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Cover image

Main Gate (Otenmon) to the renowned Heinan Shrine area, situated in close proximity to Miyako-messe, the venue of the 6th SPARC General Assembly. An image of the impressive gate, rebuilt at the end of the 19th century as a replica of an ancient structure, was chosen by the Local Organizing Committee as a cultural icon in all announcements for the General Assembly. For many of its foreign participants the actual view of Main Gate and a leisurely passage through it provided a lasting impression about traditional Japanese architecture in combination with its famous garden design.

Photo: Hans Volkert, 6 October 2018

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The sections of the report were authored by scientists involved in SPARC as indicated at their beginnings:

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Parts of it are also available in the **SPARC-newsletter** no. 52, Jan. 2019, pp 2-13; online:

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1. 26th SPARC Scientific Steering Committee meeting

by Hans VOLKERT, Neil HARRIS, and Judith PERLWITZ

The 26th SPARC Scientific Steering Group (SSG) meeting took place at International Community House in Kyoto, Japan, from 6 to 8 October 2018, organized by the Japanese SSG member, Kaoru Sato (Tokyo university) with significant assistance by Shigeo Yoden and Masato Shiotani (both from Kyoto university). It immediately followed the 6th SPARC General Assembly (see section 3 on pp. 10-19). **Neil Harris** guided through the agenda (cf. Appendix 1 on pp. 20-21) and **Judith Perlwitz** joined via a live weblink from Boulder, USA.

1.1. WCRP update

The SSG received a brief update on the overall coordination of the World Climate Research Programme (**Boram Lee**). The WCRP Joint Scientific Committee (JSC) have been developing a new Strategic Plan (SP) 2019-2028, taking into account the Review of WCRP Co-sponsors that took place in 2017. Further input from the WCRP core projects, e.g. SPARC, the Grand Challenges and various Working Groups will be sought to develop the Implementation Plan for the SP. Besides the regular reporting on the work of JSC (including the results of the 39th JSC session in Nanjing, China, in April 2018) and other WCRP groups, the new WCRP Coordination Office for Regional Activities (CORA) was newly launched, with the purpose of assisting in integration and synergizing of regional activities within WCRP.

The SSG noted ongoing changes in the international framework of WCRP and its co-sponsors; a major rotation of the JSC membership at the end of 2018 including the current chairperson, Guy Brasseur (www.wcrp-climate.org/about-wcrp/about-governance), a new arrangement of the JPS leadership by the new WMO Chief Scientist / Research Director Pavel Kabat in his capacity of overseeing all the WMO research programmes (GAW, WWRP and WCRP), and the merger and creation of the International Science Council (ISC) from the former ICSU.

The subsequent discussion centred on the future contribution and role of the WCRP core projects, like SPARC, within the broader WCRP and WMO context. The necessity of maintaining and growing a strong research community was strongly emphasized by the SSG members, in order to ensure continuous science development, to provide a trusted route for the voluntary engagement of scientists, and to integrate and engage Early Career Scientists for

future science leadership. There was considerable frustration with the speed at which the plans were being developed and with the wide number of options still being discussed. This frustration was heightened by the publication of the IPCC Special Report on Global Warming of 1.5°C with its call for an urgent response during the SSG meeting.

In the light of the uncertainty, the SSG agreed that SPARC should maintain its focus to address key scientific questions that will contribute to the short- and long-term science goals, especially for challenges that are really ‘grand’. In parallel, it would contribute fully to the discussions about the future structure of WMO and WCRP, and would stress the need for continuity and the need to evolve gradually in order to keep the international research community engaged. The key role of the SPARC International Project Office in this process was again underlined, with acknowledgement to the host (DLR, Oberpfaffenhofen, Germany), as the key infrastructure to support the research community for atmospheric dynamics and chemistry.

1.2. SPARC activity reports

Each year the SSG review the progress in SPARC’s activities and assess which are progressing well, which need revitalising and which are coming to their natural conclusion. Due to it being held in conjunction with the General Assembly, the meeting was shorter than usual as many results had already been presented.

The Long-term Ozone Trend and Uncertainties in the Stratosphere (LOTUS) activity successfully contributed to the 2018 WMO/UNEP ozone assessment (**Sophie Godin-Beekmann, Irina Petropavlovskikh**). An extended LOTUS-report was accepted in July by its review board and is being published as SPARC-report no. 9, a joint effort sponsored by SPARC, the International Ozone Commission (IO₃C) of the International Association of Meteorology and Atmospheric Sciences (IAMAS), and WMO’s Global Atmospheric Watch (GAW). Sample results were presented, among them multiple regression trend analyses involving eight combined records derived from satellite data and model data from simulations undertaken within the chemistry-climate model initiative (CCMI). In the upper stratosphere ozone is found to increase again (“recovery”), while in the lower stratosphere variability, uncertainty and discrepancies between observation and simulation can be considerable.

The second Water Vapour Assessment activity (WAVAS-II) presented an overview of relevant satellite retrievals since 1985, augmented by balloon measurements in the lower stratosphere and surface-based moisture observations at upper stratospheric and mesospheric levels

(**Kaley Walker**). The “golden age” decade after 2000 witnessed a maximum of simultaneous humidity measurements from space platforms. Reference was made to Walker’s presentation at the General Assembly and a special journal issue (cf. www.atmos-chem-phys.net/special_issue830.html).

The Atmospheric Composition and Asian Monsoon (ACAM) activity, a joint effort with the International Global Atmospheric Chemistry (IGAC) project, announced a change in leadership: **Hans Schlager** and Mian Chin taking over from Laura Pan and James Crawford. During the past years the scientific community for Asian Monsoon studies was strengthened, in particular through annual meetings with numerous early career scientists from the Asian countries. For 2019, a combined international workshop and training school is scheduled in Kuala Lumpur, Malaysia. New and existing aircraft and balloon data will continue to be scrutinized with regard to aerosols, acids and NAT. Data analyses and modelling studies concentrate on the topics “aerosol-monsoon interactions”, “impacts on PBL processes”, and “impacts on UTLS processes”.

For the Polar Stratospheric Clouds initiative (PSCi) **Michael Pitts** presented a seven-section-outline of a broad review entitled “Recent advances in our understanding of PSCs” to be submitted to Reviews of Geophysics. Daily reference data sets were highlighted from the MIPAS (cf. <https://datapub.fz-juelich.de/slcs/mipas/psc/>) and CALIPSO (https://eosweb.larc.nasa.gov/project/calipso/calipso_table) instruments that are publicly available. As in the past, PSCi receives core support from the NASA CALIPSO/Cloudsat science team in the US and German funding agencies DFG and HGF.

The Data Assimilation Working Group (DAWG; **Quentin Errera**) proposed its new four-themed structure, to be active during the next quadrennium: 1) limb sounding observations in support of SPARC; 2) chemical re-analyses; 3) data assimilation for upper stratosphere and mesosphere; and 4) new data assimilation techniques in the stratosphere. Interested institution and persons were identified. The envisaged overview publications should pave the way to a “next generation” S-RIP exercise.

Just as ACAM, the Chemistry-Climate Modelling Initiative (CCMi; **Michaela Hegglin, David Plummer**) is jointly undertaken with IGAC. With the first phase of CCMi winding down, a new mission statement defines the activity as the international forum for coordinated inter-model chemistry-climate comparisons. A timeline was presented including a science workshop in 2019 (Hongkong) and the next assessment reports for IPCC in 2021 and for ozone in 2022.

The activity dealing with the Dynamical Variability of the atmosphere (DynVar; **Edwin Gerber**) is redefining its research foci and leadership. During the past eleven years it has been instrumental in sparking off specific activities like SNAP and QBOi as well as the diagnostic model intercomparison project DynVarMIP, comprising output from 13 modelling centres as part of CMIP6. A four-day international workshop is scheduled for October 2019 in Madrid, Spain (www.sparcdynvar.org/dynvar-workshop) in order to take stock and develop the new directions.

In its second phase, the Network for Atmospheric Predictability (SNAP; **Amy Butler**) continued the cooperation with the joint WCRP/WWRP's Sub-seasonal to Seasonal prediction project (S2S). The recently created S2S database is used to determine the role of the stratosphere for the climate predictability near the surface. Currently the SNAP team involves 16 institutions in eight countries.

For the Fine Scale Atmospheric Processes and Structures (FISAPS) activity, the SPARC co-founding chair **Marvin Geller** (via remote link) officially announced a change in leadership, with **Thomas Birner** (now Univ. Munich, Germany) co-chairing together with **Hye-Yeaong Chun** (Yonsei Univ., Korea). A three-day workshop was scheduled for early November in Kühlungsborn, Germany with stratospheric turbulence as a special focus (<https://www.iap-kborn.de/en/current-issues/events/fisaps2018>).

Ongoing work of the Gravity Waves activity was presented by **Kaoru Sato** (local co-chair for the General Assembly). She introduced three new directions, i) high latitude and global observations by radar, ii) estimation of the gravity wave contribution to the Brewer-Dobson-circulation using reanalysis data, and somewhat related iii) inferring the gravity wave drag through data assimilation methods. All approaches were underpinned with sample results and publications. For direction iii) the International Space Science Institute (ISSI) is to support an international, 5-day workshop in April 2019 in Berne, Switzerland. A gravity wave symposium is being planned for 2021 in Germany.

The Quasi-Biennial Oscillation initiative (QBOi; **Scott Osprey**) completed its first phase, during which 12 modelling centres contributed coordinated simulation output from 17 different models to a common data archive. The technical description was published and results regarding topics as QBO in present-day climate versus future scenarios with two- and four-fold CO₂ content, equatorial waves and teleconnections are scheduled for submission to a special issue in the Quarterly Journal of RMS.

The SPARC Reanalysis Intercomparison Project (S-RIP; **Masatomo Fujiwara**) is preparing the 2019 publication of a complete SPARC report as final outcome of five years of coordinated work. The S-RIP inter-journal special issue in Atmospheric Chemistry and Physics / Earth System Science Data (ESSD; www.atmos-chem-phys.net/special_issue829.html) contains 24 articles in Oct. 2018, with 5 more anticipated. It includes the 4 chapters constituting the interim report.

Atmospheric Temperature Changes (ATC; **Andrea Steiner**) held its second workshop during two days by the end of June in Paris, France. Updated findings of the activity on stratospheric temperature trends appeared as a frontier article in Geophysical Research Letters (doi: 10.1029/2018GL078035). For 2019 a review article is planned addressing the challenge of keeping the average global temperature increase below 1.5 or 2 K, as formulated in 2015 at COP-21 in Paris.

In 2018, the Stratospheric Sulfur and its Role in Climate activity (SSiRC; **Jean-Paul Vernier**) organized a 6-day international conference on stratospheric aerosol in the post-Pinatubo era on Tenerife island, Spain for 90 participants from more than 10 countries. Afterwards the steering group met at ISSI in Berne and identified science links to the majority of the other APRC activities and related experimental campaigns.

The Solar Influences on climate / High Energy Particle Precipitation in the Atmosphere activity (SOLARIS-HEPPA; **Bernd Funke**, via remote link) structures its work in five working groups (WG), with coordinated CCMI analyses as a common aim. The WG-leads had a meeting in April in Karlsruhe, Germany. A science workshop took place in Roanoke, USA. Strong links to activities SSiRC, LOTUS and ATC were stressed.

1.3. SPARC emerging activities

The emerging activity Stratospheric And Tropospheric Influences On Tropical Convective Systems (SATIO-TCS; **Shigeo Yoden**, local co-chair for General Assembly) focusses on the tropics as geographical region and moist convection as chief physical mechanism for time-scale of a day or shorter. Reference was made to a broad presentation at the General Assembly stressing links to QBOi and FISAPS which were further built during a common workshop in 2017 and a side meeting during the GA. A review article about the stratosphere-troposphere coupling in the tropics is about to be submitted.

Observed Composition Trends And Variability in the Upper Troposphere and Lower Stratosphere (OCTAV-UTLS; **Peter Hoor** and **Irina Petropavlovskikh**) aims to disentangle the chemical and dynamical influences on composition trends in the UTLS. Science questions are formulated taking into account a comprehensive suite of datasets from different platforms and applying standardized metrics. A workshop was scheduled for early November in Mainz, Germany.

Towards Unified Error Reporting (TUNER; **Nathaniel Livesey**) is the third emerging activity. Following a successful application, the TUNER team held a first four-day workshop at ISSI in December 2017. For TUNER publications, a special issue was set-up with the journal Atmospheric Measurement Techniques with so far three accepted articles (https://www.atmos-meas-tech.net/special_issue921.html). The next workshop in Berne is scheduled for April 2019.

Given the progress made in all emerging activities, the SSG declared in its final session that all three are fully emerged and from now on are ordinary SPARC activities.

1.4. Partner projects

Michel Gutter, member of the IGAC scientific steering group, explained the IGAC perspective of the links of this Future Earth project to SPARC, mainly through activities ACAM and CCMI, and reported about the joint 14th iCACGP / 15th IGAC conference (<http://icacgp-igac2018.org/>) which had taken place in Takamatsu, Japan during the week prior to the SPARC General Assembly. Some 700 participants, including numerous early career scientists, from the worldwide atmospheric chemistry community with a focus in air quality and dispersion at tropospheric levels discussed latest research results and celebrated 60 years of the international Commission of Atmospheric Chemistry and Global Pollution (iCACGP within IAMAS).

Oksana Tarasova (via remote link) gave a presentation on the activities in GAW and their interaction with SPARC. Neil Harris then updated the SSG on the state of on-going discussion between SPARC, GAW and IGAC about stronger collaboration on a few focussed topics. Progress is being slowed down by the lack of clarity about how WMO wants to restructure its research programmes. There is clear value in working closer together if conditions allow. A workshop on this topic was held at WMO in early November.

Proposed joint activities of the CLIVAR/GEWEX monsoon panel and SPARC envisage different areas of common interest and expertise (**Tianjou Zhou**). Teleconnection pathways towards monsoon dynamics were found to take in parts stratospheric routes, especially from the North-Atlantic sector and polar regions; monsoon circulations tend to actively modulate conditions over the Pacific region, where El Niño anomalies originate; monsoon variability tends to control the transport of trace gases and aerosols into the stratosphere. Regarding decadal climate predictions the role of volcanic aerosols should be better quantified and their dynamical impacts investigated, as it is proposed for the numerical experiments under the heading VolMIP in CMIP6. The SSG welcomed this initiative and agreed to set up a task force to identify how SPARC could best contribute. Additionally, the Chinese initiative “Third Pole Environment” (TPE), aiming inter alia at improved observations from the Himalayas, could be involved.

1.5. Space observations

Due to the compact nature of SSG-26, the regular space observation section only featured two Japanese presentations. **Makoto Suzuki** (Japanese Aerospace Exploration Agency [JAXA], Earth Observation Research Center) gave an update about the broad meteorological satellite programme undertaken in Japan and its definite plans until 2021. The “global change observation mission – water” spacecraft (GCOM-W or Shizuku, launched in 2012) is still in operation, while the follow-on satellite for “mission – climate” (GCOM-C or Shikisai) was successfully launched in 2017. Sample results of both low orbit systems were presented. The new generation Himawari-8 (launched 2014) and -9 (launched 2016) missions in geostationary orbits provide a large number of products, which can be accessed via a web-interface at www.eorc.jaxa.jp/ptree, including aerosol information and wildfire detection outside the scope of the standard observations for numerical weather forecasting.

Masato Shiotani, who also had acted as a local co-chair for the 6th General Assembly, described the ambitious plan of a revised superconducting submillimetre-wave limb-emission sounder (SMILES-2) after the 9-month exploratory SMILES mission, which ended in April 2010 and had provided inter alia ozone distributions in the 28-km-level. The new plan encompasses a proof of technology, but also targets at daily variations in stratospheric ozone in the 20-to-60-km-range.

1.6. Other SPARC news

Since January 2018, the SPARC office has been working at and staffed by the Institut für Physik der Atmosphäre (IPA) situated at the Oberpfaffenhofen campus of Deutsches Zentrum für Luft- und Raumfahrt (DLR; **Hans Volkert**) near Munich in southern Germany. Contributions to the planning and preparation of the 6th General Assembly and the following SSG-meeting were made in close cooperation with the LOC in Japan. Support for several SPARC workshops was organized and the administration of financial assistance gradually taken over from WCRP (as formally arranged in a Letter of Agreement). The coordinating scientist, **Mareike Kenntner**, received a symbolic token of gratitude for her sustained efforts during the past year.

SSG-member Olivia **Martius** (retiring from the group at the end of 2018) was thanked for her dedication during the past three years and for her help in linking SPARC to research on atmospheric predictability, not least through her role as co-lead of the WCRP Grand Challenge on Extremes. The next call for membership from 2020 onwards is scheduled to appear in late summer 2019.

Four locations for the 27th SSG-meeting are being considered: Pune, India; Melbourne, Australia; Boulder, USA; and Madrid, Spain. A final decision will be made early in 2019.

(It will take place in Boulder during the first week of December 2019; *added before printing* .)

2. Reflections by the co-chairs on the outlook for SPARC

by Neil HARRIS, and Judith PERLWITZ

The recent SPARC General Assembly in Kyoto was simulating in many ways. Most notable were the number of attendees, the quality and enthusiasm of the presentations and discussions, and the keen interest in SPARC's future and its role in climate science. The fundamental health and vitality of the truly international SPARC community was apparent to all. The final weekend of the General Assembly coincided with the release of the IPCC special report on the impacts of global warming of 1.5C above pre-industrial levels. The IPCC findings made clear the urgency of starting to reduce the emissions of all greenhouse gases as well as the need for accurate climate information to support strategies for adaptation and mitigation. This report was followed by the UN's COP-24 conference which amid much political posturing

did agree the rules for implementation of the Paris Agreement. Based on the experience with the Montreal Protocol, agreeing these rules is a real step forward, which coupled with the periodic revision of the targets, gives hope that the Agreement might succeed. There is a long, long way to go before we know if that is the case.

The new WCRP Strategic Plan is a great opportunity to make a real contribution to achieving that. The implementation of the plan is now under discussion, and it is still far from clear whether that will involve a complete make-over of WCRP or whether WCRP can evolve to meet the new challenges. Our strongly held view is that WCRP must be allowed to evolve, as a root and branch reform aimed at producing a theoretically logical structure could set back scientific progress in WCRP by several years and leave it side-lined in the public climate debate.

An evolutionary approach would allow the communities in the core projects, grand challenges and other facets of WCRP to use their expertise to work out how best to implement the new, more integrated strategy. An increase in the number of collaborative activities building on existing strengths and developing new ones is essential, and our discussions indicate that there is a general willingness to make this happen. Maintaining core strengths is also required. Atmospheric sciences should be a vital component of this approach as they are required to improve predictability, to understand changes in composition, and to understand the decadal changes in past climate. We thus envision a period where SPARC scientists are actively involved in WCRP-led collaborative programmes that address key climate questions (e.g. a holistic understanding of convection). In parallel, a number of activities of similar size and ambition to our current ones would be maintained. SPARC would continue to support the Montreal Protocol process and help WCRP make the Paris Agreement as successful. In this way SPARC and WCRP more broadly could continue to contribute most effectively to the on-going climate debate.

Early career scientists should contribute fully to this debate and to influencing the future role of SPARC and WCRP more broadly. Their generation will be implementing the Paris Agreement and so they will need to monitor the success or otherwise of the measures taken. The earlier the young scientists take responsibility, the better. We urge them to participate in SPARC activities and to take leadership of the ECS forum we are developing.

3. 6th SPARC General Assembly

by Harry HENDON, and Amanda MAYCOCK

The SPARC 6th General Assembly (GA) was held 30 September - 5 October 2018 in the historically important and culturally rich city of Kyoto, Japan. The GA was held in parallel with a joint Belmont Forum/JPI-Climate meeting (Joint Programming Initiative “Connecting Climate Knowledge for Europe”) and was back-to-back with the Joint 14th iCACGP Quadrennial Symposium/15th IGAC Science Conference, which took place in Takamatsu, Kagawa, Japan during the previous week.

3.1. The General Assembly

SPARC General Assemblies are opportunities to take stock of and celebrate what has been achieved in the SPARC project, to identify where gaps in the portfolio of research supported by SPARC need to be filled, and to define where SPARC needs to be moving to remain responsive to the needs of both its members and the users of SPARC research products.

The year-long organization of the GA was thrown into last minute turmoil due to back-to-back landfalling typhoons in Japan during September 2018. Typhoon Jebi, which was the strongest typhoon to strike Japan in the past 25 years, struck Osaka and Kyoto on 4 September, causing loss of life and widespread damage to property and infrastructure including the Kansai international airport. Remarkably, the airport and train systems were brought back to normal in under 2 weeks, but then Typhoon Trami passed just to the south of Kyoto on the eve of the GA. This was the closest many of us had ever been to the eye of a tropical cyclone. Although the damage in Kyoto was much less than caused by Jebi, effectively all international and interstate transportation was cancelled on the Sunday before the opening ceremony causing significant travel disruption for many participants. The LOC and SOC decided to adapt the programme to accommodate the disruption, including rescheduling the traditional taiko drumming troupe that provided a spectacular opening to the GA on Monday afternoon.

The conference was attended by 382 participants from 31 countries, 120 of them registered as Early Career Scientists (Photo 1 opening ceremony). As for previous GAs, the main presentation format was poster sessions complimented by a handful of oral presentations in plenary. Over 400 posters were presented during the week. Posters were displayed in two sessions each spanning 2.5 days with three science themes covered in each session (see below). Each session was comprised of six blocks with each colour coded poster being ‘active’

in one block. This new approach to the poster scheduling meant that a spread of posters from different themes were active at any one time, so presenters had chance to see posters from their themes in the other blocks. The poster sessions were facilitated by refreshments and local sweets kindly arranged by the LOC.

The GA scientific program was built around six themes that reflected both long-standing and emerging areas of SPARC science:

1. Connections of Atmospheric Composition and Chemistry to Weather and Climate
2. Climate Prediction from Weeks to Decades
3. Role of Atmospheric Dynamics for Climate Variability and Change
4. Atmospheric Impacts and Interactions Related to Tropical Processes
5. Advances in Observation and Reanalysis Datasets
6. SPARC Science for Society

The following sections summarize some of the science highlights from each session, but this only scratches at the surface of the excellent and diverse range of science that was presented during the week.

3.2. Connections of atmospheric composition and chemistry to weather and climate

Theme 1 had three keynote presentations, six additional oral presentations, and 113 poster presentations covering topics including: aerosol observations and analysis, volcanic emissions and analysis, stratospheric ozone, dynamics and long range transport of pollutants, trace gas observations and analysis, the Asian summer monsoon, the upper troposphere and lower stratosphere (UTLS), and climate analyses. The theme provided a bridge to the Joint 14th iCACGP Quadrennial Symposium/15th IGAC Science Conference held during the previous week.

The oral presentations highlighted new understanding of the role of ozone depletion substances (ODSs) in driving the Brewer Dobson circulation (BDC) through two different chemical and radiative pathways. In a model study, the ODS warming impact on sea surface temperatures was found to dominate the global annual mean BDC response, while the ozone hole impact was larger but regionally and seasonally confined (Marta **Abalos**, keynote). The BDC is important for stratospheric ozone variability and trends; other presentations in the theme discussed the challenges and recent progress in characterising past ozone trends in midlatitudes (Leonie **Bernet**) and the tropical lower stratosphere (William **Ball**).

Another key topic in the theme related to the Asian summer monsoon (ASM) and its role in transporting Asian pollutants into the upper troposphere and lower stratosphere, leading to enhanced aerosol formation that is important for radiative forcing of climate. The first airborne measurements were described of SO₂, H₂SO₄, NO, HNO₃, and NO_y in the ASM Anticyclone between 12 km and 20 km based on observations during the StratoClim campaign with the Geophysica aircraft in Kathmandu, Nepal, in July/August 2017 (Hans **Schlager**, keynote). The importance of the ASM for transport of bromoform emissions from the ocean into the stratosphere was also highlighted (Alina **Fiehn**). The difficulty of capturing large-scale tropospheric transport in models was demonstrated in simulations from the Chemistry Climate Model Initiative (CCMI), which leads to poor constraints on modeled distributions of key tropospheric species (Clara **Orbe**, keynote).

Another topic in the theme addressed modeling the response of the climate system to external forcing, including: the effect of volcanic eruptions on the hydrological cycle (**Seungmok Paik**), the role of the ozone layer in the response to natural (solar) and anthropogenic (CO₂) forcings (Gabriel **Chiodo**) and the reduction in the global land monsoon precipitation due to increasing anthropogenic aerosols (Tianjun **Zhou**).

3.3. Climate prediction from weeks to decades

The presentations in the theme covered the possible mechanisms and sources of climate predictability on a range of time scales from subseasonal and seasonal to decadal and centennial scales. There were two keynote presentations, six contributed oral presentations and nearly 40 poster presentations.

An emerging area that was highlighted in the theme was subseasonal-to-seasonal (S2S) prediction, where recent progress in understanding how knowledge of the state of the stratosphere, along with conventional approaches based on the Madden-Julian Oscillation and the El Niño-Southern Oscillation, could improve S2S predictions (**Butler**, keynote). The importance of the coupling between the tropics and the mid-latitudes, the Arctic and the mid-latitudes, the ocean and the atmosphere and the stratosphere and the troposphere were also highlighted as prime sources of predictability across timescales (**Domeisen**, keynote).

As an example of the stratosphere-troposphere coupling, other presentations in the theme assessed prediction of sudden stratospheric warming (SSW) in operational models. It was shown that in S2S prediction models SSWs can be predicted at lead time of 8 to 12 days

(**Karpechko**) and further that such predictability is sensitive to the initial conditions in the upper stratosphere (**Noguchi**). Ensemble reforecasts with different initial conditions revealed that satellite observations in the upper stratosphere become important for the forecast skill starting about 5 days before the SSW, thereby influencing the predictability in the troposphere.

Other presentations in the theme considered predictability on longer timescales. In the Northern hemisphere, skilful predictions of the winter North Atlantic Oscillation (NAO) index using an empirical model including autumn Arctic sea ice extent, early winter stratospheric circulation and North Atlantic sea surface temperatures was described (**Wang**). The influence on longer timescales of the 11-year solar cycle on the winter NAO was examined using large ensembles of hindcast decadal predictions (**Spiegl**). Two papers addressed the predictability of the extratropical circulation in the Southern Hemisphere from the perspective of interannual variations in the delay of the break-up of the Antarctic polar vortex and its relation to the seasonal transition of the midlatitude jet in austral spring (**Byrne**). Another paper analysed the predictability of the Southern hemisphere extratropical circulation from the perspective of height-time domain empirical orthogonal function analysis, which identified a coupled stratosphere-troposphere mode that was examined in high- and low-top seasonal prediction systems (**Lim**).

3.4. Role of atmospheric dynamics for climate variability and change

The theme addressed global teleconnections, their mechanisms, and their statistical detection in reanalysis and model data. There were two keynote presentations, six contributed oral presentations and 143 poster presentations.

A teleconnection pathway linking the Australian Monsoon with the west Pacific pattern and associated extremes in the east Asian region was introduced (**Nakamura**, keynote) and questions by the audience addressed the missing role of the MJO in this teleconnection pattern. Teleconnection pathways between the MJO and stratospheric warming events were also discussed (**Wang**). These include a direct pathway where Rossby waves excited in the tropics reach the extratropics and from there the stratosphere and an indirect pathway where the MJO related Rossby waves influence the position and waviness of the jet itself and thereby the planetary wave patterns that reach the stratosphere.

Some of the key processes that influence the tropical tropopause layer on seasonal to interannual timescales as identified from observations and models were discussed (**Kim**, keynote). Variations in the width of the tropical belt and their characterisation by different

indices were discussed (**Davis**). Indices capturing the behaviour of the subtropical jet are not well correlated with indices directly capturing the poleward branch of the circulation. A Matlab package to compute Hadley cell width proxies is now available (TropD, Adams et al., 2018). Questions from the audience pointed to the importance of considering vertical trends in the location of the subtropical jet and asked for recommendations of which index to use for analyses of long-term trends in the tropical width.

At high latitudes, a teleconnection chain extending from Arctic sea ice into the stratosphere was demonstrated using a novel statistical method called Causal discovery algorithms (**Kretschmer**) but the mechanism was only captured by 50% of the analysed global circulation models. Subsequent questions from the audience acknowledged the potential for the Causal discovery method to be applied to a wide range of teleconnection process chains.

3.5. Atmospheric impacts and interactions related to tropical processes

More than 70 presentations contributed to this theme, with research topics covering the full range of tropical dynamics and composition.

One focus of the theme was on coupling and interactions between stratospheric and tropospheric dynamics. This included recent progress in understanding the connection between tropical convection and the tropical stratosphere (Garfinkel, keynote) and the tropospheric response to downward propagating tide from the stratosphere (Sakazaki, keynote).

A significant fraction of the presentations in the poster session focused on the interactions between modes of dynamical variability in the troposphere and stratosphere, including interactions between QBO, ENSO and MJO. This topic was further highlighted by some of the oral presentations showing the dependence of the organisation of moist convection by the QBO in idealized numerical experiments (Yoden) and the QBO modulation of the impact of ENSO on the Asian summer monsoon, as reflected by the strength of the South Asian High (Chen).

The representation of tropical waves, QBO and MJO in global models and reanalysis datasets was a topic of significant interest in this theme. Analyses of the resolved equatorial waves and wave-driving of the QBO in QBOi models (Holt) and the resolved equatorial waves in reanalysis datasets (Kiladis) were presented.

Atmospheric constituents and transport in the tropics were of significant interest, especially for components that have important contributions to the climate forcing such as ozone,

stratospheric water vapour, and cirrus clouds near the tropopause. New airborne observations showing evidence of deep convective transport of water vapour into the stratosphere in the Asian summer monsoon from the recent StratoClim campaign (Khaykin) and an analysis of long term records of aerosol and cirrus cloud using satellite observations, ground based lidar measurements, and balloon borne in situ measurements from India (Pandit) were presented. Dynamical variability and trends in the tropical tropopause region and the lower stratosphere were other topics of significant interest in the poster sessions. Research work contributed includes the widening of the tropics, connections between tropical convection and the tropopause properties, and impact of gravity waves in the tropopause region.

3.6. Advance in observation and reanalysis datasets

The theme had two keynote and six contributed talks, and nearly 80 poster presentations. Presentations covered on-going improvements in the observational data sets, evaluation of multiple-instrument records and global atmospheric reanalyses, and new observational technologies.

The importance of satellite-based climate data records and the "golden age" for satellite observations of the middle atmosphere over the last 10–15 years (at its peak there were twelve limb or occultation sounders operating) was discussed (Livesey, keynote), including the scientific and programmatic landscape for extending and augmenting the record from such instruments, with a focus on the findings of the US National Academy's "Decadal Survey" of spaceborne Earth Science priorities. The new records for ozone, nitrogen dioxide, and other species becoming available from the Stratospheric Aerosol and Gas Experiment (SAGE) III on the International Space Station, with both solar and lunar occultation capabilities (Flittner). Results were also presented from the SPARC Water Vapour Assessment II (WAVAS-II) using 40 water vapour data sets from 15 satellite instruments and several water vapour isotopologue data records from 1986 to 2016 (Walker).

First results of the very ambitious and impressive Atmospheric Profiling Synthetic Observation System (APSOS), which comprises five lidars, a cloud radar, and a spectroradiometer, at the Yang Ba Jing observatory on the centre part of Tibetan Plateau (Lyu, keynote); the data will start to become available to the wider research community once it undergoes quality control. The value of long-term ozonesonde measurements for the last 20 years as part of the Southern Hemisphere ADditional OZonesondes (SHADOZ) project was demonstrated and recent work to improve the homogenisation and uncertainty evaluation of tropical balloon ozone profile data was presented (Witte).

Another topic covered by many presentations was recent work using reanalysis datasets and their intercomparisons. Long-term changes in upper-tropospheric jet latitude, altitude, and strength in different regions and seasons for the period 1980–2014 are analysed using five modern reanalyses, MERRA, MERRA-2, ERA-Interim, JRA-55, and NCEP CFSR (Hegglin). The advantages and limitations of various reanalysis data sets for representing key characteristics of the tropical tropopause layer (TTL) including its basic structure and long-term changes were presented (Tegtmeier). Finally, the representation of extratropical annular mode variability in conventional reanalysis datasets was compared with those where only surface observations are included (Gerber); it was found that the annular mode in the Northern Hemisphere is well characterised with conventional observations at least from 1958 onward.

3.7. SPARC science for society

This theme covered the challenging area of making SPARC science societally relevant. There were three keynote presentations, five contributed oral presentations and 14 poster presentations. In the first keynote presentation in the theme, Guy Brasseur reviewed the new WCRP Strategic plan and the review of the WCRP, and whose discussion was picked up and expanded in the Roundtable Discussion. Rob Carver outlined the Loon project, which is attempting to provide enhanced internet coverage by flying transceivers on long-life balloons that float between 15 km and 25 km in the stratosphere. The location of the balloons is controlled by altering their buoyancy, which requires good depiction and prediction of the winds. Loon has advanced machine learning to be able to better predict the winds and balloon locations and is now able to "park" the balloons in a limited horizontal range. The project offers a unique high vertical resolution data set of winds (over the course of their 1-3 month life, their altitude is altered ~20,000 times) and offers the possibility of carrying other meteorological payloads but with a sub-kilogram weight constraint. Erica Key, the Executive Director of the Belmont Forum, explained the importance of tackling scientific problems that can lead to societal benefit and the current projects that are supported through the Belmont Forum. The GA was jointly hosted with the Belmont Forum, who held a side meeting during the GA where the 8 projects funded under the Climate2015 call discussed their progress to date. The projects cover predictability (InterDec), regional to global teleconnections (INTEGRATE, BITMAP, GOTHAM), palaeoclimate (PACMEDY) and high impact events (CLIMAX, HIWAVES3, PREREAL).

The contributed oral presentations discussed the "what-if-no Montreal Protocol" scenario, which demonstrated the enormously beneficial outcome to the biosphere of the phasing out of ozone

depleting substances beginning in 1987. Other topics included the interplay between air quality and climate change mitigation (Wuebbles), the evaluation and delivery of essential climate variables as part of the Copernicus Climate Service (Fierli), and climate change impacts on agriculture and food production (Wei) and extreme weather events (van der Wiel). In general, it was noteworthy how many abstracts in all sessions, and not just those from the Belmont Forum / JPI projects, were aimed at providing information of use to non-climate scientists.

3.8. Round-table discussion and poster wards

The GA was concluded by a roundtable discussion, led by Neil Harris (SPARC co-chair) on the future of SPARC science. The focus of the roundtable discussion was on the priority for the science that SPARC should undertake, rather than a discussion of how WCRP may be organized in the future. A consensus emerged that SPARC has been extremely successful and unique by bringing together dynamics and chemistry, and remote sensing instrumentation with theoreticians and modellers. SPARC science, which ties together tropospheric and stratospheric dynamics and chemistry, is needed now more than ever in order to tackle emerging problems such as the role of Asian summer monsoon for the global stratospheric aerosol burden, the impact of volcanic eruptions on climate change and variability, and the potential predictability of terrestrial climate originating in stratospheric processes. Community-wide action and collaboration are required in order to anticipate satellite missions to continue to monitor key aspects of the global climate, and SPARC can provide this platform. The key message from the roundtable was that SPARC science is strong and is now needed more than ever: it is a challenge to SPARC to effectively elucidate these scientific challenges in response to the recommendations in the recent WCRP review.

For early career scientists attending the GA, a meet and greet with experienced SPARC scientists was arranged on the first evening of the conference. This gave everyone the chance to get connected, between different nationalities and career stages.

Ten early career researchers (ECR) received awards for the best poster presentations (Photos 2 and 3) which were generously supported by Project Loon. The recipients were: Silvia Bucci (LMD), Roberta D'Agostino (MPI), Kevin DallaSanta (NYU), Annelize van Niekerk (UK Met Office), Patrick Martineau (Uni. Tokyo), Bianca Mezzina (BSC-CNS), Niall Ryan (Uni. Toronto), Ryosuke Shibuya (JAMSTEC), Jacob Smith (Uni. Cambridge), and Ryan Stauffer (NASA).

3.9. Appreciation of the GA organization by the SPARC-office

During the GA's closing ceremony, Hans Volkert of the SPARC-office presented his personal impression. It is recorded here in an attempt to preserve to some extent the special atmosphere prevailing during the entire week of the GA.

“And now, ladies and gentlemen – dear colleagues!

The 6th General Assembly (GA) of the WCRP core project SPARC is approaching its end, just 100 hours after it started on Monday noon – slightly delayed due to “atmospheric activity in the area”. My name is Hans Volkert. Together with Mareike Kenntner, we are representing the SPARC-office, located at DLR-IPA in Oberpfaffenhofen near Munich, Germany, since January this year.

My subjective personal judgement of the GA is this: It was a most impressive event, combining many a thread, like a fine piece of Japanese cloth: 1) talks, 2) posters, 3) discussions, 4) good food, 5) delicious drinks, and 6) incredibly kind hosts.

But *my* opinion does not matter all that much – it is *yours*, as an *ensemble*, that counts! Therefore, the SPARC-office, the SSG and its co-chairs are keen to receive your feedback – applauding as well as critical, about the GA, and more importantly, about the future development of SPARC. As you would like to see it, be it as an early career researcher, as a well-aged one ... at universities, governmental laboratories, as well as at agencies for satellites, weather forecasts, or climate scenarios. So, let your impression sink into your mind and email it to office@sparc-climate.org , once you are at home again.

The planning and preparation of the GA was an adventure and quite an experience for all concerned, as I am convinced. Formally it was based upon legal documents: a *Memorandum of Understanding* with WCRP and *Letters of Agreement* with the SPARC-office and the Local Organizing Committee (LOC). The main capital, however, was the growing personal respect and trust between all persons concerned.

I was born, decades ago, and still live in Bavaria, a part of southern Germany. In the Bavarian State Archives old legal documents are stored. The most important ones have elaborated seals attached to them (like an important email has an attachment nowadays). Waxen replicas of such seals can be purchased at modest cost (ideal for the WCRP budget).

Now, Mareike and I want to present a few individuals with such symbolic tokens of our gratitude. I show them on the screen first, and ask afterwards all those mentioned to the stage.

A really decisive impact was provided by the three co-chairs of the LOC, namely

- 1) SHIOTANI-san and 2) YODEN-san both of Kyoto university, motivated well by
- 3) SATO-san of Tokyo university, who – as I was informed during the conference dinner – had first suggested three years ago to bring the SPARC GA-2018 here to Kyoto.

A LOC is important, but without a sound scientific programme any general assembly would be an empty shell. We had two most able SOC-co-chairs spanning two hemispheres, two genders, two generations perhaps, namely

- 4) Amanda MAYCOCK (Leeds univ., UK) and 5) Harry HENDON (BoM, Melbourne, Australia).

And finally, the SSG co-chair put his mark on many details and was most helpful, namely

- 6) Neil HARRIS (Cranfield university, UK).

Now I ask all six to come forward onto the stage. Masato SHIOTANI receives the Emperor Ludwig IV, the “Bavarian”, of 1328 on his throne (a), brave Shigeo YODEN a fortified rider (d), Kaoru SATO the complete Golden Bulla of 1328 (a, b). Amanda MAYCOCK is presented with the 19th century Great State emblem of King Ludwig II of Bavaria (c) and Harry HENDON with a bird’s eye view onto Rome (b). Finally, knight Neil HARRIS can ride home on horse-back (d).

Replicas of old seals from the Bavarian State Archives, Munich, Germany:

Golden Bulla, of Emperor Ludwig IV, 1328

King Ludwig II, 1884

Burggraf Friedrich V, 1395



Front side (a)



Reverse side (b; Aerial view of Rome)



Great State emblem (c)



Fortified horseman (d)

While half a dozen of co-chairs march off the stage, we briefly mention the decisive contribution of the members of the LOC and SOC. All 23 persons, mentioned on page 2 of the programme booklet, receive after the end of closing ceremony nutritious tokens of heartfelt gratitude as their personal awards. – And I hand over to the programme co-chair ...”



Oktoberfest-style cake:
Heart-shape with icing saying “thanks” (in German)

Annex 1 – Agenda and list of participants

26th SPARC Scientific Steering Group (SSG) meeting

Time: 6 – 8 October 2018

Location: International Community House, Kyoto, Japan

Agenda

Saturday, 6 October 2018

12:45-13:00	Welcome & Meeting goals	Co-chairs
13:00-13:40	Update from Japanese initiatives	(40')
13:00-13:20	JAXA: Japan Aerospace Exploration Agency	Makoto Suzuki
13:20-13:40	SMILES-2: Planned Whole Atmosphere mission	Masato Shiotani
13:40-15:00	WCRP update, SPARC Activities [3]	(80')
13:40-14:00	WCRP update (incl. overview of SP/IP)	Boram Lee
14:00-14:15	LOTUS	Sophie Godin-Beekman
14:15-14:30	WAVAS II	Kaley Walker
14:30-14:45	ACAM	Laura Pan & Hans Schlager
14:45-15:00	<i>Discussion</i>	<i>All</i>
15:00-15:30	Coffee break	
15:30-16:30	SPARC Activities [3]	(60')
15:30-15:45	PSCi	Michael Pitts
15:45-16:00	Data Assimilation	Quentin Errera
16:00-16:15	CCMI	Michaela Hegglin
16:15-16:30	<i>Discussion</i>	<i>All</i>
16:30-17:40	Updates and new initiative Panel	(70')
16:30-16:45	IGAC update	Michel Grutter
16:45-17:00	GAW report	Oksana Tarasova (remote)
17:00-17:20	SPARC-GAW-IGAC initiative on composition	Neil Harris
17:20-17:40	<i>Discussion</i>	<i>All</i>
17:45-19:00	Closed SSG Session	(75')
17:45-19:00	First Closed SSG Session	SSG members

Agenda (cont'd)

Sunday, 7 October]

09:15-10:45 SPARC Activities [4]		<i>(90'</i>
09:15-09:30	DynVar	Edwin Gerber
09:30-09:45	SNAP	Amy Butler
09:45-10:00	SATIO-TCS	Shigeo Yoden
10:00-10:15	FISAPS	Marvin Geller (remote)
10:15-10:45	<i>Discussion</i>	<i>All</i>
10:45-11:15 Coffee break		
11:15-12:45 SPARC Activities [3] + panel report		<i>(90'</i>
11:15-11:30	Gravity Waves	Kaoru Sato
11:30-11:45	QBOi	Scott Osprey
11:45-12:00	S-RIP	Masatomo Fujiwara
12:00-12:15	Report/plan for GEWEX/Monsoon panel	Tianjun Zhou
12:15-12:45	<i>Discussion</i>	<i>All</i>
12:45-14:15 Lunch break		
14:15-15:30 SPARC Activities [3]		<i>(75'</i>
14:15-14:30	ATC	Andrea Steiner
14:30-14:45	SSiRCi	Jean-Paul Vernier, Larry Thomason
14:45-15:00	TUNER	Nathaniel Livesey
15:00-15:30	<i>Discussion</i>	<i>All</i>
15:30-16:00 Coffee break		
16:00-17:15 SPARC Activities [2]		<i>(75'</i>
16:00-16:15	OCTAV-UTLS	Irina Petropavloskikh
16:15-16:30	SOLARIS-HEPPA	Bernd Funke (remote)
16:30-16:45	SPARC-office report	Hans Volkert
16:45-17:15	<i>Discussion</i>	<i>All</i>

Monday, 8 October 2018

09:15-10:45 Discussion on WCRP SP/IP		<i>(90'</i>
09:15-09:45	Overview of SP & IP	Boram Lee/Co-Chairs/Office
09:45-10:45	<i>Discussion SP & IP, including composition initiative</i>	<i>All</i>
10:45-11:15 Coffee break		
11:15-12:30 Closed SSG Session		<i>(75'</i>
11:15-12:30	Second Closed SSG Session	

Alphabetical list of participants

No.	Surname	Given name	Role, country (of work)
01	Beig	Guftram	SSG member, <i>India</i>
02	Butler	Amy	SNAP (co-lead), <i>United States</i>
03	Errera	Quentin	DAWG (co-lead), <i>Belgium</i>
04	Fujiwara	Masatomo	S-RIP (co-lead), <i>Japan</i>
05	Gerber	Edwin	DynVar & DynVarMIP, <i>United States</i>
06	Godin-Beekmann	Sophie	LOTUS (co-lead), <i>France</i>
07	Grutter	Michel	ICAG liaison, <i>Mexico</i>
08	Harris	Neil	SSG co-chair, <i>United Kingdom</i>
09	Hegglin	Michaela	CCMi (SPARC & IGAC, co-lead), <i>United Kingdom</i>
10	Hendon	Harry	SSG member, <i>Australia</i>
11	Hoor	Peter	OCTAV-UTLS (co-lead), <i>Germany</i>
12	Horinouchi	Takeshi	observer & local organizing committee, <i>Japan</i>
13	Kenntner	Mareike	SPARC International Project Office, <i>Germany</i>
14	Lee	Boram	WCRP, Joint Planning Staff, <i>Switzerland</i>
15	Livesey	Nathaniel	SSG member, <i>United States</i>
16	Martius	Olivia	SSG member (until 2018), <i>Switzerland</i>
17	Osprey	Scott	QBOi, <i>United Kingdom</i>
18	Pan	Laura	ACAM (SPARC & IGAC, outgoing co-lead), <i>U.S.A.</i>
	Perlwitz *	Judith	SSG co-chair, <i>United States</i>
19	Petropavlovskikh	Irina	LOTUS & OCTAV-UTLS (co-leads), <i>United States</i>
20	Pitts	Michael	PSCi, <i>United States</i>
21	Plummer	David	CCMi (SPARC&IGAC, co-lead), <i>Canada</i>
22	Sato	Kaoru	SSG member & local organizing committee, <i>Japan</i>
23	Schlager	Hans	ACAM (SPARC & IGAC, new co-lead), <i>Germany</i>
24	Schmidt	Hauke	SSG member, <i>Germany</i>
25	Shepherd	Theodore	observer (former SSG co-chair), <i>United Kingdom</i>
26	Shiotani	Masato	Satellite expert & loc. organizing committee, <i>Japan</i>
27	Son	Seok-Woo	SSG member, <i>Republic of Korea</i>
28	Steiner	Andrea	ATC (co-lead), <i>Austria</i>
29	Suzuki	Masato	Satellite expert (JAXA), <i>Japan</i>
30	Tegtmeier	Susann	WDAC liaison, <i>Germany</i>
31	Vernier	Jean-Paul	SSiRC, <i>United States</i>
32	Volkert	Hans	SPARC Internat. Project Office director, <i>Germany</i>
33	Walker	Kaley	WAVAS II, <i>Canada</i>
34	Wen	Chen	SSG member, <i>China</i>
35	Wuebbles	Donald	SSG member, <i>United States</i>
36	Yoden	Shigeo	SATIO-TCS (co-lead) & local organ. comm., <i>Japan</i>
37	Zhou	Tianjun	SSG member, <i>China</i>

* via remote link from Boulder, United States



Majority of participants at the SSG-meeting on 6 October 2019 observing the presentation of Masato Suzuki. The numbers correspond to the left column in the table on the previous page. Photos & composition: Hans Volkert

Annex 2 – List of Acronyms

ACAM	Atmospheric Composition and Asian Monsoon (SPARC activity)
ATC	Atmospheric Temperature Changes (SPARC activity)
CORA	WCRP Coordination Office for Regional Activities
CCMi	Chemistry Climate Model initiative (SPARC activity)
DAWG	Data Assimilation Working Group (SPARC activity)
DynVar	Dynamical Variability (SPARC activity)
FISAPS	Fine Scale Atmospheric Processes and Structures (SPARC activity)
IGAC	International Global Atmospheric Chemistry project (of Future Earth)
JSC	WCRP Joint Scientific Committee
LOTUS	Long-term Ozone Trends and Uncertainties in the Stratosphere (SPARC activity)
OCTAV-UTLS	Observed Composition Trends And Variability in the Upper Troposphere and Lower Stratosphere (SPARC activity)
QBOi	Quasi-Biennial Oscillation initiative (SPARC activity)
PSCI	Polar Stratospheric Clouds initiative (SPARC activity)
S2S	Subseasonal-to-Seasonal prediction project (joint WCRP/WWRP)
SATIO-TCS	Stratospheric And Tropospheric Influences On Tropical Convective Systems (SPARC activity)
SNAP	SPARC Network for Atmospheric Predictability (SPARC activity)
SOLARIS/ HEPPA	Solar Influences on climate / High Energy Particle Precipitation in the Atmosphere (SPARC activity)
S-RIP	SPARC Reanalysis Intercomparison Project (SPARC activity)
SSiRC	Stratospheric Sulphur and its Role in Climate (SPARC activity)
SSG	SPARC Scientific Steering Group
SPARC	Stratosphere-troposphere Processes and their Role in Climate
TUNER	Towards Unified Error Reporting (SPARC activity)
WAVAS	Water Vapour Assessment (SPARC activity)
WCRP	World Climate Research Programme
WDAC	WCRP Data Advisory Council
WMO	World Meteorological Organization
WWRP	World Weather Research Programme

**The
World Climate
Research Programme
(WCRP)**

*facilitates analysis and
prediction of Earth system change
for use in a range of practical
applications of direct relevance,
benefit and value to society.*

