SPARC

Stratosphere-troposphere Processes And their Role in Climate

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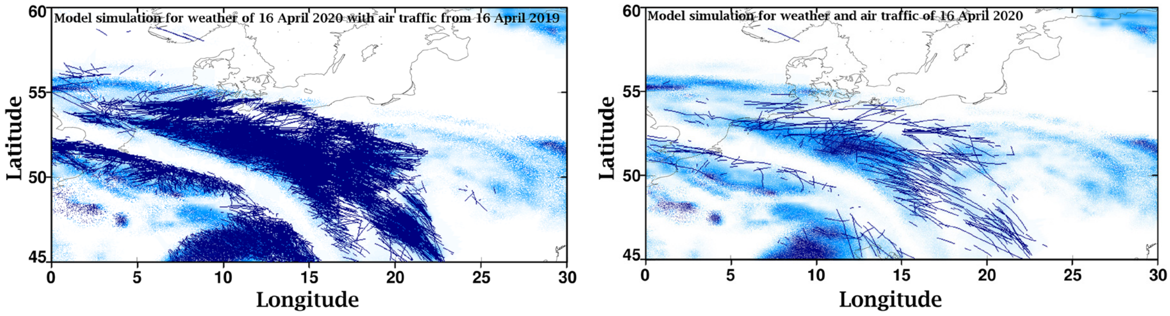

Clear skies over the Barvarian landscape (top) and modelled condensation trail coverage using meteorological conditions of 16 April 2020 for different air traffic conditions (bottom; contrails graphically highlighted). The lockdown caused by the COVID-19 pandemic has stopped international travel and forced scientists to use different ways of communicating. This enhanced the discussion on options to reduce the carbon footprint of scientists involved with SPARC and WCRP as a whole (see page 11), and has led to the first-ever full online JSC meeting (see report on page 2) as well as the cancellation or postponement of almost all SPARC meetings and workshops in 2020. Reports of the few workshops that happened before the lock-down can be found inside this newsletter.

Image credit: M. Heckl / SPARC IPO; bottom: DLR/EUROCONTROL/ECMWF

www.dlr.de/content/en/articles/news/2020/02/20200520_fewer-condensation-trails-due-to-reduced-air-traffic.html

Contents

WCRP World Climate Research Programme

WORLD METEOROLOGICAL ORGANIZATION

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

International Science Council

Report on the 41st Session of the Joint Steering Comittee

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The 41st session of the WCRP Joint Scientific Committee (JSC) was held on 18 – 20 May 2020. It was the first online-only JSC meeting in the history of WCRP. Originally planned to take place in Sydney, Australia, the COVID-19 pandemic prevented an on-site meeting. The meeting was organized into three online sessions, and mainly focused on moving forward with the implementation of the strategic plan WCRP had established last year. A detailed report has already been published by WCRP (**https://wcrp-climate.org/WCRP-publications/2020/0520-JSC-41 Report Final.pdf**). The following report mainly summarizes the discussions on the new structure of WCRP with an emphasis on discussions relevant to SPARC sciences.

Welcome session

In their welcome messages, JSC Chair **Detlef Stammer** and Vice-Chair **Helen Clough** highlighted the need for a fit-for-purpose structure of WCRP to be able to answer the formidable questions and challenges arising within society.

The formal opening of the meeting included short statements from the sponsors. The COVID-19 crisis offers opportunities and challenges, as mentioned by **Heide Hackman**, Executive Director of the International Science Council (ISC). She stated that ISC is working on global funding opportunities for achieving the Sustainable Development Goals (SDGs). On a regular basis, ISC continue to convene leadership of various science programs to promote their acting in union as a global voice for science. **Vladimir Ryabinin**, Executive Secretary of the Intergovernmental Oceanographic Commission of UNESCO (IOC-UNESCO) recognized significant developments in the ocean domain, but pointed out the need for further development of ocean modelling, and the continued need for observing systems. He reminded that ideas what WCRP is trying to achieve on ocean sciences should be stated in the implementation plan. The Deputy Secretary General of the World Meteorological Organization (WMO), **Elena Manaenkova**, stated that WMO is putting more emphasis on Earth System Science and modelling, with possibilities to directly interact with its member states. A 5-year climate state was released by WMO in September, and preparations for a data exchange conference as well as a new WMO report in September are ongoing.

WCRP Strategy Implementation and Transition

During a brainstorming workshop in Hamburg in February (**https://www.wcrp-climate.org/wcrp-ip-meetings/wcrp-hamburg**), flagship science questions were discussed. The discussion centred around the Vision and Mission stated in the WCRP strategic plan, and the following high-level implementation priorities were identified:

1. Foster and deliver the scientific advances and future technologies required to:

a. Advance understanding of the multi-scale dynamics of Earth's climate system
b. Quantify climate risks and opportunities including AI and other new technologies

2. Develop new institutional and scientific approaches required to:

a. Co-produce cross-disciplinary regional to local climate information for decision support and adaptation
b. Inform and evaluate mitigation strategies such as geoengineering and climate intervention

The outcome of the Hamburg workshop was the proposal of Lighthouse Activities (see Figure 1), briefly explained by JSC Chair **Detlef Stammer**.

The Lighthouse Activities are the action plans for the new WCRP Implementation Plan, aiming to promote collaborative activities across WCRP (they are a more inclusive version of the current Grand Challenges). The individual activities focus on different objectives which are briefly summarized below:

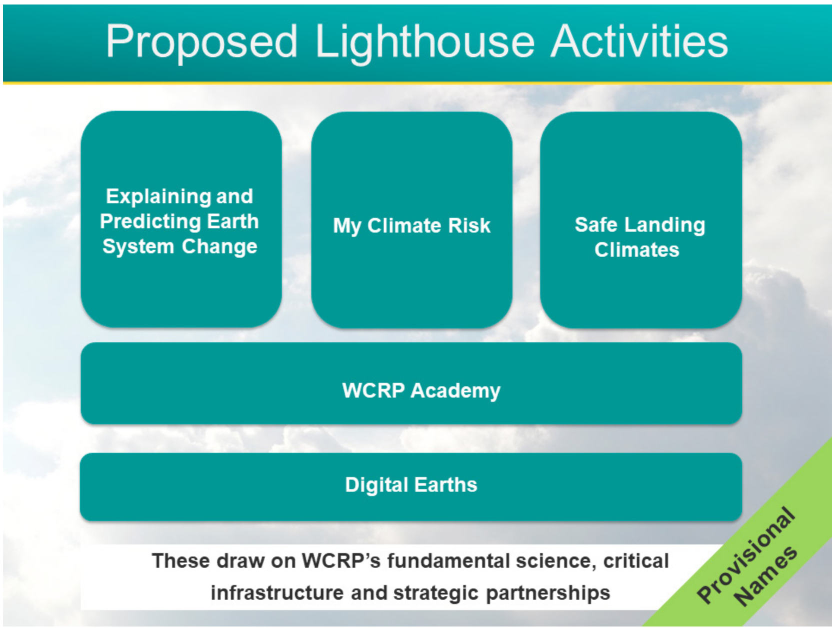

Figure 1: *Proposed Lighthouse Activities, as shown in Figure 1 of the JSC meeting report. For more details see the Hamburg Workshop Report.*

1. *Explaining and Predicting Earth System Change:* To design and take major steps toward delivery of an integrated capability for quantitative observation, explanation, early warning and prediction of Earth System Change on global and regional scales, with a focus on multi-annual to decadal timescales.
2. *My Climate Risk:* To develop a new framework for assessing and explaining regional climate risk to deliver climate information that is meaningful at the local scale.
3. *Safe Landing Climates:* To explore the routes to climate safe landing 'spaces' for human and natural systems, connecting climate, Earth system and socio-economic development sciences.
4. *Digital Earths:* To develop a digital and dynamic representation of the Earth system in the past, present and future, founded on an optimal blend of models and observations.
5. *WCRP Academy:* To establish one or more targeted capacity exchange climate programmes, working with Lighthouse Activities and established climate education providers including universities.

The first objective also includes observational activities, and it could culminate in an Earth Year. The second objective focusses on new ways of making climate information useful and available to regional services and users, which requires engagement with stakeholders. The UN SDGs are a basis for the third objective (especially SDG13), and the digital earth basically relates to digital twins of the Earth, blending models & observations. This can only happen in partnership with high-performance computing centres. It will not replace existing earth system models as they will be required for evaluating different scenarios and for the assessment of uncertainties and risk for the foreseeable future. The WCRP Academy, meant to be an instrument for outreach, is still work-in-progress.

A second brainstorming workshop to be held in Washington D.C. had to be cancelled due to the COVID-19 crisis, and was replaced by an online consultation process. The workshop was planned to determine the structure and elements of the new WCRP. A proposed structure was now mainly based on the outcomes of the Hamburg workshop (see Figure 2).

The Lighthouse Activities, green elements in Figure 2, would act as an integrating element, worked on by the different 'homes' (yellow elements in Figure 2) for the WCRP communities which may include the current core projects, a regional equivalent based on existing WCRP regional initiatives such as CORDEX, WGCM, *etc*., and a modelling/data one. Core projects should redefine or reorganize themselves, and they might have different names in the future, but a division based around ocean, atmosphere, cryosphere and water cycle still seemed appropriate. It was recognized that International Project Offices (IPOs) would still be needed to support the workflow and administration, but the IPOs could also be organized differently to support the Lighthouse Activities.

The way forward

Upcoming actions, as summarized in the WCRP report, are:

1. Start regional and community consultations with the aim of including developing and other countries in the co-production of the new WCRP. Discussions should include members from regional WCRP communities and funding agencies (JSC and IPO contact points led by JSC Chair and Vice-Chair; Begin immediately with a view to holding first consultations by August 2020).

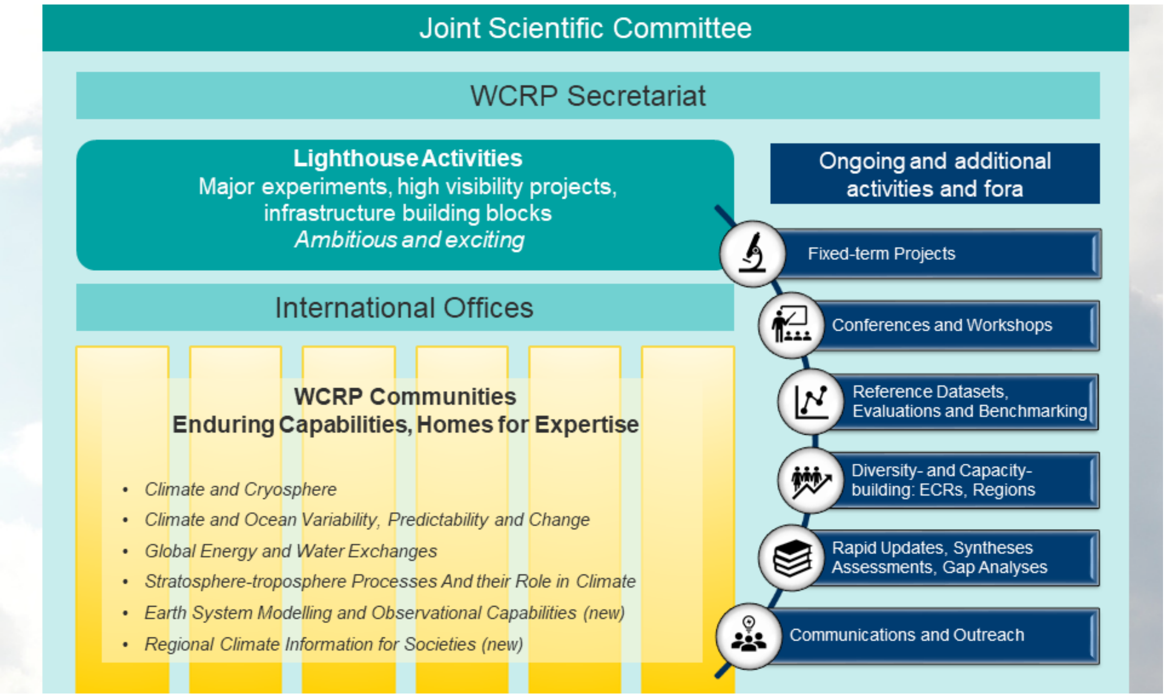

Figure 2: *A DRAFT schematic for discussion on a possible new WCRP structure,.*

2. Create a Lighthouse Activity Task Team to include representatives of the original authors as well as core project and core activity representatives. Ensure engagement of developing countries, early career researchers and partners as appropriate (JSC Chair, Vice-Chair, and JSC Officers; Report back to WCRP Extraordinary Session in November 2020). Each core project is to nominate a member for each task team of the Lighthouse Activities.
3. Core projects to review and consolidate their structures to ensure efficiency and relevance to WCRP's new strategic directions and draft structure (Core project chairs; Report back to WCRP Extraordinary Session in November 2020).

Over one hour was reserved for open discussion on the proposed structure and the way forward, summarized in the official JSC-41 meeting report by WCRP. The discussion included various comments from sponsors and partner projects, emphasizing the need for communication towards the public, and for more collaboration with partner projects outside WCRP as well as engagement with regional communities.

An important point was made by Detlef Stammer, in response to a question from **Jürg Luterbacher**, Director of the Science and Innovations Department of WMO, stating that the new structure is meant to be flexible enough for short-term response to requests from politics and society. This could be a part of the blue elements in Figure 2.

There will be an extraordinary JSC session in November 2020 to review the "homework" given to the activities and decide on what will be put into place and what will fade out. The new WCRP structure will be final by that session. Input from the SPARC community will be required for that JSC session.

Reports from Task Teams

Paco Doblas-Reyes reported for the Task Team on Modelling and Computing Infrastructure, which recommends to put in place a mechanism (e.g., on-line map) to coordinate modelling activities across WCRP/WWRP/GAW. Other recommendations by the task team included financial support for modelling activities, including support for data infrastructure, coordination of sources and analysis tools, prioritiseing process understanding on various time scales, exploring machine learning (beyond initial efforts by WGNE) and to illustrate best practices and risks from exascale computing.

On behalf of the Task Team on Seamless Data and Data management, **Susann Tegtmeier** recommended closer coordination of observations, reanalyses (in particular around Earth system reanalysis), data science and management issues across the programme, and to enhance collaborations with modelling groups. They also point out the necessity for better transfer of experiences in data management across WCRP entities and propose stronger links to GCOS and space agency bodies for an exchange on plans and the promotion of a broader Earth System approach to observations.

Finally, the Task Team on Regional Activities (**Daniela Jacob**) recommended re-framing the "Recommendations on a Framework for WCRP Regional Activities" (JSC-38/Doc.11) in the context of the four WCRP pillars; replace the Working Group on Regional Climate (WGRC) with a Working Group on Information for Regions and Society (WGIRS) and to use Frontiers of Climate Information (FoCI) projects as a vehicle for co-design and co-production with stakeholders of climate information for regions. They also recommend stronger links to society, *e.g.* through GFCS, Future Earth, Climate Services, Social Science, Disaster Risk Reduction Communities, *etc.*, and finally to draw on the experience and expertise of the regional chapters of WGI IPCC AR6 report.

Reports from core projects, grand challenges and working groups

The reports from the various activities within WCRP are available on the WCRP webpage, and are also summarized in the WCRP report on the JSC-41. The Grand Challenges, many of which contribute to IPCC AR6, are due to sunset after 2021, but are all confident that the science will be continued in the various core projects or new homes, as many of them relate to the proposed Lighthouse Activities.

Concerning SPARC, **Neil Harris** presented a few science highlights from the past year, and pointed out that collaborations within WCRP can work well, using SNAP and S2S as an example. He reminded that SPARC sciences are directly related to the Montreal Protocol, and stated that there is still a large gap in WCRP concerning work on atmospheric composition. The desire for more collaboration within and beyond WCRP was also expressed, while at the same time pointing out that the current re-structuring process makes developing collaborations hard for now. An important point was that capacity building and climate science and society could be organized more efficiently, if a pan-WCRP plan would exist. Neil also presented that SPARC is looking at ways to ensure success in capacity building and reducing their carbon footprint. He mentioned the call for expressions of interest for the next SPARC General Assembly, encouraging the use of innovative meeting concepts to reduce the carbon footprint of the meeting (looking closely at the GCOS plan). Outcomes from the SPARC SSG meeting in December (see report in SPARC Newsletter No. 54), were presented, showing the three main questions SPARC wants to work on in the future:

1. How will climate change on interannual to centennial timescales?
2. How can prediction of weather and climate-related extreme events on sub-seasonal to decadal (S2D) timescales be improved?
3. How/why is atmospheric composition changing over time and what are the impacts?

These topics fit well into the new WCRP structure. Neil stated that SPARC could fill one of the proposed new "homes" as a whole atmosphere approach. SPARC work would have more impact with the extra opportunities for integrated sciences provided by the Lighthouse Activities (monsoon, convection, cloud/aerosol, *etc.*). To achieve this, SPARC operations need to be reviewed. Immediate actions include communicating with the SPARC SSG and community. The next step is to set up a broadly representative and balanced SPARC group to explore where SPARC science contributes in new WCRP.

Sonya Legg, presenting for Climate and Ocean Variability, Predictability and Change (CLIVAR), mentioned a new focus on Tropical Basin Interaction with emphasis on teleconnections. The International CLIVAR Monsoon Project Office (ICMPO) in Pune has been extended for one year (until February 2021) to enable consultations on future evolution of ICMPO. It was noted by the JSC chair, that the Monsoon office for CLIVAR alone is not ideal, since other activities also participate in Monsoon activities. There are discussions on whether this should be a pan-WCRP focus with WWRP as well, since monsoons cross the boundary between climate and weather.

The Global Energy and Water Exchanges (GEWEX) project (**Graeme Stephens**), has a number of new activities, including the International Satellite Cloud Climatology Project - Next Generation (ISCCP-NG), among others. There is a new collaboration with START and other partners to develop new activities in Africa and central Asia with the idea of addressing regional issues and capacity building in those regions. The GEWEX Global Land/Atmosphere System Study (GLASS) Panel is developing a strategy for a planetary boundary layer spaceborne observing system. In the near future there will be new climate data records, new process-orientated activities and assessments, and new modelling activities.

Data, created as hindcasts and forecasts from models, are the essential basis driving the Subseasonal-to-seasonal prediction (S2S) project (**Andrew Robinson**).

Their work is important in the context of regional activities and climate services. The Working Group on Subseasonal to Interdecadal Prediction (WGSIP; **Bill Merryfield**) proposed a climate prediction summit, as all core projects show interest in subseasonal to decadal prediction.

On behalf of the WCRP Data Advisory Council (WDAC), **Susann Tegtmeier** reminded everyone that connections between communities has to be maintained and that new 'homes' for data management should be considered with interfaces with providers maintained or even strengthened. In the following discussion, the attendees agreed that the Lighthouse Activity on "Digital Earths" must include both modelling and data. The activity will be useful to point to gaps in the observing system.

Paco Dolas-Reyes noted that the WCRP Modelling Advisory Council (WMAC) has been very involved with the Task Team on 'Model Development and Computing Infrastructure', and that many discussions take place about involvement of different groups in the various model activities within WCRP. The council also recommends a stronger integration with the data activities as well as a broad coordination of modeling activities on top of the projected CMIP Office. Activities on AI/Machine learning were mentioned again, also by the Working Group on Numerical Experimentation (WGNE; **Keith Williams**), who also noted that work on systematic errors is still needed.

Other business

Vladimir Ryabinin briefly talked about the Ocean decade and the importance of WCRP participating. There are many activities within WCRP related to Ocean science, and in the new structure there is room for Ocean science within the "Safe Landing Climates" as well as through the "Academy" for which the decade is an opportunity to engage with the public.

WCRP/JSC has instituted a task team trying to reduce the WCRP carbon footprint led by **Pierre Friedlingstein** and **Pedro Monteiro** with support from **Narelle van der Wel**. They propose to aim at a 75% reduction in direct CO_2 emissions by 2030. Details of the planned process are written in the comment on page 11. There was a consensus among meeting participants that the efforts should really try to cut emissions rather than "planting trees".

The JSC-41 closed with a number of comments from partners attending the online meeting. **Sarah Jones** (WWRP; Chair WMO Research Board) explained the task of the WMO Research Board (RB), which translates decisions of WMO members into research priorities and works with the research programmes toward any needed advances. She mentioned that one decision by the RB was to establish a Task Team on Exascale Computing, Data Handling and Artificial Intelligence, which should provide leadership and also a mechanism to coordinate data handling. Sarah emphasised the need to coordinate modelling and data activities across WMO, and engagement with other groups is important before the new WCRP structure is decided. **Chris Davis** (WWRP) noted that the complexity of the current WCRP is a challenge for partners to see how and where they intersect with the emerging WCRP structure. Detlef Stammer answered that WCRP wants to continue its strong interactions with WWRP and GAW, and reminded the community that with ISC as a sponsor social sciences will play a role. This might be something WWRP can benefit from. The long-existing partnership with PAGES (**Marie-France Loutre**) might need a bit of a revival, and is looking for partnerships within the new WCRP structure. Finally, WCRP is looking to establish MoUs with SOLAS (**Lisa Miller**) and IMBER to strengthen those partnerships, and **Viktor Brovkin** (AIMES) confirmed that during the process of building the new WCRP structure, guidance is important for outside partners to know where to look for the collaborations.

Concerning the WCRP Budget, **Mike Sparrow** (Officer in Charge of the WCRP Secretariat) informed the attendees that WCRP is looking to increase income and to focus expenditure on science activities. It was noted that a lot of the WCRP budget goes to travel, so having more virtual meetings will impact the way of spending money.

The meeting was ended by a summary by Detlef and Helen, recognizing the significant progress that has been made since the AGU event in December 2019, thanking everyone for their engagement, the lively discussions, and expressing their gratitude to see a lot of enthusiasm for the plan WCRP is building. Some emerging issues identified during the meeting were pointed out, which are summed up in the WCRP report.

Participants of the 41st Session of the

WCRP Joint Scientific Committee

18-22 May 2020, Online

1. Detlef STAMMER, JSC Chair, DE
2. Helen CLEUGH, JSC Vice-Chair, AU
3. Lisa ALEXANDER, JSC, AU
4. Tercio AMBRIZZI, JSC, BR
5. Pascale BRACONNOT, JSC, FR
6. Jens Hesselbjerg CHRISTENSEN, JSC, DK
7. Susanna CORTI, JSC, IT
8. Pierre FRIEDLINGSTEIN, JSC, UK
9. James HURRELL, JSC, USA
10. Masahide KIMOTO, JSC, JP
11. Thomas PETER, JSC, CH
12. Krishnan RAGHAVAN, JSC, IND
13. Pedro MONTEIRO, JSC, ZA
14. Igor SHKOLNIK, JSC, RU
15. Ken TAKAHASHI, JSC, PE
16. Martin VISBECK, JSC, DE
17. Hui-Jun WANG, JSC, CN
18. Sandrine BONY, GC Clouds, FR
19. Wenju CAI, CLIVAR, AU
20. Francisco DOBLAS-REYES, WMAC, ES
21. Clare GOODESS, WGRC, UK
22. Neil HARRIS, SPARC, UK
23. Gabriele HEGERL, GC Extremes, UK
24. Tatiana ILYINA, GC Carbon, DE
25. Daniela JACOB, CORDEX, DE
26. Yochanan KUSHNIR, GC NTCP, USA
27. Sonya LEGG, CLIVAR, USA
28. Gerald MEEHL, WMAC, USA
29. William MERRYFIELD, WGSIP, CA
30. Timothy NAISH, GC Melting Ice, NZ
31. Robert NICHOLLS, GC Sea Level, UK
32. Jan POLCHER, GEWEX , GC Water, FR
33. James RENWICK, CliC, NZ
34. Andy ROBERTSON, S2S, USA
35. Adam SCAIFE, GC NTCP, UK
36. Cath Senior, WGCM, UK
37. Silvina SOLMAN, CORDEX, AR
38. Seok-Woo SON, SPARC, KR
39. Graeme STEPHENS, GEWEX , USA
40. Susann TEGTMEIER, WDAC, CA
41. Jean-Noel THÉPAUT, WDAC , UK
42. Keith WILLIAMS, WGNE, UK
43. Xuebin ZHANG, GC Extremes, CA
44. Heide HACKMANN, CEO, ISC, FR
45. Daya REDDY, ISC President, ZA
46. Vladimir RYABININ, Exec. Sec., IOC-UNESCO, FR
47. Elena MANAENKOVA, Dep. SG, WMO, CH
48. Susanne MECKLENBURG, ESA, UK
49. Sarah JONES, WWRP Chair, DE
50. Chris DAVIS, WWRP Chair (incoming), USA
51. Viktor BROVKIN, AIMES, DE
52. Gregory CARMICHAEL, GAW Chair, USA
53. Blaize DENFELD, US GCRP, USA
54. Jessica GIER, Exec. Dir., SOLAS, DE
55. Lisa MILLER, SOLAS, CA
56. Anna RUTGERSSON, SOLAS, SE
57. Wayne HIGGINS, NOAA, USA
58. Jack KAYE, NASA, USA
59. Erika KEY, Exec. Dir., Belmont Forum, UY
60. Marie-France LOUTRE, Exec. Dir., PAGES, CH
61. Valentina RABANAL, YESS, AR
62. Gaby LANGENDIJK, YESS, DE
63. Yuhan RAO, YESS, USA
64. Maria UHLE, NSF/Belmont Forum, USA
65. Florin VLADU, UNFCCC, DE
66. David BEHAR, SFPUC, USA
67. Salvatore ARICO, IOC-UNESCO, FR
68. Michael MORGAN, UW-AOS, USA
69. Kathleen MCINNES, CSIRO, AU
70. Beatriz BALINO, CORA/BCCR, NO
71. Tore FUREVIK, CORA/BCCR, NO
72. Paul BOWYER, CORA/GERICS, DE
73. Anke SCHLUENSEN-RICO, CORA/GERICS, DE
74. Gwenaelle HAMON, CliC, WCRP, CH
75. Iréne LAKE, Dir. CORDEX, SE
76. Lindha NILSSON, CORDEX, SE
77. Jose SANTOS, Dir. CLIVAR, CN
78. Liping YIN, CLIVAR, CN
79. Jing LI, CLIVAR, CN
80. Peter VAN OEVELEN, Dir., GEWEX, USA
81. Hans VOLKERT, Dir., SPARC, DE
82. Mareike HECKL, SPARC, DE
83. Rupa Kumar KOLLI, Exec. Dir., ICMPO, IND
84. Jürg LUTERBACHER, SI Director, WMO, CH
85. OksanaTARASOVA, Head GAW, WMO, CH
86. Paolo RUTI, Head WWRP, WMO, CH
87. Wenchao CAO, WMO, CH
88. Michael SPARROW, OiC WCRP, CH
89. Michel RIXEN, WCRP, CH
90. Josefa POTTER, WCRP, CH
91. Narelle VAN DER WEL, WCRP, CH

Website: https://www.wcrp-climate.org/jsc41-about

Personal reflections on the outlook for SPARC

The preparation of the new WCRP strategy and implementation plans started some time ago. While progress has been slow, there are good reasons for this. Conditions have changed substantially in the public arena, *e.g.* several countries declaring climate emergencies, bushfires in the USA and in Australia, and record heatwaves in Siberia. Moreover, two of WCRP's sponsors (WMO and the International Science Council) have undergone their own restructuring. These circumstances have made it particularly hard to manage change in what WCRP does and how it does it.

Two factors are uppermost in the planning for the new WCRP. First, defining the fundamental research questions is hard when the need for answers is so pressing and it feels as though the solutions are needed before the research can be done. Second, WCRP has many strengths which it needs to keep: it has global reach and excellent scientists are involved. These are the reasons why the late Sir John Houghton worked to create the WCRP and they are still as valid today as in the 1980s. WCRP is thus facing the challenge of redefining its research questions while continuing to involve the existing global climate science community.

The proposed WCRP structure has been developed following extensive discussions (Figure 2 of the JSC-41 report) and is now ready for community discussion. We see it as an excellent opportunity for SPARC science to continue to thrive. Atmospheric dynamics will directly address the internal variability of the whole atmosphere system which is central to understanding and improving predictability across all scales. It will include regional climate impacts, compound events, and extremes. Improved knowledge of atmospheric composition is required for understanding radiative forcing and how it relates to climate changes in order to underpin development of effective climate mitigation measures. Both will require underpinning from continued evaluation of long-term observations, a traditional SPARC strength. SPARC will continue to promote research to support the decision-making on ozone depletion as well as climate change.

So, what has changed? The overall context has. The headline questions will be defined by a wider group as exemplified in the Lighthouse Activities (Figure 1 of the JSC-41 report). For instance, 'My Climate Risk' focuses on producing a much more risk-based approach to climate science with the emphasis on the probability of occurrence of events rather than on the central estimate of climate variables. This change has started and WCRP can promote research on the scientific underpinnings and make the results globally accessible. 'Safe Landing Climates' is about planning a safe route through the climates the world might encounter in the coming decades for human and natural systems. This aims to provide a way to achieve key Sustainable Development Goals (SDGs).

We see SPARC science as being an essential element for such issues, contributing to the Lighthouse Activities where a broader cooperation is needed for the best results. Much, where less 'external' cooperation is required for the core work, would continue internally. What will be important is that all SPARC science is critically evaluated for how it contributes to understanding the climate system. It will also be important to operate differently, reducing our carbon footprint, being more accessible and more sustainable.

How will we define all this? WCRP is now encouraging much broader discussion on its plans. We want to mirror that in SPARC by organising on-line meetings and setting up groups to define SPARC science relevant to the new WCRP plan. These groups will be as balanced as we can make them, with involvement of all countries, levels of experience, background, etc. The global element must be revived, not least because many future questions are likely to involve strong regional components. SPARC's views will feed into the special WCRP JSC meeting in November this year. They will also be used in the preparation of the new SPARC Implementation Plan which has been delayed a little to be consistent with the WCRP planning. If you want to be involved in these discussions, please contact the SPARC Office.

Finally, we would like to thank our colleagues who have helped direct SPARC over the past few years. We would particularly like to thank Judith Perlwitz who provided an excellent leadership as co-chair in the most uncertain times of the development of the new WCRP. Her good sense and good humour were invaluable and greatly appreciated. As you can see elsewhere, Hans Volkert is retiring. He was central to the smooth transition of the SPARC Office from ETH-Zurich to DLR. Boram Lee has left the WCRP JPS for a position elsewhere in WMO, having given much shrewd advices on how to make things work with WMO and WCRP. Finally, the long-serving Activity Leaders, Joan Alexander and Kaoru Sato (Gravity Waves), Ed Gerber and Eliza Manzini (DynVar), and Michaela Hegglin (CCMi) have stood down, though they remain involved. All of them deserve our thanks.

Neil Harris and Seok-Woo Son
(SPARC co-chairs)

SPARC SSG members in 2020:

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Nathaniel Livesey
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Hauke Schmidt
Max Planck Institute for Meteorology in Hamburg, Germany

Tianjun Zhou
LASG, Institute of Atmospheric Physics,
Chinese Academy of Sciences,
Beijing, China

Tom Peter, JSC-liaison
Institute for Atmospheric and Climate Science, ETH Zürich,
Zurich, Switzerland

The JSC has approved the appointment of **Dr. Andrea Carril** (CIMA/CONICET-UBA, Ciudad Univeritaria, Argentina), **Prof. Michael Prather** (University of California, USA), and **Dr. Viktoria Sofieva** (Finnish Meteorological Institute, Finland), who will join the SPARC SSG in January 2021.

Update from the SPARC International Project Office

From 1 August 2020 Dr. Mareike Heckl (née Kenntner) will be directing the SPARC International Project Office (IPO) at DLR's Institut für Atmosphäre (IPA). IPO@IPA began taking over the baton from IAC-ETH in Zurich three years ago, and became fully operational in January 2018 (SPARC-newsletter no. 50, p. 29). During the past five semesters, it was my duty and pleasure to serve the international SPARC community and WCRP at the IPO-wheel together with Mareike as coordinating scientist, Brigitte Ziegele as administrative assistant and Winfried Beer as IT-advisor. Soon I will retire from regular scientific work at IPA, where I had started pursuing a PhD-project back in September 1980.

Over the past four decades the World Climate Research Programme (WCRP) developed, inter alia by establishing four core projects, SPARC being the one with a special focus on the atmosphere well above its lower boundary. From 1993, SPARC newsletters were arriving in the pigeon holes (anybody remembers term and function?) of colleagues every six months. I started to take curious looks and eventually began to admire their unique mix of committee reports, brief science news and topical articles. During the production of issues 50 to 55, I became to fully appreciate both the vision of the SPARC founders and the dedication of the members of the Scientific Steering Group and the wider SPARC community regarding a steady flow of quality information in a traditional format.

As WCRP's new strategic and implementation plans are taking shape, I am confident that a solid atmospheric pillar (sounds rather paradoxical!) will remain to be an essential ingredient. I wish the rejuvenated IPO team, which is looking for a project scientist, all the best and I extend my most grateful regards to all the fine folks whom I had the privilege to cooperate with for the benefit of SPARC: among them the staff at WCRP/JSP, the colleagues engaged with SPARC-SSG and WCRP-JSC, all the co-organizers of the SPARC General Assembly 2018 in Kyoto, the many contributors to the numerous SPARC activities and, by no means least, the benevolent sponsors of SPARC within DLR, the German Aerospace Center.

Hans Volkert, SPARC-IPO director 2018-2020

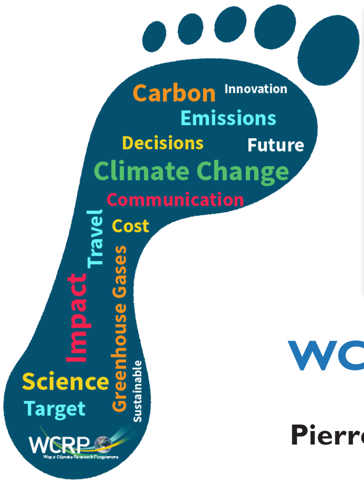
SPARC General Assembly 2022

We are starting to plan for the SPARC General Assembly which is due to be held in 2022. In line with the SPARC goal to reduce our climate footprint, we want to organise it in as environmentally friendly way as possible while meeting the aim of a General Assembly to be a community-building event. We are therefore looking for innovative ways[*] to hold the conference. Andrew Charlton-Perez has kindly agreed to chair the planning group discussing ways in which this could be achieved.

We want to recruit volunteers interested in brainstorming ideas for the SPARC GA. Please contact the SPARC Office (office@sparc-climate.org) or Andrew (a.j.charlton-perez@reading.ac.uk), if you would like to contribute or pass this on to anyone you think might be interested. We hope that scientists with varied backgrounds and levels of experience will contribute. We are looking for outline proposals to be prepared this autumn.

The experience of holding on-line conferences is being greatly accelerated as part of the response to the Covid-19 pandemic. We want to learn all we can from this experience. If you have experienced or are aware of examples of holding on-line meetings, please do contact us with what you think worked well, did not work, and the lessons learned. Please visit the SPARC webpage to let us know about your experience .

[*] e.g as described in **SPARC newsletter No. 54** or by Klöwer, M. et al., 2020: **An analysis of ways to decarbonize conference travel after COVID-19**, nature 583



Members of the SPARC community are discussing the carbon footprint of their research activities with a focus on meetings and workshops and in particular, the travel carbon emissions of the meeting participants (see article in the last issue of the SPARC newsletter). Such discussions are not exclusive to the SPARC community, and some strategic points have been presented during the first online-only JSC-41 meeting in May 2020 (see report onpage 2), and are further expressed in this summary.

WCRP plans to reduce its carbon footprint

Pierre Friedlingstein[1,2] and Narelle van der Wel[3]

[1] University of Exeter, UK; [2] LMD/IPSL, ENS, PSL Université, Paris France, [3] WCRP Secretariat, Switzerland (**nvanderwel@wmo.int**).

The World Climate Research Programme (WCRP) pursues – through international coordination – frontier scientific questions related to the coupled climate system, which are too large and too complex to be tackled by a single nation, agency, institution, or scientific discipline. Hence, by its very nature, the Programme involves the global cooperation of scientists.

It may come as a surprise, then, that WCRP does not currently monitor its carbon footprint. This is partly because emissions from operations of the WCRP Secretariat, hosted by the World Meteorological Organization (WMO), and WCRP-funded travel are automatically offset by WMO. It is also because the dominant feeling has been that WCRP could not successfully conduct international collaboration without international travel and there has been some fear that reducing travel equates to reducing the impact and visibility of the Programme. However, over recent years, the emergence of a state of climate emergency has made it clear that this mode of operation has to change. Also, with the recent travel restrictions imposed by the Coronavirus (COVID-19) epidemic, we have all had to learn to use online means to communicate in a wider range of situations – sometimes in situations we previously would not have considered as appropriate.

This was the case with the 41st Session of the Joint Scientific Committee (JSC-41), the first ever online Session of the JSC, held in May 2020, which was a great success. The physical presentations and face to face discussions were replaced by virtual presentations and chat room discussions, without significantly affecting the level of scientific interactions. At that JSC Session, a Carbon Footprint Report was submitted by JSC members Pierre Friedlingstein and Pedro Monteiro, which made recommendations to the JSC on how to proceed with reducing WCRP's carbon footprint. It was agreed that a Working Group on WCRP's Carbon Footprint will be established to ensure WCRP monitors its travel related carbon emissions and, more importantly, commits to significantly reduce these emissions over the coming years. It will advocate to strategically limit face-to-face connections to when they offer critical scientific benefits and to use online connections to maximize inclusivity and truly global participation.

The Carbon Footprint Working Group will include representatives from across WCRP, including early career researchers. Many individuals and projects within WCRP are already thinking and moving in this direction. In a JSC-41 feedback survey, 78% of respondents supported future meetings taking a hybrid format[1]. One of the main reasons that respondents gave for preferring hybrid meetings was to reduce carbon emissions, but it was also recognized that online meetings allow a broader range of people to attend and interact. In parallel, some WCRP projects and activities are already thinking about reducing their carbon footprints. SPARC is calculating the carbon footprint of its meetings and is looking at innovative ways of hosting its General Assembly 2022 (SPARC eNews, May 2020). The WCRP Grand Challenge on Near-Term Climate Prediction (GC-NTCP) has conducted all of its meetings online since it began in 2015 and they reported at JSC-41 that they have almost delivered all of their initial outcomes (JSC-41 GC-NTCP Report).

It is important that this is a community-driven effort, supported by the WCRP JSC and Secretariat to ensure that a best practice framework is in place. It is recognized that this cannot be done successfully in isolation, so WCRP will be looking to its sponsors and partners to unite on this important initiative.

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[1] 'hybrid' in this context can have many meanings, but it generally refers to a meeting that has face-to-face and online components. It could mean online and face-to-face meetings in alternate years, several regional hubs connecting online or other variations.

WCRP/SPARC SATIO-TCS joint workshop on Stratosphere-Troposphere Dynamical Coupling in the Tropics

Shigeo Yoden[1], Peter H. Haynes[2], Peter Hitchcock[3], Matthew H. Hitchman[4], Tieh-Yong Koh[5], Takatoshi Sakazaki[1], Sourabh Bal[6], and Achmad Fahrudin Rais[7]

[1] Kyoto Univ., Japan, (**yoden.shigeo.53r@st.kyoto-u.ac.jp**); [2] Univ. of Cambridge, UK; [3] Cornell Univ., USA; [4] Univ. of Wisconsin-Madison, USA; [5] Singapore Univ. of Social Sciences, Singapore; [6] Swami Vivekananda Inst. of Science & Technology, India; [7] Indonesian Agency for Meteorology, Climatology and Geophysics, Indonesia.

DATE: 21-25 February 2020

NUMBER OF PARTICIPANTS: **57**

ORGANISING COMMITEE:
Shigeo Yoden (Kyoto Univ.), Peter H. Haynes (Univ. of Cambridge), Peter Hitchcock (Cornell Univ.), Matthew H. Hitchman (Univ. of Wisconsin-Madison), Tieh-Yong Koh (Singapore Univ. of Social Sciences), Takatoshi Sakazaki (Kyoto Univ.)

HOST INSTITUTION:
Seminar House of Graduate School of Science, and Raku-Yu Kaikan, Kyoto University, Kyoto, Japan

SPONSORS:

BACKGROUND:
SATIO-TCS (Stratospheric and Tropospheric Influences On Tropical Convective Systems) is a SPARC activity focussed on enhancing our understanding of the coupling between stratospheric processes and tropospheric convective systems, particularly in the tropics.

WORKSHOP WEBAGE:
www-mete.kugi.kyoto-u.ac.jp/Kyoto2020/

ACTIVITIY WEBPAGE:
www.sparc-climate.org/activities/satio-tcs/

A five-day joint workshop on the stratosphere-troposphere dynamical coupling in the tropics was held in February 2020 at Seminar House of Graduate School of Science, and Raku-Yu Kaikan, Kyoto University, Kyoto, Japan. There were 57 participants, including 21 from abroad, even though over 10 people had registered but could not come to Kyoto due to the influence of the COVID-19 pandemic. (If the meeting had been in March, we would have not been able to hold it because of the rapid worsening of the situation.)

The workshop was organised as part of SATIO-TCS, which is an international research activity under WCRP/SPARC focussing on stratosphere-troposphere coupling both upward and downward in the tropics associated with moist convection and its organized systems (see Figure 3). There is an increase in reports of observational evidence that stratospheric variations, such as sudden stratospheric warming (SSW) events, the equatorial quasi-biennial oscillation (QBO), the 11-year solar cycle (SC), and the anthropogenic cooling trend (CT) in the lower stratosphere, influence tropospheric variations in the tropics by modulating moist convection and its large-scale organization into meso-to-planetary-scale systems, in addition to diurnal and annual responses of the atmosphere to the periodic solar forcings. Such multi-scale interactions cover a wide range of space- and time-scales, including phenomena ranging from convective plumes, mesoscale moist convective systems, their diurnal variations, tropical convective clusters, tropical cyclones (TCs), intraseasonal variability (e.g., the Madden-Julian Oscillation; MJO), monsoon as the seasonal variations, interannual variations like El Niño Southern Oscillation (ENSO) and decadal variations, to long-term change due to anthropogenic and natural forcing (e.g., major volcanic eruptions). Some global general circulation models (GCMs) and regional cloud-resolving models show similar features as these observations, but such modelling studies are still in a rather preliminary state. Tropical stratosphere-troposphere coupling may play a significant role in long-term climate change and might also be exploited in sub-seasonal and seasonal weather prediction.

The Kyoto workshop not only covered stratosphere-troposphere dynamical coupling in the tropics, but also teleconnections to the extratropics, and was jointly organized with:

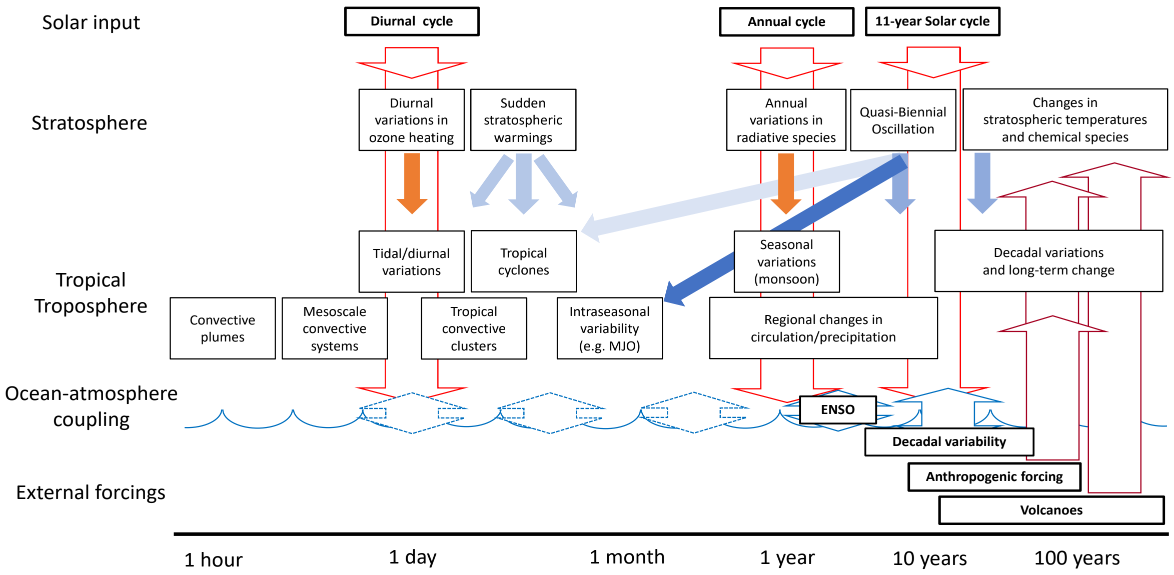

Figure 3: *Stratospheric and tropical tropospheric processes on different timescales and possible couplings between them indicated by red (periodic response to solar forcings) and blue (responses on other timescales) arrows. Darker blue indicates coupling that has been clearly identified from either observations or models, lighter shades indicate coupling for which some evidence exists but which are still subject to uncertainty. (Haynes et al., 2020)*

Years of the Maritime Continent (YMC), Project for solar-terrestrial environment prediction (PSTEP), JSPS KAKENHI "Stratosphere-troposphere dynamical coupling in the tropics", JSPS-DG-RSTHE of Indonesia Bilateral Joint Research Project "Scientific research on extreme weather in changing climate in the Maritime Continent and its societal application". Two-day core sessions were planned for the latest results of observations and data analyses, numerical experiments, and theoretical studies on the stratosphere-troposphere dynamical coupling in the tropics, with further sessions included on some specific subjects related to the influences of solar activity variations on weather and climate, and the implications for extreme weather and climate in the Maritime Continent under the scope of stratosphere-troposphere dynamical coupling.

A detailed account of the talks and posters presented at the workshop is set out below. There have been several interesting developments since the introductory workshop on this topic held in Kyoto in October 2015 (Geller *et al.*, 2017), including further model studies of QBO-MJO connections, of possible effects of SSWs on the tropical troposphere and of the effect of tropopause temperature structure on the intensity of tropical cyclones.

Stratosphere-troposphere dynamical coupling in the tropics

The workshop was opened by **Peter Haynes**, who provided a review of stratosphere-troposphere coupling in the tropics, including current observational and modelling evidence for coupling from the stratosphere to the tropical troposphere, the current understanding of potentially relevant mechanisms for communication and for feedbacks with the troposphere, and the possible implications of the coupling for weather and climate prediction (Haynes *et al.*, 2020). The impact of an SSW through dynamically induced tropical stratospheric cooling that further triggers deep convective activity in the troposphere was shown by **Kunihiko Kodera**. **Nawo Eguchi** used NICAM (Nonhydrostatic ICosahedral Atmospheric Model) to study enhanced deep convection and TCs over the southwestern Indian Ocean and the southwestern Pacific Ocean during the SSW event in January 2010. Further, results of the examination of the impact of the stratospheric circulation changes related to SSW on the tropical troposphere was presented by **Kohei Yoshida**, who used 5,000-year ensemble simulations with a 60 km horizontal resolution global atmospheric model MRI-AGCM3.2.

A comparison of the representation of the semi-annual oscillation (SAO) in the equatorial stratosphere and lower mesosphere among six major global atmospheric reanalysis datasets was shown by **Yoshio Kawatani**. The climatology of residual mean meridional circulation – a main component of the Brewer–Dobson circulation – and the potential contribution of gravity waves (GWs) for the annual mean state and each season in the whole stratosphere based on the transformed-Eulerian mean zonal momentum equation were examined by **Kaoru Sato** using four modern reanalysis datasets.

Masato Shiotani explained his proposal about Superconducting Submillimeter-Wave Limb-Emission Sounder (SMILES-2) satellite observation to obtain global information with unprecedented accuracy on the whole atmosphere including upper mesosphere and lower thermosphere.

On the second day, **Matt Hitchman** gave a historical review on the downward influence of the QBO on the tropical and subtropical troposphere based on observational studies (Hitchman *et al.*, 2020). **Chidong Zhang** tested the hypothesis that the static stability near the tropopause can be modulated by the temperature perturbations of the QBO through diagnosing precipitation changes between QBO easterly and westerly phases as a function of the cloud-top height. A set of GCM experiments in which the model's stratospheric winds are nudged to observations in order to ensure a better representation of the QBO in the tropopause region were described by **Zane Martin**. **Hyemi Kim** (presented by I. Simpson) assessed the representation of this connection in 29 models participating in the Coupled Model Intercomparison Project 6 (CMIP6) in capturing the observed QBO-MJO connection. The role of tropical stratospheric zonal winds on QBO influences on the Arctic-midlatitude linkage and sea-ice were studied by **Jinro Ukita** using reanalysis data.

Isla Simpson used 20-member ensemble simulations of CESM-WACCM with greenhouse-gas driven warming, under a high emissions scenario, to understand dynamical response to tropical lower stratospheric heating in the context of stratospheric sulfate geoengineering. Anticyclonic Rossby wave gyres that form near the tropopause due to equatorially-symmetric Matsuno-Gill heating provide a mechanism to influence tropical and subtropical atmospheric chemistry, as shown by **Catherine Wilka**. **Suhas Ettammal** showed the relationship between the strength of convectively coupled mixed-Rossby-gravity waves and troposphere-stratosphere coupling based on ERA-Interim data.

A three-dimensional minimal model that produces a self-sustained oscillation reminiscent of the QBO in a radiative–moist convective quasi-equilibrium state was presented by **Shigeo Yoden**, who showed the influence of QBO-like oscillations on the aggregation of moist convective systems. **Tieh-Yong Koh** reported the universal scaling characteristics of rain cluster distribution which favours a hypothesis coined as self-organized criticality (SOC) of organized rain clusters over tropical oceans, while **Takatoshi Sakazaki** identified the theoretically expected high-frequency global normal modes in the atmosphere with the use of newly-available ERA5 hourly global reanalyses dataset.

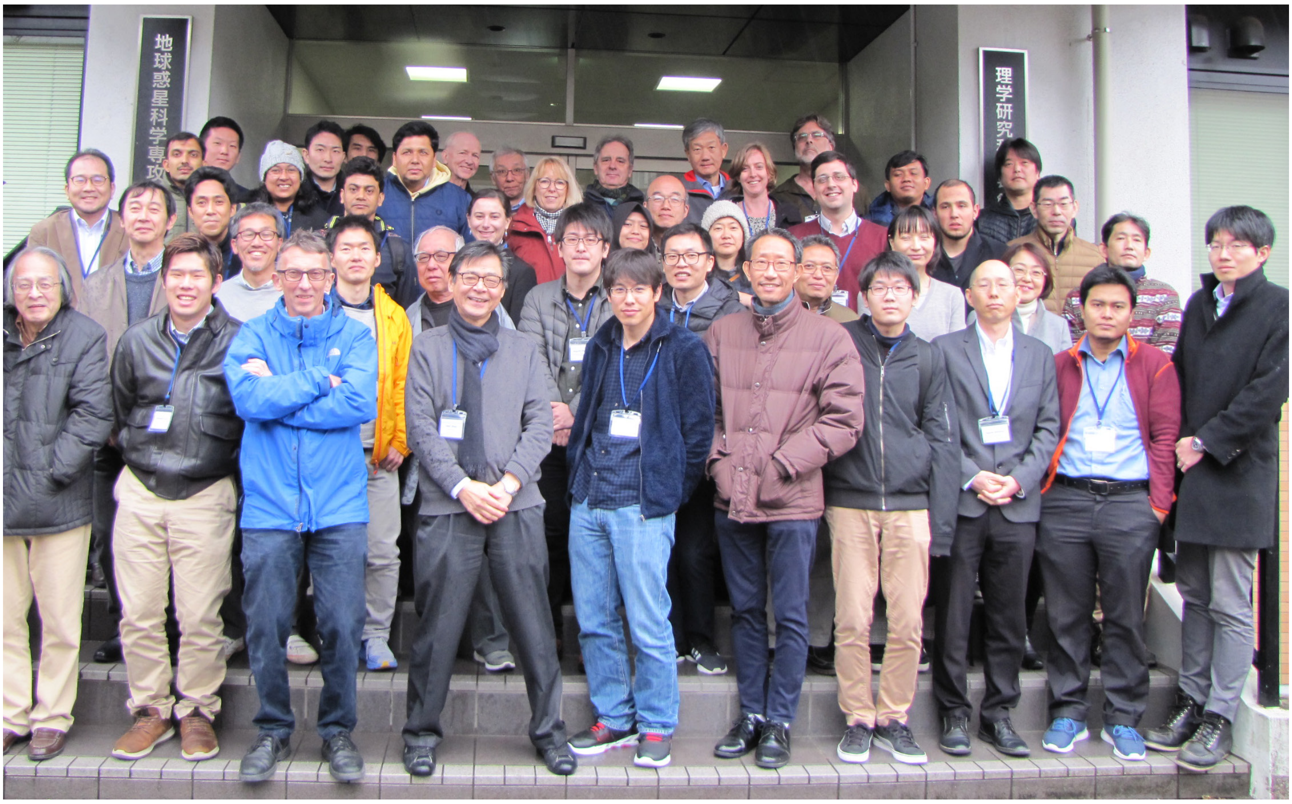

Figure 4: *Workshop participants at the Department of Geophysics, Kyoto University.*

Poster session I

Poster presentations showed the variable influence of stratospheric vortex splits on the equatorial troposphere (**Sourabh Bal**), the signature of strong meridional coupling between polar and tropical regions due to SSW events during 2007-2017 (**Surendra Dhaka**, presented by V. Kumar), and modelling studies of the response of tropical lower stratospheric circulation and convective systems to the 2019 SSW event in the Antarctic Stratosphere (**Shunsuke Noguchi**). Further, topics included the downward propagation of planetary wave packets to the troposphere during the Northern Hemisphere (NH) Winter (**Yuya Matsuyama**), the climatology of traveling and stationary planetary waves in the NH winter middle atmosphere (**Koki Iwao**), the evaluation of the QBO's impact on the NH winter stratospheric polar vortex in CMIP5/6 models (**Jian Rao**), and descriptions of the 3D structure and formation of UTLS jetlets associated with potential vorticity dipoles in TCs (**Matt Hitchman**), and of the the response of the tropical troposphere to SSWs in simulations previously used to study the extratropical response (**Peter Haynes**). Other presentations focussed on the remote influences of the QBO on the troposphere with a composite difference analysis (**Vinay Kumar**), the possible mechanisms of QBO and ENSO influence on the MJO-induced Rossby wave train (**Lon Hood**), and the downward extension of QBO-related zonal wind anomalies to the troposphere (**Masakazu Taguchi**). Furthermore, insights were given on the evaluation of the QBO effects on ENSO teleconnections and the Walker circulation (**Jorge Garcia-Franco**), as well as results from MIROC Models with and without non-orographic GW parameterization to examine the ENSO modulation of the QBO (**Yoshio Kawatani**) and the influences of the SC and the QBO on the NH winter polar vortex (**Yusuke Aimono**).

Influences of solar activity variations on weather and climate

Lon Hood presented evidence that the 27-day solar oscillation has an influence of UV spectral irradiance variations on both tropical tropospheric temperature and the occurrence rate of MJO events in boreal winter. He also reported the influence of SC on MJO occurrence rate. **Yuhji Kuroda** explained that solar related North Atlantic Oscillation (NAO) signal tends to peak in February of solar maximum year, but it also tends to show long-term drift with lags of few years. A study on the relationship between oxygen isotope variations in an ice-core from Dome-Fuji as a temperature proxy with solar activity and oceanic variations, with 10-year and 20-year periodicitieswas presented by **Yuko Motizuki**. The 10-year periodicity correlate significantly well with the SC when the solar activity is strong.

Yousuke Yamashita reported the outcome of numerical experiments which simulate the negative anomalies of total ozone in Arctic spring in the QBO-West phase of solar minimum years, largely due to the transport effect. Results from using a chemistry-climate model under the potential of Grand Solar Minimum (GSM) scenarios to counter the climate change by projected anthropogenic greenhouse gas emissions through the 21st century were presented by **Ulrike Langematz**. Under the influence of a GSM, they found a less pronounced warming in the eastern part of the Pacific Ocean and enhanced longitudinal temperature and pressure gradients, accompanied by stronger easterlies and an overall stronger Walker Circulation. **Yvan Orsolini** reviewed on the solar impacts on climate through energetic particle precipitation (EPP) in the mesosphere and lower thermosphere. He emphasized a role of EPP in explaining the lagged response of the NAO to the SC. **Tobias Spiegl** presented about modelling the transport and deposition of 10 Be produced by the strongest solar particle event during the Holocene. The result agrees well with the proxy reconstructions, and the timing of the event in NH spring is most robust in their model simulations.

Extreme weather and climate in the Maritime Continent

Kunio Yoneyama reviewed the typical features from ocean surface to the stratosphere observed during YMC intensive observation periods. He also added that the measuring campaign for 2020 will focus on the relationship between meso-scale sea surface temperature (SST) distribution and atmospheric convection, and also high accurate water vapor measurement in the upper troposphere. Results from numerical experiments on the intensity and structure of TCs modulated by SST, were given by **Tetsuya Takemi,** highlighting the role of temperature lapse rate around the tropopause. **Tri W. Hadi** reported on the synoptic component of Borneo Vortex in the Maritime Continent using space-time frequency analysis of outgoing long wave radiation to investigate the role of equatorial waves.

Takeshi Enomoto reported the model predictability of two heavy rainfall events on July 2018 and October 2019 in Japan. The model output highlighted that the north-eastward migration of TC in the Sea of Japan is a key and the vortex intensity affects forecast tracks.

Manabu D. Yamanaka argued that tropical land-sea contrasts played an important role in regional and larger-scale strato-tropospheric water and momentum budgets. He described that the most dominant mode of cloud-rainfall generation is the diurnal cycle mainly around the tropical coastal regions. The extreme rainfall causing flood in Jakarta at the end of 2019 evidently coincides with the strong cross equatorial northerly surge, as shown by **Rezky Yunita**. **Nurjanna Joko Trilaksono** reported characteristics study of hailstorm over Greater Bandung Area, Indonesia during March-April 2017 obtained with an X-band radar observation.

Poster session II

The second poster session contained results from using the COSMIC data to detect the SC signal in the tropospheric temperature (**Surendra Dhaka;** presented by V. Kumar), a simulation of the ozone change of Halloween event in 2003 and Carrington event in 1859 using MIROC3.2 Chemistry-Climate Model (**Hideharu Akiyoshi**), and a verification of precipitation forecast by pattern recognition with a new metric, the Pattern Similarity Index (**Shigenori Otsuka**). Others presented examinations of the stratospheric influence on the aggregation of tropical moist convective systems with a regional cloud-system resolving model (**Takahiro Banno**), the characteristics of jumping cirrus at the top of deep convective clouds based on the ground observations by visible light cameras (**Takafumi Seguchi**), the analyses of the seasonal variation of the tropopause height using a diagnostic equation for the lapse-rate-tropopause heights (**Masashi Kohma**), and usage of the hourly CMORPH dataset to determine the diurnal pattern of extreme rainfall over Java and the surrounding waters (**Achmad Fahrudin Rais**). Further, an explanation how the eastern pacific El Niño brings warm and non-warm winters to the Far East by composite analyses with reanalysis datasets (**Masahiro Shiozaki**) was shown along with the investigation of projected future changes in extreme precipitation in a 60-km AGCM large ensemble and their dependence on return periods (**Ryo Mizuta**), the 21st century drought projection in the Indochina region based on the optimal ensemble subset of CMIP5 models (**Rattana Chhin**), and the proposal of a new framework to visualize impacts of a model change or multi-model results in a single diagram for climate sensitivity experiments (**Shipra Jain** presented by S. Yoden).

Acknowledgments

The workshop conveners (SY, PHH, PH, MHH, TYK, and TS) would like to thank the generous sponsors of the meeting: The SPARC project of the World Climate Research Programme (WCRP), the Grants-in-Aid for Scientific Research <KAKENHI>, 15H05816 and 17H01159, and Bilateral Joint Research Project with Indonesia DG-RSTHE, through the Japan Society for the Promotion of Science (JSPS) and the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan. S. Bal and A.F. Rais thank WCRP/SPARC for their travel grant support. Thanks also to local technical support by the staff of the Integrated Earth Science Hub, Kyoto University (Y. Uemoto, A. Abe, and T. Takahata). We also thank invited speakers and all attendees whose participation made it a most successful workshop.

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The third SPARC OCTAV-UTLS meeting

Thierry Leblanc[1], Luis Millán[2], Peter Hoor[3], and Irina Petropavlovskikh[4]

[1] Jet Propulsion Laboratory, California Institute of Technology, Wrightwood, CA, USA (**thierry.leblanc@jpl.nasa.gov**); [2] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA; [3] Johannes Gutenberg Univ., Mainz, Germany ; [4] Cooperative Institute for Research in Environmental Sciences (CIRES), NOAA ESRL Global Monitoring Lab, Boulder, CO, USA.

Date:

3-5 March 2020

Number Of Participants: **15**

Organisers:

Thierry Leblanc (local host), Luis Millán, Peter Hoor, Irina Petropavlovskikh

Host Institution:

JPL-Table Mountain Facility, Wrightwood CA, USA

Sponsors:

Background:

The complex dynamical processes at the tropopause and their effect on the UTLS composition contribute to uncertainties affecting near-time climate predictions (related to the WCRP Grand Challenge #7). The community thus faces the challenge of optimally exploiting the existing portfolio of observations to better understand the UTLS physical composition and processes. This approach will help with the interpretation of the past long-term changes in trace gas distributions and the processes that control them.

Workshop webpage:

https://www.octav-utls.net/meetings

The SPARC OCTAV-UTLS (Observed Composition Trends And Variability in the Upper Troposphere and Lower Stratosphere) Third Workshop was hosted by Thierry Leblanc at the JPL-Table Mountain Facility in Wrightwood, California, March 3-5 2020. About 15 scientists from Europe, Canada, and the USA attended the workshop in-person or online. The OCTAV-UTLS activity's overarching goal is to identify and characterize variability and trends in the UTLS. Because of the UTLS inherent high dynamical variability, interpreting and reconciling trends inferred from observational platforms with different sampling characteristics and measurement representativeness has proved challenging, even after decades of aircraft, balloon, ground-based and satellite observations. To reduce the high geophysical variability and therefore reduce the uncertainty in the detection and quantification of composition trends, OCTAV-UTLS has been focusing on the selection and use of specific geophysically-based coordinates, which allow to reference chemical observations relative to the tropopause location or the jets (*e.g.*, remapping observation locations to the distance relative to the nearby sub-tropical jet core or relative to a specific tropopause altitude, see Figure 5). The purpose of the third OCTAV-UTLS workshop was to review changes to the UTLS variability and trend results obtained from a wide range of ozone and water vapor observations, after these observations were mapped onto several coordinate systems (based on the recommendations of the previous meeting). Robust reduction in variability guides with selection of the most adequate coordinate system(s) and plan the next steps to proceed towards a consistent trend analysis across the different platforms.

After an introduction by host **T. Leblanc**, **P. Hoor** presented the objectives of OCTAV-UTLS, identified the goals of the workshop, and opened the aircraft session. He showed that coordinate-mapping can be used to identify different dynamical sources for composition variability and that the combination of dynamical tropopause coordinates with jet-based analysis significantly reduces variability of ozone in the UTLS. **L. Millán** presented an update on the JETPAC (Jet and Tropopause Products for Analysis and Characterization) processing tool. JETPAC is the software package (Manney *et al.*, 2011) that extracts the dynamical fields from a state-of-the-art global model, in this case the MERRA2 (Modern-Era Retrospective analysis for Research and Applications, Version 2) reanalysis fields at a desired observation location and time, which then allows to re-map this observation onto dynamical coordinates.

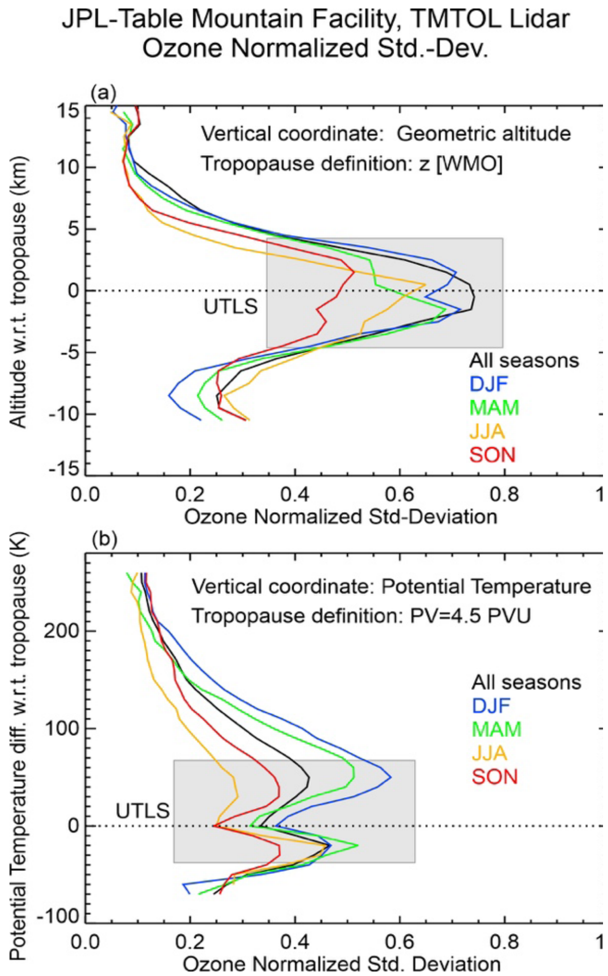

Figure 5: *(a) Ozone normalized standard-deviation computed from the JPL Table Mountain Facility tropospheric ozone lidar (TMTOL) profiles (2000-2017), using geometric altitude as the vertical coordinate and the WMO tropopause as the tropopause definition. (b) Same but using potential temperature and the PV=4.5 PVU surface as the vertical coordinate and tropopause reference respectively.*

In the aircraft observations session, **D. Kunkel** presented ozone variability results for the analysis of the SPURT (Spurenstofftransport in der Tropopausenregion, trace gas transport in the tropopause region), TACTS/ESMVal (Transport and Composition of the LMS/Earth System Model Validation), PGS ("Polar Stratosphere in a Changing Climate" / "Gravity Wave Life Cycle" / "Seasonality of Air mass transport and origin in the Lowermost Stratosphere using the HALO Aircraft"), and WISE (Wave-driven ISentropic Exchange) research aircraft campaigns and highlighted the importance of using a consistent approach when deriving the dynamical coordinates. He showed that the interpolation of meteorological fields onto highly resolved research aircraft vastly depends on the interpolation method, the order of those interpolations, and the field variable of interest. Using 15 years of IAGOS-CARIBIC (In-service Aircraft for a Global Observing System Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container) airborne measurements, **H.Bönisch** reported that dynamical tropopause and subtropical jet-based coordinates largely reduce the variability of ozone observations. First preliminary results for ozone show non-significant negative trends in the lower stratosphere indifferently of the coordinates system used, but the analysis regions for trend estimates need to be further refined.

In the ground-based session, **I. Petropavlovskikh** reviewed the ozonesondes records (Boulder, CO and Hilo, HI) mapped in several transformed coordinates. She compared UTLS trends and their uncertainties in records split in two sub-sets based on location of the Subtropical jet relative to station location, either the Equator-ward or Polar-ward side of the station. She found small differences in trends, but uncertainty remained high even in dynamically referenced ozonesonde datasets. She found that weekly sampling frequency in ozonesonde records make detection of trends highly uncertain if data are further separated into seasonal averages. In order to improve sampling limitations, she suggested combining several mid-latitude ozonesonde records referenced in dynamical coordinates. Using the Table Mountain, CA lidar measurements and ozonesonde from Boulder, CO and Trinidad Head, CA, **T. Leblanc** showed statistically non-significant positive ozone trends below the tropopause and negative above, and noted that a monotonic tropopause-based coordinate is ill-defined in the presence of tropopause folds (double-tropopauses).

The following day, **C. Rolf** used the JULIA (the Jülich In-Situ Airborne) database to show that water vapor variability in the UTLS was best reduced using a combination of jet-based and tropopause-based coordinates. He also showed that below 350 K water vapor variability was not reduced by any coordinate transformation. Hence, trend estimates remain highly uncertain below 350 K, but show indications for slightly negative trend of water vapor in the lower stratosphere. A statistically non-significant negative (respectively positive) ozone trend around (respectively below) the tropopause was also found. Then, **S. Hicks-Halali** showed a climatology and trend results in the upper troposphere water vapor using the Raman Lidar of Meteoswiss in Payerne, Switzerland.

During the satellite session, **K. Walker** and **P. Jeffery** presented ozone and water vapor results from ACE-FTS (Atmospheric Chemistry Experiment Fourier Transform Spectrometer) in different tropopause and jet based coordinates.

A key result of their analysis showed a reduction of trend variability only for ozone, but not for water vapor, since water vapor is under temperature control in addition to UTLS dynamics. **L. Millán** discussed trends using MLS (Microwave Limb Sounder) ozone measurements; and lastly, **G. Manney** discussed SAGEII and SAGEIII/ISS (Stratospheric Aerosol and Gas Experiment) ozone measurements.

In the model session, **E. Knowland** presented stratospheric intrusions identified using MERRA2 reanalysis and the GMAO forecasting products. **K. Wargan** reported on the feasibility of study lower stratospheric trends and variabilities using MERRA2. **J. Neu** discussed the importance of disentangling QBO (quasi-biennial oscillation) and ENSO (El Niño–Southern Oscillation) effects when studying stratospheric trends, which may eventually concern trend studies in the UTLS. Following the last session of the day, **T. Leblanc** provided a tour of the lidar facility, and an ozonesonde was launched in the presence of the group.


Figure 6: *Participants of the third OCTAV-UTLS workshop. From left to right: (front) E. Knowland, T. Leblanc, (back) J. Neu, N. Livesey, I. Petropavlovskikh, M. Brewer, H. Bönisch, P. Wang, P. Hoor, and L. Millán. Online attendees: Y. Cohen, R. Damadeo, S. Hicks-Halali, D. Hubert, P. Jeffery, D. Kunkel, G. Manney, J. McCormark, C. Rolf, K. Walker, K. Wargan.*

Lastly, the discussions focused on the connections between OCTAV-ULTS and other SPARC activities. **N. Livesey** reported on the TUNER (Towards Unified Error Reporting) activity; **D. Hubert** summarized findings from the LOTUS (Long-Term Ozone Trends and Uncertainties in the Stratosphere) activity; **J. McCormack** presented an overview of the DAWG (Data assimilation working group) activity; lastly, **Gloria Manney** discussed findings from the SPARC Reanalysis Intercomparison Project (S-RIP) differentiating between robust and non-robust trends of jet and tropopause location among different reanalysis .

Overall, a coordinate system based on potential temperature with respect to a dynamical tropopause seems to provide the most reduction of ozone variability in the UTLS in most observational records. Analyses of UTLS variability separated by seasons (e.g., March-April-May) are consistent with the expected geophysical variability and the position of the jets relative to the location of ground-based stations. It was proposed to use MLS data (high sampling frequency) sub-sampled at the time and location of the ground-based observations to determine the significance of the represented trends. Reanalysis can be a good complement of the observations in the UTLS. Trends are possible from reanalysis but users have to be cautious, for example when reanalysis show discontinuities related to major changes in data inputs, for example, the transition between TIROS Operational Vertical Sounder (TOVS) and the Advance TOVS (ATOVS) suites in October 1998. Reanalysis can help identify and understand trends in the coordinate variables themselves (jets, tropopauses, equivalent latitude) and associated uncertainties. More work is needed to assess the implications of instrumental artifacts on trends and their uncertainty. The next OCTAV-UTLS meeting will take place probably at KIT in Karlsruhe (Germany) in spring 2021.

OCTAV-UTLS contributes to the research lead by a number of programmes (WCRP and GAW of WMO and IUGG), sponsored by the IO3C (International Ozone Commission) under the IAMAS (International Association of Meteorology and Atmospheric Sciences) and collaborates with other SPARC activities, such as LOTUS, SSRiC, S-RIP with links to FISAPS. Partners for this activity are: SPARC, WMO and GAW.

Acknowledgements

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Update from the SPARC Gravity Wave Activity

M. Joan Alexander[1]**. Kaoru Sato**[2]

[1] NorthWest Research Associates, Boulder, CO, USA, (**alexand@nwra.com**), [2] Univ. of Tokyo, Japan.

SPARC Gravity Waves has new leadership in 2020! Please welcome Drs. **Laura Holt** and **Riwal Plougonven**, who will co-lead the activity into the new decade. Laura brings deep expertise on gravity waves in very high-resolution global models, which is a key focus area for the future gravity wave activity and a growing area for atmospheric research in general. Riwal has been a leader and mentor on a broad range of gravity wave research topics, including the dynamics of sources, parameterization methods in climate models, and observations from stratospheric super-pressure balloon platforms. Together, they have a wide range of interests and knowledge base to tackle current challenges relevant to SPARC.

"We will be happy to take up the torch and try to continue fostering interactions and complementary investigations from observations, modelling and theory to advance the understanding and representation of gravity waves."

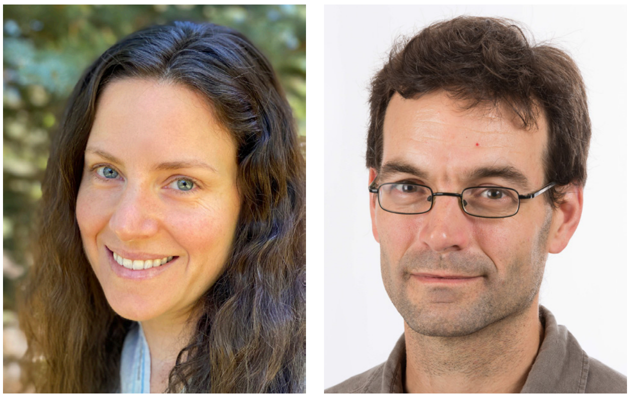

Figure 7: *The new leaders of the Gravity Wave activity: Laura Holt and Riwal Plougonven.*

Gravity waves occur at scales such that they are partially resolved in current global forecast models and next generation climate models. Accurate methods for describing sources of gravity waves that change with changing weather and climate conditions are urgently needed, as well as methods for including realistic scale-awareness in these parameterization methods. Studies on gravity waves also have a growing number of applications in a wide range of new research fields, like strong tropical cyclones, convective organization, mesoscale systems, boundary layer, regional climate, chemical transport and mixing, teleconnections, long-range forecasting, and others. This presents opportunities for collaboration with other SPARC activities, other WCRP projects and working groups, WWRP, and a variety of groups outside of WMO. The current focus of Gravity Wave Activity involves an International Space Science Institute International Team focusing on orographic wave drag (www.issibern.ch/teams/consonorogravity/), a project that has close connections with GEWEX/GASS and WGNE.

Future foci may include the maintenance and development of observation records, which are needed to build-in realistic sensitivity to climate into gravity wave parameterizations. Continued development of high-resolution simulations is also needed, since we know for example that simply adding horizontal resolution does not lead to improved gravity wave simulations or gravity wave drag effects. Continued focused research in the upper stratosphere and mesosphere is needed as reanalyses and forecast models recognize the need to remove sponge layers at these altitudes, replacing them with more realistic dynamics.

Planning for the next SPARC Gravity Wave Symposium in Frankfurt, Germany, 27 September – 1 October 2021, is underway and will be hosted by Ulrich Achatz. This follows the tradition of a major focused meeting once every 5 years since the first organized in 1996 by Kevin Hamilton. In addition, we see great value in possible joint meetings with other SPARC activities every other year or so on topics of mutual interest. Next opportunities may be joint with FISAPS, Data assimilation (DAWG), SNAP, QBOi, SOLARIS-HEPPA, chemistry (CCMi), DynVar, SATIO-TCS, or OCTV-UTLS. Joint meetings with other WCRP groups may also be beneficial, especially WGNE, GEWEX/GASS/COORDE, and HighResMIP. We have greatly enjoyed our associations with SPARC and the Gravity Wave Activity over the years, and look forward to learning of the exciting developments in years to come.

International Conference on the Asian Summer Monsoon Anticyclone: Gateway of Surface Pollutants to the stratosphere

Sanjay Kumar Mehta[1], **Masatomo Fujiwara**[2], **Susann Tegtmeier**[3], **M. Venkat Ratnam**[4], **Suvarna Fadnavis**[5], **Michelle Santee**[6], **and Hans Schlager**[7]

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Date:
10-11 February 2020

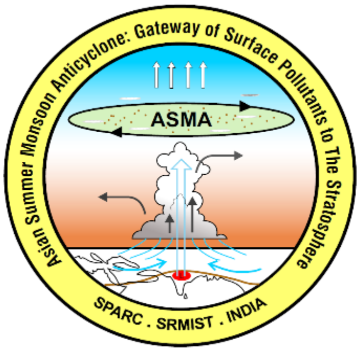
Number Of Participants: **45**

Organisers:
Sanjay Kumar Mehta (SRM Inst. of Science and Technology); Masatomo Fujiwara (Hokkaido Univ., Japan); Susann Tegtmeier (Univ. of Saskatchewan, Canada)

Scientific Organisisng Committee:
Sanjay Mehta, Masatomo Fujiwara, Susann Tegtmeier, M. Venkat Ratnam, Suvarna Fadnavis, V. Rakesh, D. Narayana Rao, K. Ramasamy, C. Muthamizhchelvan, K. Mohan Kumar, B.V. Krishna Murthy, S.R.S. Prabhaharan, B. Neppolian and D. John Thiruvadigal

Local Organising Committee:
Arijit Sen, Ritesh Kumar Dube, Bhalchandra Kakde, S. Venkat Prasad Bhat, S. Anandkumar, Paromita Chakraborty, P. Malar, K. M. Ramkumar, M. Sasidharan, A. Jesuarockiaraj, S. Harinipriya, T.V. Lakshmi Kumar, and K. Namitharan

Host Institution:
SRM Institute of Science and Technology, Chennai, India



To promote the better understanding towards the increasing emission and its transport to the upper troposphere and lower stratosphere (UTLS) the International Conference on Asian Summer Monsoon Anticyclone (ASMA): Gateway of surface pollutants to the stratosphere was organized at SRM Institute of Science and Technology (SRMIST) in association with Hokkaido University, Japan and University of Saskatchewan (USask) Canada as the part of the Scheme for Promotion of Academic and Research Collaboration (SPARC) project funded by Ministry of Human Resource and Development (MHRD), Govt. of India. SPARC provides a platform to facilitate academic and research collaborations between Indian institutions and the best institutions in the world so that Indian scientists and students can interact with the finest minds in the world. SRM IST has recently initiated activities on atmospheric observations and modelling works with micropulse lidar and radiosonde experimental facilities. International ASMA Conference was provided with an excellent opportunity for scientists and students to demonstrate their research results.

The first International ASMA Conference was held on 10-11 February 2020 at SRMIST, Chennai, India, with 45 participants from 5 countries, mostly from India. Scientific presentations and discussions covered a focused and thematic topic on the transport of the surface pollutants to UTLS via ASMA region, its transport pathways, deep convection, the tropical easterly jet, cirrus clouds and their nucleation, the Asian tropopause aerosol layer (ATAL), and long-term changes and climatology of the ASMA. The ASMA is an important component of the circulation system that enables direct transport of surface pollutants and climate-active gases to the UTLS. Observational and modelling studies confirm that the ASMA confines maximum concentrations of surface trace gases such as CH_4, CO, and HCN. The strong anticyclonic circulation couples their convective transport during the Asian summer monsoon with their entrainment deep into the stratosphere. This unique dynamical situation is characterized by warm tropospheric air overlaid by cold stratospheric temperature anomalies, and frequent occurrence of cirrus clouds. The ASMA has recently drawn much attention within the scientific communities and unprecedented campaigns using ground-based instruments and research aircraft are being carried out to understand associated sources and transport pathways.

SPONSORS:

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1951
योगः कर्मसु कौशलम्

InterMet
International Met Systems

BACKGROUND:

Asian Summer Monsoon Anticyclone (ASMA) is a joint project between SRM, IST, India, CSIR 4PI, Bangalore, India, Hokkaido University, Japan and University of Saskatchewan, Canada sponsored by MHRD, Govt of India under its SPARC initiative started in the year 2018. The aim is to establish a strong research collaboration to peruse the sources and pathways of the atmospheric compositions in the Asian monsoon region which has global impact.

WORKSHOP WEBPAGE:

https://www.srmist.edu.in/asma-2020/

The International ASMA Conference program was structured according to the four ASMA sub-themes which will highlight the current status of how the ASMA variability and dynamical mechanisms link to the stratospheric entrainment of surface trace gases.

1. Variability and Long-term changes of the trace gases in the ASMA
2. Transport pathways: relative roles of TEJ and deep convection
3. Cirrus cloud nucleation process and thermodynamical structure of the ASMA
4. Transport of ABL pollutant to free troposphere

The international ASMA conference included 30 oral and 10 poster presentations. This includes 9 keynote speakers, 6 invited talks and about 40 % of the presentations from early carrier scientists and students. The presentations from early carrier scientists and students were examined by expert panels. The best two oral and poster presentations were awarded, each with a memento and cash prize. Due to the novel coronavirus outbreak in China just a week before the conference, international participants opted to deliver their presentations remotely. The conference was started with a formal inaugural function including lighting lamp followed by the welcome address by **Sanjay Mehta** (SRMIST, India) and the release of the abstract book and proceeding of the conference. The conference was divided into four oral sessions and one poster session. Each oral session began with a keynote presentation followed by invited talks and presentations from early carrier scientists and students. During this conference, a 3-day radiosonde campaign was also conducted to train the master degree students from SRM IST. The radiosonde system was recently purchased from InterMet, USA, who sponsored five radiosonde payloads for this conference.

Variability and long-term changes of the trace gases in the ASMA

The Aura Microwave Limb Sounder (MLS) has provided unprecedented measurements of trace gas species of tropospheric origin: CO, CH_3Cl, CH_3CN, HCN, CH_3OH, H_2O and stratospheric origin: O_3, HNO_3 and HCl. Of the 3500 daily profiles from MLS, ~300 falls within the general ASM region enclosed by the 10° - 50°N latitude × 0° - 140°E longitude. MLS is well suited to characterize UTLS composition in the ASM region and quantify its considerable spatial, seasonal, and interannual variations. Based on 15 years of MLS observations, **Michelle Santee** (JPL, California Institute of Technology, USA) presented a comprehensive overview of the climatological composition of the ASMA and interannual variations in the UTLS response to the monsoon as well as trends. **M. Venkat Ratnam** (NARL, Gadanki, India) described that the ASMA is strongly affected by long-period oscillations such as QBO, ENSO and Solar Cycle.

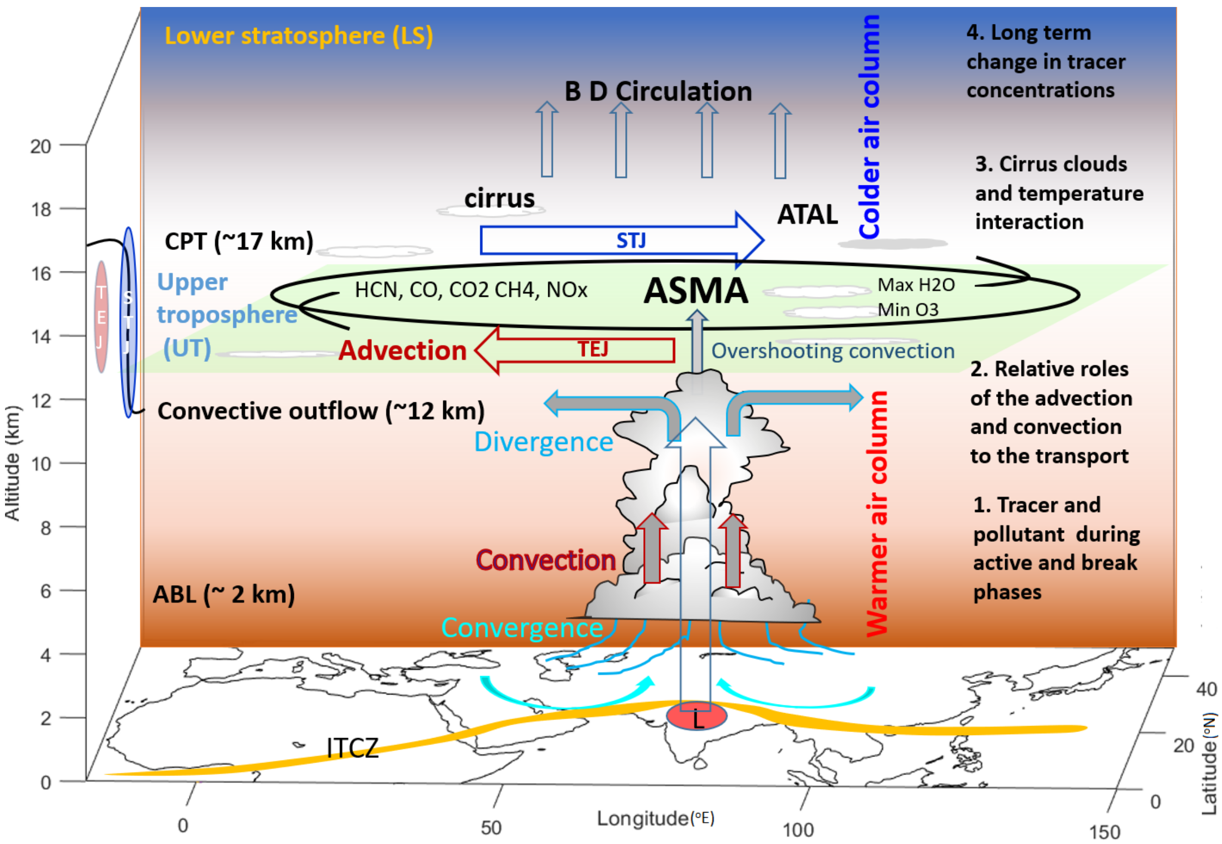

__Figure 8:__ Schematics of the vertical structure of the troposphere (red) and lower stratosphere (blue) showing the transport of the surface pollutant over the Indian monsoon region. The Asian summer monsoon anticyclone (ASMA, green) horizontally confined within subtropical jet (STJ) in the northern flank and tropical easterly jet (TEJ) in equatorial side and vertically confine within top of the convective outflow level and cold point tropopause (CPT). During ASM inter tropical convergence zone (ITCZ) shifts towards the northward create low pressure in central India. The deep convection transports the surface pollutants from the South Asian atmospheric boundary layer (ABL). ASMA contains chemically active gases and surface pollutants which is slowly enters to the deep stratosphere possibly by Brewer-Dobson circulation. Four main subthemes of the conference are listed in the diagram.

The SPARC Reanalysis Intercomparison Project (S-RIP) is a coordinated activity to compare key diagnostics that are important for stratospheric processes and their tropospheric connections among available reanalyses. **Susann Tegtmeier** (Univ. of Saskatchewan, Canada) presented the bimodality of the ASMA, cold point tropopause temperature, vertical velocity and diabatic heating proxy for convective transport, residence times based on diabatic Lagrangian transport calculations and cloud properties in ASMA and their differences amongst reanalysis. All reanalyses generally agree on the climatological mean position of the ASMA core with smaller differences. Detailed understanding of Upper tropospheric ozone transport from the sub-tropics to tropics was discussed by **Siddarth Das** (SPL, Trivandrum, India). **Sabin T.P.** (IITM, Pune, India) using CMIP5 output, MRI-20 km model simulations and global climate model presented the intensity of the boreal summer monsoon overturning circulation and the weakening of associated south-westerly monsoon flow during the past 50-years. **Ghouse Basha** (NARL, Gadanki, India) presented variability of ASMA in association with active monsoon and La Niña years. Other presentations focussed on the water vapor distribution with increasing concentrations in the UTLS over ASM region El-Niño years (**K. V. Suneeth**; SPL, Trivandrum, India), ASMA variability during active break phases of monsoon (**Aneesh S.**; SRM IST, Kattankulathur, India) and a review on climatological feature of the ASMA and trace gases in the UTLS (**Sanjay Mehta**).

Transport pathways: relative roles of TEJ and deep convection

Airborne measurements such as during the OMO and StratoClim campaigns have been carried out to understand the chemical compositions of the ASMA. Based on these campaigns, **Hans Schlager** (DLR, Istitut für Physik der Atmosphäre, DLR, Germany) described that Southeast Asia (India/Nepal/Pakistan and China) are the main source regions to contribute the air in the ASMA, sharp gradients of traces gases across the edge of the ASMA, convective transport indicating enhanced SO_2 and NO observation above the CPT in the ASMA, observed mixed particles, nitrates and organics in the ASMA and nucleation of HNO_3 in ice clouds.

__Figure 9:__ Participants at the International Conference on the Asian Summer Monsoon Anticyclone held in Chennai, India, during February 10-11, 2020. International participants attended online due to the then emerging COVID-19 issue.

Suvarna Fadnavis (IITM Pune, India) presented transport of trace gases via eddy shedding from ASMA to the extratropical upper troposphere and lower stratosphere using MIPAS satellite, ECHAM5–HAMMOZ global chemistry-climate model. The simulations show persistent maxima in black carbon, organic carbon, sulphate, and mineral dust aerosols within the ASMA throughout the ASM season (June to September). Effects of Asian monsoon convection on the tropical tropopause layer (TTL) based on observations from StratoClim campaign was presented by **K. Mohankumar** (ACAAR, Cochin, India). The StratoClim aircraft campaign under Indo-French joint research program took place from 27 July to 10 August 2017 and provided an extensive dataset of observations of air composition inside the ASMA region. Analysis of campaign data indicates the origin of convective air mainly from local sources, like North India, Nepal and Tibetan Plateau, injected at heights between 14 and 15 km. **Revathy S. Ajayakumar** (SPL, Trivandrum, India) presented the results on the tropospheric ozone measurements by balloon-borne ozonesondes during 2011 to 2014. **Akhil Raj S.T.** (NARL, Gadanki, India) described the results on trace gases measurements under ISRO-NASA BATAL Campaigns which includes Radiosonde, ozonesonde, Cryogenic frost Point Hygrometer (CFH), Compact optical Backscatter Aerosol Detector (COBALD) and optical particle counters measurements. The Influence of the bimodality in the ASMA on the UTLS chemical composition was shown by **A. Hemanth Kumar** (NARL, Gadanki India). **N. Kowshika** (TNAU, Coimbatore, India) presented the overview on TEJ over Indian monsoon region and **Sanjay Mehta** discussed the Relationship between the tropical tropopause and TEJ streams over Indian monsoon region. **Selvaraj Dharmalingam** (Ecole Polytechnique, France/ University of Central Florida, Orlando, USA) presented the accuracy of super-pressure balloon trajectory forecasts in the lower stratosphere. The observed trajectories were made during the (tropical) Pre-Concordiasi and (polar) Concordiasi campaigns in 2010, while the simulated trajectories are computed using analyses and forecasts from the European Centre for Medium-Range Weather Forecasts (ECMWF) Integrated Forecast System model. **Satheesh Chandran P R** (SPL, Trivandrum, India) presented the results on the effect of monsoon dynamics on the variability and distributions of ozone in the tropical UTLS using radiosonde/ozonesonde observations.

Cirrus cloud nucleation process and thermodynamical structure of the ASMA

ASMA transport processes with proposed simultaneous measurement of balloons, Lidars, and aircraft under proposed Asian Summer Monsoon Chemical and Climate Impact Project (ACCLIP) was presented by **Masatomo Fujiwara** (Hokkaido University, Sapporo, Japan). The primary goal of this program is to investigate the impacts of Asian gas and aerosol emissions on global chemistry and climate via the linkage of ASM convection and associated large-scale dynamics. A case study of lidar aerosol measurements in Japan during July-August-September 2018 was conducted to understand the capability of measuring UTLS aerosol particles coming from ASMA region. **Karanam Kishore Kumar** (SPL, Trivandrum, India) presented vertical distributions of multi-layered cloud and their types, the spatial distribution of convectively active regions, and associated dynamics from the five years (2006–2010) of CloudSat observations over the Indian summer monsoon region.

The frequency of occurrence of various cloud types their vertical structure was used to identify the preferential regions for particular cloud types. A possible role of the large-scale circulation in the formation of multi-layered clouds was suggested. The role of latent heat released in the clouds in driving the mesoscale to synoptic-scale circulation needs to be explored. **Mushin M** (NIT, Calicut, India) presented heterogeneity in diurnal variation of tropospheric convection over Indian region, **Sunil Kumar SV** (SPL, Trivandrum, India) described the deep convection, inter-tropical convergence zone and ASM. He used balloon-borne cryogenic frost-point hygrometer (CFH) observations during the period 2014-2017 over Hyderabad and Trivandrum to determine the amount of water vapor transport into UTLS and its role in the formation of cirrus clouds. These observations reveal the persistence of thin cirrus overlying a thick cirrus associated with the deep convective outflows mainly hydrate the region while the thin cirrus layer can cause hydration or dehydration in the TTL depending upon the temperature anomalies. **Ajil Kottayil** (ACARR, Cochin, India) presented the factors behind the variability of cirrus clouds using TRACZILLA model over the ASM region. It is suggested that an increase in the cirrus frequency (~ 60 %) towards the westward direction from north Bay of Bengal over the regions lying within 72-90°E and 0-12°E during ASM season. **Saleem Ali** (SRMIST, Chennai, India) nvestigated the occurrence of cirrus clouds and its seasonal variability using micro-pulse lidar (MPL) observations for the period 2016-2018 over Chennai.

Transport of ABL pollutant to free troposphere

The atmospheric boundary layer is the source region for the transport of pollutants into the UTLS via monsoon convection process. Organic species are ubiquitous and often found to be a dominant component of atmospheric fine particles. **Neeraj Rastogi** (PRL, Ahmedabad, India) discussed the atmospheric ageing of Organic aerosol (OA) during horizontal and vertical transport and their effects on air quality and climate. **Vinoj V** (IIT Bhuvneshwar, India) presented the simulation simulate the observed changes in dust aerosol loading over the Indian region using regional climate model and attributed the role of large scale dynamics. The exchange process and aerosol properties from the boundary layer to free troposphere was the focus of **Aravindhavel A**'s (SRMIST, India) presentation and **Balasubramanian** (SRM IST, India) presented important emission regions for atmospheric industrial persistent organic pollutants (iPOPs) and its implications for atmospheric transport using HYSPLIT trajectory model. **Ramesh Reddy** (SRM IST, India) presented the performance of different PBL parameterization schemes available in weather research and forecasting (WRF) to simulate the observed characteristics of atmospheric boundary layer height over Chennai.

Acknowledgements

We acknowledge support for the conference by MHRD, Govt of India under SPARC Program and SRM IST.

Figure 10: *Conference activities left to right release of the Abstract book and conference proceeding, Participants during inaugural day, poster presentations by participants and Radiosonde balloon launch during the International ASMA Conference.*

The Discovery of the Stratopause and the Mesosphere

Kevin Hamilton

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SPARC science is still a young field. Just a century ago the nature of the atmosphere above the lowermost stratosphere was unknown. This article reviews the key developments in the discovery of the structure of the middle atmosphere up to the mesopause during 1923-1947.

Introduction

Near the end of the 18th century the great chemist and meteorologist John Dalton was able to summarize the available instrumental observations of air temperature as follows: *"the temperature of the air over any place, in clear, serene weather, decreases in ascending above the earth's surface ... at a rate of 1 degree for every hundred yards. Experience proves this, as far as the summits of the highest mountains, which is about 3 miles; and hence it may be inferred to be so above that height"* (Dalton, 1793).

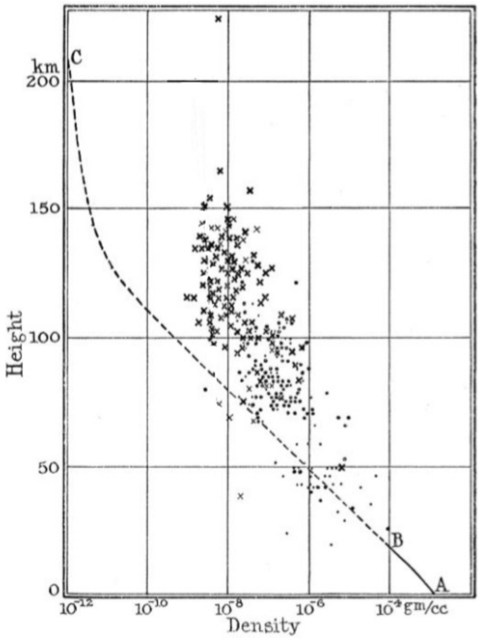

Figure 11: *The density of the atmosphere as a function of height determined from observations of the appearance and disappearance of visible meteor trails. Each cross (dot) shows a determination for an individual meteor of the density at appearance (disappearance). The larger (smaller) crosses and dots show results from trails seen by multiple (single) skilled observers. The dashed curve shows the density expected if the temperature everywhere above 20 km was 220 K. Figure adapted from Lindemann and Dobson (1923).*

He suggested that over 97 % of the mass of the atmosphere should be below about 19 km above sea level and discounted inferences that others had made from observations of twilight that the atmosphere might extend to 60 km or more.

A century later a major breakthrough occurred with the development of unmanned sounding balloons and the observations of an "isothermal layer" above heights of ~10 km by Leon Teisserenc de Bort in France and Richard Assmann in Germany, both reported in 1902. Teisserenc de Bort introduced the terms troposphere and stratosphere for the lower atmosphere and this overlying apparently isothermal layer. Sir Napier Shaw (1926) referred to the tropopause as *"the most surprising discovery in the whole history of meteorology"*. Hoinka (1997) has discussed the discovery of the tropopause and lower stratosphere in an excellent detailed historical review.

In the first two decades of the 20th century the established view was that the atmosphere consists simply of the troposphere overlaid by a nearly isothermal stratosphere. Gold (1909) presented theoretical calculations and arguments suggesting that this temperature structure can be explained by what is referred to now as "radiative-convective" equilibrium, and proposed that the stratosphere (at least away from the polar regions) may indeed be close to radiative equilibrium. He realized that ozone is a strong absorber of radiation but effectively assumed a constant ozone mixing ratio throughout the depth of the atmosphere so had no reason to suppose that there should be a significant temperature inversion in his radiative-equilibrium stratosphere.

The altitude range of in situ temperature observations slowly increased, but this extension was limited by the capability of high altitude platforms. Even by the late 1930's the highest balloon ascents extended only to about 30 km (Paneth, 1939). It was not until after World War II that rockets were used to directly probe the atmosphere into the upper stratosphere and mesosphere.

However, the investigation of the temperature structure above the tropopause proceeded by a range of clever indirect techniques and the existence of the stratopause, mesosphere and mesopause were inferred, although important details ultimately needed to be established later via in situ measurements.

Meteor trails

The first indication that the stratosphere could not simply be an isothermal layer came in the work of Lindemann and Dobson (1923; hereafter LD) who advanced a quantitative theory of the heating and ablation of meteors. In a virtuoso display of physical reasoning, they obtained expressions for the atmospheric density at which a meteor will become visible and the density at which the meteor will completely ablate, ending the visible meteor trail. Using various assumptions they came up with predicted atmospheric densities at the appearance and disappearance levels that depended mainly on the velocity and path of the meteor. The present Figure 11 is adapted from their paper and summarizes data from visual observations of meteors that had been reported by skilled observers. The crosses and dots show the observed heights of appearance and disappearance, respectively, and are plotted at the corresponding air density determined from LD's theoretical calculations. The dashed curve shows the density expected if the atmosphere above 20 km was entirely at 220 K. There is a great deal of scatter in the plot, attributable to the simplifications in the theory and the inexactness of the meteor observations, but as LD note: *"between 60 and 160 km there are abundant meteor observations, but here they all indicate densities very much greater than those calculated on the assumption of a uniform air temperature of 220 K but consistent with a considerably higher temperature. ... Such a result is, of course, entirely contrary to previously accepted views that the temperature would remain constant, or even decrease at very great heights."*

Acoustic inversion

Whipple (1923) was inspired by the LD findings to suggest they might also explain anecdotal observations of peculiar patterns of sound propagation. The phenomenon of "zones of silence and audibility" for sounds from battlefields had been reported at least as far back as 1666 (Ross, 1999). Reynolds (1876) earlier had suggested that the familiar decrease of temperature with height would lead to horizontally propagating sounds refracting upwards thus explaining the regions of silence often found surrounding battlefields. Whipple (1923) notes that *"The work of LD on the theory of meteors, with the remarkable conclusion that the temperature of the atmosphere at heights ... is about the same as near the earth's surface will be far-reaching in its influence ... one of the phenomena for which an explanation probably will be provided is the occurrence of zones of audibility and zones of silence, surrounding scenes of powerful explosions."*

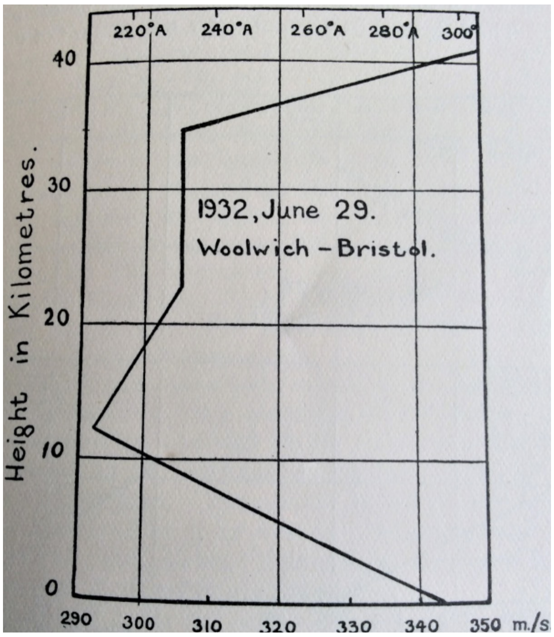

Figure 12: *Inferred temperature as a function of height based on observations made on June 29, 1932, of acoustic propagation between a source at Woolwich and an array of microphones at Bristol about 180 km away. From Whipple (1934).*

Over the next decade Whipple followed up his initial suggestion with quantitative analysis of systematic observations of acoustic propagation (Whipple, 1931, 1934, 1939). Whipple (1934) notes that "*systematic research on the airwaves from gunfire has been going on in England since 1927*". Artillery practice by the military at Woolwich, near London, provided the most common acoustic sources for the analysis.The British Broadcasting Corporation assisted by transmitting via radio the sounds observed near the artillery, allowing time of passage of the acoustic perturbations through the air to be determined from recording microphones at various locations in England.

Each acoustic listening station deployed a triangle of microphones, allowing an estimation of the angle of descent of the incoming sound waves. Balloons were flown to determine the tropopause height and temperature. Then all this information was used in a kind of simple inversion which notably yielded estimates of what today would be called the stratopause temperature and height. Figure 12 reproduces one of Whipple's inversions from observations of sounds from Woolwich observed at Bristol on one day in 1932. Whipple (1939) summarized his results from many years of such observations as inferring *"temperatures averaging about 280 K at 40 km, 310 K at 45 km and 335 K at 50 km"*, which we now know is a significant overestimate of the stratopause temperature. These three temperature values are plotted on Figure 13 where they can be compared to the temperatures from the midlatitude profile of the modern US Standard Atmosphere (USSA).

Noctilucent clouds

The acoustic inversions could only infer temperatures up to the stratopause. The first indication of how the temperatures varied higher up came from the work of Humphreys (1933). Humphreys noted the many reported observations in the high latitude summer of noctilucent clouds at about 80 km altitude. The nature of these clouds was not known for certain, but Humphreys proposed a simple explanation: *"[my] hypothesis is that they are produced by the condensation of water vapor just as are all the clouds of the lower atmosphere ... let the water vapor at every level be one part in 4,000 of all the gases present, the amount we have assumed to be present at the base of the stratosphere. ... Then ... saturation over ice (ice because these clouds do not show iridescence) could again occur and cloud begin to form at a height of 80 to 83 kilometers, roughly, and temperature of about 160°K."* It is not clear how he arrived at the 1/4000 water vapor mixing ratio (more than an order of magnitude larger than modern observations would indicate), but Humphreys showed that the temperature has to drop rapidly above the stratopause to quite low values by ~80 km. The existence of the mesopause temperature minimum was then indicated by inferences of warmer temperatures at still higher altitudes from spectrographic observations of auroral and airglow emissions (see Whipple, 1943).

Ozone and solar influence

Parallel to these attempts to infer the temperature structure were efforts designed to understand the radiative processes that largely control middle atmosphere temperatures. At least as early as Gowan (1928) researchers were speculating that the existence of a warm upper atmosphere might be caused by solar absorption by ozone and that this implied that ozone mixing ratios had to rise significantly through the stratosphere. The 1930's then saw the development of a photochemical theory for stratospheric ozone as well as attempts to observe the vertical profile of ozone from ground-based spectrophotometer measurements (Chapman, 1930). Götz *et al.* (1934) produced the first accurate Umkehr profiles of ozone mixing ratio up to 45 km altitude and thus helped explain the temperature structure up to that height.

Semidiurnal tide

Our story takes an interesting detour with the work of Pekeris (1937). The strikingly large amplitude of the solar semidiurnal (12-hour) barometric oscillation relative to the diurnal (24-hour) oscillation in the tropics was a matter of common observation and considerable puzzlement since the late 18th century. In the late 19th century Lord Kelvin hypothesized that the atmosphere may have had a natural oscillation very close to 12-hour period and that the solar thermal forcing resonantly excited this mode (see Chapman and Lindzen, 1970). Pekeris (1937) examined Kelvin's resonance hypothesis quantitatively within the context of somewhat simplified linear dynamics, with the specific purpose of inferring the vertical temperature structure of the atmosphere. Pekeris (1937) describes his project as follows: *"when the increase of temperature between 30 and 60 km, which was inferred by Whipple from the anomalous propagation of sound waves, is assumed it is possible to find a temperature distribution above 60 km such that the atmosphere has a free oscillation of a period very close to 12 solar hours."* He found that the resonance required a stratopause near 60 km that was even somewhat warmer than that determined by Whipple from his acoustic measurements.

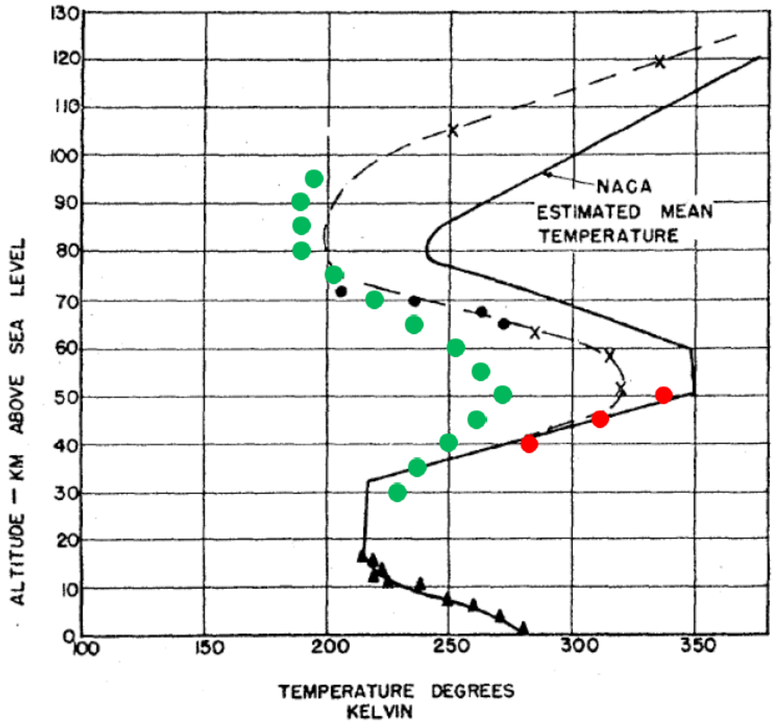

Figure 13: *Temperature as a function of height in the NACA standard atmosphere (solid curve), the midlatitude profile in the modern US Standard Atmosphere (green circles), the climatological temperatures estimated based on many acoustic observations by Whipple (1939; red circles), observations on March 7, 1947 above New Mexico by balloons (triangles) and by a V-2 rocket (crosses and black circles). Figure adapted from Best et al. (1947).*

It seems that Pekeris' result was actually regarded at the time as quite convincing (Chapman and Lindzen, 1970) and seems to have influenced the very early simplified climatologies described in Whipple (1943) and Warfield (1947).

The first "standard atmosphere" temperature profile

Warfield (1947) published a "standard atmosphere" temperature profile prepared under the auspices of the U.S. National Advisory Committee for Aeronautics (NACA, the direct predecessor of NASA) and reflecting the consensus that a special committee reached in June 1946. The profile was based on all available published observations including all those discussed earlier here (notably including the very indirect inference of Pekeris, 1937). The solid black curve in Figure 13 shows the temperature as a function of altitude in the NACA standard atmosphere and can probably be regarded as representative of conditions in midlatitudes where most of the observations were made. The NACA profile differs substantially from more recent (and more reliable) climatologies in the upper stratosphere and mesosphere such as the USSA. Notably the NACA profile has a much warmer stratopause than the midlatitude profile from the USSA (350 K in NACA vs 270 K in the USSA). Warfield (1947) acknowledged the limitations of the indirect inferences used in constructing this standard atmosphere and called out the need for in situ measurements to confirm the inferred temperature profile: *"In the absence of direct data, such as might be obtained by soundings with high-altitude rockets, the values adopted are based upon existing information obtained by indirect measurements of certain quantities. As a consequence, the tables are only tentative."*

Insights from in situ observations

The first platforms allowing for in situ sounding of the atmosphere in the upper stratosphere and mesosphere were the V-2 rockets assembled in the USA from captured German components and used in a multiyear campaign of launches from the White Sands Proving Ground in the US state of New Mexico. Launches of 67 V-2s at White Sands were attempted during 1946-1952. The first successful launch took place on May 10, 1946, reaching an altitude of 112 km (Eidenbach, 1997). A launch on October 24, 1946 was notable for returning the first photographs of the earth from nearly 100 km altitude. Following this launch, in situ pressure information (returned via telemetry), along with radar observations of the altitude and speed of the rocket, were analyzed to produce an estimate of the air pressure as a function of altitude up to nearly 100 km (Best *et al.*, 1946). Best *et al.* (1946) did not convert their pressure as a function of altitude relation into actual air temperature estimates but they did note that their data appeared consistent with temperature decreasing with height in the 60-80 km range. By the time of a March 7, 1947 launch the method of determining the in situ pressure was refined enough that Best *et al.* (1947) used the data collected as the basis for a published temperature profile (reproduced here in Figure 13).

Best *et al.* noted some factors affecting their determination (notably uncertainty in the rocket velocity derived from radar data) limited the precision of the temperature estimates. They estimated the probable error of the temperature determination in the 50-60 km range as 25°C. As seen in Figure 13 the rocket-derived profile has a stratopause temperature about 30°C lower than the NACA standard atmosphere, but is still about 50°C higher than the modern standard atmosphere would indicate. The lower stratopause temperatures from these (and subsequent) rocket observations ruled out the Kelvin/Pekeris resonance theory of the prominent solar semidiurnal tide (Chapman and Lindzen, 1970). Soon researchers proposed competing systems of nomenclature for the now clearly established regions above the tropopause (Chapman, 1950; Flohn and Penndorf, 1950).

In the subsequent decades new meteorological rocket platforms would be developed along with better methods of in situ observation of air temperature (*e.g.* Chapter 2 of Webb, 1966) and our knowledge of the climatological temperature structure of the upper stratosphere and mesosphere would be refined. Observations of the wind in the upper stratosphere and mesosphere would reveal the seasonally-reversing pole-to-pole circulation that has been called “earth’s grandest monsoon” (Webb *et al.*,1966). However, the Best *et al.* (1947) results represent a final confirmation of the existence of the stratopause, mesosphere and mesopause. In contrast to the discovery of the tropopause - which was announced nearly simultaneously by Teisserenc de Bort and Assmann in 1902 - the discovery of the stratopause and mesosphere unfolded over a quarter-century, a period bookended by the investigations of Lindemann and Dobson (1923) and Best et al. (1947).

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