SPARC Implementation Plan 2016-2020

SPARC
Stratosphere-troposphere
Processes And their Role in Climate

The Stratosphere-troposphere Processes and their Role in Climate (SPARC) Implementation Plan 2016-2020

SPARC is sponsored by the
World Climate Research Programme (WCRP)

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Overall challenge

The overall challenge for SPARC is to promote and coordinate cutting-edge international research activities on how chemical and physical processes in the atmosphere interact with climate and climate change. Historically SPARC concentrated on the role of the stratosphere in climate, but now includes foci throughout the atmosphere in recognition of the latest research, which clearly calls for a "Whole Atmosphere" approach. Furthermore, the interdisciplinary nature of climate research has led SPARC to develop collaborations with other WCRP core projects and working groups, including support of the WCRP Grand Challenges. Beyond WCRP, SPARC will continue close collaborations with IGBP / Future Earth programmes, such as IGAC (International Global Atmospheric Chemistry). Effective implementation of the priorities below will ensure that SPARC continues to make significant contributions to policy-relevant global change research, such as through the WMO/UNEP Ozone Assessments in support of the Montreal Protocol and IPCC Reports in support of the UNFCCC. To fulfil these objectives, SPARC needs to continue to attract the support of the global scientific community by promoting and coordinating activities on high-priority climate research topics. As SPARC research evolves to include more regional foci, entrainment of researchers in regions of interest, including scientists from countries whose scientific infrastructure is still developing, will be essential.

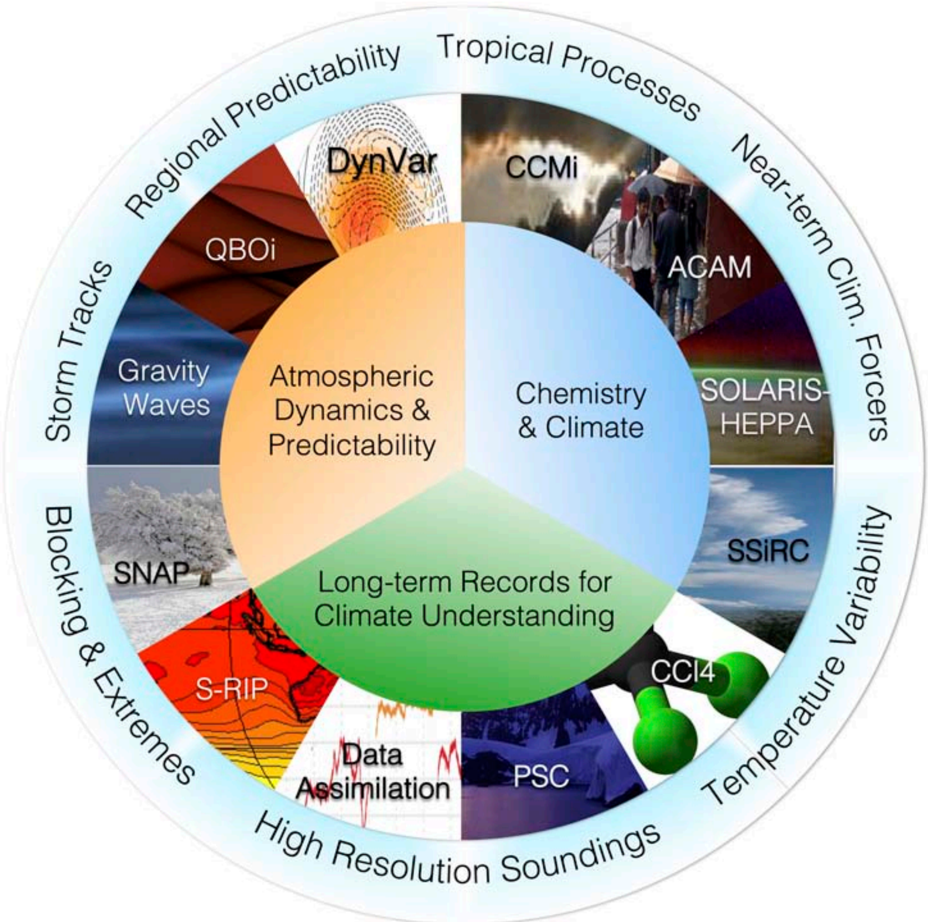

Figure 1: Schematic of the SPARC themes (centre) and current activities (middle ring) in 2015. The outer ring shows the areas in which new activities are being considered and the WCRP Grand Challenge topics in which SPARC is involved.

Science Themes

SPARC Scientific Themes define the breadth and foci of the project's work and form the foundation on which individual SPARC Activities are based (see **Figure 1**). The themes for SPARC's post-2015 Implementation Plan are (1) Atmospheric Dynamics and Predictability, (2) Chemistry and Climate, and (3) Long-term Records for Climate Understanding. As input to this implementation plan, key science questions were identified by SPARC leaders and community members over the last two years that provide a focus for activities in the coming 5+ years.

Theme 1 - Atmospheric Dynamics and Predictability

From gravity wave generation to Rossby wave breaking, SPARC research has long provided world-leading expertise in atmospheric dynamics. Indeed, the theory of wave mean flow interactions now used so widely in atmospheric science originated from stratospheric research, with early applications to the Quasi-Biennial Oscillation and sudden stratospheric warmings.

New challenges now face the climate science community, including the need to provide skilful and reliable regional climate predictions from months to decades ahead. On regional scales, unlike the global mean, it is the dynamics as much as the thermodynamics that determines climate. Regional variations in atmospheric circulation can greatly exacerbate or completely counter the thermodynamic component of climate change, especially for rainfall and circulation-related quantities such as storminess or atmospheric blocking. Because these quantities have crucial socio-economic impacts, they are foci of the WCRP Grand Challenges, and it is clear that atmospheric dynamics is a key focus area for future research in climate predictability. Similarly, there is a growing realisation that it is the shorter timescale, out to months or years ahead, where climate science can influence many government and business decisions. Given the dominance of climate variability on these timescales, a parallel focus on seasonal and decadal climate predictions, initialised with the current climate state, is also necessary. Although seasonal-to-decadal prediction has been regarded as primarily a challenge of the coupled troposphere-ocean system, there is increasing evidence that for extra--tropical regions stratosphere-troposphere coupling also plays an important role. This calls for involvement of new and existing SPARC activities.

The SPARC community includes leading atmospheric dynamicists who, as the focus on stratosphere-troposphere interaction has increased, have increasingly turned their attention to surface and tropospheric climate in recent years. SPARC scientists and others in the WCRP community have the atmospheric dynamics expertise to better understand tropospheric climate variability and near-term climate predictions. To help attain WCRP's goals, and to aid development of a scientifically robust WMO Global Framework for Climate Services, this implementation plan steers the SPARC community towards research activities focused on tropospheric variability and dynamics with an emphasis on near-term predictions.

Science Questions

- Do models reproduce the pattern and strength of atmospheric teleconnections?
- Are observed and modelled teleconnections robust given sampling and/or ensemble size limitations? These include tropical-extra-tropical links, horizontal and vertical connections, and sensitivity to the fidelity of the modelled basic state.
- What are the mechanisms of stratosphere-troposphere coupling across time scales? We still do not fully understand the mechanisms by which the stratospheric signal affects the troposphere and particularly storm tracks. Yet this produces large impacts on surface climate, especially in winter in the Northern Hemisphere and summer in the Southern Hemisphere, and it involves dynamics (such as wave momentum forcing) well known to SPARC scientists.
- How do external forcings of both natural and anthropogenic origin affect regional climate, and how do the regional circulation changes influence processes on smaller scales?
- How predictable is the atmosphere across time scales and regions? What are the mechanisms underlying this predictability and what limits does unpredictable internal variability impose on regional climate predictions? Are there emergent dynamical constraints that allow a reduction of uncertainty in future climate based on what we know about the recent past? How representative is our relatively short sample of observed historical climate variability?
- How is predictability affected by the atmosphere, ocean, sea-ice, and land surface conditions? These are key areas of overlap where collaboration and cross-project activities are needed with CLIVAR, CliC, and GEWEX through the proposed WCRP Grand Challenge on near-term prediction.
- Numerous questions arise on the role of atmospheric dynamics in understanding the occurrence and predictability of future extreme events in surface climate including: How extreme could future events be? What patterns in atmospheric circulation will increase the risk of unprecedented and damaging climate extremes? Can these be predicted or at least understood so as to provide better warnings? What dynamical circumstances are likely to lead to extreme regional events? Can we predict periods in which the risk of these extremes is enhanced?

The SPARC contribution

SPARC will assess atmospheric predictability and variability, and the underlying mechanisms. A growing data resource is available from initialised, ensemble climate predictions out to seasons and years ahead. SPARC science should take advantage of the growing resource of monthly, seasonal, and decadal forecast databases, for example the sub-seasonal to seasonal forecast database currently being developed in WMO, the seasonal forecasts in the WGSIP Climate Historical Forecast Project, and decadal forecasts in the CMIP5 database. CMIP5 already contains a comprehensive multi-model set of such predictions that will be extended in CMIP6 along with new century-scale projections. Analyses of these data are the primary source of our knowledge of actual climate predictability. While real-time forecasts are now regularly produced by climate centres worldwide, our relatively poor understanding of longer timescale predictability needs to be strengthened to make climate forecasts more useful to society.

SPARC will bring its observational expertise to bear on climate models. Accurate, long-term observational datasets serve as benchmarks for the model predictions and projections described above. SPARC expertise in critically assessing as well as producing long observational records will continue through Theme 3 "Long-term records for climate understanding." Such records form a basis for assessing model performance and set priorities for future model development, for example with WCRP's WGNE.

SPARC will actively promote research on the dynamics of surface climate extremes. The activities above point toward a primary driver for climate science research: That future climate, on whatever timescale, might contain extreme or unprecedented events with potentially devastating impacts. SPARC, in collaboration with the climate dynamics panel in CLIVAR, is well positioned to address the large-scale drivers of extreme events and their fidelity in climate models in support of the Grand Challenge on Climate Extremes led by GEWEX. This fidelity is crucial not only for climate predictions, but also for the attribution of past events – a topic of growing interest to governments and private entities alike. Immediate benefits could be gained by using the large ensemble of climate model data now available to draw conclusions about the potential magnitudes of extreme events.

Theme 2 - Chemistry and Climate

Changes in the chemical composition of the troposphere and stratosphere are critical factors determining radiative forcing and decadal-scale climate change. Understanding the interactive role of atmospheric chemistry in the climate system demands both new and continuing observations along with development and validation of chemistry-climate models.

Radiative forcing from long-lived gases (CO_2, CH_4, N_2O, CFCs, etc.) is well understood. The main uncertainties are associated with (i) future biogeochemical changes in the carbon cycle; (ii) natural and anthropogenic emissions of these gases (CH_4 especially) and (iii) assessing the future emission scenarios of CH_4 and N_2O. In addition, new gases such as HFCs are expected to make major radiative forcing contributions in the future. There are many more unknowns associated with short-lived climate forcers (gases and particles) and SPARC will promote activities to reduce their climate-related uncertainties. In addition, SPARC has an identifiable role to play in better understanding the emissions of the gases covered by the Montreal Protocol, with the CCl_4 emissions budget a current topic of concern.

Because the formation pathways for atmospheric aerosols are diverse and complex, resulting in a range of physical and chemical aerosol properties, the simulation of aerosol formation in models is challenging. Resulting uncertainty in aerosol concentrations and properties creates uncertainty in aerosol radiative forcing. Indirect aerosol forcing through cloud feedbacks is also uncertain since the processes involved are poorly understood and therefore poorly quantified. SPARC will expand its existing expertise in polar stratospheric clouds, cirrus, and convection processes to better understand chemistry-aerosol-cloud processes that are important for climate.

Three-way coupling between chemical, dynamical, and radiative processes in the upper troposphere and stratosphere could have important effects on climate, including modulation of climate sensitivity. While stratospheric ozone is expected to recover from the effects of ozone-depleting substances over the coming decades, the chemical impact of N_2O and CH_4 on stratospheric ozone and water vapour will likely increase. Resulting changes in ozone, water vapour, NO_x and HO_x will occur simultaneously with changes in stratospheric CO_2 and temperature. The increased stratospheric aerosol following strong volcanic eruptions can influence stratospheric ozone and have a strong impact on tropospheric climate. SPARC will promote a holistic view of the effect of these concurrent changes in order to understand the implications for climate.

Influx from the stratosphere is a major source of tropospheric ozone. Projected increases in the stratosphere to troposphere ozone flux are driven in part by strengthening of the Brewer-Dobson circulation and by increases in ozone concentrations in the lower stratosphere. These changes can have a significant impact on the interannual variability and long-term trend of tropospheric ozone, with these effects felt regionally. Such increases would lead to increased radiative forcing from tropospheric ozone and higher background ozone concentrations in the lower troposphere with implications for air quality. SPARC will promote activities to advance quantitative understanding of this stratosphere-troposphere exchange issue.

Science Questions

On interactions between composition, clouds, and radiation…

- How do volcanic eruptions affect atmospheric composition, radiation, and dynamics and what are the effects on surface climate?
- How will tropopause layer cirrus and their associated radiative effects change in a warming climate?
- How does varying solar UV irradiance influence decadal-scale climate?
- What determines the long-term changes in stratospheric water vapour and its feedback on radiative forcing?

On tropospheric ozone and stratosphere-troposphere exchange…

- What trends in stratosphere-troposphere exchange have occurred on hemispheric and regional scales and how robust are projections of future trends?
- How does climate change affect transport of stratospheric ozone to the troposphere, and thereby influence tropospheric composition and air quality given expected changes in tropospheric emissions?

On the role of atmospheric chemistry in climate change…

- What changes in surface climate can be attributed to interactive atmospheric chemistry? Can the importance of near-term climate forcers be better understood and quantified?
- By what processes, and to what extent, might changes in the chemical composition of the stratosphere influence climate sensitivity?
- How might coupling between changes in atmospheric dynamics and chemical composition affect future climate?
- What are the anticipated regional impacts of solar radiation management approaches such as stratospheric aerosol injection?

The SPARC contribution

SPARC will continue to develop its activities on aerosol / cloud interactions with the aim of reducing model uncertainties in radiative forcing. Because the issue is complex and requires expertise from several disciplines, SPARC will entrain expertise from initiatives like the SPARC-IGAC activity on Atmospheric Composition and the Asian Summer Monsoon (ACAM) and target those aspects of the problem where it can best advance scientific understanding.

SPARC will increase its activity related to effects of stratosphere-troposphere exchange on tropospheric composition with a focus on improved understanding of key processes. Understanding differences between model simulations of stratosphere-troposphere exchange and observed changes in tropospheric composition will provide an indicator of which processes may be inadequate in models.

SPARC will assess the critical factors limiting our knowledge of the impact of changes in atmospheric composition on radiative forcing and climate. Urgent needs include a better understanding of global and regional impacts of changes of water vapour and ozone in the UTLS on climate, improved quantification of short-lived climate forcers and the potential roles that ozone and water vapour processes and feedbacks may play in climate sensitivity. In addition SPARC will support the proposed Grand Challenge on Biogeochemical Cycles and Climate Change aimed at improved understanding of the biogeochemical processes which control the carbon cycle, e.g. by assessing the potential importance of regional variations in climate and through coordination with the SPARC activities on short-lived climate forcers.

Theme 3 - Long-term Records for Climate Understanding

SPARC has a well-established history of assessing the quality and utility of long-term climate records of temperature, water vapour, ozone, and aerosols. These assessments can now form a springboard for SPARC to meet the evolving needs of its primary user communities by establishing a theme dedicated to promoting the creation, analysis, and interpretation of climate data records (CDRs) of a range of essential climate variables (ECVs). A continued focus on CDRs of temperature, water vapour, ozone, aerosols, and potentially other ECVs, is a key service that SPARC can provide, in particular in support of WMO/UNEP scientific assessments of ozone depletion and IPCC assessments of the physical science basis of climate change. Ozone CDRs are essential for assessing the effectiveness of the Montreal Protocol and are needed for prescribing forcings in climate model simulations without stratospheric chemistry.

Such a theme would align SPARC's activities with those in the Global Climate Observing System (GCOS) and the Global Framework for Climate Services, as well as with other efforts such as Obs4MIPs, to which SPARC may contribute. SPARC will promote activities to guide construction, analysis, and interpretation of CDRs that require international cooperation. For example, merging ground-based, balloon, aircraft, and space-based measurements and accounting for the spatial and temporal sampling characteristics of each measurement type. GCOS guidelines for the generation of datasets and products (GCOS-143[1]) will be promoted for the construction of CDRs.

The theme will also provide feedback to data providers by articulating the evolving needs of SPARC for the construction of CDRs, including identifying and prioritising the most critical measurements required for SPARC science. This will go beyond simple advocacy with funding agencies and will include quantitative assessments of the impacts of the loss or degradation of any particular measurement series on the ability to detect trends in ECVs. SPARC will provide a forum for discussion of measurement needs, which includes the modelling community, to keep the list of ECVs fresh, to identify threats to key measurements, and to encourage the initiation of new measurements to meet newly identified needs, such as those associated with process-based emergent constraints.

The theme will promote activities that pay particular attention to uncertainties. An uncertainty should be associated with each datum in a CDR and, in the case of merging datasets, will be traceable to the uncertainties in the original measurement series and to uncertainties introduced in the measurement merging process. Uncertainties in original measurement series will, in turn, be further validated through additional measurement intercomparisons. The goal will be to achieve, and document, traceability of original measurements and their uncertainties to internationally accepted calibration standards. Close cooperation with the metrology community for ground-based measurements, and bodies such as the Global Space-based Inter-Calibration System (GSICS) for space-based measurements, will be required. Collaboration will also be required with observing networks that provide the raw measurement series used for CDR construction, including the Network for the Detection of Atmospheric Composition Change (NDACC), Global Atmosphere Watch (GAW), Southern Hemisphere ADditional OZonesondes (SHADOZ), the GCOS Reference Upper Air Network (GRUAN), and various space agencies that provide space-based measurements. Closer collaboration with observing networks will help to promote the expansion of those networks and will contribute to SPARC's capacity development initiative.

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[1] *GCOS-143: Guideline for the Generation of Datasets and Products Meeting GCOS Requirements, May 2010 (WMO/TD No. 1530.*

Science Questions

Determining trends:

- What are the vertically and spatially resolved trends in SPARC-relevant ECVs?
- What are the requirements on observing programmes, both in terms of measurement uncertainties and measurement sampling regimens, such that these observing programmes can reliably detect and quantify trends?
- Which species and state variables are needed, and with what resolution, frequency, and uncertainty, to better diagnose those changes in atmospheric composition and dynamics relevant to SPARC research?
- Is the atmosphere, both in terms of chemistry and dynamics, evolving in a way that is consistent with our understanding?

Understanding variability:

- What is the temporal evolution of global and regional forcing of the climate system, considering both natural and anthropogenic forcing?
- To what extent do current observations test our knowledge of atmospheric composition and dynamics? Which observations would provide more robust tests of our current level of understanding?

The SPARC contribution

SPARC will explore, develop, and document new methodologies for the construction of climate data records, time series analysis, and detection and attribution studies. Methods for merging and homogenising disparate measurement series should be critically assessed, including ways of providing quantitative and traceable uncertainties of merged datasets. Standardised products for community use should be improved and developed, including time series analysis techniques and tools to access the merged datasets.

As an essential component of CDR construction, SPARC will promote the collection and curation of CDR metadata. This will encompass dataset versioning, the use of digital object identifiers (DOIs), availability through long-term archives, and peer-reviewed publication of the CDRs. Close collaboration with the modelling community will be required. In addition to model validation with CDRs, models can be used to ensure that trends detected in multiple ECVs are physically and internally consistent.

SPARC will establish new activities to achieve these goals in conjunction with the international groups listed above. Potential activities recognized as having high priority include:

- Generating the forcings needed by CMIP6.
- Generating homogenised CDRs.
- Generating datasets required for the evaluation of Earth System Models.
- Defining measurements that would be needed to detect geoengineering and/or the effects of geoengineering.

- Defining and promoting measurements of selected ECVs in the upper troposphere and lower stratosphere.

Implementation of the SPARC plan

While many of the new directions highlighted in this Implementation Plan point to activities led solely by SPARC, other activities in WCRP projects and working groups will be approached to ensure relevant skills and expertise from across WCRP are involved. In particular, the WCRP Grand Challenges have identified high-priority societal problems that generally require new collaborative and interdisciplinary approaches to solve them. SPARC will take leading roles on foci within these Grand Challenges that benefit from SPARC expertise in atmospheric dynamics and chemistry. Collaborations with Future Earth projects such as IGAC, SOLAS, and AIMES will be developed to facilitate progress in chemistry-climate modelling, air quality issues, and emissions and lifetimes of ozone-depleting and climate-forcing agents.

Cross-cutting SPARC contributions

SPARC will make a strong contribution to CMIP6. In addition to its leadership in chemistry climate modelling jointly with IGAC, SPARC scientists have a number of key modelling and observational resources at hand. The WGCM coordination of CMIP provides the core resource for model-based information on climate in the coming century. SPARC analysis of these datasets already makes a strong contribution to current climate research and will continue to do so. SPARC also has a key role to play in the design and execution of these experiments, for example, in specifying external forcings such as ozone change or future solar irradiance changes, as well as coordinating specific MIP experiments and advising on optimal model configurations and formulation.

SPARC will be the lead core project facilitating the proposed new Grand Challenge on Biogeochemical Cycles and Climate Change. Natural biogeochemical cycles sequester carbon and thereby serve to mitigate human impact on climate. How these cycles will change is very uncertain and this mitigating role may become less effective in a future climate. The challenge is to understand how these biogeochemical cycles and potential feedbacks control greenhouse gas concentrations and climate. This Grand Challenge will involve scientists from other WCRP core projects as well as from former IGBP projects such as AIMES, IGAC, iLEAPS and SOLAS.

SPARC will lead the new focus on "How will storm tracks change in a future climate?" within the Grand Challenge on Clouds, Circulation, and Climate Sensitivity. Storm tracks and jets, together with their modes of variability, affect the regional distribution of precipitation, temperature, and wind in the mid-latitudes of both hemispheres. One of the most pressing questions regarding the impacts of climate change concerns how storm tracks will evolve. While comprehensive climate models predict a poleward shift of the zonal-mean mid-latitude westerlies in response to global warming, observational evidence is mixed, and such a shift may or may not occur regionally. This cross-cutting activity, while led by SPARC, will involve scientists from all WCRP core projects. The issues demand expertise in clouds and storm dynamics; land, ocean, and sea-ice forcings; paleoclimate; and weather and climate modelling.

SPARC will lead new foci on the dynamical processes behind extreme events, working with the Grand Challenge on Weather and Climate Extremes. Members of the SPARC community have played leading roles in research on the underlying dynamical processes such as large-scale modes of variability and blocking anticyclones that affect the occurrence and amplitude of weather and climate extremes. A new focus is needed on the representation of these processes in models and their usefulness for better predictions of extremes.

SPARC will work with other WCRP core projects and WWRP on the Polar Climate Predictability Initiative (PCPI). Predictability in a world with retreating polar ice caps is an issue of importance to the *Grand Challenge on Cryosphere in a Changing Climate*, and atmospheric processes link polar climate with changing weather and climate at lower latitudes. The Year of Polar Prediction should provide a good focus for this cross-cutting work.

SPARC will work to improve representation of chemical, dynamical, and radiative processes spanning the tropopause in models. Chemistry, dynamics, cloud physics, and radiative processes link the tropopause and stratosphere to surface temperature and climate. Prediction of regional climate change patterns on seasonal to centennial timescales depend sensitively on processes that require a "Whole Atmosphere" approach. SPARC will work in coordination with the IGAC and GEWEX communities to ensure the relevant research is accomplished without duplication of effort.

SPARC will contribute to the development and evaluation of high-resolution Earth system models. Global high-resolution models naturally seek to better resolve clouds and precipitation processes, but they also need to resolve the broad spectrum of atmospheric waves and their contributions to the momentum budget. Atmospheric waves and modes communicate climate signals across and through the troposphere, stratosphere, and mesosphere. Teleconnection pathways in models are highly sensitive to biases in general circulation that result from misrepresentation of atmospheric wave effects. Leading SPARC experts on waves and the atmospheric momentum budget will increasingly work with the WGNE and GEWEX communities on ensuring realistic simulation of momentum forcing and feedbacks in high-resolution global models.

The Approach

SPARC's approach will continue to focus on targeted activities with near-term achievable goals and an emphasis on tangible products that maximize benefit to the international community of scientists and stakeholders. As in the past, these products may include consensus reports, international review papers, and specialized or merged data records. We plan to maintain a flexible approach to the structure, size, and duration of SPARC activities: some will accomplish their goals in 1-3 years, while others will need a longer lifetime to maintain and promote vital links between previously disconnected scientific communities. Organization of focused workshops will remain a major mechanism for bringing the necessary cross-disciplinary expertise to bear on emergent issues. As always, SPARC will continue to support, encourage, and empower early career researchers and scientists from under-represented groups or nations with developing/transitional economies. This is part of SPARC's work to promote diversity in scientific participation in the broadest sense (see below).

Societal impact

Since its inception SPARC has always been focused on providing policy-relevant science. This has resulted in significant contributions to the WMO/UNEP Scientific Assessments of Ozone Depletion prepared quadrennially at the request of the Parties to the Montreal Protocol (e.g. the reports on ozone trends and on CFC lifetimes in 2014); more fundamental contributions which have taken more time to be absorbed into the scientific community have contributed to successive assessments (e.g. the dynamical picture of stratosphere-troposphere exchange developed in the 1990s (Holton et al., 1995)). Similar contributions have been made to the series of IPCC Reports with, for example, SPARC research showing the importance of including the stratosphere in climate models. SPARC will continue to identify scientific issues important for future assessments and organise activities to improve the quality of scientific information available to the assessment authors.

A new emphasis in SPARC is on regional predictions on sub-seasonal to decadal time-scales. These activities will help to provide information directly relevant to decision-makers about what changes might be expected in regional climate and the probability of extreme events.

Capacity building

The global nature of climate change, coupled with the regional nature of many of the signatures of this change, means that an internationally connected but regionally-focused research community is needed. In many countries there is still a shortage of high quality scientific expertise, which is needed to evaluate available scientific evidence and help to develop appropriate responses.

SPARC is assessing ways in which it can help develop expert capacity, particularly in developing countries. A capacity development strategy has been published in parallel with this Implementation Plan. Using this strategy, SPARC aims to make concrete steps toward developing scientific expertise and leadership within its programme. The strategic objective is "to encourage involvement in, and create opportunities for participation in SPARC activities by establishing and supporting collaborations and training of scientists internationally, and to foster careers of the next generation of scientists".

More regionally-focused SPARC activities will be developed further to build scientific capacity and develop international connections. These regional contacts will be leveraged to ensure that data sharing is strongly promoted, helping, for example, to collect high-resolution radiosonde observations and ease the organisation of field campaigns. Several training schools will be carried out on SPARC-related science topics and will further help to build capacity in regions where this is most needed.

Public Engagement

SPARC will actively promote its findings outside the climate research community in order to ensure the maximum impact of SPARC science. As well as continuing the excellent contribution that SPARC makes to peer-reviewed science, increased activity to promote SPARC science across WMO, to the public, media, and government stakeholders could multiply its impact on society. WMO press releases on key findings, case studies where SPARC science leads to impacts outside our field, and engagement with other WCRP groups and the public would help to educate and inform those outside our field of the importance of SPARC science.

Organisation

SPARC also has concrete organizational goals including establishing a new home for the SPARC Office, which provides essential support to the project. The Office ensures smooth communication within the SPARC community as well as between SPARC and the wider scientific community. It also serves a wide variety of other functions, ranging from organisation of travel support and meetings, to producing SPARC scientific publications. Finally, the sixth SPARC General Assembly is planned for 2018, to be held in Japan. These meetings, which take place every 4-5 years, provide a platform to share research results and scientific ideas. General assemblies are also opportunities for the SPARC community to come together to take stock of what has been achieved as well as to define where SPARC needs to be moving in order to respond to the needs of both its members and the users of SPARC research products.

By December 2020…

This 2015 SPARC implementation plan lays out the project priorities and new foci for the coming five years. The underlying work will be met by the individual SPARC activities, each of which has its own implementation plan. These are discussed annually at the SSG meetings and redefined on a regular basis to ensure that the science is kept fresh and vital. The on-going assessment of the activities will ensure that the overall aims laid out in this document for 2020 are realised. Here we highlight the main contributions SPARC will make.

Contributing to model development
Activities will identify model requirements to resolve stratospheric teleconnection pathways, to simulate the QBO, to resolve gravity wave effects on circulation, and to represent chemistry-climate coupling.

Providing guidance for next-generation reanalysis systems and climate models.

Activities will provide extensive analysis of output from the CMIP6 model intercomparison projects (MIPs), (for example, VolMIP, GeoMIP, AerChemMIP, and the DynVar diagnostic MIP) and will assess the results to highlight important areas for model improvements. SPARC activities will assess the major international reanalysis datasets, examining a wide range of state variables, constituents, and transport diagnostics, with foci on both trends and variability.

Providing community-supported forcing and validation datasets

SPARC activities will assess and distribute a number of forcing and validation datasets to support future climate and ozone assessments. Forcing datasets in support of CMIP6 include ozone, aerosols, solar UV irradiance, magnetospheric particles, and future solar-induced ozone effects. Assessed datasets for model validation will include ozone, upper troposphere and stratosphere water vapour, and temperature, including both variability and long-term trends, and the stratospheric sulfur burden. These data activities include careful quantification of uncertainties.

Improving process understanding

SPARC activities will report on the reconciliation of observed and reported emissions of certain ozone-depleting substances, e.g. CCl4, of particular interest to the Parties to the Montreal Protocol. They will provide a better quantitative understanding of the processes leading to the observed composition and temperature changes. Other studies will document model process descriptions and associated uncertainties of strong volcanic forcing, near-term climate forcers, chemistry-climate interactions, and the atmospheric momentum budget.

Availability of results and datasets

Results will be published in journals and/or SPARC reports. These publications and the datasets used will be made easily accessible

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