemistry Panel. It was also noted that there is an increased focus on understanding and monitoring air sea fluxes on shorter timescales, given the developments in coupled forecasting. This may require OOPC to reach out to atmospheric groups other than AOPC. Given the many potential connections to make, OOPC representatives will need to be careful to focus effort where it is most impactful (actions for this work plan area are embedded in the Energy Fluxes breakout session).

7.2 Heat and Freshwater Storage

Matt Palmer (OOPC) is co-leading this task with Paul Durack; building on the OceanObs'19 whitepaper they also led (in press), which has now been accepted for publication. Matt and Paul plan to oversee a series of workshops in the coming years.

The first workshop will be at the UK Met office in April 2020, following on from the WCRP Workshop on the Earth's Energy Imbalance which was held in November 2019 in Toulouse,

France, and building on the CLIVAR Research Focus on the Planetary Heat Balance and Ocean Heat. The workshop aims to:

- Explore the use of emerging observation-based estimates of large-scale energy and water transports in model evaluation, assessment and development.
- Assess the current capability of the ocean observing system to constrain changes in heat and freshwater storage and identify priority areas for new observations.
- Assess the current state of heat and freshwater conservation in Earth system and climate models.

A small organizing committee is being developed, and more details will be circulated shortly.

A second workshop is being considered by Paul's home institute, Lawrence Livermore Laboratory, Program for Climate Model Diagnosis & Intercomparison. The focus will be on integration of some of the 1st Workshop developments into the Earth System Model Validation (ESMVal) tool for the consistent analysis of CMIP Climate Models.

The panel agreed that the integrated observations-modelling approach taken with this task is an example of how we can use the available tools to advance how we understand, model and predict aspects of the ocean. The OceanObs whitepaper had a focus on global and regional case studies, synthesis of existing observations. The progress and developments of these case studies will also need to be synthesised as part of this task. While the current activity is focussed on the climate aspects, there are broader applications to be considered, for instance ocean heat content has shorter timescale applications such as cyclone forecasting, and ocean health applications, e.g. marine heat waves and distribution changes.

N°	Action	Responsibility
O14	Form organizing committee and initiate planning for the 1st OOPC Ocean Heat and Freshwater Workshop	Matt Palmer, Paul Durack, OOPC Secretariat.

7.3 Boundary Systems

Marjolaine Krug and Maria Paz Chidichimo are leading the boundary systems task team for OOPC, with Robert Todd and John Wilkin. This has gained momentum through the OceanObs'19 Open Ocean-Shelf Interactions white paper (in press), and a task team is now in the process of being formed. The Task Team has three main focii:

- Boundary fluxes and circulation;
- Air Sea Fluxes;
- Shelf-deep ocean exchange.

The Task Team membership is currently missing satellite expertise as well as substantive representation from OceanPredict (formerly GODAE OceanView). The team will be considering both eastern and western boundaries: though given the broad scope, will need to identify early priorities to address.

Ahead of the first Task Team call, the Task Team leads plan to review and draw on priorities from relevant OceanObs'19 whitepapers. It was noted that OceanObs'19 whitepapers were focused on societal needs and current status of observations, rather than gaps in the observing system or a future vision. The Observations Coordination Group emphasised that it needs guidance in observing the boundaries, given many of the observing networks are already working in, or have aspirations to enhance effort in boundary regions.

Approaches that could be considered include:

- Consider existing observing networks aspirations in boundary regions in an integrated context.
- Portable 'laboratory' approach to test observing system enhancements in different boundary systems
- Consider regional gaps in global boundary systems observations, and the minimum observations needed to be able to connect the global picture.
- Prioritize boundary systems to focus on given their role/significance in the global context.

In the discussion that followed, the panel discussed whether under currents and extension regions were in scope, or something to be considered for a later stage. These topics would also be of relevance to the Ocean Heat and Freshwater task. The Panel also discussed the range of applications for boundary systems observations including seasonal-decadal forecasting, and fisheries stock assessments and fisheries management projections. It would be helpful to articulate these applications in order to help prioritise effort. The deep boundary currents were also discussed, but it was agreed these were a focus for the Deep Ocean Observing Strategy (DOOS).

N°	Action	Responsibility
O15	Set up a call for the Boundary Systems TT, to consider 'Charge', priorities and next steps	Marjolaine Krug, Maria Paz Chidichimo

8. Regional Reviews

8.1 Tropical Atlantic Observing System (TAOS)

Sabrina Speich outlined the progress to date with the TAOS. The review report will be available for expert review in April 2019. The report includes a matrix of EOV requirements by phenomenon, so it could be a useful test for the application of the OOPC Specifications in a regional context.

N°	Action	Responsibility
O16	OOPC members to review the TAOS report, and particularly consider connections with other reviews	OOPC, Sabrina Speich

8.2 Indian Ocean Observing System (IndOOS)

Tony Lee gave an overview of the IndOOS review, which outlines a number of recommendations, which include:

- Tier 1. Core System including Argo, Satellites and Moorings (with recommendations to consolidate existing mooring array design due to vandalism and/or challenges occupying sites.
- Tier 2. Proposed enhancements, particularly to address operational needs, biogeochemistry, cyclogenesis.
- Tier 3. Pilot projects.

The panel discussed the need to connect up efforts in the Pacific and Indian Ocean, and particularly efforts in the Maritime Continent. For instance, it is not clear how the Indonesian

Throughflow is addressed with these reviews, and how the Year of the Maritime Continent is considered. A core role of OOPC is to broker the outcomes of these regional efforts into a global observing system view.

N°	Action	Responsibility
O17	OOPC members to review IndOOS review, particularly in the context of the other regional reviews, building a global view	OOPC, Tony Lee

8.3 TPOS 2020

Weidong Yu gave an overview of progress with the TPOS 2020 Project, including the outline of the 2nd Report (currently being revised following international review). Building on the first report, the 2nd report provides a refined view of the proposed observing system.

The Panel discussed the rationale for the revised design, which is driven by the need to track coupled ocean-atmosphere interactions, with enhancements regimes. The new design includes some lower priority components, driven by investment verses impact. Notably some have raised concerns about existing mooring sites being considered low priority. However, proposed mooring design will have significantly enhanced capability, resulting in enhanced coverage by variable for all variables being measured. The observing system can and will change into the future, to respond to new requirements, capitalise on new understanding and technological developments and it is a role for OOPC to oversee how that is managed.

The 2nd report attracted over 800 comments, so these are currently in the process of being addressed.

David Legler, Chair of the TPOS 2020 Resources Forum, noted it was a very robust implementation of the Framework for Ocean Observing, and the most comprehensive assessment of requirements he had seen.

N°	Action	Responsibility
O18	OOPC members to read Chapter 7 of the second report (as a minimum), in order to advise community and consider how the TPOS 2020 approach fits in with the global observing system development.	OOPC

9. OceanObs'19 OOPC Whitepaper

Bernadette presented the OOPC OceanObs whitepaper, which needs revision following peer review. The panel particularly discussed the recommendations, to see if these still were accurate following the panel's discussion on its role and vision. The group agreed that consistency and integration needed to be included, and some wordsmithing could be done re. The role of OOPC, given the many connections we need to foster with atmosphere, land activities as well as ocean biogeochemistry and biology. The group agreed that OOPC's charge is focussed on observing the role of ocean physics in the earth system. The panel also needs to articulate how it will fulfil its charge. It was noted that many of the reviewer comments were quite general and required more thought.

N°	Action	Responsibility
O19	Respond to reviews of the OceanObs'19 OOPC whitepaper and submit an updated manuscript	Bernadette Sloyan, OOPC Secretariat

10. Close of meeting, and arrangements for OOPC-23

The main actions are summarised in the section below. For the 23rd Session of OOPC, Marjolaine Krug has offered to host in Cape Town, South Africa, in the week of the 9-13 March 2020.

Annex O1: OOPC-22 Agenda

Wednesday PM. 2-5.30

Continue discussion of cross-panel,

- Progress made, implications for OOPC work plan, and issues for follow up from cross cutting discussions with GCOS Atmosphere and Terrestrial panels. GOOS Biogeochemistry and Biology panels.
- How to fold into the panel work plan, particularly relation to Air Sea Fluxes, Boundary Currents, Ocean Heat and Freshwater Content.

Thursday 11-5.30

- OOPC Forward vision and the role of the panel. (DISCUSSION – Agreed guidance from GCOS/GOOS also relevant here but perhaps we need also a motivational background doc/presentation re. a coherent vision for OOPC's role?)
    - o What is the role of OOPC?
    - o How do we fulfil that role?
    - o How do we interact/intersect with other groups (e.g. JCOMM OCG, regional observing systems? (reference to WMO reform).
- Guidelines for Observing System Reviews (see draft document).
- OOPC and JCOMM Obs Coordination Group Intersect and future joint work, e.g. Observing System development and review, Best practices by Variable, Data Management(?).

Friday 9am-2pm

- Regional Observing System development and review (TPOS 2020, TAOS, IndOOS, etc.), discussion: guidance and oversight from OOPC?
- GCOS IP Actions Physics, Biogeochemistry, Biology (see tracker)
- Review OOPC 21 Actions,
- Agree OOPC Workplan, input to GOOS Implementation Plan.
- Any other business?

Actions from OOPC-21:

https://docs.google.com/document/d/1_I1TwTT-77wRcrqzkYN_TAoo4UtOnusL_zDw4iruIx4/edit?usp=sharing

GCOS Implementation Plan Ocean Actions:
https://drive.google.com/open?id=1V7udFHUTB1Dr0tM1i2w_7EfXbqQs4XXjdg5Tp--Qbkg

Annex O2: OOPC-22 Actions

N°	Action	Responsibility
O1	Consult with CLIVAR-GSOP to re-energise the global ocean reanalysis effort and entrain them into ongoing OOPC-led assessments of the observing system	Matt Palmer, Tony Lee
O2	Seek clarity from GOOS SC regarding extent of interest in including Biosphere in the next GCOS IP	Bernadette Sloyan, Nic Bax
O3	GOOS Biogeochemistry Panel to identify carbon fluxes expertise to join the Air Sea Fluxes Task Team	Masao Ishii, Maciej Telszewski, Meghan Cronin, Bob Weller
O4	Consider raising specific needs for ocean surface stress ECV/EOV Data for Carbon applications	OOPC Chair, Secretariat
O5	Raise OOPC engagement with WGNE and WGCM Chairs/Secretariat	Matt Palmer, OOPC Secretariat
O6	Initiate discussions with TOPC Hydrology representatives on applications, in preparation for the launch of Swath Altimetry (SWOT) for tracking mass changes/transport changes across the planetary surface	Tony Lee, TOPC
O7	OOPC to draft a letter to the GCOS SC highlighting activities in support of Adaptation, recommendations for where effort, guidance is needed from the SC task team on Adaptation Strategy	Bernadette Sloyan, Matt Palmer, Nic Bax
O8	Task leads to work with Katy to develop the webpages to outline current activities, contact points, etc.	Meghan/Bob, Matt/Paul, Marjolaine/Maria Paz
O9	OOPC review breakout sessions, and decide where OOPC needs to engage and who will represent the panel. (breakout sessions released late April, OOPC to discuss on telecon in mid-May).	OOPC
O10	Refine Terms of reference for OOPC	Bernadette Sloyan, OOPC Secretariat
O11	Review OOPC membership, skills mapping and identify gaps	Bernadette Sloyan, OOPC Secretariat
O12	Form organizing committee and initiate planning for the 1st OOPC Ocean Heat and Freshwater Workshop	Matt Palmer, Paul Durack, OOPC Secretariat.
O13	Set up a call for the Boundary Systems TT, to consider 'Charge', priorities and next steps	Marjolaine Krug, Maria Paz Chidichimo
O14	OOPC members to review the TAOS report, and particularly consider connections with other reviews	OOPC, Sabrina Speich
O15	OOPC members to review IndOOS review, particularly in the context of the other regional reviews, building a global view	OOPC, Tony Lee
O16	OOPC members to read Chapter 7 of the second report (as a minimum), in order to advise community and consider how the TPOS 2020 approach fits in with the global observing system development.	OOPC
O17	Respond to reviews of the OceanObs'19 OOPC whitepaper and submit an updated manuscript	Bernadette Sloyan, OOPC Secretariat

D. TOPC

21st Session of the Terrestrial Observation Panel for Climate (TOPC-21)

Opening

Wolfgang Wagner, Chairman of TOPC, opened the 21st Session of the TOPC officially and thanked the Secretariat for organizing the Joint Panel Meeting. He welcomed the opportunity to discuss with the other panels on common issues and explained that the work of TOPC will benefit from the interaction. This TOPC session would be mainly dedicated to digest all the information from the joint sessions held earlier in the week and include the new topics into TOPC's work plan.

Wolfgang Wagner announced that this will be his last TOPC meeting as a chair since he will step back at the end of the year due to other obligations at his university. He explained that he enjoyed having been member and being chair of TOPC and that he generally appreciates the work and approaches of GCOS as very useful for the climate observation community. He also mentioned his concerns about the handover to the next chair, yet to be assigned. As a chair of TOPC, he will participate in this years' GCOS Steering Committee meeting in Paris and in his view, it would be good if the new chair could already participate there as well in order to plan the handover of the panel. He encouraged all members of TOPC to continue their work as before and offered to continue to host the TOPC online platform also after his resignation.

All team members and the secretariat expressed their great appreciation leadership of TOPC and thanked Wolfgang Wagner for his outstanding work as a chair.

Wolfgang Wagner reported further that the online forum of TOPC is a success and that the other panels expressed their intention to also establish a similar forum. Also during this meeting, he suggested to work practically and update discussions etc. directly in the forum.

1. Output from Joint Panel Meeting

1.1 Discussion on outputs from the first two days and implications for TOPC

Biosphere

The first discussion dealt with the expressed need to promote the biosphere more within GCOS agenda and the role of biosphere observations for climate, as discussed during agenda item A.9.20. TOPC agreed to increase their engagement, focusing on biodiversity and phenology. Nadine Gobron accepted to make a first effort for phenology.

N°	Action	Responsibility	Deadline
T1	Prepare proposals for monitoring phenology, probably as part of an existing ECV.	Nadine Gobron	15/06/2019

Coast

Following the discussion on coastal issues during the cross-panel discussion item A.9.2, Sarah Carter confirmed that it would be possible to have changes of coastline as an ECV product, however it is currently not operationally monitored. It was further noted that OOPC is interested in nutrient and sediment data, river and groundwater discharge but these are far from being monitored and/or shared globally. GCOS should promote data access and data and

information exchange of existing platforms. For potential topics for a coastal working group nutrient and sediment load into oceans and sediments of melting permafrost were mentioned.

N°	Action	Responsibility	Deadline
T2	Develop proposals for use of land use product to monitor coastlines.	Sarah Carter	1/12/2019
T3	Promote data access and data and information exchange of existing platforms for river discharge (both quantity and quality).	TOPC, the Secretariat	N/A
T4	Ask OOPC if sediment data from melting permafrost in the arctic ocean is relevant.	Secretariat	15/06/2019
T5	If a joint task team with OOPC will be established, Stephan Dietrich and Claudia Ruz Vargas would be members from TOPC.	Stephan Dietrich; Claudia Ruz Vargas	N/A

Energy Cycle

Following the earlier discussion on the energy cycle (item A.7.4) and energy fluxes (Item A.9.1). it was noted, that the land aspect has been ignored so far in the energy cycle scoping paper despite the relevance of many terrestrial ECVs, particularly from the cryosphere and land surface fluxes and temperature. Therefore Darren Ghent, Huilin Li and Philippe Schoeneich will connect to the current working group and contribute to the paper.

N°	Action	Responsibility	Deadline
T6	Connect and contribute to Energy Cycle paper with focus on land surface fluxes.	Darren Ghent	15/06/2019
T7	Connect and contribute to Energy Cycle paper with focus on cryosphere.	Huilin Li; Philippe Schoeneich	N/A

Carbon Cycle

The carbon cycle scoping paper was presented and discussed earlier, agenda item (A.7.2). The co-location of in situ sites was discussed and Stephan Dietrich volunteered to reach out to Fluxnet to clarify open questions. In addition, it was noted that currently an ECV steward for soil carbon is missing and Wolfgang Wagner suggest to identify one during the World Soils Workshop 2019.

N°	Action	Responsibility	Deadline
T8	Connect to Fluxnet and see if it could contribute to the discussion on closing the carbon budget	Stephan Dietrich	15/06/2019
T9	Identify and informally approach new steward for ECV soil carbon during World Soils Workshop.	Wolfgang Wagner	15/06/2019

Water Cycle

TOPC discussed water in the light of the discussions on closing the water cycle, (item A.7.3). Currently the ECV lake is not well covered and Stephan Dietrich will reach out to identify new ECV Stewards. For rivers, he suggested to add a satellite expert as ECV Steward, working with NASA's Surface Water Ocean Topography (SWOT) Mission. Stephan Dietrich will lead the water cycle paper.

N°	Action	Responsibility	Deadline
T10	Identify and informally approach new Stewards for ECV lake.	Stephan Dietrich	15/06/2019
T11	Identify and informally approach an additional steward for ECV river with satellite expertise (SWOT).	Stephan Dietrich	15/06/2019

1.2 TOPC work updating IP for 2022

Speaker: Simon Eggleston

Simon Eggleston repeated his presentation from (item A.8) and the implications for TOPC were discussed. Since the suggested changes were proposed by TOPC; it was decided to accept all changes and continue to work on the requirements in the forum as before. During the discussion, several actions were proposed and the new definitions related to uncertainty were discussed. Wolfgang Wagner pointed to the triple collocation method that includes satellite, insitu and modelled data to quantify uncertainty.

N°	Action	Responsibility	Deadline
T12	Explore if Country Profile Data Base and WMO's extended extranet can replace the current forum once it is available.	GCOS Secretariat	When available
T13	For the requirements on stability the decadal timescale should be clearly stated in the related forum discussions.	GCOS Secretariat	15/06/2019
T14	Send around paper of Merchant et al 2017 and Gruber et al. 2016 on uncertainties.	Wolfgang Wagner	15/06/2019

In addition it was discussed, if TOPC and the terrestrial ECV requirements are ready for adaptation as discussed during item A.10 and to cover extremes as discussed during the cross-panel discussion A.9.3. Following a general discussion about observations for/of adaptation, the participants checked some example ECVs to see if their requirements are appropriate for adaptation and covering extremes. It was suggested, that the proposed requirement stratification in threshold, breakthrough and goal could be used to include these aspects, for example goal values for covering the temporal and spatial resolution for extremes. For some ECVs like river discharge, it might be advisable to add have an additional product for daily maximums like maximum daily river discharge following the example of daily maximum air temperatures. Also, cross-consistency between ECV requirements was discussed and it was decided to work towards a fully-fledged data assimilation approach for land.

- Next step adaptation TT:
  - Write up position paper

- Table with potential ECV for and few for ECV of adaptation ECVs and their readiness: first step: different requirements and then readiness.

N°	Action	Responsibility	Deadline
T15	Check if requirements are appropriate to cover adaptation aspect and extremes and consider these if applicable for future requirements.	ECV Stewards	Continuous

2. Review of IP Actions

2.1 Introduction and discussion

Given the limited time, the chair decided to not break into groups and discuss individual IP actions but rather discuss how to proceed in general with the IP actions.

2.2 Break-out groups, to review IP actions and status in forum

TOPC decided to continue working and reporting on progress in the TOPC forum as before since the forum has proven to be an efficient tool. It was also noted that many actions were not dealt with at all and that the respective IP Action Rapporteurs should check and update their topics.

N°	Action	Responsibility	Deadline
T16	Check if progress on IP Action are reported and if additional measures need to be taken to address the action.	IP Action Rapporteurs	Continuous

3. ECV requirements update and forum

TOPC reviewed the requirements and products of many ECVs for which experts have been present at the meeting. Therefore, it was decided to not break into groups but cover agenda items 3.1 – 3.4 as TOPC plenary discussions. This is reflected in this report.

The goal was to discuss issues but also see if the proposed requirements for individual ECVs for the next IP update in 2022 capture adaptation requirements and the observation of extremes. The following list follows the order as the ECVs have been discussed during the meeting:

- Albedo: not relevant for adaptation and extremes; ECV Steward NG will add unit.
- LAI: It might be relevant for adaptation or to monitor impacts of extremes, but the requirements currently do not reflect that.
- Permafrost: The suggested requirements are fit for extremes and the ECV is relevant for adaptation, e.g. is a lot of infrastructure in Siberia built on permafrost.
- Land surface temperature: This ECV is very relevant for extremes: urban heat, plant stress, droughts. To capture this, a different set of requirements is needed, e.g. less than 100m horizontal resolution, but also the timeliness of data delivery would need to be at least 6 hours. In regard of adaptation, the extremes are relevant.

- Glaciers: It was noted that the horizontal resolution for this ECV is practically limited by the satellite pixel size. For extremes, glaciers surges might be relevant but they are very hard to capture. Products like temperature at the base of the glaciers, glacier velocity and perhaps other products would be necessary. For adaptation current requirements seem adequate.

N°	Action	Responsibility	Deadline
T17	To note the discussions from TOPC-21 concerning issues of individual ECVs in the forum.	ECV Stewards present at TOPC-21	15/06/2019
T18	Discuss with WGMC (M. Zemp) about potential way forward for glacier mass change, and relevance for adaptation and extremes.	Huilin Li	15/06/2019

- Snow: For extremes, snow changes in the mid latitudes could be relevant. Hiroyuki Enomoto will check if temporal and spatial resolution are adequate. Another relevant product might be snow wetness since this can lead to collapse of infrastructure. For adaptation, the current information and requirements seem to be sufficient. More information will be available when the IPCC report "The Ocean and Cryosphere in a Changing Climate" (SROCC) will be published at the end of the year.

N°	Action	Responsibility	Deadline
T19	Update ECV data for snow in forum.	Hulin Li	15/06/2019

- Ice sheets and Ice shelfs in order to capture extremes, products like velocity, calving, ice temperature would need to be covered. It was noted that this needs to be considered further.

N°	Action	Responsibility	Deadline
T20	Propose new products for Ice Sheets and Ice shelfs in the forum.	Hiroyuki Enomoto	15/06/2019

- Groundwater: This ECV needs some changes as current products seem not to be adequate or observable. This is already reflected in the forum discussions and the new suggestions will be reflected on the ECV website.

N°	Action	Responsibility	Deadline
T21	Propose new products for groundwater in the forum. Decide if groundwater discharge into oceans can be covered or not.	Claudia Ruz-Vargas	15/06/2019

- Anthropogenic Water Use: Currently it is not clear if this variable is feasible for GCOS, but it is very relevant for adaptation and extremes.

N°	Action	Responsibility	Deadline
T22	Come up with recommendations if Anthropogenic Water Use should be kept as an ECV or not.	Nigel Tapper, Stephan Dietrich	15/06/2019

After the individual discussion, TOPC decide that for the next meeting, all ECV Stewards need to be prepare a proposal for the requirements that consider extremes and adaptation if relevant.

N°	Action	Responsibility	Deadline
T23	Update ECV data in TOPC forum	ECV Stewards	15/06/2019
T24	Prepare requirement proposals for all ECVs that consider extremes and adaptation if relevant.	ECV Stewards	For next TOPC meeting
T25	Notify absent ECV stewards and update them with meeting sand need for future work.	GCOS Secretariat	30/04/2019

4. Network Updates

4.1 GTN-H

Speaker: Stephan Dietrich

Presentation link

Stephan Dietrich reported of activities of GTN-H since the last TOPC meeting.

Negations underway for International Soil Moisture Network host – only Germany is interested so far.

GTN-H is active in bringing centres together and starting to generate combined products and improving access to data. It was noted that isotopic composition is part of GTN-H but not GCOS.

N°	Action	Responsibility	Deadline
T26	Consider isotopic composition of precipitation and water as tracer in climate studies	GCOS Secretariat	Until next TOPC

4.2 GTN-P

Speaker: Philipp Schoeneich

Presentation link; document links: Frozen Ground 42, Nature communication

Philippe Schoeneich reported on the progress of GTN-P and distributed two key publications, the new issue of "Frozen Ground" and a Nature Communication of GTN-P on Permafrost (both linked above). GTN-P is currently working on inventories of rock glaciers and once the measurements have been proven to be sustainable, rock glaciers could be considered as an additional ECV product for Permafrost. Rock glaciers In addition, there was a general

discussion if rock glaciers might become a product, they would be relevant for extremes due to rock fall. This will be considered further at the next meeting.

5. Conclusions

5.1 Actions from TOPC-20

TOPC approved the closure of all TOPC-20 actions as they are completed.

5.2 Actions

Wolfgang Wagner read out the collected actions and everybody approved. See all Actions in Annex T2.

5.3 Any other business and next year meeting

The timing and venue of the next TOPC meeting was discussed but since there will be a new chair, nothing could be decided. Two venues were suggested, Chamonix, France by Philippe Schoeneich and Ispra, Italy by Nadine Gobron.

Wolfgang Wagner will resign from being chair of TOPC and in order to support a smooth transition, NG as most senior member of TOPC was appointed as new co-chair by Wolfgang Wagner and she accepted.

The following milestones for TOPC in 2019 were agreed:

1) Meeting report: End May

2) Teleconferences:

   a) Update of ECV requirements, agree stewards to fill gaps in June 2019

   b) Update of IP actions, in September 2019

3) GCOS Steering Committee Meeting in Paris October, last GCOS meeting of Wolfgang Wagner.

Annex T1 : TOPC-21 Agenda

1.	Output from JPM		
1a.	Discussion on outputs from the first two days and implications for TOPC	Simon/ Wolfgang	Agreement on additional tasks for TOPC, if any.
1.b	TOPC work updating IP for 2022	Simon	Agreement of future way forwards to 2022
2	Review of IP Actions		
2a	Introduction and discussion	Wolfgang+ all	
2b	Break-out groups, to review IP actions and status in forum		Updated status of IP actions in forum
3.	ECV requirements update and forum		
3.a	Current status		
3.b	Discussion on way forward		Agree to input requirements into WMO OSCAR database
3.c	Break-out groups		Updated ECV products list and definitions.
3.	Presentation from BoGs		Identify gaps, and solutions
4.	Network updates		
4a	GTN-H	Stephan Dietrich	Information
4b	GTN-P	Philippe Schoeneich	Information
4c.	Others?		
5	Conclusion		
5.a	Actions from TOPC-20	Simon	Closing/reviewing open actions
5.a	Actions	Wolfgang	Agree actions and TOPC workplan
5.b	AOB and next year meeting	Wolfgang	

Annex T2 : TOPC-21 Actions

N°	Action	Responsibility	Deadline
T1	Prepare proposals for monitoring phenology, probably as part of an existing ECV.	Nadine Gobron	15/06/2019
T2	Develop proposals for use of land use product to monitor coastlines.	Sarah Carter	1/12/2019
T3	Promote data access and data and information exchange of existing platforms for river discharge (both quantity and quality).	TOPC, the Secretariat	N/A
T4	Ask OOPC if sediment data from melting permafrost in the arctic ocean is relevant.	Secretariat	15/06/2019
T5	If a joint task team with OOPC will be established, Stephan Dietrich and Claudia Ruz Vargas would be members from TOPC.	Stephan Dietrich; Claudia Ruz Vargas	N/A
T6	Connect and contribute to Energy Cycle paper with focus on land surface fluxes.	Darren Ghent	15/06/2019
T7	Connect and contribute to Energy Cycle paper with focus on cryosphere.	Huilin Li; Philippe Schoeneich	N/A
T8	Connect to fluxnet and see if it could contribute to the discussion on closing the carbon budget.	Stephan Dietrich	15/06/2019
T9	Identify and informally approach new steward for ECV soil carbon during World Soils Workshop.	Wolfgang Wagner	15/06/2019
T10	Identify and informally approach new Stewards for ECV lake.	Stephan Dietrich	15/06/2019
T11	Identify and informally approach an additional steward for ECV river with satellite expertise (SWOT).	Stephan Dietrich	15/06/2019
T12	Explore if Country Profile Data Base and WMO's extended extranet can replace the current forum once it is available.	GCOS Secretariat	When available
T13	For the requirements on stability the decadal timescale should be clearly stated in the related forum discussions.	GCOS Secretariat	15/06/2019
T14	Send around paper of Merchant et al 2017 and Gruber et al. 2016 on uncertainties.	Wolfgang Wagner	15/06/2019
T15	Check if requirements are appropriate to cover adaptation aspect and extremes and consider these if applicable for future requirements.	ECV Stewards	Continuous
T16	Check if progress on IP Action are reported and if additional measures need to be taken to address the action.	IP Action Rapporteurs	Continuous
T17	To note the discussions from TOPC-21 concerning issues of individual ECVs in the forum.	ECV Stewards present at TOPC-21	15/06/2019
T18	Discuss with WGMC (M. Zemp) about	Huilin Li	15/06/2019

	potential way forward for glacier mass change, and relevance for adaptation and extremes.		
T19	Update ECV data for snow in forum.	Hulin Li	15/06/2019
T20	Propose new products for Ice Sheets and Ice shelfs in the forum.	Hiroyuki Enomoto	15/06/2019
T21	Propose new products for groundwater in the forum. Decide if groundwater discharge into oceans can be covered or not.	Claudia Ruz-Vargas	15/06/2019
T22	Come up with recommendations if Anthropogenic Water Use should be kept as an ECV or not.	Nigel Tapper, Stephan Dietrich	15/06/2019
T23	Update ECV data in TOPC forum.	ECV Stewards	15/06/2019
T24	Prepare requirement proposals for all ECVs that consider extremes and adaptation if relevant.	ECV Stewards	For next TOPC meeting
T25	Notify absent ECV stewards and update them with meeting sand need for future work.	GCOS Secretariat	30/04/2019

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