

The 27th SPARC Scientific Steering Group Meeting

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The 27th SPARC Scientific Steering Group (SSG) meeting took place in Boulder, Colorado, USA from December 4th to 6th, prior to the AGU fall meeting in San Francisco. It was hosted by the National Center for Atmospheric Research (NCAR) at the Table Mesa Laboratory, and focused on the development of a new SPARC implementation plan for the upcoming 5 years (2021-2025).

Owing to the strategic focus of the meeting, the agenda included considerable time for discussion rounds and break-out sessions. Latest SPARC activity achievements were summarized in three sessions following SPARC's current research themes: "Atmospheric dynamics and predictability", "Chemistry and Climate", and "Long-term observation records for climate understanding". The meeting was also attended by a number of SPARC activity leads and liaisons from partner projects and agencies, who provided valuable input to the strategic discussions (Figure 1). On the last day, the World Climate Research Programme (WCRP) chair Detlef Stammer provided his perspective on WCRP and the envisaged route to realize its Implementation Plan.

SPARC updates and overview talks

The current SPARC co-chairs **Neil Harris** and **Judith Perlwitz** opened the SSG meeting and informed the community that they requested the Joint Steering Committee of WCRP to confirm the SSG member **Seok-Woo Son** as a third co-chair.

In his SPARC Office update, **Hans Volkert** announced that DLR has agreed to extend the position of Science coordinator **Mareike Kenntner** for three more years, which secures the office hosting at DLR-IPA until 2023. Since Hans is to retire from DLR in August 2020, Mareike is prepared to take over the task as office director. Another scientist will be hired to support her as science coordinator. During the past year, accomplishments include the publication of SPARC report No. 9 (LOTUS

report), the coordination of 11 SPARC workshops, and assisting WCRP in the preparation of the climate science week at the AGU fall meeting. It is planned to advance the SPARC website by facilitating links to important research publications, assessment reports, webinars and glossaries. It will serve as a resource for early career scientists who are new to SPARC-related research topics. SSG member **Gufan Beig** extended an invitation for SSG-28 to be held in autumn 2020 at the Indian Institute of Tropical Meteorology (IITM) in Pune, India. At this venue SSG-18 had taken place in February 2011 (cf. Newsletter no. 37). The final decision including dates is scheduled for March 2020.

The local host, **Yaga Richter**, gave a brief overview of SPARC-related research at NCAR. She described a model intercomparison study about the future projections of the quasi-biennial oscillation (QBO) and research findings on running and analyzing subseasonal-to-seasonal (S2S) forecasts. The S2S project revealed in particular that the influence of model resolution in the stratosphere tends to be rather model specific, and the models with a coarsely resolved stratosphere often perform quite well. She also introduced a new NCAR Earth-System model, which is running subseasonal forecasts in real time.

Two presentations of a more general nature (i) summarized the discussions at the DynVar/SNAP meeting in October about possible practices to reduce the carbon footprint of conferences (**Andrew Charlton-Perez** and **Elena Saggioro**; see report on page 40) and (ii) addressed the 2019 Southern Hemisphere polar stratospheric warming and ongoing surface impacts (**Harry Hendon**, see report on page 10).

WCRP update

Boram Lee (via remote link) gave the update on WCRP. She pointed out that the World Meteorological Organisation (WMO) is also undergoing changes.



Figure 1: Majority of participants at SSG-27 in the afternoon of 4 Dec. 2019 at the NCAR Mesa Laboratory main entrance.

01 Frédéric VITART, INT; **02** Joan ALEXANDER, US; **03** Donald WUEBBLES (SSG), US; **04** John McCORMACK, US; **05** Shigeo YODEN, JP; **06** Marvin GELLER, US; **07** Hans SCHLAGER, DE; **08** Gufranullah BEIG (SSG), IN; **09** Beatriz BALINO, NO; **10** Marilyn RAPHAEL, US; **11** Andrea STEINER, AT; **12** Larry THOMASON, US; **13** Takeshi HORINOUCI (SSG), JP; **14** Nathaniel LIVESEY (SSG), US; **15** Neil HARRIS (SSG co-chair), UK; **16** Amy BUTLER, US; **17** Mareike KENNTNER, DE; **18** Harry HENDON (SSG), AU; **19** Stefanie KREMSEK, NZ; **20** Scott OSPREY, UK; **21** Hauke SCHMIDT (SSG), DE; **22** Judith PERLWITZ (SSG co-chair), US; **23** Martine DE MAZIÈRE, BE; **24** Irina PETROPAVLOVSKIKH, US; **25** Karen ROSENLOF (SSG), US; **26** Hans VOLKERT, DE; **27** Wen CHEN (SSG), CN; **28** Megan MELAMED, US; **29** Yaga RICHTER, US; **30** Seok-Woo SON (SSG), KR; **31** Masatomo FUJIWARA, JP.

photo: Stephanie Shearer; annotation: Hans Volkert.

From January 2020, its structure consists of three pillars, one of which is “Science and Innovation”. It is led by Jürg Luterbacher, and comprises the WCRP, the World Weather Research Programme (WWRP), and the Atmospheric Environment Research (AER) Division.

Currently WCRP moves forward with developing its new implementation plan, after the basic structure and general direction were decided during the Joint Steering Committee meeting last May (Figure 2). As a next step the key science questions are to be defined which WCRP plans to tackle during the next decade. A dedicated workshop is planned for the end of February in Hamburg to finalize high-level science questions. In parallel, WCRP is assessing its current structure through task teams on modelling, data and regional activities. The updated structure is to be discussed at an “Elements and Structure” workshop in March or April 2020. A consolidated

version of the implementation plan is envisioned to be ready for approval by the JSC-41 meeting in Sydney in May 2020. It will contain the high-level science questions, the elements of the new WCRP, the collaboration landscape and interfaces to partners, the governance and a financial plan. Following the JSC-41, the document is to be approved by the sponsors, and the final version will be released. A transition phase to the new WCRP structure is envisioned to start in April 2021. It was stressed that the SPARC community should develop scientific priorities that could become integrated in the WCRP agenda for the next 10 years.

Boram announced that she is leaving her current position within the Joint Planning Staff (JPS) and will move to a different position within WMO. The SPARC community represented at the meeting expressed their sincere gratitude for Boram’s dedicated and cooperative work-style over many years.

WCRP chair **Detlef Stammer** described current plans for WMO, WCRP and the way forward with WCRP's new implementation plan. He stressed that WCRP needs to enhance its strength in order to be able to provide guidance to stakeholders on relevant topics, while taking into account, however, that WCRP is a research programme and not a weather forecast activity. He further emphasized that formulating the key science questions will be crucial as WCRP continues to be a scientific enterprise. The credible integration of social science aspects would provide additional strength. Detlef commented that the number of questions is growing for which the WCRP community is asked to provide convincing answers. He also reminded the community that the complexity of WCRP's structure was criticized repeatedly by reviewers and that WCRP was struggling to financially sustain all working groups and core projects. The Grand Challenges are scheduled to end in the coming years. The number of core projects may change in the new structure. Any transition has to be undertaken in agreement with the sponsors of the existing project offices.

Annalisa Bracco (via remote link) summarized the structure of the WCRP core project "Climate and Ocean – Variability, Predictability, and Change" (CLIVAR) with oceanography as a main discipline and the various large ocean basins as regional foci. A natural regional cooperation with the CLIVAR-GEWEX Monsoon Panel was reported. Storm track analyses in south-eastern Asia are regarded as an important issue within the CMIP6 efforts. CLIVAR is also much interested in atmospheric composition when tackling carbon fluxes into the ocean.

Beatriz Balino introduced CORA, the Coordination Office for WCRP Regional Activities, which became operational in 2019 and is engaged in the current WCRP task team on regional activities. Three regions of high scientific and societal relevance were identified as the Arctic (Greenland ice sheet), the Andes and the Himalayas (Third Pole).

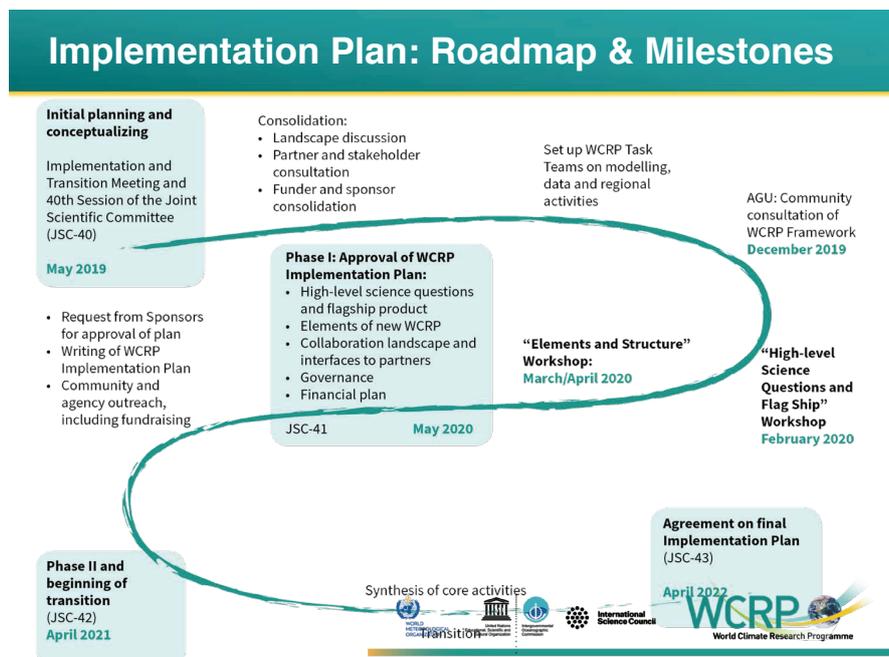


Figure 2: Roadmap and milestones for the finalization of the WCRP Implementation Plan.

Discussion session on "Atmospheric dynamics and predictability"

Twelve of the current 18 SPARC activities contributed to this theme. A number of achievements and developments were reported, summarized by the session leads **Amy Butler** and **Seok-Woo Son** at the beginning of the session. Time was also provided for updates from partner projects, namely the "Sub-seasonal to Seasonal prediction project" (S2S; **Frederic Vitart**), the "Polar Climate Predictability Initiative" (PCPI; **Marilyn Raphael**), the "Working Group on Numerical Experimentation" (WGNE; **Julio Bacmeister**), and the "World Weather Research Programme" (WWRP; **Judith Berner**). Each partner project was briefly introduced, results were presented with relevance for SPARC topics under discussion, and expectations were stated regarding possible cooperation with SPARC.

Activity progress and achievements

The *Data Assimilation Working Group (DAWG)* is aiming at 'Dynamical Reanalyses' for which a work plan was developed during a working group meeting held at the University of Colorado/LASP in September 2019 (see report on page 28). 94 scientists participated in the joint workshop of the *Dynamics and Variability (DynVar)* and the *Assessing predictability (SNAP)* activities in Madrid in October 2019 (see report on page 33). DynVar reported that within the DynVarMIP project of CMIP6 dynamical diagnostics are becoming available and three community papers are in preparation.

SNAP acknowledged the special effort by Daniela Domeisen to coordinate two community papers on predictability of the stratosphere and stratosphere-troposphere coupling on S2S timescales. A summary of these papers can be found on page 14.

Research within the *Fine Scale Atmospheric Processes and Structures (FISAPS)* activity showed that reanalyses indicate increasing wind-shear over the North Atlantic (Lee *et al.*, 2019), consistent with climate model projections. The *Gravity Waves* activity received support from the International Space Science Institute (ISSI) to form an international team examining the topic “New Quantitative Constraints on Orographic Gravity Wave Stress and Drag: Satisfying emerging needs in seasonal to sub-seasonal and climate prediction” with a first meeting held in Bern, Switzerland in April 2019. Progress was also reported from the *Observed Composition Trends and Variability in the Upper Troposphere and Lower Stratosphere (OCTAV-UTLS)* activity, with a new update of the JETPAC (JEt and Tropopause Products for Analyses and Characterization) algorithm to analyze multiple satellite-, ground-based and airborne in-situ ozone records in various dynamical coordinates. Furthermore, ozone datasets were remapped in the UTLS for an evaluation and ranking regarding coordinate-dependent reduced UTLS ozone variability.

The *Quasi-biennial Oscillation Initiative (QBOi)* contributed six publications on QBO modelling inter-comparison to a special section of the Quarterly Journal of the Royal Meteorological Society in addition to a final publication of previous modelling studies (Butchart *et al.*, 2018). The new *Stratospheric And Tropospheric Influences On Tropical Convective Systems (SATIO-TCS)* activity coordinated its work during a number of meetings and workshops during the past year. The *Solar Influences for SPARC (SOLARIS-HEPPA)* activity fostered evidence that solar variability is indeed a source of decadal climate predictability (Kushnir *et al.*, 2019). Progress was also made on the challenging subject of how to separate solar-induced dynamical signals from internal climate variability as was reported during a working group meeting in Granada, Spain (see report on page 30). The *SPARC Reanalysis Inter-comparison Project (S-RIP)* is on track towards a successful completion as report chapter manuscripts were submitted in November 2019. The SPARC Office is currently handling the review, and plans to finalize and publish the full report during 2020.

Future plans

In parallel to shaping the WCRP implementation plan and defining a new SPARC strategy, SPARC activities expressed concrete plans for future studies. These include a systematic reanalysis inter-comparison in the upper stratosphere/lower mesosphere (*DAWG*) and dynamic diagnostic output for CMIP6 (*DynVarMIP*). *DynVar* will place emphases on the troposphere and extremes, while continuing to consider stratosphere dynamics and stratosphere-troposphere coupling. *FISAPS* envisages orchestrated efforts to document and understand fine-scale structures in the vicinity of the tropopause as well as dissipative processes and their treatment in global models.

The *Gravity Waves* activity plans to advance efforts regarding their study on orographic gravity wave stress and drag, also through a joint workshop with the Pan-GASS project on surface drag and momentum transport. Mechanisms controlling the relation of ozone with dynamical coordinate variables are to steer future work of the *OCTAV-UTLS* activity, while *QBOi* will concentrate on QBO-influences for seasonal to decadal prediction. In 2020, a dedicated workshop is planned to commemorate the 60th anniversary of QBO’s discovery, including the composition of a review publication. *SATIO-TCS* will concentrate on the downward influence of the stratosphere with regard to tropical convection. They also plan two review publications and have scheduled a workshop in February 2020. *SNAP* plans an additional community paper on stratosphere-troposphere coupling biases in S2S prediction systems, while working on further understanding stratospheric influence on tropospheric predictability on S2S timescales. Finally, the research interest of the *SOLARIS-HEPPA* activity will lie on extracting solar-induced dynamical signals and their influence on decadal climate predictability.

Future science questions

The various activity reports contain a number of promising topics for future research, e.g., the quantification of different classes of uncertainties in both reanalyses and prediction, specific improvements in current simulation models, modification of general circulation structures (e.g. Brewer-Dobson circulation, QBO) in a changing climate, and regional aspects of global climate change.

The discussions in the break-out groups revealed further topics of interest (summarized by **Scott Osprey**). These included:

- systematic stratosphere errors/uncertainties/biases impacting forecasts and forecasting skill,
- assessing resolution and resolution dependent processes for alleviating stratosphere biases,
- space weather impacts on composition in mesospheric and stratospheric levels,
- tropospheric impacts of stratospheric extremes, e.g. sudden warmings, volcanic eruptions,
- tropospheric dynamical extremes and compound events, e.g. blocking and stalled Rossby waves,
- tropical stratospheric impact on atmospheric rivers and possible precipitation extremes,
- climate change effects on weather and regional circulations (recognizing the opportunity to establish and strengthen links to the WWRP).

During the plenary discussion the following additional topics were mentioned: the systematic use of the novel AEOLUS wind data, envisaged longer lead times for S2S-simulations, and the role of ozone with regard to thermodynamic/circulation feedbacks in model simulations.

Discussion session on “Chemistry and Climate”

This session addressed eight of the SPARC activities. It was introduced by **Don Wuebbles** and **Gufran Beig**, who provided a grand overview starting from the WCRP’s implementation plan structure via fundamental physical and chemical processes to a list of emerging issues. The session also included presentations from the International Global Atmospheric Chemistry Project (IGAC; **Megan Melamed**) and the Network for the Detection of Atmospheric Composition Change (NDACC; **Martine De Mazière**).

Activity progress and achievements

The *Atmospheric Composition and the Asian Monsoon* (ACAM) activity held its 4th workshop following the 3rd training school in Kuala Lumpur with a total of

154 scientists from 22 countries in attendance (see report on page 19). Another training school was held by the *Chemistry-Climate Model initiative* (CCMi) in Hong Kong in August (see report on page 22). CCMi has juxtaposed advantages and disadvantages of applying CCM-nudging to reanalysis data, published in various papers in the ACP/AMT/ESSD/GMD special issue. The *Atmospheric Temperature Trends* (ATC) activity produced two publications; one addressed the signal-to-noise ratio in temperature trends and time of emergence (Santer *et al.*, 2019), while the other determined the dynamical contribution to temperature trends in the lower stratosphere (Fu *et al.*, 2019). A ‘Chemical Reanalysis’ theme was newly established by the *Data Assimilation Working Group* (DAWG) with the goal to evaluate and intercompare different chemical reanalysis datasets in order to tackle issues such as the estimation of instrument bias, data homogenization and bias correction among different datasets for the purpose of trend estimation.

An assessment of change in ozone distribution within the upper troposphere / lower stratosphere (UTLS) region was carried out by the *OCTAV-UTLS* activity, which used their JETPAC algorithm to evaluate changes in jet-strength and tropopause-heights. The *Polar Stratospheric Cloud* (PSC) activity compiled the state of polar stratospheric cloud science in the draft of a review article. Improved process understanding of solar-chemistry interactions became a central objective of the *Solar Influences for SPARC* (SOLARIS-HEPPA) activity, which is preparing an overview publication on this topic. Data from the Stratospheric and upper tropospheric processes for better climate predictions (StratoClim) campaign were evaluated within the *Stratospheric Sulfur and its Role in Climate* (SSiRC) activity; it also developed an initiative, termed VolRes, to facilitate cooperation between experimentalists and modellers immediately after major volcanic eruptions.

Future plans

ACAM intends to support the Asian Summer Monsoon Chemical and Climate Impact Project (ACCLIP) field campaign in Japan, to coordinate model simulations in cooperation with Aerosol Comparison between Observations and Models (AeroCom) and CCMi, and to further analyse and publish StratoClim data. DAWG will work to further develop the new Chemical Reanalysis theme and reach out to other SPARC activities with demands for data assimilation.

Transport barriers and stratosphere-troposphere exchange are to be examined by *OCTAV-UTLS*, where topics such as mixing processes across dynamical barriers, relationships of ozone to natural modes of variability (*i.e.* QBO, ENSO), and climate impacts on long-term changes in UTLS composition are of particular relevance.

SSiRC sets out to determine constraints for the pathways of stratospheric aerosol and its precursors by investigating various radiative effects. The *PSC* activity is to come to a close during 2020 after the publication of the review article and a summary to be published in the SPARC newsletter.

Future science questions

The activity reports listed future research topics as, *e.g.*, the interrelation of aerosol-cloud-effects and radiative forcing, a systematic quantification of uncertainties in reanalyses, and thorough investigation of different coupling mechanisms across the UTLS-layer.

The break-out group discussions revealed further topics of interest (summarized by **Hans Schlager**), including:

- the role of intense convection and lightning induced NO_x,
- investigation of aerosol-cloud interaction (including secondary organic aerosol),
- monitoring emission change following measures to mitigate climate change.

The plenary discussion revealed that the spatial extent of future SPARC activities needs to be agreed upon, *i.e.* whether or not processes at mesospheric and thermospheric levels should be considered to determine their impact on the stratosphere.

Discussion session on “Long-term records for climate understanding”

Achievements and developments from six relevant activities were reported, summarized by the session leads **Nathaniel Livesey** and **Andrea Steiner**. Partner presentations included an overview of activities at the Japanese Space Agency (JAXA, **Masatomo Fujiwara** on behalf of **Makoto**

Suzuki) and the WCRP Data Advisory Panel (WDAC, **Susann Tegtmeier**).

Activity progress and achievements

The SPARC/IO3C/GAW Report on *Long-term Ozone Trends and Uncertainties in the Stratosphere*, (*LOTUS*) was published as SPARC Report No. 9. It was prepared by the members of the *LOTUS* activity, and underwent scientific review organized by the SPARC Office. Essential parts had provided timely input to chapter 3 of the WMO/UNEP Ozone Assessment 2018. The activity started its next phase with foci on stratospheric ozone trend models, its own multiple linear regression trend model, and a comparative homogenization of ozone records. The *Atmospheric Temperature Changes and Their Drivers* (*ATC*) activity is preparing a community paper about an update on atmospheric trends from observations that is providing valuable input to chapter 2 of the IPCC sixth Assessment Report. The *Water Vapour Assessment II* (*WAVAS II*) activity prepared consistent water vapour datasets from satellite observations, which are publicly available and carry a digital object identifier (DOI) number.

The *Stratospheric Sulfur and its Role in Climate* (*SSiRC*) activity has completed its work on revising key aerosol datasets, and started the second phase termed Interactive Stratospheric Aerosol Model Intercomparison Project (*ISA-MIP*). Analyses and comparisons of long-term datasets (ground-based as well as from commercial aircraft) were carried out by the *OCTAV-UTLS* activity, using their *JETPAC* algorithm. The activity also assessed reduction of uncertainties in dynamical coordinates through trend analyses on Aura MLS records. Meanwhile, the *Towards Unified Error Reporting* (*TUNER*) activity has developed a framework unifying error reporting approaches of a range of remote measurement techniques, observing wavelengths, target parameters, as well as retrieval approaches. A fundamental paper (von Clarmann *et al.*, 2019) was submitted to the *TUNER* special issue in *Atmospheric Measurement Techniques*.

Future plans

The collection and archival of updated ozone records will be one future activity of *LOTUS*, while participants also want to study regional trends especially in polar regions, coherence of stratospheric/tropospheric/total column ozone and trend model optimisation.

LOTUS will hold a joint TRENDS workshop with the ATC activity, which will also finalize their contributions to IPCC AR6 and their community papers. Scientific focus will be on the uncertainty of observations, analysis of CMIP6 warming trends and attribution studies.

SSiRC has defined three questions that they want to answer in their future work: (i) How does ultra-fine ash influence the volcanic sulphate radiative forcing? (ii) How do anthropogenic emissions of aerosol precursors affect stratospheric aerosol variability? And (iii) How does the tropospheric sulfur cycle respond to climate change and how does that affect stratospheric aerosol? CCMi plans to assess the science coming out of CMIP6 Aerosol Chemistry Model Intercomparison Project (*AerChemMIP*), and to organize simulations to support the 2022 Ozone Assessment.

A paper aimed at explaining the updated JETPAC output products and showcasing some of the dynamical coordinates selected to reduce ozone variability in the UTLS is planned by OCTAV-UTLS. TUNER plans a paper aimed at data users and will work on the quantification of the impacts of spatio/temporal variability on “coincidence based” validation studies. The WAVAS II activity will end during 2020, but hopes that research questions related to stratospheric water vapour will be incorporated into other SPARC activities. S-RIP will focus on finalising its SPARC report (number 10), and intends to start a Phase 2 in 2022.

Future science questions

Future science questions within this theme focus on improved understanding of the uncertainties in observations and reanalysis, and of composition changes in a changing climate. A number of activities pointed out the need to improve climate models’ representation of natural variability. Attribution of extreme events and climate variability (How do long-term changes alter atmospheric weather patterns and trigger atmospheric extremes, regional response and surface impacts?) were also identified as an important topic for the future, along with the idea to exploit long-term climate data records for gaining fundamental understanding of short-term climate variability and long-term climate trends from the troposphere to the mesosphere and their causes.

The question was asked, whether SPARC can help to monitor and measure progress towards interna-

tional targets, and to address societal challenges, low carbon transitions, as well as geoengineering impacts on atmospheric composition. SPARC could define the observing system needed to address those topics, and assess whether current and planned observing systems meet those needs.

Nathaniel Livesey summarized the following discussion, in which further activities were mentioned, such as sustaining and increasing observation and modelling interactions (looking for suitable cross-sections between activities, following the example of S-RIP). Furthermore, improved reanalyses leading to the need for more exact measurements and analyses were mentioned. Full resolution data is often available, but not provided, as it is often cut to the needs of operational agencies. Again, the plenum discussed possible SPARC work to identify critical needs for sustained and new measurements, and agreed that it would be good to hear what operational agencies use or plan to use, however, keeping in mind that data for fundamental research might have to meet different needs. It was mentioned, that a paper on looming gaps was submitted but not welcome in chosen journals.

SPARC Strategy discussions

Neil Harris started the strategic discussion on SPARC’s new Implementation Plan 2021-2025, with a retrospective on the challenges and conditions that the SPARC community faced during development of its current strategic plan. He also illustrated that SPARC has been very productive and suggested that it will be useful to produce a brief achievement report to summarize SPARC’s success.

A few conditions for the key science questions of SPARC’s new strategic plan for 2021-2025 were addressed. The key questions should build on information and identified gaps of recent assessment reports including IPCC’s 1.5°C and Land Use special reports, or the WMO/UNEP ozone report. Identified key questions should also contribute to the four science objectives stated in the WCRP strategic plan:

- (1) *Understanding Earth System processes,*
- (2) *Variability, Predictability and prediction*
- (3) *Climate change projections and ESM feedbacks, and*
- (4) *Bridging climate science and society, managing climate risks.*

Lively strategic discussions continued in two breakout sessions and subsequent synthesis. The overarching key science questions that could be included in WCRP's Implementation plan are first formulated:

1. How can prediction of weather and climate-related extreme events on sub-seasonal to decadal timescales be improved?
2. How will climate change on interannual to centennial timescales?
3. How and why is atmospheric composition changing over time and what are the impacts?

Then, all participants formulated a list of SPARC specific research topics and questions that would address the overarching questions together and identified the potential partners that SPARC would work with.

Input from SPARC activity reports, and feedback during discussions

There is an understanding that SPARC should continue to lead the focus on the "atmosphere" aspect in climate research with its balance between observations and modelling and its balance between dynamics and chemistry. Suggestions were made to extend to the mesosphere-lower thermosphere region in cases where an important role in the climate system exists.

The SPARC community expressed support for fundamental research, arguing against using poorly understood aspects of model simulations for impact studies. They want to retain focus on basic science issues that underpin climate modelling, such as process-level understanding to improve physics in models for timescales from long-range weather to climate. At the same time, they support the need to improve capacity building activities and to put more emphasis on fostering engagement with society.

SPARC's role in infrastructure aspects (*i.e.* the role of SPARC data centre, archiving model data and observational records) was brought up, along with a strongly expressed need for continued long-term measurements and global observations, driven by a concern about the availability of satellite datasets in the future. Observational data with high vertical resolution are needed to be available in the future. SPARC could formulate what observing systems are needed for climate research.

SPARC activities expressed willingness and need of increased interaction among activities (*e.g.* joint webinars or workshops), still valuing the current diverse portfolio of SPARC activities. They value of the bottom-up approach to answering science questions was strongly promoted, acknowledging that SPARC works well through a combination of match-making and ground-up initiatives – a practice that should be continued.

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