GCOS

GLOBAL CLIMATE OBSERVING SYSTEM

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AOPC Atmospheric Observation Panel for Climate

GCOS • WCRP

22nd Session of the GCOS/WCRP Atmospheric Observation Panel for Climate

(AOPC-22)

Exeter, United Kingdom

27-31 March 2017

GCOS-207

WCRP-7/2017

Chair, Publications Board

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Note this report does not describe all the presentations but summarises the discussions and actions agreed.

Presentations are made available at:

http://www.wmo.int/pages/prog/gcos/AOPC-22.htm

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22nd Session of the GCOS/WCRP Atmospheric Observation Panel for Climate (AOPC-22) 28-31 March 2017

1. Opening of the Meeting

The meeting opened with a welcome to all participants from the AOPC Chairman, Ken Holmlund. Carolin Richter, Director of the GCOS Secretariat, introduced the panel and participating Secretariat staff; Tim Oakley, Caterina Tassone and Valentin Aich. Carolin Richter noted also that this year GCOS is going to celebrate its 25th anniversary.

The goal of the meeting was to allow the members of the AOPC panel to review progress and to address identified issues with the global observing system for climate.

The list of participants can be found in Annex 1.

The agenda (Annex 2) was adopted.

In order to allow progress on the politically important Climate Indicators, additional time for discussion was added.

Ken Holmlund welcomed the new panel member, Elizabeth Kent. All other participants introduced themselves.

Roger Saunders from the UK Met Office explained general logistics and organization of additional activities.

Ken Holmlund explained that the main focus of this meeting was the newly approved GCOS Implementation plan (GCOS-200), including the review of its actions.

The GCOS Steering Committee Chair Stephen Briggs emphasized the importance of continuous work and participation throughout the year.

2. Update from the Secretariat

2.1 Update from GCOS

Carolin Richter	Update from GCOS (link to presentation)

Carolin Richter presented the strategy of GCOS, the new IP, including its six aims of:

- Ensuring that the climate system continues to be monitored;
- Improving global, regional and local long-term climate forecasts;
- Supporting adaptation;
- Improving the provision of useful information to users;
- Better communication of the state of the climate; and
- Facilitating resilient and effective to national observation systems.

Reports on adequacy of the Climate Observing System were published in 1998, 2003 and 2015.Previous GCOS Implementation Plans (IPs) were published in 2004 and updated in 2010. The latest GCOS IP, published in 2016, touches on four new items:

- Adaptation and mitigation;
- Climate cycles;
- New ECVs;
- GCOS Cooperation Mechanism.

Carolin Richter presented the list of Climate Indicators so far identified by the GCOS Secretariat through two workshops held at WMO in December 2016 and February 2017 and the current planning of future activities.

It was suggested to add a timeline for a new status report and it was decided that the status report is the report of the adequacy of the climate systems rather than the report on how the IP is being implemented.

2.2 WCRP and Data Council update

Michel Rixen	WCRP (link to presentation)

Michel Rixen recalled the vision and mission of the WCRP facilitating the analysis and prediction of Earth system variability and change for use in an increasing range of practical applications of direct relevance, benefit and value to society. This is achieved through Earth System models, reanalyses and observations targeting subseasonal to decadal and longer time scales and all domains (atmosphere, land, ocean, cryosphere, and biosphere to some extent). Seven Grand Challenges provide medium-term science priorities for the programme, each of them being concerned with specific observational requirements.

He presented the outcome of the WCRP Data Advisory Council (WDAC) meeting, which was held in Frascati, Italy (22-23 March 2017). WDAC serves as a platform to identify data issue across the programme pertinent issues from a modeling aspect and bring them to the attention of GCOS via the co-sponsored AOPC, TOPC and OOPC panels. It was suggested to streamline and formalize this process across the panels to ensure proper inclusion and reference in future GCOS Implementation Plans.

In the context of the WMO Rolling Review of Requirements (RRR) and the OSCAR database, WDAC recommended to fold the WCRP requirements into the 'Climate Monitoring' ones envisaged by GCOS by default, and the WCRP ones where stated otherwise, under a 'goal' value. It was noted that WCRP might need an additional way outside the OSCAR framework to state its requirements as the RRR and OSCAR are not adequate to capture requirements for WCRP process studies.

During the Council's session, the co-chairs of joint GCOS-WCRP panels also invited WDAC to consider becoming more active in advocating for sustained monitoring systems. WDAC recently released a new WCRP Data Policy which builds on several policies within the programme and across partners.

WCRP is currently undergoing a sponsors' review to inform the development of its new strategy in the context of a possible restructuring of WMO Technical Commission, in particular the Commission for Atmospheric Sciences (CAS), where a new research structure may broaden beyond the atmospheric domain into a wider WMO integrated science and technology strategy.

The WCRP-GCOS International Data Prize was awarded to Kate Willett from the UK MetOffice. It was suggested that the Prize needs to recognize people working behind the scene, and should

therefore not be restricted to young scientists. The WCRP-FPA2 Polar Challenge with a 500,000 CHF Prize was highlighted.

It was also suggested that efforts should be made to facilitate interaction between WCRP and those WMO groups working on subseasonal and interdecadal prediction.

The following action was proposed by WCRP:

Action: GCOS and WCRP cooperation	Who	When
1) GCOS and WCRP Secretariats to develop a formal process for collecting observational requirements for Climate Monitoring from the research community.	GCOS Secretariat	January 2018

2.3 Actions from AOPC-21 and discussion

Caterina Tassone — Actions AOPC-21 (link to presentation)

Actions from panel meeting in 2016 were reviewed. All actions were closed with the exception of action 21/2 on open data policy (Action 21/2: GCOS Director to use letters and other means to encourage countries to allow full open access to data). It emerged from the discussion that it is important for AOPC to keep an open action about data policy in the countries. The WIGOS manual signed by congress states that data should be shared, but nevertheless this is not always followed. The situation is complicated by the fact that different policies apply to different data, and as a result, data policy for each country should be verified. As part of a European Commission C3S Data Rescue Service, ground based observations are today collected, albeit with some issues on access. Hence the following Action was placed:

Action: Open data policy	Who	When
2) Copernicus to request support from GCOS on national data availability and associated metadata. Involve WIGOS.	Peter Thorne	October 2017

2.4 Presentation on web presence including GOSIC

Valentin Aich — GCOS web presence (link to presentation)

Valentin Aich reported on the current state of the web presence of GCOS, including current efforts for ECV inventories by CEOS/CGMS Joint Working Group on Climate (WGClimate) and the Global Observing Systems Information Center (GOSIC).Action G9 of the IP 2016 demands the development and implementation of a GCOS communications strategy, including the production of an “improved website”. The current website of GCOS under gcos.wmo.int will be switched off at the end of 2017. The new website will be included in the structure of the public website of WMO (https://public.wmo.int/en/programmes/global-climate-observing-system) and the Secretariat will develop the website with the help of WMO experts and an external consultancy. The new website should additionally mirror the information on ECVs (definition, products, requirements, networks information) of the GOSIC. The ECV inventory currently under development of WGClimate will not be included since it is currently tailored for satellite products and is developed independently from GCOS.

3. General information

3.1 GSN, GUAN and GCM

Tim Oakley	GCOS networks (link to presentation)

Tim Oakley, GCOS Network Manager, summarized his annual report on the performance of the GCOS Surface Network (GSN), GCOS Upper Air Network (GUAN) and recent projects undertaken through the GCOS Cooperation Mechanism (GCM). The 2016 statistics were very similar but slightly improved to those from previous years (2011 to 2015), with RA I (Africa) being by a significant margin the worst performing region. Details were provided on several successful GCM projects in Kenya, the Maldives and Yerevan (Radiosonde); Botswana (Data Rescue); Bahamas (Surface Instrumentation) and Peru (Radiation Instrumentation). An ongoing project in Chad for new surface instrumentation will be implemented during April 2017, and involves a new specification for measuring temperature without the use of mercury. Funds for these projects were donated by Germany, Switzerland and Greece.

A proposed update to the GSN (1 change in Canada) and GUAN (6 new stations in India) station lists was discussed and approved by AOPC.

A recent audit of the GCOS Focal Points, as detailed in the WMO Country Profile Database (CPD), was undertaken and only 25% of those contacted by Email responded, either confirming the details as correct or giving a new contact. Work is now being undertaken to contact other focal points within the CPD in an attempt to improve on this.

3.2 GRUAN report

Peter Thorne	GRUAN (link to presentation)

Peter Thorne in his role as co-chair WG-GRUAN provided an update on GRUAN activities highlighting recent progress towards implementation and the newly funded Copernicus Climate Change Service for baseline and reference observation networks data access to be led by WG-GRUAN member Fabio Madonna. GRUAN is in the process of transitioning to a new website which should be more accessible and allow greater community interaction. A video promoting GRUAN was highlighted. He also pointed out the new GRUAN Implementation Plan and how this responded to a number of GCOS IP actions. He provided a brief update on the RS92 radiosonde transition progress, underlining that each site had made the decision to continue using Vaisala radiosonde and move to RS41 independently. A paper describing rationale and approach is being draft and will be submitted to a journal. He highlighted three potential new contributions put forward by Spain and Japan. Progress on certification of both new sites and new processing streams (GRUAN products) was briefly highlighted. Some work arising from GAIA-CLIM on the system of systems concept development and assessment was outlined. He also noted the need for more stations in Africa, South America and in the tropical west Pacific.

Action	Who	When
3) Consider to invite Fabio Madonna to next AOPC as the service lead for lot 3 of Copernicus C3S_311a about access to high quality networks (baseline and reference network). The objective for this Lot is to rationalize, harmonize and generally improve access to measurements provided by the large variety of existing networks, to facilitate climate monitoring, estimation of ECVs and uncertainty assessments.	GCOS Sec	January 2018

3.3 News about monitoring and archiving activities from DWD

Andreas Becker DWD (link to presentation)

Andreas Becker summarized the monitoring and archiving activities from DWD, including the report for the 2016 GSNMC and GPCC activities. Statistics for the GSNMC show that overall, arrival rate, defined as the percentage of received CLIMAT reports until the 20th day of a month following the month to be monitored, is well above 80%. Data receipt in RA I (Africa) is however still poor. Error rates for monthly daily maximum and minimum temperature data have slightly decreased compared to the previous years. Some countries report CLIMAT in BUFR code besides ASCII format, while a few countries are including more information in BUFR code or reporting only in BUFR code. Therefore BUFR code should be included in GSNMC routine in the future. GSNMC routine is currently run for the (ca. 1000) GSN stations and should be extended to all RBCN stations in future, and ultimately to the RBON. In terms of the GPCC products, homogenized Precipitation Analysis (HOMPRA) for 1951-2005 for Europe (in cooperation with Met. Institute of Univ. Bonn) is now scheduled to become available in late spring 2017[1]. A new release of GPCC's product portfolio (Precipitation Climatology, Full Data Reanalysis V.8, Monitoring Product) is now planned for fall 2017 and daily updated daily totals products (First Guess Daily) in early 2018.

3.4 Data Rescue

Robert Allan Data Rescue (link to presentation)

Robert Allan presented two international weather/climate initiatives.

- ACRE (Atmospheric Circulation Reconstructions over the Earth) undertakes and facilitates historical global surface terrestrial and marine weather data recovery, imaging and digitization, feeding these data into the international repositories responsible for such material, seeing that they provide the best quality and quantity of surface weather observations for assimilation into all reanalyses, and ensuring that reanalyses outputs are freely available and feed seamlessly into the climate science, climate applications and services, impacts, risks and extremes communities. The advisory board includes WMO Data, JCOMM & GCOS. The C3S Data Rescue Service, will be implemented, in the first instance, over the next 4 years. Building upon existing WMO and international data rescue activities and standards, the Service will construct a managed, integrated, state-of-the-art

[1] HOMPRA DOI

repository (portal and registry) of information about past, current and planned data rescue projects. It will also track and update this information for, and provide new terrestrial and marine observations to, C3S via the Copernicus Data Store (CDS). The C3S Data Rescue Service has recommended three locations in high priority data rescue areas for both funding support and testing of new data rescue tools and procedures. The new ACRE regional data rescue foci will be centring on Argentina, South Africa and the higher latitude Pacific sector of the Antarctic continent.

4. GCOS Implementation Plan

4.1 Presentation of GCOS Implementation Plan

Ken Holmlund	IP actions (link to presentation)

Ken Holmlund presented the AOPC relevant actions of the GCOS Implementation Plan. For each action, a panel member with relevant expertise will be identified and will be the primary responsible leader for this action. The leader is responsible to oversee the implementation of the action, including reporting back on the progress to the panel and following the expected timeline.

For the list of the leaders for the IP actions, see Annex 4.

4.2 Presentation of CEOS/CGMS WG on plans for GCOS IP actions

Pascal Lecomte	CEOS/CGMS-WG (link to presentation)

Pascal Lecomte, as the WGClimate Chair, presented the Space Agency response to the GCOS IP. The 7th WGClimate meeting has been held in Saõ José dos Campos, Brazil, hosted by INPE on February 8th and 9th, 2017. The work of the WGClimate is focusing on two main topics, the Space Agency Response to the GCOS IP and the Implementation of the Climate Architecture via the population of the ECV inventory followed by the Gap Analysis and the Action Plan, but this report focuses on the former.

The Writing team set up has been completed and a schedule was agreed, and it includes a statement at SBSTA-47 and COP 23 (Bonn, Germany) in November 2017.

The document structure was agreed, aiming at a lighter document compared to the past but still addressing all GCOS actions, and also providing feedback to the requirements process within GCOS. At a later stage (2018) an annex that would include more technical elements might be added to complement the main report.

Ken Holmlund underlined that the WGClimate plan is relative to the CDRs, while actions relative to satellite missions need to be addressed outside this context. It is therefore only a partial response to the GCOS IP.

4.3 Breakout session to work on actions from IP

Actions from the IP were divided in 5 groups. A first group is for ongoing actions. These actions need continuous monitoring but as they are already being implemented, no further discussion is needed. A second group includes actions relative to radiation and lightning that are going to be postponed to next year. The other three groups are for actions respectively related to atmospheric composition, satellite data and in-situ

observations and requiring discussion and planning. Participants were hence divided into three associated groups and asked to assign a leader and a timeline to each of the action in their assigned category. The final table can be found in Annex 4. AOPC needs to find experts to address the actions of the second group.

Action : IP actions:	Who	When
4) Identify experts on the way forward for IP actions postponed for future meetings	AOPC	March 2018

5. General on ECV

5.1 Presentation on ECV requirements

Caterina Tassone ECV requirements (link to presentation)

Caterina Tassone gave a brief description of the OSCAR database and its three key components, the OSCAR/Space database, which lists the capabilities of all satellite sensors, the OSCAR/Surface, which lists surface-based capabilities and the OSCAR/Requirements, in which technology free requirements are provided for each of the WMO application areas and for all relevant variables. For each variable 3 values are specified in the requirements, a threshold, (observations not useful unless this is met), a break-through (the level which, if achieved, will deliver significant additional benefit for the application) and a goal (exceeding this provides no additional benefit). There are currently 20 application areas listed in the OSCAR/requirements database, nine of them are owned by GCOS/WCRP and are sources of information rather than actual application areas, with both variable lists and actual information out of date. GCOS has been asked to revise the current application areas, including the specific requirements for the variables. There is a need to take into account also climate process studies and reanalysis when considering the climate application areas. However, it was decided that it would be best to start with a single application area, climate monitoring, that will include also the needs of WCRP (except for process studies – see section 2.2). It was also noted that there may be a problem for the marine observations as the format of OSCAR is not optimal for that. However, it is necessary to harmonize across the panels. The requirements listed in the GCOS IP, Annex A, are going to be used as a first entry for the OSCAR/requirements database. As action G10 of the GCOS IP calls for the panels to routinely maintain, review and revise list of ECV product requirements, C. Tassone introduced to the panel a suggestion for a formal process for the revision of the ECVs and the update of the requirements in 5 years. The process includes 3 public reviews and will provide a transparent and open process, more visibility of GCOS and is going to be adopted by the 3 panels. The panel accepted the proposed mechanism.

Action : ECV requirements	Who	When
5) Write a complete description of the Application Area (Climate monitoring) to be submitted to the other two panels, to be used for the OSCAR/requirements DB	GCOS Secretariat	April 2017

The choice of whether to use the three values specified in the OSCAR/requirements table, the threshold, the break-through and a goal or just the threshold and the goal, was further discussed. AOPC agreed on using the three values, however further discussion is needed with the other panels.

Action: OSCAR/requirements	Who	When
6) Secretariat to discuss with the other panels the use of 3 values for the OSCAR requirements tables	GCOS Secretariat	GCOS Steering Committee

6. Upper Air: Radiosondes

6.1 Presentation on requirements for RS launches (A21/23 of AOPC21)

Bruce Ingleby Radiosondes (link to presentation)

Bruce Ingleby talked about radiosonde trends and data continuity. This includes:

- The move to BUFR: 20% of stations are now sending high resolution data. The move to BUFR showed up a small temperature offset (0.05 deg with ECMWF decoding) in TEMP data from RS92 with DigiCORA III processing;
- Reductions in launches from some countries due to austerity measures. In early 2015 Russia reduced from two ascents a day to one but this was reversed after representations from ECMWF and WMO. Mexico and Brazil have reducing radiosonde reporting somewhat and African numbers are fluctuating;
- Introduction of some new radiosonde types as Vaisala will stop supplying RS92-SGP at the end of 2017.

Radiosonde O-B statistics show various features, including a wide variation of RH quality in the upper troposphere. Some types appear worse (in rms O-B) for temperature, and in Northern high latitudes the temperature and humidity statistics for the GUAN stations are adversely affected by the inclusion of Russian stations (the mean differences are more similar). Despite this, Russian radiosondes are still valuable for NWP (item in ECMWF newsletter 149). There are some ongoing problems with metadata including latitude, longitude and height. Some radiosonde types (even "good" ones) are not well documented. Information on which of the radiosondes data are transmitted is often not followed up on. However, CBS is planning to monitor which radiosondes data are not arriving and the reason for that.

6.2 Radiosondes needs

Roger Saunders	Radiosondes 2 (link to presentation)

Roger Saunders (UK Met Office) summarized the actions related to the requirements pertaining to radiosondes which were identified in the new GCOS-IP. Various globally averaged statistics on the number of radiosondes which have sent data and on their information content as a function of time were presented. One issue discussed related to the maximum height that agencies should aim to operate their sondes up to with 30hPa and 10hPa being suggested as the target pressure. Almost 80% of operators reach 50hPa whereas less than 40% reach 10hPa. It was agreed that NWP centres and other users should provide a justification for the upper limit specified. Another issue addressed the transition from TEMP code to BUFR which is causing some gaps in the data records and processing centres need to be aware of the problems which occur in the transition. The AOPC stated the desirability of archiving raw sonde data, to allow an end-to-end reprocessing of the data in the future. Finally the further expansion of the GRUAN into areas with no GRUAN station was encouraged and it was reported that there was some hope to fill the voids in the future.

In the discussion that followed it was noted that there is a need to study the impact of the daily versus twice a day launches for radiosondes and a recommendation on optimum launch times should be given. Radiosonde uncertainty in the stratosphere is lower at night than in day, so requirements might be different depending on the time of the day. Furthermore, dusk and dawn should be avoided, which points to using a local night or day time, with a night time preferred. Missing radiosondes have a negative impact on reanalyses. Radiosondes have a significant impact for NWP in the troposphere and stratosphere, with stratospheric radiosonde observations being especially important for Tropical wind forecasts, as GPS radio occultation compensates for temperature but not for wind. There is a difference in the impact of radiosondes according to the application, so a study from AOPC, concentrating on assessing the impact for climate, would be very useful to add to the ongoing one for NWP[2]. The need for the development and deployment of technologies to measure vertical in-situ profile of radiation (A28 from IP) was also discussed. The original problem of significant variation of the radiation readings with the movement of the balloon has been addressed by using the two balloons approach. It was suggested that action A28 is of relevance to GRUAN, while for actions, A17 and A28, improvements can be obtained by working with manufacturers to implement a design more suitable for climate applications.

Finally, the use of aircraft data for climate purposes was also discussed. Aircraft data is widely used for NWP, even though it is not possible to get unbiased data since planes fly where wind conditions are favourable. However, aircraft data are not used for climate applications except in reanalyses.

Considering the wide range of studies implied with radiosondes, the following action was proposed, noting also that CBS recommendation should be considered in the terms of reference.

[2] WMO Impact Studies Workshop, Shanghai,2016

Action: Requirements for RS launches	Who	When
7) Put together the terms of reference for a task team to study the relationship between GUAN and the broader GOS radiosonde networks, including studying impacts on obtaining higher altitude for radiosondes, flexible launch time and keeping the original data from radiosondes.	GCOS Sec, Phil Jones, Peter Thorne, Ken Holmlund	May-June 2017

7. Upper Air: Cloud

Hélène Chepfer — Cloud observations (link to presentation)

Hélène Chepfer presented a talk focused on the contribution of the observations to the study of cloud feedback mechanisms now and in the future. It has been shown that the cloud climatologies derived from space passive sensors cannot observe the cloud and water vapour vertical distributions with the accuracy required to help understanding cloud feedback mechanisms. Vertical dimension is critical for atmospheric circulation, convection, radiation, cloud processes, cloud feedback.

A detailed summary of the presentation and details on the two proposed actions can be found in Annex 6.

As a long- term project, it is suggested to revise the ECV Cloud definition in the GCOS IP by including the relevant cloud properties. Suggestions were also made about using satellites for the aerosol monitoring and to use all the possible ground-based measurements. However, even if surface based radiation measurements can be useful, global coverage is necessary. It was agreed that the requirement for a lidar type mission, similar to CALIPSO, to complement passive sensors should be presented to CEOS and CGMS.

Action: Clouds	Who	When
8) Ken Holmlund to discuss with Carolin Richter and Stephen Briggs how to best bring up to the space agencies the requirement for lidar type of mission. Possibly produce an AOPC position paper.	Ken Holmlund	May-June 2017
9) Include discussion in report for AOPC22 (include notes sent from Hélène Chepfer)	GCOS Sec	May 2017
10) Bring up the requirement for lidar type of mission at CEOS and CGMS	Ken Holmlund, Carolin Richter	Ongoing

8. Atmospheric Composition ECV requirements

From the GCOS IP, a need of coordination between GCOS and GAW to ensure compatibility of all observation requirements for GHG has been identified(see footnote 98 in GCOS IP).

8.1 Presentation of GAW IP and ECV requirements

Greg Carmichael GAW requirements (link to presentation)

Greg Carmichael presented the new GAW IP, that builds upon the growing importance of atmospheric composition observations and predictions, and the vision for the next decade of GAW, which is to grow the international network of high-quality atmospheric observations across the global to local scale to drive high quality impact science while co-producing a new generation of research enabled products and services. Over the 2016-2023 IP time-period, GAW will place an increased emphasis on the translation of its research to produce more value- added products and services that are relevant to society, and that support the United Nations Agenda 2030 and the Sustainable Development Goals, including climate, weather forecasting, human health, mega-city developments, terrestrial and aquatic ecosystems, agricultural productivity, aeronautical operations, renewable energy production and many more. GAW is now formalizing a series of MoU with UNEP and WHO.GAW shares many common interests with GCOS. Ideas to strengthen interactions GCOS/GAW were discussed and included:

- Requirements for ECVs;
- Mutual work on AOPC action items;
- Enhancing observations and data flows;
- Clarifying GAW network(s) status within GCOS;
- Establishing GRUAN as a contributing network for water vapor;
- Supporting applications. e.g., IGI3S.

8.2 Presentation from IP requirements

James Butler IP requirements (link to presentation)

James Butler explained that GCOS and GAW work closely but nevertheless there is an evident disconnect between the WMO GAW Guidelines, that are updated every 2 years by a meeting of experts of GHG, and the GCOS IP requirements. To understand how we manage these differences, we need an expert group. GCOS will coordinate with GAW to ensure compatibility of all observational requirements and the possibility of inviting experts from GAIA-CLIM to the experts meeting as well as experts from the community working on traceability has to be considered.

Action: IP requirements for GHG	Who	When
11) Unify the IP requirements for GHG. Jim Butler to start working at the GGMT in August.	James Butler, Greg Carmichael	August, AOPC23

9. Metadata standards

9.1 Presentation on Copernicus metadata standards

Dick Dee	C3S (link to presentation)

Dick Dee presented the Climate Change Service (C3S) which is being implemented at ECMWF, and Copernicus's plans on managing metadata.

The main idea of C3S is to go from climate data to climate services, by making available climate data and the needed expertise to use them. Data access will occur via the Copernicus Climate Change Service Data Store (CDS) catalogue, currently under development, that will include observations, global and regional ECV products derived from observations, global and regional climate reanalysis, seasonal forecast data and output from climate model simulations. A Common Data Model (CDM) will be established to provide a uniform description of all data and products in the CDS, so that they can easily be combined and processed by users in workflow and applications. Harmonising metadata with data suppliers is key to the CDM feasibility, so data suppliers need to comply with existing standards. To ensure the quality of all products delivered by C3S, including assessing the integrity and traceability of the ECV products and their ease of use, a C3S Evaluation and Quality Control (EQC) function will be provided.

9.2 Presentation on WIGOS metadata standards

Tim Oakley	WIGOS Metadata (link to presentation)

Tim Oakley updated the meeting on the current status of the WIGOS MetaData (WMD) standard and showed an overview slide of the key components of the standard. As the GCOS representative on the WMD WIGOS task-team he has contributed to the development of the standard and believed that it is relevant to all observing systems. He made the point that the WMD standard had been approved by all WMO Members at Congress-19 (2015) and thus should be considered as the primary metadata standard considered by GCOS

9.3 Discussion on metadata standards

There were 2 main outcomes of the discussion that followed the two presentations.

1. More information is needed on how to get a new station into OSCAR. OSCAR so far uses only pub 9 as ID, but Copernicus needs a larger set of station identifiers. Copernicus C3S311a Lot2 (lead: Peter Thorne) would like to use OSCAR/surface ids but to do so would require coordination with WIGOS.
2. GCOS would endorse the WIGOS metadata standards as a first step. The needed extension for climate record standards will be addressed at a later stage. It is noted that Copernicus will also address metadata standards for ocean and terrestrial ECVs, taking into account the differences in how these communities describe the data.

Action: Metadata standards	Who	When
12) Facilitate contact with regard to the potential for the Copernicus service to use OSCAR (WIGOS). OSCAR only uses pub 9 as id, but Copernicus needs the ability to populate OSCAR/surface with a larger set of station ids.	GCOS Sec and Peter Thorne	End of June 2017
13) AOPC to communicate to the other panels the decision to use WIGOS metadata standards and follow up. Set up a joint group to consider an extension for climate records standards that can build up on work already done by the climate CEOS CGMS JWG.	GCOS Secretariat	GCOS Steering Committee

10. G13: Review of ECV observation networks

10.1 Introduction of G13

Caterina Tassone Overview (link to presentation)

Caterina Tassone briefly introduced action G13 from the IP, which addresses the need for a sustained ECV adequacy review. It will be the panel responsibility to assign a member for each ECV who will have to identify who is doing the monitoring and propose plans to identify gaps between the observations and the requirements, develop remediation plans, ensure data is discoverable and accessible and finally report back to GCOS. Champions for each ECVs were identified during a plenary at the end of this session and the list can be found in Annex 5. In this context, it was suggested that Copernicus EQC could be used as part of the review of adequacy. The EQC contract will be awarded during the summer and GCOS should follow up to engage in further discussions.

Action: Review of ECV Observation Networks:	Who	When
14) Contact Dick Dee in September to ask who was awarded the EQC contract and initiate a discussion, which includes details on how the work will move forward	GCOS Sec	September; then report to AOPC

10.2 RRR and WMO gap analysis

John Eyre RRR and WMO gap analysis (link to presentation)

On behalf of WMO/CBS, John Eyre (Met Office, UK) presented the WIGOS Rolling Review of Requirements (RRR) process and the WIGOS Vision for global observing systems. He explained how the RRR process works, with emphasis on the role of GCOS in providing the user requirements for observations and the analysis of gaps for the RRR Application Area (AA) "Climate Monitoring". He briefly described the WIGOS "Vision" for observing systems in 2025. He outlined the timeline for developing the new "Vision 2040" and the

role of GCOS and other stakeholders in this process. He asked GCOS: to confirm its "ownership" of the AA "Climate Monitoring"; to update the information on GCOS documents that act as the SoG for Climate Monitoring; and to update the data for Climate Monitoring in OSCAR/Requirements. The lack of recent information from WCRP on observational requirements for climate process studies was noted. Carolin Richter confirmed that GCOS owns the climate monitoring application area.

These requests are summarized in the following actions:

Action: RRR and OSCAR	Who	When
15) Confirmation of ownership of RRR Application area Climate monitoring	GCOS Secretariat	Done-record on report
16) Assistance in updating content of OSCAR/requirements for AA Climate Monitoring.	GCOS Secretariat	To record
17) Update of references to GCOS documents that act as RRR s Statement of Guidance (gap analysis) for Climate Monitoring.	GCOS Secretariat	June 2017
18) Review of contents of OSCAR/Requirements, Space, Surface.	GCOS Secretariat	Recommend ation

10.3 WIGOS data quality monitoring system

Stuart Goldstraw WDQMS (link to presentation)

Stuart Goldstraw presented the WIGOS Data Quality Monitoring System (WDQMS), which is one of the 5 priority areas identified by congress for WIGOS for the 2016–2019 period. WDQMS's aim is to provide a framework that enables the actual performance of the observing networks to be assessed, identifies issues to be addressed and, if appropriate, defines action(s) to be taken. It is important to recognize that there are a range of data requirements arising from distinct users and therefore one user's issue is another user's normal expectation. As a first step, surface pressure management monitoring and evaluation has started, which will be followed by a wider set of traditional surface parameters and radiosonde data and progressively expanded into other established surface GCOS components. At the moment, only metadata is being monitored, however there will be also monitoring for accuracy and stability in the future.

10.4 GAW monitoring system

Greg Carmichael GAW monitoring (link to presentation)

Greg Carmichael introduced the RRR process within GAW. Three broad application areas have been identified based on their temporal and spatial scales: monitoring of atmospheric composition, forecasting atmospheric composition change and their induced environmental phenomena and providing atmospheric composition information to support services in urban and populated areas. The RRR activity is led by a task team

and the process engages all of the SAGs (Scientific Advisory Groups). The requirements have been drafted for each of the above application areas and are now under review and will be added into OSCAR in 2017. GAW observations are in OSCAR/GAWSIS. A GAP analysis is planned for 2018.

10.5 Break out groups.

No break-out groups were necessary, and instead champions for each ECVs were identified (See Annex 5).

10.6 Summary from discussions

In the final discussion, it was agreed that, as there are no experts on lighting within AOPC, an ad-hoc group of experts arising from the broader scientific community should be involved.

Action: Lightning	Who	When
19) AOPC to engage a Task Team to work on lightning. John Eyre and Bruce Ingleby to give us names of possible experts. Task team to write a position paper on lightning that should then be peer reviewed.	AOPC	March 2018

11. General information on topics of interest to AOPC

11.1 News about monitoring and archiving activities from NCEI

Matthew Menne NCEI (link to presentation)

Matt Menne presented an update on the monitoring and archiving activities at NCEI. NCEI is taking part in the Copernicus project on constructing a comprehensive global land and ocean database. In particular, NCEI is cooperating with C3S on Lot 1 (coordination of data rescue activities), but has a bigger role in Lot 2 (Access to observations from global climate data archives). The transfer of data holdings to Copernicus is underway and the inventory will be completed by the end of August. Harmonization of data records will begin thereafter. WMO station histories will be extracted from US Air Force archives and integrated into NCEI metadata archives, with both data and metadata being transferred. Menne presented also an update for the following datasets: the Integrated Global Radiosonde Archive (IGRA), the ERSST v5 and the GHCN-Monthly v4.

11.2 Sea Surface Temperature Presentation

John Kennedy SST (link to presentation)

John Kennedy presented the recent issues in in situ observing systems for SST, including the decline in number of ships, the oscillating numbers of drifters, the TAO drop outs for moored buoys and homogeneity issues. A range of bias-adjusted SST datasets now exists and there is a call for new approaches to quantifying biases in observations of sea-surface temperature. Recommendations include to add more data and metadata to

ICOADS and to reprocess existing ICOADS records (to be attempted under the new Copernicus service lot 2), to improve physical and statistical models of SST bias, to ensure adequacy and continuity of the observing system and to improve openness and access to information.

11.3 Ocean-atmosphere cross-cutting observation needs

Elizabeth Kent	Ocean-atmosphere (link to presentation)

Elizabeth Kent summarized the actions from the GCOS IP calling for measurements of variables over the ocean, such as air temperature, humidity, SST, wind speed and direction, surface pressure. Different methods for assessing adequacy were also presented. There is a need to better define the requirements, and it is suggested to work with JCOMM to establish climate Key Performance Indicators (KPIs). In the presentation it was suggested that the WMO RRR approach has proved problematic as requirements of surface air temperature on land are different than the ones over ocean, which is not reflected in the RRR application areas. However, if users have different requirements over land and sea, then RRR allows these to be stated through the creation of different variables. There is also a need for requirements for accurate large space and time averages.

11.4 Reanalysis

Shinya Kobayashi	Reanalysis (link to presentation)

Shinya Kobayashi presented current status and future plans of several global atmospheric reanalysis projects on behalf of those reanalysis groups. JMA is currently preparing for their next reanalysis project, JRA-3Q (the Japanese Reanalysis for Three Quarters of a Century), which will go to higher resolution (40 km in horizontal), extend the reanalysis period back in time (possibly to the year 1948) and use new boundary conditions, new forcing fields and newly available observations. ECMWF recently started the production of their new high-resolution atmospheric reanalysis, ERA5, which will produce spatially and temporally higher resolution products as well as uncertainty estimates based on a 10-member 4D-Var ensemble. ECMWF has also released a new century-long climate reanalysis, CERA-20C, which was produced by a coupled atmosphere-ocean data assimilation system. NASA has recently released their new reanalysis, MERRA-2, which incorporates several new features such as aerosol assimilation and constraints on dry mass and globally integrated water. NOAA/NCEP is currently developing a Unified Global Coupled System (UGCS), which will include fully coupled components of the Earth system both for data assimilation and model forecasts. NOAA-CIRES have recently released a new version of 20CR (the 20th Century Reanalysis) version 2c, which covers the period from 1851 to 2014. NOAA-CIRES are currently working on the 20CR version 3, which will go to higher resolution and use an improved data assimilation algorithm and observational quality control.

11.5 Parallel observations collection and analysis effort

Victor Venema	Parallel observations (link to presentation)

Victor Venema introduced the activities of the Parallel Observations Science Team (POST). POST is compiling a database of parallel measurements, which is important for a better understanding of inhomogeneities affecting the evaluation of long term changes in (daily) climate data. Parallel measurements consist of overlap periods of measurements of the same ECV(s) either at the same or proximal locations over a period of time. Many NMHSs have in the past undertaken such measurements to manage change across their networks. However, historically, such measurements have not been shared. The POST effort aims to collate and analyse these data. As such, it would provide a hugely valuable second line of evidence, next to statistical homogenisation, on biases in the climate station record.

AOPC was invited to consider:

1. Recognition of the activity as scientifically valuable and some form of appropriate recognition of the activity by GCOS, which may help build community and stakeholder buy-in to the activity;
2. Via GCOS focal points or other appropriate mechanisms solicit help in the sourcing of historical parallel observations from WMO members;
3. Work with WMO Commissions to formalise a process of permanent archiving and sharing of parallel measurement activities as part of future network change management;
4. Formalize the archiving and sharing of metadata on known inhomogeneities. For example, the year Stevenson screens or AWS was introduced or an airport was opened. That would make the information from the parallel measurements more valuable.

The discussion pointed out that there is a lot of work already done for SST with buoys and satellite and for surface winds. It is also important to consider two measurements at the same location as measurements can differ. Within the requests to AOPC, point 3 and 4 are requests to WIGOS, while for requests 1 and 2 the following action is agreed:

Action: Parallel observations collection and analysis effort	Who	When
20) GCOS sec to discuss with the other panels requests 1. and 2. from text above (Section 11.5 of AOPC 22 report)	GCOS Secretariat	GCOS Steering Committee

12. GCOS Surface Reference Network (GSRN)

12.1 Presentation on current state of planning

Peter Thorne — Current plan (link to presentation)

Peter Thorne presented a high level overview of progress to date scoping a surface reference network. He highlighted how both CCI and GCOS had expressed interest in ascertaining what would be required. An ad hoc author group has been constituted to create a position paper for submission to a relevant journal. This draft was made available to AOPC participants in advance along with a short version. The presentation covered the why, the what and the how at a generic level noting that substantive further details would still require to be worked out. Possible next steps were outlined to AOPC.

Link to short paper: GSRN short version

Link to long paper: GSRN long version

12.2 Presentation on a Global Land-Surface Climate Reference Network: Technical reflections

Michael De Podesta	Global Land-Surface Climate Reference Network (link to presentation)

Michael De Podesta presented some of the major features of the US Climate Reference Network, its strength, its weakness and its technical characteristics. Ten years of records have proven to be already valuable for climate studies. For a global CRN a low-density network of ca 150 stations would be adequate. For air temperature, triple redundancy and platinum resistance thermometers are strongly recommended and either aspirated enclosures or passive screens would be acceptable. For precipitation, tipping bucket rain gauge or weighing rain gauge would be acceptable with appropriate wind screens. Also humidity measurements would benefit from triple redundancy. Selection of sites could be done by following US CRN procedures or similar procedure used by GCOS-34.

12.3 Discussion on GSRN

During the discussions about the instigation of a GCOS Surface reference network, it was noted that WIGOS has already accepted the concept of a reference network and therefore should be approached with a proposal. It is important to engage CBS, CIMO, CCl and possibly have an expert from BIPM. The decision taken by AOPC will be forwarded to TOPC, as they have expressed an interest in the GSRN. The best way to proceed is to set up a task team with a ToR that will then be formally established by the GCOS SC.

Action: Global Surface Reference Network	Who	When
21) GSRN (GCOS Surface Reference Network) : Set up a task team to work on the way forward for establishing a GSRN. This includes writing a term of reference and selecting the composition and leader of the task team.	Peter Thorne, Ken Holmlund, Phil Jones, Caterina Tassone	GCOS Steering Committee

13. Weather radar (21/28 AOPC-21)

13.1 Presentation on current state of planning and OPERA

Elena Saltikoff	Radar (link to presentation)

Elena Saltikoff addressed the issue of radar observations and climate. The discussions between radar and climate communities should start at the fundamental level: Definition of data to be saved and ways it should be processed. Radar people feel there is more to be studied than just rainfall. Old data is very heterogeneous, but many radars

in Europe were upgraded after 2012, with more homogeneous data sets available . For the generation of future time series, the definition work should start now.

Discussion following this presentation concentrated on the existing record length. There is an agreement that data prior to the last update, 2010, should not be used. Use of auxiliary data (e.g. gauges, satellites) is necessary for homogenization, especially if we want to use some of the older datasets. There would also be the need to create an archive. As of now, there is NEXRAD in US holding data since 2001, Canada has its own archive, OPERA data is collected at UK Met Office and Meteo France is archiving. Data from the NMHs is often not made available.

Link to short paper: Report weather radar for climate

13.2 Presentation on work of IPET-OWR

Andreas Becker	IPET OWR (link to presentation)

Andreas Becker attended the IPET-OWR meeting, which was held in Japan in March 2017. AOPC motivation to make climate requirements for radar, is due to the importance of detection of extreme precipitation that can be seen only by radar. The challenge of using radar based quantitative Precipitation Estimation (QPE) for global applications and in the context of the GCOS IP are:

- The existing short time series;
- No ocean coverage;
- Homogeneity;
- In-situ validation data not available everywhere;
- Calibration and retrieval algorithms need to be harmonized,
- Adequate treatment and documentation of missing data; and
- No international standards in data storage and documentation yet in place.

In order to keep historic radar data assessable for future utilization, a data storage and documentation standard should be identified and applied ASAP to keep existing data in a secure manner. Recommendations are that AOPC should stay an interested, active and consulting partner to the work of IPET-OWR in order to warrant that decisions made on standards, metadata and methodologies are taken while having at least considered the climate related requirements. A key issue is to find a suitable context in this respect for EUMETRAD to make substantial process beyond the awareness that radar data should be stored appropriately given their long-term value.
It was decided that radar data is key through either a task team or a working group.

Action: Weather Radar	Who	When
22) Weather radar: Write a proposal on how best to proceed on AOPC input upon the use of radar data for climate studies. Submit the proposal to the panel, to Carolin Richter and after approval to the GCOS SC.	Andreas Becker, Ken Holmlund, Phil Jones, Elena Saltikoff	September 2017. GCOS Steering Committee

15.Climate Indicators

15.1 Presentation of current state of Climate Indicators

Valentin Aich	Overview on indicators (link to presentation)
Stephen Briggs	Summary of discussion (link to presentation)

Valentin Aich presented the progress of GCOS on climate indicators, including the outcome from the two workshops held in Geneva in December 2016 and February 2017.

Climate indicators need to be simple, unarguable, clearly measured and measured/analysed by different techniques and groups. Climate indicators are for information of general public and not for scientists and should not be confused with the ECVs. The following climate indicators were proposed: surface temperature, ocean heat content, sea level, as this is an integrator of several things, CO_2 and arctic ice extent. Extreme events are interesting but difficult to define. Deforestation is problematic but there is a desire to see some land-based indicator, and suggestions included total area of permafrost, seasonal indicators, like for example the start of spring (phenology), desertification, greenness. Concerns about the best possible way to convey the message to the public was expressed, and several strategies were proposed, like including more detailed stories and more local information to attract the people's attention. The concept of a suite of historical indicators was endorsed and next step will be to choose a small group of indicators and to implement them. After that, future indicators will be discussed.

16. Any other business

16.1 Support of climate stations

Tim Oakley presented a recent request from MeteoSuisse to the GCOS Cooperation Mechanism (GCM) to support 5 CATCOS stations for ongoing operational and emergency repair costs. A business case had been drafted by MeteoSuisse giving more details, and Tim Oakley confirmed that there were sufficient funds in the GCM to provide a one-off payment (20,000 CHF). The meeting approved the request for a one-off support payment, but requested that the GCOS Network Manager reported back to AOPC on the ongoing performance of these 5 CATCOS stations and how the support funds were used.

Action: CATCOS	Who	When
23) Report back to AOPC on performance of 5 CATCOS stations and use of support funds.	GCOS Network Manager	Annual report and next AOPC

16.2 Actions

Actions, see Annex 3, were discussed and approved by the panel. It was agreed that regular telecom for the panel members will take place every three months to check on the progress of the implementation of the actions in the IP and of other work agreed during this meeting.

Four task teams were proposed to address some of the topics discussed at the AOPC meeting. The list of these task teams, including a brief description, can be found in Annex 7.

17. Closure

The GCOS Secretariat and the panel participants expressed their sincere gratitude to the host of the meeting, Roger Saunders. The AOPC benefited greatly from the provision of excellent meeting facilities and enjoyed thoroughly the generous hospitality of UK Met Office.

The meeting closed on 31st March 11:00 hrs.

ANNEX 1: List of Participants

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ANNEX 2: Agenda

	ITEM	N°	Presenter	Targeted outcome
Opening	**Opening of the Meeting**	**1.**		
	Welcome and introductions	1.1	Holmlund; Richter; Briggs;	
	Adoption of Agenda	1.2	Holmlund	
	Introduction of participants	1.3	All	
	Conduct of the Meeting	1.4	Saunders	
	Aims and expectations	1.5	Holmlund	
	Update from the Secretariat	**2.**		
	Update from GCOS (30 min)	2.1	Richter	Information
	WCRP and Data Council update (15min)	2.2	Rixen	Information
	Presentation of actions from AOPC-21 and discussion (10 min)	2.3	Holmlund/ Tassone	Closure of AOPC-21 actions and update of open actions for AOPC-22
	Presentation on GOSIC (10 min)	2.4	Aich	Information
	General information	**3.**		
	GSN, GUAN and GCM Presentation (30 min)	3.1	Oakley	Information
	GRUAN report (15 min)	3.2	Thorne	Information
	News about monitoring and archiving activities from DWD (15 min)	3.3	Becker	Information
	Data Rescue (10 min)	3.4	Allan	Information
Implementation Plan	**Implementation Plan**	**4.**		
	Presentation of actions in the Implementation Plan	4.1	Holmlund	Work plan for AOPC
	Presentation of CEOS/CGMS WG on plans for GCOS IP actions	4.2	Lecomte	Work plan for AOPC
	Breakout session to work on actions from Implementation Plan (~3 groups)	4.3		Work plan for AOPC
	Presentation of breakout groups	4.4	Group rapporteur	Work plan for AOPC

	(10 min each)			
	Plenary discussion on outcome	4.5		Work plan for AOPC
ECVs	**General on ECV**	**5.**		
	Presentation on ECV requirements: application areas, mechanism for maintaining, reviewing and revising ECV requirements (IP G10) (15 min)	5.1	Tassone	
	Upper Air: Radiosondes	**6**		
	Presentation on requirements for RS launches (A21/23 of AOPC21)	6.1	Ingleby	
	Presentation as introduction to discussion	6.2	Saunders	Planning for future ECV requirements
	Discussion on requirements			
	Upper Air: Cloud	**7.**		
	Presentation (15 min)	7.1	Chepfer	Planning ECV requirements
	Discussion on observation needs and requirements	7.2		
	Atmospheric composition ECV requirements	**8.**		
	Presentation on GAW IP and ECV requirements(15 min)	8.1	Carmichael	
	Presentation from IP requirements (10)	8.2	Butler	
	Discussion on observation needs	8.3		ECV requirements
	Metadata standards	**9.**		
	Presentation on Copernicus metadata standards (15 min)	9.1	Dee	
	Presentation on WIGOS metadata standards (15 min)	9.2	Oakley	
	Discussion on metadata standards	9.3		Decide on metadata standard
	G13: Review of ECV Observation networks	**10**		
	Introduction of G13	10.1	Tassone	
	RRR and WMO gap analysis (15min)	10.2	Eyre	
	WIGOS data quality monitoring	10.3	Goldstraw	

	system (15min)			
	GAW monitoring system (15min)	10.4	Carmichael	
	Break groups (Atmos composition, surface and upper ECVs)	10.5		
	Summary from discussions	10.6		
General Information	**General information**	**11.**		
	News about monitoring and archiving activities from NCEI (15 min)	11.1	Menne	Information
	Sea Surface Temperature Presentation (10 min)	11.2	Kennedy	Information
	Ocean-atmosphere cross-cutting observation needs (10 min)	11.3	Kent	Information
	Reanalysis (10 min)	11.4	Kobayashi	Information
	Parallel observations collection and analysis effort (10 min)	11.5	Venema	Information
GSRN	**Global Reference Surface Network (GSRN)**	**12.**		
	Presentation on current state of planning (15 min)	12.1	Thorne	
	Presentation (15 min)	12.2	De Podesta	
	Continue Discussion on GSRN	12.3		Establish Task Team
Radar	**Weather radar (21/28 AOPC-21)**	**13.**		
	Presentation on current state of planning and OPERA (30 min)	13.1	Saltikoff	
	Presentation on work of IPET-OWR (15 min)	13.2	Becker	
	Discussion	13.3		Establish task team
Task Teams	**Breakout session**	**14.**		
	Tasks: GSRN, Weather radar (more as needed)	14.1		
	Presentation of breakout groups	14.2	Group rapporteur	
	Plenary discussions	14.3		

Indicators	**Climate Indicators**	**15.**		
	Introduction to climate indicators	15.1	Aich	
	Discussion	15.2		Approval of Climate Indicators
Closure	**Closing discussions/decisions**	**16.**		
	Discussion: Presentation from groups on their conclusions • Actions from AOPC-22 • Venue of next meeting Date of next meeting	16.1	Holmlund	New AOPC-22actions

ANNEX 3: List of Actions from AOPC-22

N°	Action	Responsibility	Deadline
22/1	**GCOS and WCRP cooperation:** GCOS and WCRP Secretariats to develop a formal process for collecting observational requirements for Climate Monitoring from the research community	GCOS Secretariat	January 2018
22/2	**Open data policy**: Copernicus to request support from GCOS on national data availability and associated metadata. Involve WIGOS.	Peter Thorne	October 2017
22/3	**Access to high quality networks:** Consider to invite Fabio Madonna to next AOPC as the service lead for lot 3 of Copernicus C3S_311a about access to high quality networks (baseline and reference network). The objective for this lot is to rationalise, harmonise and generally improve access to measurements provided by the large variety of existing networks, to facilitate climate monitoring, estimation of ECVs and uncertainty assessments.	GCOS Secretariat	January 2018
22/4	**IP actions**: Identify experts on the way forward for IP actions postponed for future	AOPC	January 2018
22/5	**ECV requirements** : Write a complete description of the Application Area (Climate monitoring) to be submitted to the other two panels, to be used for the OSCAR/requirements DB	GCOS Secretariat	April 2017
22/6	**OSCAR/requirements**: Secretariat to discuss with the other panels the use of 3 values for the OSCAR requirements table	GCOS Secretariat	GCOS Steering Committee
22/7	**Requirements for RS launches**: Put together the terms of reference for a task team to study the relationship between GUAN and the broader GOS radiosondes networks, including studying impacts on obtaining higher altitude for radiosondes, flexible launch time and keeping the original data from radiosondes	GCOS Secretariat, Phil Jones, Peter Thorne, Ken Holmlun	May-June2017
22/8	**Cloud and water vapour**: Ken Holmlund to discuss with Carolin Richter and Stephen Briggs how to best bring up to the space agencies the requirement for lidar type of mission . Possibly produce an AOPC position paper.	Ken Holmlund	May-June 2017
22/9	**Cloud and water vapour**: Include discussion and notes sent from Helene Chepfer in report of AOPC22	GCOS Secretariat	May 2017
22/10	**Cloud and water vapour**: bring up the requirement for lidar type of mission at CEOS and CGMS	Carolin Richter, Ken Holmlund	Ongoing
22/11	**IP requirements for GHG**: Unify the IP requirements for GHG. Jim Butler to start working at the GGMT in August.	James Butler, Greg Carmichael	August, AOPC23
22/12	**Metadata standards**: Facilitate contact with regard to the potential for the Copernicus service to use OSCAR (WIGOS).	GCOS Secretariat and Peter	End of June 2017

	OSCAR only uses pub 9 as id, but Copernicus needs a larger set of station ids.	Thorne	
22/13	**Metadata standards:** AOPC to communicate to the other panels the decision to use WIGOS metadata standards and follow up. Set up a joint group to consider an extension for climate records standards that can build up on work already done by the climate CEOS CGMS JWG.	GCOS secretariat	GCOS SC
22/14	**Review of ECV Observation Networks**: Contact Dick Dee in September to ask who was awarded the EQC contract and initiate a discussion, which includes details on how the work will move forward	GCOS secretariat	September and then report to AOPC
22/15	**RRR and OSCAR**: Confirmation of ownership of RRR Application area Climate monitoring	GCOS secretariat	done-record on report
22/16	**RRR and OSCAR**: Assistance in updating content of OSCAR/requirements for AA Climate Monitoring.	GCOS secretariat	to record
22/17	**RRR and OSCAR :** Update of references to GCOS documents that act as RRR s Statement of Guidance (gap analysis) for Climate Monitoring	GCOS secretariat	June 2017
22/18	**RRR and OSCAR :** Review of contents of OSCAR/Requirements, Space, Surface.	GCOS secretariat	recommendation
22/19	**Lightning**: AOPC to engage a Task Team to work on lightning. John Eyre and Bruce Ingleby to give us names of possible experts. Task team to write a position paper on lightning that should then be peer reviewed.	AOPC	March 2018
22/20	**Parallel observations collection and analysis effort**: GCOS sec to discuss with the other panels requests 1. and 2. from text above (Section 11.5 of AOPC 22 report)	GCOS Secretariat	GCOS Steering Committee
22/21	**GSRN (GCOS Surface Reference Network):** Set up a task team to work on the way forward for establishing a GSRN. This includes writing a term of reference and selecting the composition and leader of the task team.	Peter Thorne, Ken Holmlund, Phil Jones, Caterina Tassone	September 2017 (GCOS Secretariat)
22/22	**Weather radar:** Write a proposal on how best to proceed on the use of radar data for climate studies. Submit the proposal to the panel, to Carolin and after approval to the GCOS Steering Committee	Andreas Becker, Ken Holmlund Philip Jones, Elena Saltikoff	September 2017GCOS Steering Committee
22/23	**CATCOS:** Report back to AOPC on performance of 5 CATCOS stations and use of support funds.	GCOS Network manager	Annual report and AOPC23

ANNEX 4: List of Atmosphere related Action from IP

N°	Action	Responsible	Background	Timeframe / Deliverables
1	Near-real-time and historical GSN availability	GCOS Network Manager (GNM)	Monitoring statistics for GSN & RBCN stations are provided monthly and quarterly by NCEI to GNM. These are used for fault monitoring and diagnostic by GNM and CBS-LC-GCOS, and summarized in an annual report.	ONGOING Annual report and presentation to AOPC Summary text and statistics included in GCOS reports to WMO CG & EC, Regional Association and Technical Commission Sessions.
2	Land database	Matt Menne (NCEI)	NCEI is an in kind partner to a four-year Copernicus (EU) funded project to produce a harmonized global land in situ database as well as a next generation ICOADS over the marine domain. [3]	Annual report and presentation to AOPC
3	International exchange of SYNOP and CLIMAT reports	GSNMC Andreas Becker	Monthly and Annual statistics are provided by the GSNMC (DWD)	Annual report and presentation to AOPC
4	Surface Observing stations transition to automatic	Phil Jones	Ongoing challenge, despite there being support and documentation on how to manage the change. KNMI report (need details of this). Parallel observations database project being led by Victor (also Victor would	Annual report and presentation to AOPC With KNMI report as an example, request from WMO Regional Associations and Technical Commissions any other national and regional reports (and datasets of

[3] http://journals.ametsoc.org/doi/abs/10.1175/BAMS-D-16-0165.1

			like any parallel measurements)	parallel measurements that might be available).
5	Transition to BUFR	GCOS Network Manager (Radiosonde Task Team)	Monitoring Statistics being produced by ECMWF and DWD. Proposed to be included under the terms of reference of the Radiosonde Task Team	Report from Radiosonde Task Team Annual statistics on GUAN stations reporting in BUFR Presentation at AOPC as required
6	Air temperature measurements	Phil Jones	Increased global coverage of and access to air temperature measurements Linked to the work under A2 and likely to be included in the metadata inventory	Linked to A2. C3S/NCEI working on this 2017-21, so annual reports of the increase in station numbers by WMO Regions. Reports to AOPC and also to WIGOS and WMO Regions and CBS Lead Centres.
7	Atmospheric pressure sensors on drifting buoys	Liz Kent	More information required on the true cost of adding pressure sensors and the cost benefit.	Assessment of network costs by end of July 2017
8	Provide precipitation data to the Global Precipitation Climatology Centre	Andreas Becker and Leader of the task team for radar for climatology	Getting also radar data into precipitation data; associated with Task Team for radar data for climatology (Elena)	Useful to supply precipitation data to C3S/NCEI
9	Submit Water Vapour data	Matt Menne(NCEI)	Linked to the work under A2 and likely to be included in the metadata inventory Assessment of RH Quality	Linked to A2 and also A6 and A7

10	National sunshine records into Data Centres		Future	
11	Operation of the BSRN	BSRN Project Lead GCOS Network Manager		ONGOING BI-ANNUAL Workshop Report Presentation at AOPC as required
12	Surface Radiation Data into WRDC		Future	
13	Implement vision for future of GUAN operation	Peter Thorne GCOS Network Manager	Updated requirement for GUAN as a baseline network, focusing on availability, scheduling and burst heights. Linking GUAN with GRUAN. BUFR take-up. Global coverage including remote locations	Agree Terms of Reference for Radiosonde Task Team and proposed membership (May 2017) Meeting of Task Team (2nd half 2017) Report to next AOPC (April 2018)
14	Evaluation of benefits for GUAN	Peter Thorne GCOS Network Manager	Included in TOR for Radiosonde Task Team See A13	See A13
15	Implementation of GRUAN	Peter Thorne		Report to AOPC Deliver GRUAN IP
16	Implementation of satellite calibration missions	Ken Holmlund	Ken as chair of AOPC should go to CEOS and keep this ongoing. GCOS/AOPC needs to make a strong user requirements to space agencies for this mission, by writing a 1 page doc to show science benefits and to which the space agency should reply. Action is then on CEOS.	Milestone: report of meeting addressing this request (CGMS:June2017 CEOS:October2017) Next AOPC session

17	Retain original measured values for radiosonde data	Peter Thorne GCOS Network Manager	Included in TOR for Radiosonde Task Team See A13	See A13
18	Hyperspectral radiances reprocessing	Ken Holmlund	This action is about reprocessing level 1 radiances. In process. There is a need to involve American Cirs and AIRS experts to share experience on how to produce a consistent record and to ensure consistency with IASI.	
19	AMV reprocessing	Roger Saunders Ken Holmlund	GOES has some unprocessed records for early data in 1970s (Roger to check) . GCOS to invite the CGMS international winds working group (IWWG) to explain their plans for reprocessing. Ken to write a letter to the IWWG chairs. Note: SCOPE-CM activities is relevant here.	
20	Increase the coverage of aircraft observations		Future	
21	Implementation of space-based wind profiling system	Ken Holmlund(follow progress with EUMETSAT)	Not currently being addressed by EUMETSAT. Needs to be reviewed a year from now. CGMS and CEOS to keep it on the agenda. In China: the prototype is organized potentially in 10 years.	To be reviewed before AOPC 2018 Milestone: update after CEOS meetings
22	Develop a repository of water vapour CDRs	Roger Sanuders	Develop a repository of ZTD/water vapour CDRs. The action is about gathering the data in a recognized	Status report until AOPC-23 2018

			archive and reprocessing in the future. GNSS has a recognized center, E-GVAP for Europe. Roger to provide more information. AOPC recognized the champion, needs now to see whether is implemented.	
23	Measure of water vapour in the UT/LS	Peter Thorne	Promote development of more economical and environmentally friendly instrumentation for measuring accurate in-situ water vapour concentrations in the UT/LS. To be addressed under action 15	
24	Implementation of archive for radar reflectivities	Andreas Becker	Task Team on Radar data for climatologies	
25	Continuity of global satellite precipitation products.	Ken Holmlund	See A16 - Continue to push the importance of the missions to space agencies.	Milestone: report of meeting addressing this request (CGMS:June2017 CEOS:October2017) Next AOPC session
26	Development of methodology for consolidated precipitation estimates	GCOS Secretariat	Work with WMO technical Commissions	Interim report next AOPC
27	Dedicated satellite ERB mission	Ken Holmlund	See A16 - Continue to push the importance of the missions to space agencies.	Milestone: report of meeting addressing this request (CGMS:June2017 CEOS:October2017) Next AOPC session
28	In-situ Profile and Radiation		Future	
29	Lightning		Future	
30	Water vapour and ozone	Ken	No planned mission for limb sounders	Milestone: report of meeting addressing

	measurement in UT/LS and upper stratosphere	Holmlund Peng Zhang Zhanqing Li	except of Altius- Belgian proposal with support from ESA measuring atmospheric composition and to be launched in 2020. See A16	this request (CGMS:June2017 CEOS:October2017) Next AOPC session
31	Validation of satellite remote sensing	James Butler Olga Kalashnikova Peng Zhang	To be coordinated between satellite and composition. Needs to be more specific and give specific examples on what is needed. Jim is going to be responsible for the gases and Olga for aerosols. On the satellite side, possible point of contact from working group climate is Stephan Bojinski and from the panel Peng.	Interim report for AOPC-23 2018
32	FDCRs and CDRs for GHG and aerosols ECVs	Ken Holmlund Zhanqing Li	Follow with WGClimate	Interim report for AOPC-23 2018
33	Maintain WMO GAW CO_2 and CH_4monitoring networks	James Butler	Generally ongoing, advance the measurement of isotopic forms of CO2 and CH4, and of appropriate tracers, to separate human from natural influences on the CO2 and CH4 budgets	Interim report for AOPC-23 2018 on data flow
34	Requirements for in-situ column composition measurements	James Butler; Peter Thorne	Define the requirements for providing vertical profiles of CO2, CH4 and other GHGs using recently emerging technology	During 2018
35	Space-based measurements of $C0_2$ and CH_4 implementation	Greg Carmichael	Ongoing, develop and implement proposals for follow-on missions accordingly	Interim report for AOPC-23 2018; full report for AOPC-24 2019

36	N_2O, halocarbon and SF6 networks/measurements	James Butler		During 2018
37	Ozone networks coverage	Greg Carmichael	restore the coverage as much as possible and maintain the quality and continuity of the GCOS Global Baseline	Status report until AOPC-23 2018
38	Submission and dissemination of ozone data	Greg Carmichael	Improve timeliness and completeness of submission and dissemination of data	Status report until AOPC-23 2018
39	Monitoring of aerosol properties	Olga Kalashnikova	Ask Olga to present a proposal on how to implement this action	Interim report for AOPC-23 2018
40	Continuity of products of precursors of ozone and secondary aerosols	Greg Carmichael	Space-based, ground-based and in situ measurements.	Interim report until AOPC-23 2018

ANNEX 5: List of ECV Stewards

(responsible for the ECV adequacy review)

ECV	Steward(s)
Surface wind speed and direction	Matthew Menne, Elizabeth Kent, Philip Jones
Precipitation	Andreas Becker
Temperature (surface)	Matthew Menne, Elizabeth Kent, Philip Jones
Pressure (surface)	Matthew Menne, Elizabeth Kent, Philip Jones
Water vapour (surface)	Matthew Menne, Elizabeth Kent, Roger Saunders
Temperature (upper air)	Peter Thorne
Wind speed and direction (upper air)	Shinya Kobayashi
Earth radiation budget	Peng Zhang
Surface Radiation Budget	James Butler
Water Vapour	Roger Saunders
Cloud properties	Zhanqing Li, Roger Saunders
Lightning	➔ identify expert
Carbon dioxide, Methane and other greenhouse gases	James Butler, Greg Carmichael
Aerosol properties	Peng Zhang , Olga Kalashnikova, Greg Carmichael
Precursors (supporting the aerosol and ozone ECVs)	Greg Carmichael
Ozone	James Butler, Greg Carmichael

ANNEX 6: Rationale for observing cloud structure for climate information and proposed actions

Clouds, Climate and Observations

By Hélène Chepfer, LMD/IPSL, Univ. Pierre and Marie Curie, Paris, France

Including contributions from: S. Bony (LMD/IPSL/CNRS), H. Brogniez (LATMOS/UVSQ), M. Chiriaco (LATMOS/UVSQ), S. Kato (NASA/LaRC), J. Kay (Univ. Colorado), A. Morrison (Univ. Colorado), V. Noel (LA/CNRS), B. Stevens (MPI), G. Stephens (NASA/JPL), D. Winker (NASA/LaRC)

Cloud feedbacks remain the main source of uncertainty for predicting the evolution of future climate since the first IPCC report. During the last decade, multi-models analysis allowed refining the cloud feedbacks problem in identifying some critical cloud feedback mechanisms and in distinguishing three categories: the ones that are likely positive and thus enhance the greenhouse gases warming, the ones that are likely negative and thus weaken the greenhouse gases warming, and the ones which are uncertain when the sign of the feedback depend on the model. Building on these results, more advanced studies helped re-thinking the inter-play between cloud, circulations and climate sensitivity.

After a short introduction on the state of the art on cloud feedbacks mostly inherited from multi-models analysis, this talk focused on the contribution of the observations to the study of cloud feedback mechanisms now and in the future.

Field experiment and ground base observations have helped improving our understanding of critical cloud-related processes involved in cloud feedback mechanisms, whereas passive space observations have helped observing the global view of the top of the atmosphere cloud radiative effect and estimate some vertically integrated cloud properties.

For helping reducing uncertainties on cloud climate feedbacks, the space observations need to include the detailed cloud vertical distribution, which is shaped by convection, by exchanges of radiation and by the vertical distribution of water vapor in the lower troposphere. It has been shown that the cloud climatologies derived from space passive sensors cannot observe the cloud and water vapour vertical distributions with the accuracy required to help understanding cloud feedback mechanisms.

The active sensors, such as the Calipso lidar and the Cloudsat radar have collected 10 years of observations collocated with passive sensors within the A-train. Their detailed observations of the cloud vertical distribution bridges the gap between the local precise process-oriented observations collected during field experiment or in ground base observatories, and the global scale 2D view collected by passive sensors for a few decades.

Some examples of the usefulness of the detailed vertical profiles observed by space borne active sensors for cloud feedback studies have been presented: 1) the capability to derive radiative heating rate profiles in presence of clouds from Calipso/CloudSat at a vertical resolution better than hundred meter at global scale; this is a key information for studying the interplay between clouds and atmospheric circulation 2) the capability of monitoring the tropical high cloud rise up predicted by climate models (a dominant positive LW cloud feedback term) with a space lidar, as demonstrated by simulating the observations that would be collected by a virtual lidar (COSP/lidar) overflying the atmosphere predicted by climate models over several decades 3) the lack of measurement of water vapour vertical profiles in the tropical boundary layer from existing space born sensors ; this profile of water vapour is the critical input for forming clouds and has been observed by airborne lidar 4) the arctic low cloud response (non-response) to sea ice loss in fall (summer) when the ocean and the atmosphere are strongly (poorly) coupled, has been monitored by active space sensors thank's to their capability to observed the cloud vertical profile whatever the surface type.

In conclusion, this talk highlights the needs for

- Observing cloud profiles from space over several decades with a vertical resolution better than 30m (see Action attached on Cloud Profiling)
- Developing a strategy to observe water vapor profile from space in the tropical boundary layer with a vertical resolution of 100m (see Action attached on Water vapour profiling)

in order to progress on our understanding of cloud feedback mechanisms, and to monitor cloud changes induced by greenhouses gazes climate warming.

Proposed actions:

Action : Implementation of space-based clouds and aerosols profiling

Action: Prepare and implement a follow-on lidar-radar mission to Calipso-CloudSat and EarthCare

Benefit: Monitoring and understanding of the clouds and aerosols vertical distributions and their impact on climate and weather.

Who: Space agencies

Time-frame: Launch as soon as possible to minimize the gap with EarthCare.

Performance Indicator: Long-term homogeneous satellite-based clouds profiles and aerosols profiles

Annual Cost : 100-300M US$ (tbc)

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Cloud feedback is considered to be one of the most uncertain aspects of future climate projections and is responsible for much of the wide range of estimates of climate sensitivity from models

Thanks to their ability to accurately profile clouds, active remote sensing instruments in space (like Calipso/CloudSat) have helped to characterize cloud processes, and

contributed to identifying possible critical feedback mechanisms. They also made possible to estimate vertical profiles of radiative heating rates, which are essential to understand and predict the large-scale atmospheric circulation, the position of rain belts and the occurrence of extreme events. Ten years of such observations are now available, which are sufficient to characterize cloud interannual variability but not yet long enough to detect cloud changes in response to increasing greenhouse gas concentrations.

Long-term monitoring of the vertical distribution of clouds with active sensors will provide weather and climate models with vital constraints on the impact of clouds on circulations, and will allow detecting cloud changes due to anthropogenic forcing before they become observable with passive sensors, because the cloud vertical distribution is expected to change faster than parameters available from passive sensors.

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Geophysical variable: Cloud Profiles

Horizontal resolution: <300m
Vertical resolution: 30m
Temporal resolution: instantaneous
Timeliness: 3 hours
Uncertainty: 1%
Stability: 50 m / decade (altitude), 0.1% / decade (cloud fraction)

Action : Water vapour profiles in low tropical troposphere

Action: develop a strategy for measuring low troposphere water vapour profiles from space
Benefit: vertically resolved water vapor in lower troposphere
Who: WCRP GC and space agencies
Time-frame: ongoing
Performance indicator: definition of a three years mission concept for a space water vapour lidar
Annual cost:

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Atmospheric water vapour plays a fundamental role in many processes critical to both weather and climate. In particular, deep convection and clouds in the lower tropical troposphere over the ocean are intimately connected to the vertical profile of water vapour. The absolute humidity in the marine boundary layer (i.e below 950 hPa) determines the convective potential, and the surface evaporation. The vertically resolved structure of water vapour (between 950 and 650 hPa) influence the distribution of deep convection, the pattern and amount of cloudiness in the lower troposphere, as well as its response to other perturbations, such as from aerosols. Because tropical cloudiness and convection are so intimately linked to water vapour understanding how it changes with warming is crucial, not just for understanding convection, but also for the circulation of the tropics and how both change with climate warming.

Advancing our understanding of weather and climate will require measurements of water vapor at higher vertical resolution than is available from current sensors, particularly in the lower troposphere. Despite this crucial need, no satellite missions are currently planned which could overcome the limitations of sensors currently flying.

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Geophysical variable: Water vapour profiles below 600hPa
Horizontal resolution: 10km
Vertical resolution: 300m
Temporal resolution: instantaneous
Timeliness:
Uncertainty: 3%
Stability:

ANNEX 7: List of proposed Task Teams

Requirements for RS launches: Put together the terms of reference for a task team to study the relationship between GUAN and the broader GOS radiosondes networks, including studying impacts on obtaining higher altitude for radiosondes, flexible launch time and keeping the original data from radiosondes.

Peter Thorne, Ken Holmlund, Tim Oakley, Caterina Tassone

GSRN (GCOS Surface Reference Network): Set up a task team to work on the way forward for establishing a GSRN. This includes writing a term of reference and selecting the composition and leader of the task team.

Ken Holmlund, Philip Jones, Peter Thorne, Caterina Tassone

Weather radar: Write a proposal on how best to proceed on the use of radar data for climate studies. Submit the proposal to the panel, to Carolin and after approval to the GCOS SC.

Andreas Becker, Ken Holmlund, Philip Jones, Elena Saltikoff

Lightning: AOPC to engage a Task Team to work on lightning. John and Bruce to give us names of possible experts. Task team to write a position paper on lightning that should then be peer reviewed.

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