SPARC

Stratosphere-troposphere Processes And their Role in Climate

Newsletter n° 61
July 2023

www.sparc-climate.org

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After 30 years of SPARC the future of this great comunity core Project by WCRP is pointing into a new direction. Multiple changes are underway, desingning a new way forward. In this issue you will read about the progress of implementing the new SPARC strategy on page 2 and some other changes while the great work of the comunity is ongoing. This Issue will also be the last one publisched by the SPARC Office hosted at DLR, Germany. It's been a pleasure to work with you. Thank You!

Contents

WCRP World Climate Research Programme
World Meteorological Organization
United Nations Educational, Scientific and Cultural Organization
Intergovernmental Oceanographic Commission
International Science Council

New Implementation plan for SPARC – Update

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In January 2023, the SPARC SSG gathered online to discuss a few topics regarding the project's future. In a 3-hour discussion, the co-chairs updated the SSG members on the details of the new SPARC strategy and implementation plan, which was presented to the WCRP Joint Scientific Committee (JSC) for approval during this year's JSC meeting in May. This plan was discussed in more detail to prepare the establishing of the new groups and panels that are intended to facilitate inter-activity collaborations as well as strategic support with outreach activities, partnerships with groups outside of SPARC, and coordinating work towards assessments and reports.

New groups and panels to serve SPARC science

Following the discussions with the SSG in January, and a series of phone calls with those SSG members interested in taking a lead in each of the panels, another series of telecons was held together with the SPARC community – represented by the Activity leads – to discuss the purpose of each group, and find out how they should be implemented to best serve their purpose towards the SSG and the SPARC community.

The telecons were held in early May, and were attended by nearly all SSG members and activity leads, forming a strong basis to form useful structures for the SPARC community. In all those discussions it was explained, that there will not be a new layer of bureaucracy, but rather a new forum to facilitate communications between SPARC activities. At the same time, the new groups and panels are ways for the SSG members to further engage with the SPARC community, and aid the co-chairs in their strategic decisions towards new science initiatives, collaborations, and SPARC contributions to major reports and assessments.

The groups that most directly affect SPARC activities are the new **Activity Collaboration Groups** (**ACGs**). There will be three such groups, focussing on atmospheric composition, on variability and trends, and on dynamics. As with SPARC's current themes, there will be overlap between the groups, and many SPARC activities will associate themselves with more than one of these groups. Already established collaborations between SPARC activities will be maintained in the way they were before, and new ones can be established directly between the activities or through the help of the ACGs. However, any ongoing collaborations should be made known to the ACG leads. ACGs will focus on science, and are intended to be a tool to bring in expertise from other SPARC activities, where needed. ACGs may also spark new activities or **Limited-Term Cross-Activity Focused Projects** (**LTCFs**). The format of communication will be very informal, and meetings will be held 3-4 times a year, perhaps with a focussed science topic. All meetings are always open to any interested SPARC activitiesy – they may choose themselves, whether the topic is of interest to them or not, and who they choose to send as a representative. There might be collaborative meetings organised by multiple ACGs where appropriate.

There will be written Terms of Reference, in which the role of permanent panel members will be defined, and the purpose of the groups will be written down. During the telecons and discussions it was agreed that the number of permanent panel members should be small, but in all ACGs there will be one dedicated panel seat reserved for an ECR (to be nominated by the SPARC activities and appointed by the SPARC SSG).

The remaining panels are of more strategic nature. All SPARC activities are welcome to contribute, and there will be calls for input to the SPARC community.

There will be also three advirosry panels; partnership advisory panel, assessment coordination panel, and outreach advisory panel. The a **Partnership Advisory Panel** will be informed about ongoing and possible new collaborations. Thise panel will exclusively support SPARC's connections to projects outside of SPARC (the ACGs will take care of internal collaborations). It will not be approving partnerships, but improve, help establishing, and keep track of existing partnerships and help maintaining and strengthening those where wanted and needed, and act as a contact point for other groups.

The mode of operation still needs to be determined, but the general idea is to have targeted discussions and invite the SPARC representatives in other WCRP groups. When appropriate, the panel will invite people from outside of SPARC. During the kick-off telecons, everyone agreed, that telecons may not be the only/most efficient way to share information, but rather exploring the possibility to create a central point to collect information and feedback with the help of the IPO.

To start off the panel's work, it will start with finding and efficient way to collect and keep track of reports from liaisons to partner projects. They would like to hold a census to identify SPARC members, who are already part of non-SPARC groups, and find out if and how those could feed back to SPARC. The panel will be involved in starting off new projects and identifying groups to include or collaborate with in connection with priority areas identified by the SPARC SSG. This could potentially include the upcoming collaborations with the WCRP Explaining and Predicting Earth System Changes Light House, connections to CLIVAR, or potential new activities on Rossby waves that could lead to collaboration with, *e.g.*, the storm-track community.

The main purpose of the **Assessment Coordination Panel** will be assisting SPARC activities in working towards larger assessments and reports, by keeping track of deadlines and coordinating the necessary science output. The panel should be able to give advice to activities when/where to place their output more strategically and to make sure data is available on time so analysis can be done and published in time for assessment deadlines (*e.g.*, forcing data sets for Ozone, solar forcing, *etc.*).

The panel's work will also be important to make contributions visible towards WCRP and other sponsors. This includes identifying existing works towards assessments already being done by SPARC activities or individual scientists.

Participants agreed that the discussions during the second kick-off telecon already felt like a proper panel meeting. A mode of operation for this panel will include having an open meeting at least once a year. The panel will also work to stay in touch with those involved in the main assessments and reports, such as IPCC, GAW, BAMS, WCRP, Ozone Assessment, and other regular updates to stay informed of upcoming tasks, timelines, and required scientific input. This information will be made available to SPARC activities with the help of the IPO.

Discussions on how to set up the **Outreach Advisory Panel** were centered around three main areas this panel will oversee:

1. Data repositories: Keeping track of SPARC data sets and where they are stored and how they can be accessed, as well as maintaining the collaboration with CEDA.

2. Public outreach: Supporting/Informing IPO on website content, blogging, web collections, presentations, including possibly creating a deck of overview slides to introduce and highlight SPARC science.

3. Capacity building: Picking up and maintaining SPARC efforts to support ECRs.

This panel will work to support any efforts of SPARC activities to organize ECR events, while working on their own projects such as webinar series or summer school organization. It is also a goal of the panel to work towards better connecting SPARC with the Global South science community. The discussions already spawned a number of ideas what SPARC can do to better support ECRs in various ways. **Moha Diallo** volunteered to use the upcoming WCRP Open Science Conference to connect to the YESS network and potentially organise a workshop in conjunction with the conference in Kigali. He also informed the panel about his efforts to organise a workshop/ lecture series with the University of Dhakar. Africa, next year. He will stay involved and contribute to the work of the panel.

A new name for SPARC!

Connected to the new SPARC strategy and implementation plan, the SSG also discussed the project's name. Since the General Assembly, SPARC received 53 entries to the google sheet with suggestions for the new name. Next to 15 entries asking to keep the name, or make only slight changes (*e.g.,*. SPARC+, SPARC 2, SPARCC), the majority of submissions did make suggestions for new project names.

Some of those suggestions still resembled the well-known name of the project, and in the discussions among SSG members, it became clear, that the choice for the SPARC SSG was to be made between updating the old acronym with something meaningful, or changing the project name to **APARC** (**Atmospheric Processes and their Role in Climate**), which resembles the original acronym, while still being new.

The group agreed that having "Processes" as part of the acronym is important, as well as reflecting that the project is about the whole atmosphere. Hence avoiding naming specific parts of the atmosphere (as in the old acronym; so far), the final vote was clear to move to a new era of the project now called APARC. Everyone agreed, that the community will stick together, no matter what they are called, but for new people coming in, the new acronym should signal that APARC is not solely about stratospheric (and tropospheric) processes anymore, but take a look at the whole atmosphere. It is time for a new generation of scientists to make this project their own, and bring in new ideas and topics to tackle together with this well-established community.

The name will be implemented starting on 1 January, 2024, when the new SPARC Office will take over from the one in Oberpfaffenhofen. In the most-recent SSG meeting in Oberpfaffenhofen, the SSG decided that they are aiming at planning some events during the 2024 EGU in Vienna to introduce the new name. Sessions connected to SPARC/ APARC may be submitted using the new acronym already. Additionally, ideas for promoting the new name include another webinar series, a short video, and other forms of public outreach.

SSG Membership and JSC liasons

Finally, during the meeting four new SSG members, Qiang Fu (Univ. Washington, USA), Marc von Hobe (FZ Jülich, Germany), Martin Jucker (Univ. New South Wales, AUS), and Yaga Richter (NCAR; USA) were welcomed to the committee. The four new members fill seats left vacant by leaving SSG members Gufran Beig, Harry Hendon, Michael Prather, and Don Wuebbeles.

There is also a change in SPARC's connection to the WCRP JSC with Tom Peter rotating off, SPARC has been looking for a new liaison to work together with Tercio Ambrizzi (who stays on, and continues to support SPARC). SPARC has found this new liaison in Christiana Stan, who volunteered for this role. We thank both of them for their engagement, and look forward to working together closely throughout the transition time that lies ahead of (A)SPARC with the move to a new IPO, its name change, implementation of new structures, and a new generation of scientists taking on leadership roles in the project.

Personal reflections on the outlook for SPARC

SPARC is beginning an exciting new era. As briefly reported in this issue, SPARC will be renamed to APARC, which stands for Atmospheric Processes And their Role in Climate, from January 2024, coinciding with the launch of new SPARC International Project Office (IPO). This change is not just a rebranding. It comes with a new strategy and implementation plan that was approved by the WCRP Joint Scientific Committee in May this year. More information on the launch of APARC will be shared in conjunction with the new IPO.

Since its establishment in 1992, SPARC has coordinated cutting-edge research activities in atmospheric dynamics and predictability, chemistry and climate, and long-term records for climate understanding. These activities have contributed to a better understanding of the dynamical, chemical, and physical processes in the atmosphere and their interactions with climate change. Building on these accomplishments, SPARC has introduced a new structure and implementation plan. As outlined in the January issue and updated in this issue, the new structure features three thematic Activity Collaboration Groups (ACGs) alongside three Engagement Panels focusing on external impact. These structural changes were further discussed at the SPARC SSG meeting held in July at Oberpfaffenhofen, Germany. It became clearer that the SPARC community needs more active and regular communication channels through the ACGs. The SPARC SSG also agreed to strengthen partnerships within and beyond the WCRP, and to promote ECR activities in the Global South.

Through ACG discussions, a new Limited-Term Cross-Activity Focused (LTCF) project on the Hunga Tonga eruption has already been initiated (see the January issue). Another LTCF project, addressing halogenated very short-lived substances (VSLS), was approved at the July SSG meeting. Plans to produce new SPARC science on attribution of climate change and extremes using the Large Ensemble Single Forcing Model Intercomparison Project (LESFMIP) dataset was also approved as an emerging LTCF project. These projects tackle atmospheric processes not only in the middle atmosphere but also in the troposphere, in line with the new SPARC strategy. They will be achieved through close collaboration with current SPARC activities, spanning observations, modelling and process studies. We look forward to receiving further proposals encompassing ongoing SPARC activities.

We are pleased to announce that the new SPARC (APARC in 2024) IPO will be hosted by Forschungszentrum Jülich (FZJ), Germany, with the transition starting later this year. FZJ is highly recognized for its excellence in atmospheric and climate research. With strong support from FZJ, the IPO will support the implementation of the new SPARC structure, coordinate SPARC activities, and promote capacity building. We expect a smooth transition from the current office in Oberpfaffenhofen to Jülich. During this transition period, multiple SPARC workshops are planned, offering an opportunity for engagement and feedback on SPARC's direction. We hope to see many of you there.

SPARC co-chairs
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The Changing-Atmosphere Infra-Red Tomography Explorer (CAIRT)

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Introduction of the Project

The Changing-Atmosphere Infra-Red Tomography Explorer CAIRT (www.cairt.eu) is currently one of four candidate missions for the European Space Agency (ESA) Earth Explorer 11 (EE11) satellite. If ultimately successful in the selection process, CAIRT would be launched in the 2031-2032 timeframe. The overarching science goal of CAIRT is to reveal, resolve and unravel the complex coupling between circulation and composition in our middle atmosphere, and the links with regional climate change (see Figure 1). CAIRT will thus provide important and novel observations throughout a large depth of the Earth atmosphere, at high spatial resolution, and should therefore be of great interest to the SPARC community.

The CAIRT mission has a heritage in previous very successful limb sounders but it will be the first such space instrument with imaging Fourier-transform infrared technology. Thus, it will provide 3-D observations at unprecedented resolution (~50 km horizontally) from such a platform. By observing the atmosphere simultaneously from the mid-troposphere to the lower thermosphere (about 5 to 115 km altitude), CAIRT will provide global observations of ozone, temperature, water vapour, along with key halogen, nitrogen and sulfur compounds, as well as aerosols. It will therefore also fill an impending gap in the data record in the profiles of many atmospheric constituents during a time of rapid climate change.

Science Aims and Links to SPARC

To achieve the desired step change in our understanding of the coupling of atmospheric circulation, composition and regional climate change, CAIRT will address the following five main science objectives:

1. Diagnose the atmospheric circulation between the upper troposphere and the lower thermosphere through observations of temperature, long-lived trace gases and derived age-of-air, from the global scale down to spatial scales associated with mixing and exchange processes.

2. Quantify the gravity wave driving of the middle atmosphere circulation, by resolving gravity waves with 100-1000 km horizontal wavelength and characterizing their sources, propagation, and dissipation from the lower stratosphere into the mesosphere.

3. Investigate upper atmospheric coupling and regional surface climate variability associated with transient solar events and space weather through the downward flux of NO_x from the thermosphere and its impacts on stratospheric ozone.

4. Quantify lower atmospheric coupling associated with the lofting or injection of natural and anthropogenic plumes of pollutants and aerosol precursors into the upper troposphere and stratosphere (UTS), their impacts on UTS composition and their crucial role for climate forcing and feedbacks.

5. Attribute changes in UTS ozone, water vapour, and broader composition to changes in circulation, chemistry, and stratosphere-troposphere exchange.

These scientific objectives clearly have a strong overlap with SPARC science, in particular in the areas of Chemistry and Climate and Atmospheric Dynamics and Predictability. CAIRT will also lead to a range of applications for data exploitation and synergy with other missions and disciplines. These will include:

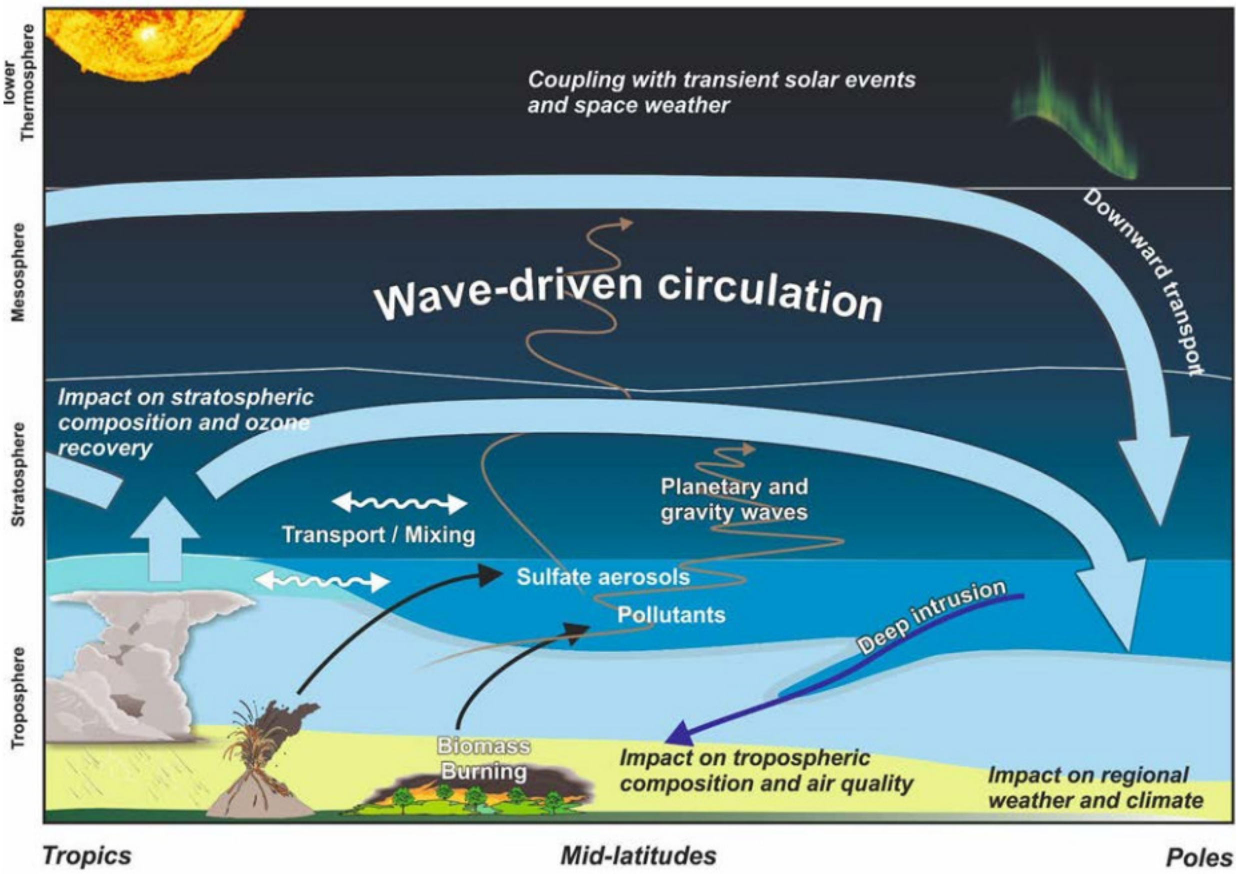

Figure 1: *Schematic of the middle atmosphere science issues that data from CAIRT will address.*

- Improve the retrieval of height-resolved and total column trace gases in the troposphere from nadir-observing systems through synergistic data fusion approaches and better quantification of trace gas amounts throughout the middle atmosphere.

- Contribute to the understanding of the impacts of UTS aerosol-water-ice cloud processes on the outgoing longwave radiation, in conjunction with spectrally resolved radiance measurements across the infra-red spectrum from nadir-observing systems along the same flight-track.

- Support numerical weather, air quality, and space weather forecasting, as well as climate re-analyses through assimilation of limb data (radiances, temperature, and relevant chemical trace species) from the stratosphere to the lower thermosphere.

- Contribute to the representation, evaluation and validation of parameterized and resolved processes (e.g., gravity wave drag, chemistry schemes, source/production terms, advection schemes, transport) in General Circulation, Chemistry-Transport and Chemistry-Climate Models.

Technology, Heritage and Airborne Demonstrator

CAIRT will be the first limb-sounder with imaging Fourier-transform infrared technology in space. CAIRT will measure limb radiances from 5 to 115 km altitude with a nominal horizontal sampling of about 50 by 50 km (and subsampling for selected science targets) and a vertical sampling of about 1 km. The wavelength range will cover 720 cm^{-1} to 2200 cm^{-1} (4.5 µm to 14 µm) with a spectral resolution of 0.2 cm^{-1}. With an across-track coverage of 400 km, near-global coverage is achieved within about two to three days. Tomographic retrievals will provide temperature and trace gas profiles at a much higher horizontal resolution and coverage than achieved from space so far, enabling us to address new science questions. Flying in loose formation with the Meteorological Operational Satellite - Second Generation (MetOp-SG) will enable combined retrievals with observations by the Infrared Atmospheric Sounding Interferometer - New Generation (IASI-NG), as well as from the other nadir sounders, resulting in consistent atmospheric profile information from the surface to the lower thermosphere.

The CAIRT concept has benefitted from many successful flights of the aircraft demonstrator Gimballed

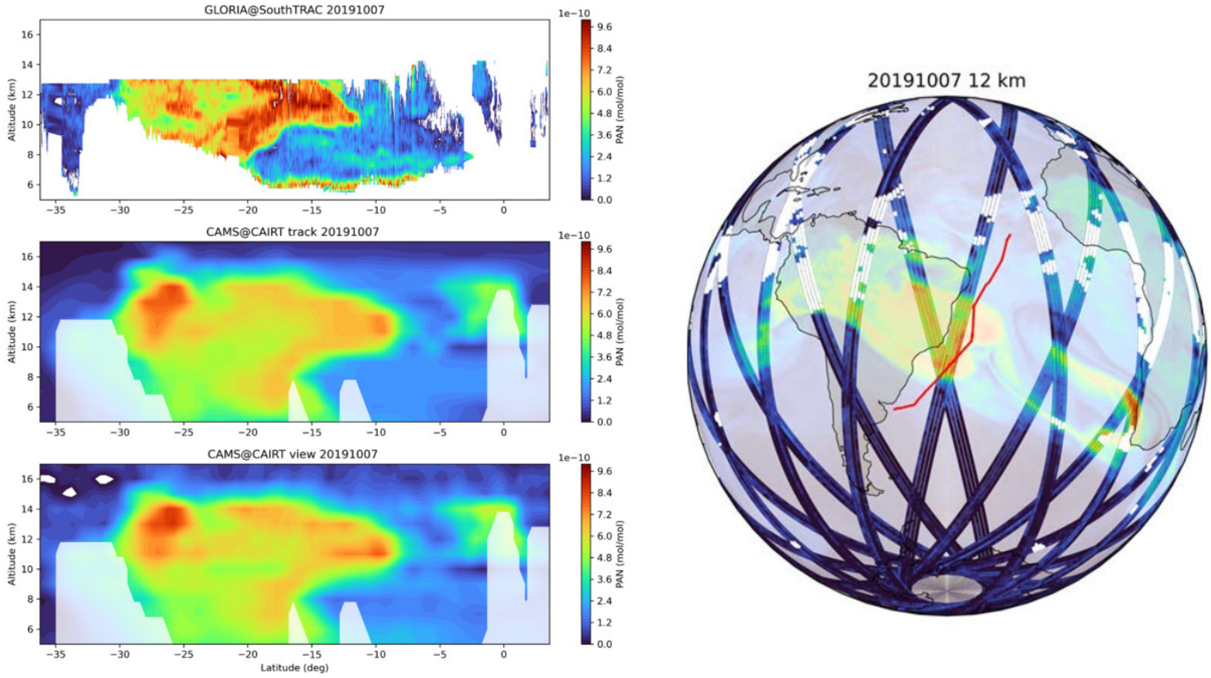

Figure 2: *Comparison of GLORIA observations of peroxyacetyl nitrate (PAN) during the SouthTRAC campaign on 7 October 2019 (upper left panel) to interpolated CAMS simulation (middle left) and expected performance of CAIRT (incl. noise and systematic errors, bottom left). The right panel shows the CAMS simulation at 12 km in the background with the SouthTRAC flight track in red and indicated CAIRT retrievals of one day. White symbols indicate high clouds where no CAIRT data is available. Adapted from Johansson et al. (2022).*

Limb Observer for Radiance Imaging of the Atmosphere (GLORIA, https://gloria.helmholtz.de/). GLORIA (Friedl-Vallon *et al.*, 2014; Riese *et al.*, 2014) is a unique atmospheric remote sensing instrument that bridges the gap from scanning to imaging in the infrared spectral domain and combines a classical Fourier transform spectrometer (FTS) with a tailored 2-D detector array. The instrument is a joint development of the Karlsruhe Institute of Technology (KIT) and Research Centre Jülich (FZJ) and builds upon the heritage of those institutes in developing and operating IR limb sounders (CRISTA, MIPAS). Imaging allows the spatial sampling to be improved by up to an order of magnitude when compared to state-of-the-art limb scanning instruments. GLORIA is designed to operate on various high altitude research platforms (aircraft and stratospheric balloons).

Figure 2 (top left panel) shows, for example, GLORIA results for peroxyacetyl nitrate (PAN) from the SouthTRAC (Transport and Composition in the Southern Hemisphere Upper Troposphere/Lower Stratosphere) campaign with the German High Altitude and Long Range Research Aircraft (HALO). Johansson *et al.* (2022) compared these GLORIA measurements of PAN along with vertical cross-sections of further pollution tracers ethane (C_2H_6), formic acid (HCOOH), methanol (CH_3OH), and ethylene (C_2H_4) with model data from the Copernicus Atmosphere Monitoring Service (CAMS). These comparisons revealed a good model performance for PAN, but large discrepancies for the other species. As shown in the bottom left panel of Figure 2, CAIRT will have the capability to

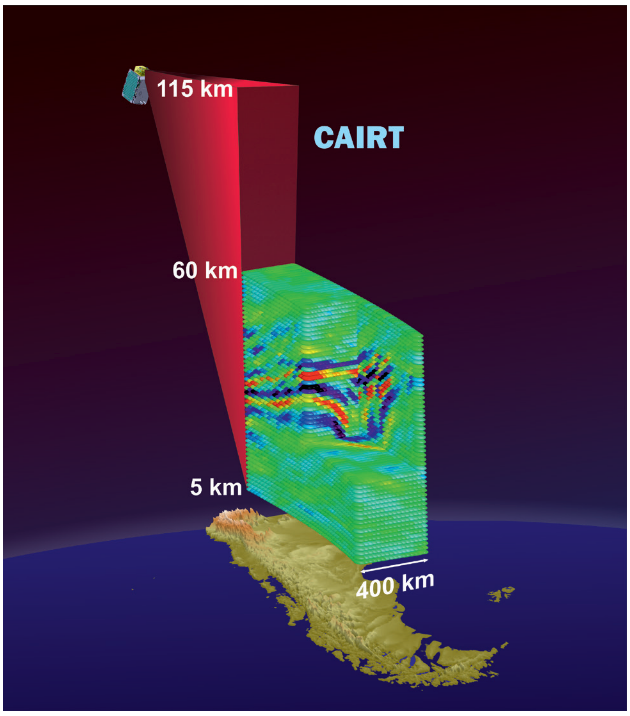

Figure 3: *High resolution temperature structure expected from CAIRT. Example showing a gravity wave formed by flow over the Andes, from ECMWF data. The high resolution CAIRT observations will enable the retrieval of gravity wave momentum flux, direction and drag.*

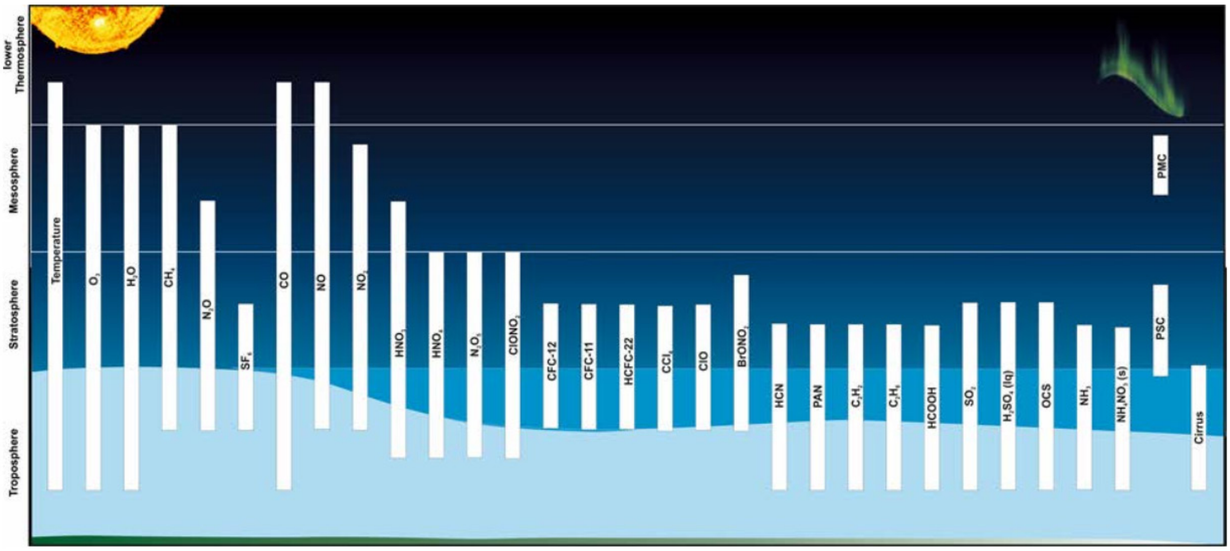

Figure 4: *Altitude range of CAIRT primary and secondary targets.*

deliver a similar performance to derive those trace species in the upper troposphere on a global scale and, hence, provide an essential basis to understand processes and improve models at altitudes important to Earth's radiative budget in an environment affected by increasing influence from, for example, enhanced wild fires.

Figure 3 provides an example of high resolution measurements of temperature fluctuations expected from CAIRT and shows a case study of gravity waves generated by flow over the Andes. The wave fronts are leaning towards the ocean and demonstrate oblique propagation. The case was studied in detail using GLORIA 3D tomography and temperature observations from the ALIMA lidar instrument (Krasuaskas *et al.*, 2023).

Data Products

Figure 4 gives a summary of primary and secondary target species for CAIRT with their approximate height range. Temperature observations at a spatial resolution of about 25×50×1 km will enable the retrieval of gravity wave momentum flux, direction and drag. A range of long-lived tracers with different lifetimes will provide diagnostics of age-of-air and circulation over a large altitude range. CAIRT will provide a near complete budget of nitrogen compounds in the middle atmosphere, enabling the flux of nitrogen compounds from the thermosphere down into the stratosphere to be derived. Together with key halogen species this will provide essential information to attribute changes in stratospheric ozone due to changes in chemistry and transport. Essentially a complete budget of sulfur in the stratosphere can be derived from observations of sulfur dioxide (SO_2), sulfate aerosols (H_2SO_4) and carbonyl sulfide (COS). As a secondary target, CAIRT will provide also information on cirrus clouds, polar stratospheric clouds and polar mesospheric clouds. Near real time data of selected primary species are foreseen for assimilation in operational systems.

Next Steps

The CAIRT Science Team are currently preparing documents for the next stage of the ESA EE11 selection process. Following an open User Consultation Meeting (UCM) in Bucharest on **October 10th-11th 2023,** ESA will select up to two of the current four candidate missions to continue to the next stage of investigation and planning. All interested members of the SPARC community are encouraged to attend the User Consultation Meeting in October. If you would like more information about CAIRT please contact one of the coauthors, email Martyn Chipperfield or visit our web page (www.cairt.eu).

References

Friedl-Vallon, F., T. Gulde, F. Hase, A. Kleinert, et al.: Instrument concept of the imaging Fourier transform spectrometer GLORIA, *Atmos. Meas. Tech.*, 7, 3565-3577, https://doi.org/10.5194/amt-7-3565-2014, 2014.

Johansson, S., Wetzel, G., Friedl-Vallon, F., Glatthor, *et al.*: Biomass burning pollution in the South Atlantic upper troposphere: GLORIA trace gas observations and evaluation of the CAMS model, *Atmos. Chem. Phys.*, 22, 3675–3691, https://doi.org/10.5194/acp-22-3675-2022, 2022.

Krasauskas, L., Kaifler, B., Rhode, S., Ungermann, J., *et al.*: Oblique propagation and refraction of gravity waves over the Andes observed by GLORIA and ALIMA during the SouthTRAC campaign, J. *Geophys. Res.*, e2022JD037798, https://doi.org/10.1029/2022JD037798, 2023.

Riese, M., Oelhaf, H., Preusse, P., Blank, J., Ern, M., *et al.*: Gimballed Limb Observer for Radiance Imaging of the Atmosphere (GLORIA) scientific objectives, *Atmos. Meas. Tech.,* 7, 1915–1928, https://doi.org/10.5194/amt-7-1915-2014, 2014.

Documenting the Impacts of Climate Change on the Middle and Upper Atmosphere and Atmospheric Drag of Space Objects

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Dates:
9-13 January 2023

Team Leaders:
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Meeting venue:
International Space Science Institute Bern

Number Of Participants: 17

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Sponsors:

International Space Science Institute

Report from the ISSI TEAM 544

Over recent decades, increasing concentrations of greenhouse gases have affected the Earth's radiative balance, leading to a pronounced cooling of the middle and upper atmosphere. Consequently, these layers of the atmosphere have contracted, a result predicted years ago, but only recently quantified for the stratosphere (Pisoft *et al.*, 2021), mesosphere and lower thermosphere (Mlynczak *et al.*, 2022). This contraction of the upper atmosphere has seen a downward shift of the height of pressure levels, and decreasing density at fixed altitudes has been observed (Lübken *et al.*, 2013; Stober *et al.*, 2014; Emmert, 2015; Solomon *et al.*, 2018). As model projections for the 21st century indicate a continuation of these trends if anthropogenic greenhouse gas (GHG) emission trajectories are not reversed, a detailed understanding and quantification of middle and upper atmosphere changes will be needed. The effects of this atmospheric contraction will reach altitudes of low Earth orbit (LEO) and is thought to impact satellite trajectories, orbital lifetimes, and retrievals from satellite remote sounding (Schrøder *et al.*, 2007, Shine *et al.*, 2008). The propagation of radio waves and the performance of space-based navigational systems (*e.g.*, GPS (Lastovicka *et al.*, 2006)) can also be affected via indirect effects on ionospheric electron density. To address some of the gaps in our understanding of these processes, the ISSI Team 544 - Impacts of Climate Change on the Middle and Upper Atmosphere and Atmospheric Drag of Space Objects - held for the first time a hybrid meeting at the ISSI Headquarters in Bern, Switzerland (9-13 January 2023). The team of 17 scientists in attendance had expertise on satellite observations; climate and whole atmosphere modelling; reanalyses; long-term changes in the vertical structure of the middle and upper atmosphere and ionosphere; changes of satellite drag, and impacts on satellite trajectories and debris. Discussions at the meeting are summarised in this report.

Discussion on the Impacts of Increasing CO_2 and other drivers

Fundamentals of the increasing GHG effects on the middle and upper atmosphere are well understood. From the stratosphere to the lower thermosphere, the growing CO_2 concentrations enhance the optical thickness and emissivity of the atmosphere, jointly resulting in radiative cooling (Goessling and Bathiany, 2016). Except for its lower part, the thermosphere is not affected directly by changes in CO_2 because there is very little CO_2 above about 150 km. Instead, the thermosphere exchanges energy by molecular diffusion (i.e. heat conduction) with the radiatively cooling lower layers; the energy is then radiated by CO_2 and NO (the 'heat sink' region; Mlynczak *et al.*, 2018), particularly in the lower thermosphere. Subsequently, the middle and upper atmosphere react to changes in GHG concentrations very quickly, on the order of days (Mlynczak *et al.*, 2022). Due to this cooling, the affected layers contract and therefore change the vertical structure of the middle and upper atmosphere (the geopotential height of constant-pressure levels decreases). The relation between cooling and vertical structure changes on a global scale can be described by the hypsometric equation with good precision.

The atmospheric contraction starts in the stratosphere, but its effects are cumulative with increased height, producing a pronounced downward shift of the thermosphere. Hence, in the thermosphere we can observe also the strongest effects. In the LEO region the density trend driven by the contraction is around ~4 % per decade, depending on solar activity variations (due to changes in UV heating), superimposed on the secular cooling due to increasing GHGs. However strong the GHG induced trends in the middle and upper atmosphere are, they cannot be detected on time-scales shorter than the solar cycle, which is the dominant driver of multiannual natural variability of temperature and density in the middle and upper atmosphere. Also, geomagnetic disturbances play a significant role and secular variations in Earth's main magnetic field can also contribute to trends in the ionosphere and thermosphere (Cnossen, 2022). Besides this, the team discussed the role of internal gravity waves that are a major dynamical driver (inducing density fluctuations and mixing) and source of uncertainty in this region. Ozone depleting substances (ODSs) are considered to be an important driver of trends in the lower stratosphere (Polvani *et al.*, 2018), but for the contraction of the middle and upper atmosphere in a global mean sense their effects are most likely negligible , because their mixing ratio decreases rapidly with altitude as they are photolyzed.

Discussion on the Observational Gaps

Observations of the neutral atmosphere at the stratopause level and above are made possible using three primary platforms: satellite observations, satellite drag through orbit tracking and ground based measurements, including rocketsondes, ionospheric radars and lidars. Given the difficulties for long-term trend detection in the middle and upper atmosphere, a major point of team discussion was the critical requirement for stability, quality and length of record, which holds for all observational datasets. For satellite observations, various historical datasets exist and there is an activity within the team to produce a merged temperature dataset from satellite observations similarly to ozone datasets (Sofieva *et al.*, 2017; 2021). Reflecting the recent loss of ICON (NASA, 2022a), the decommissioning of AIM (NASA, 2023), and the pending decomissioning of the Aura satellite (NASA, 2022b), the team identified the exceptional importance of continuing routine operation of the SABER instrument in view of the looming observational gap, which can render impossible any trend detection based on satellite observations in the future (Loeb *et al.*, 2009; Weatherhead, 2017). SABER is currently operating nominally with no degradation in performance over its 21-plus year lifetime. Its calibration has proven to be remarkably stable (Mlynczak *et al.*, 2020). SABER is currently in the NASA Senior Review process as part of the TIMED mission and anticipates approval for an additional three years of operations (through September 2026). The TIMED satellite carrying SABER is not expected to deorbit for ~ 50 years. The team appeals to international space agencies to address the need for continuity of observations as part of their regular program planning and to focus part of their portfolios on long-term, dedicated observations.

Since at least the 1970's some stratospheric lidars have been conducting upper atmosphere density observations from 30 to 80-90 *km*. The Network for the Detection of Atmospheric Composition Change (NDACC) maintains a public data repository of several of those lidar datasets located at different latitudes; at least five of those records span 25 or more years. Lidars have already provided evidence of middle atmosphere cooling and are a useful tool to validate satellite measurements of atmospheric density (Wing *et al.*, 2018).

Figure 5: *Participants of the ISSI TEAM meeting at International Space Science Institute Bern.*

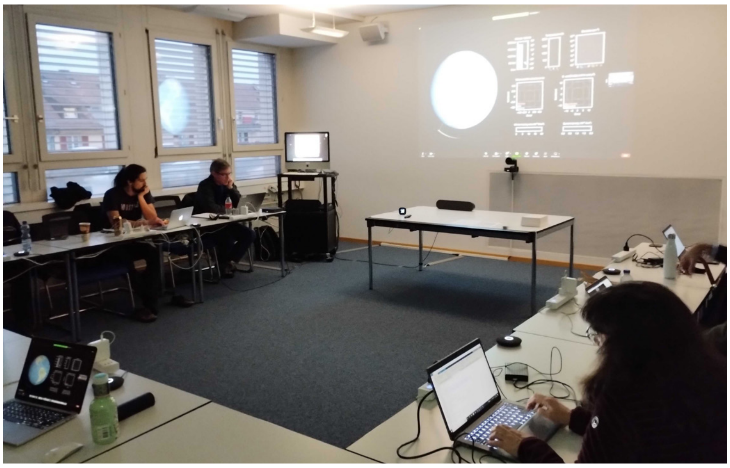

Figure 6: *Discussion at the workshop.*

Ionospheric radars are an effective tool for sensing the thermospheric temperature at altitudes between 100 and 250 km. Above 250 km, these radar data are also useful for gauging upper thermospheric trends (Zhang *et al.*, 2016). Rocketsonde data (SPARC, 2023) provided original evidence for the cooling of the upper stratosphere and lower mesosphere (Dunkerton *et al.*, 1998), with additional rocket soundings hosted by the World Ozone and Ultraviolet Radiation Data Centre (WOUDC) and the Research Data Archive-NCAR (WOUDC, 2023; RDA-NCAR, 2023). However, rocketsonde data suffer from limitations such as insufficient spatio-temporal coverage or lack of metadata (*e.g.,* precise information on the latitude and longitude of the launch sites). Also, a significant fraction of rocketsonde data in some countries is not included in the repositories. Ongoing activities also within the team are attempting to update the database by adding existing rocketsonde data available in other countries and to recover historical measurements (including lidar). For all this, international collaboration is critical, as many measurements are owned by a few countries and not publicly available. Regarding rocketsonde and lidar, there was some discussion about their suitability for performing studies on trends, and if it would be necessary or convenient to improve the network for these kinds of observations. It is agreed that they provide relevant information and that they should be used; however, it is not perceived as a priority to promote more launches with improved regional coverage at the moment, at least for the research purposes deemed necessary within the framework of this team.

Further, the team discussed observations of satellite drag by active or passive tracking systems as well as by satellites equipped with accelerometers. The scientific use of the data for the analysis of long-term trends is made difficult by uncertainties in the data and data processing since the measurement systems were not designed for this purpose. However, the team encourages a two-way transfer of knowledge with satellite operators and solicits the transfer of information from commercial satellite operators for scientific use.

Additional discussion centered around what chemical species need to be measured to monitor all the relevant changes at upper levels. Carbon dioxide, ozone, methane, atomic oxygen, water vapour, NO_x and aluminium were singled out as potentially relevant. Particularly for aluminium, its atmospheric abundance (and subsequent deposition) could increase substantially because of the re-entry of satellites and their debris following launches. Uneven vertical coverage of observations throughout the middle and upper atmosphere was another issue discussed. The team deems it necessary to perform a systematic study connecting the time-span of observations with the vertical levels observed to identify potential existing or emerging gaps. Full vertical coverage is desirable, as the effects of climate change can depend on the level for fixed geometric altitudes, being sometimes of opposite sign.

Discussion on Debris

Satellites continue to be launched into LEO, with the launch rate significantly increasing due to the building of mega-constellations such as Starlink and OneWeb (ESA, 2022). Most active LEO satellites attempt to meet the Inter-Agency Space Debris Coordination Committee (IADC) guideline to de-orbit within 25-years to limit the build up of space debris (UNOOSA, 2007). However, the amount of traceable debris continues to increase over time, and are mostly made up of inactive satellites and rocket bodies, but can arise from accidental collisions and deliberate anti-satellite (ASAT) tests. There are active debris removal demonstration missions, such as Astroscale's ELSA-d (Blackerby et al, 2019). However, atmospheric drag remains the primary method of space debris removal.

The decreasing density trend caused by CO_2 results in longer orbital lifetimes in LEO, increasing the probability of space debris being involved in collisions. This creates a feedback loop with more debris causing more collisions. Although large uncertainties exist (*e.g.,* future ASAT tests or other black swan events), we have solid modelling evidence for the pronounced impact of the long-term changes of density on projections of debris (Brown *et al.*, 2021). The development of new constellations of satellites by private companies and how this satellite launch sector evolves over the coming years will determine how much the LEO is used. This will determine the size of the source of potential space debris, while understanding future atmospheric contraction will determine the size of the sink for removing these debris.

The decreasing neutral density trend also has implications for current satellite operators. Empirical atmospheric models such as NRLMSIS 2.1 or the COSPAR International Reference Atmosphere (CIRA) are used in operations to predict satellite trajectories, and the chances of conjunctions and collisions with other satellites. However these empirical models are based on climatological data which is decades old, and so these empirical models increasingly over-predict current neutral densities.

Operators targeting the 25-year guideline will see significantly lower neutral densities at the end-of-life of their satellites, and risk exceeding the guideline if operating at a close margin. However, licensing agencies are moving to impose more stringent rules on satellite operators, with the US Federal Communications Commission (FCC) requiring satellites below 2000 km altitude that are no longer operational to de-orbit within 5 years.

Outlook

The team considers it a priority to support and promote new and existing measurement capacities, mostly satellite instruments and missions. For example, the team supports making the most of the potential lifetime of SABER as it provides the only ongoing long-term measurements and new proposed satellite missions, such as CAIRT (Changing Atmosphere Infra-Red Tomography Explorer) a candidate mission for the European Space Agency Earth-Explorer 11. The proposed CAIRT is a global infrared limb-sounder, with very fine vertical and horizontal resolution. Science goals of CAIRT include the detection and characterisation of internal gravity waves in the stratosphere and mesosphere, alongside their role in circulation linked to upper-air composition and its sensitivity to both tropospheric variability and solar effects (*e.g.*, energetic electron precipitation processes). CAIRT would operate from the mid-troposphere to the lower thermosphere (5-115 km) and would be an ideal mission to better constrain the wave driven residual meridional-vertical circulation in the stratosphere-mesosphere-thermosphere, which is in large part driven by gravity waves. By better constraining the relative contributions of solar variability, small-scale dynamical processes and changes in atmospheric composition, CAIRT will be invaluable for attributing circulation and composition change in the upper atmosphere and first-order trends. Finally, as SABER has no inherent limit on its operational lifetime (*i.e.*, no finite expendables) and none of its systems have switched to their backups, it is conceivable that CAIRT and SABER could overlap if the anticipated 2031 launch date for CAIRT is met.

In addition, the team supports efforts to examine the open research questions mentioned, including inter-model differences in the simulation of impacts on upper levels. Also, it is important to communicate actively the science perspective on impacts of climate change in the middle and upper atmosphere and debris to the wider public and to satellite operators. Collaboration with the satellite operators in the private sector can be of great importance. Soliciting transfer of information for scientific use from commercial satellite operators is suggested as a possibility, and it is discussed if it could be requested to commercial operators on exchange of the use of space environment. Finally, specific scientific forums to discuss the questions here mentioned are being promoted, including debate and sessions in main scientific conferences, the future TRENDS 2024 Workshop, and highlighting the profile of this question in other relevant forums.

Acknowledgements

This team is supported by the International Space Science Institute (ISSI) in Bern, through the ISSI International Team project #544 (Impacts of climate change on the Middle and Upper Atmosphere and Atmospheric Drag of Space Objects).

References

Brown, M.K., H.G. Lewis, A.J. Kavanagh, and I. Cnossen, 2021: Future decreases in thermospheric neutral density in low Earth orbit due to carbon dioxide emissions, J. *Geophys. Res. Atmos.* 126, e2021JD034589.

Blackerby, C. et al., 2019: The ELSA-d end-of-life debris removal mission: Preparing for launch. *In Proceedings of the International Astronautical Congress, IAC* (Vol. 8).

Cnossen, I., 2022: A realistic projection of climate change in the upper atmosphere into the 21st century. *Geophys. Res. Lett.* 49, e2022GL100693. doi.org/10.1029/2022GL100693

Dunkerton, T.J., D.P. Delisi, and M.P. Baldwin, 1998: Middle atmosphere cooling trend in historical rocketsonde data. Geophsical Research Letters 25, 3371-3374. 10.1029/98GL02385

Emmert, J.T., 2015: Altitude and solar activity dependence of 1967–2005 thermospheric density trends derived from orbital drag, *J. Geophys. Res. Space Physics* 120, 2940–2950, 10.1002/2015JA021047.

ESA Space Debris Office: Annual Space Environment Report 2022, ESA_s_Space_Environment_Report_2022

Goessling, H.F., and S. Bathiany, 2016: Why CO2 cools the middle atmosphere – a consolidating model perspective, *Earth Syst. Dynam.*, 7, 697–715, doi.org/10.5194/esd-7-697-2016.

J. Laštovička et al. ,Global Change in the Upper Atmosphere.Science 314,1253-1254(2006).10.1126/science.1135134

Loeb, N.G., B.A. Wielicki, T. Wong, and P.A. Parker, 2009: Impact of data gaps on satellite broadband radiation records, *J. Geophys. Res.*, 114, D11109, doi:10.1029/2008JD011183.

Lübken, F.-J., U. Berger, and G. Baumgarten, 2013: Temperature trends in the midlatitude summer mesosphere, *J.Geophys.Res. Atmos.*118, 13, 347-13,360, 10.1002/2013JD020576.

Mlynczak, M.G. et al., 2018: Space-based sentinels for measurement of infrared cooling in the thermosphere for space weather nowcasting and forecasting. *Space Weather,* 16, 363– 375. doi.org/10.1002/2017SW001757

Mlynczak, M.G., et al., 2020: Radiometric stability of the SABER instrument. *Earth and Space Science*, 7, e2019EA001011. doi.org/10.1029/2019EA001011

Mlynczak, M.G. et al., 2022: Cooling and Contraction of the Mesosphere and Lower Thermosphere From 2002 to 2021, *J.Geophys. Res. Atmos.*, 127, e2022JD036767.

NASA planning document (2022b), aura.gsfc.nasa.gov/2022_RFI/AuraLifetimeSummary4HQ.pdf.

Official NASA statement (12/2022a), blogs.nasa.gov/icon/2022/12/07/icon-mission-out-of-contact/.

Official NASA Statement (03/2023). blogs.nasa.gov/sunspot/2023/03/16/nasas-aim-mission-ends-operational-support/

Pisoft, P. et al., 2021: Stratospheric contraction caused by increasing greenhouse gases, *Environ. Res. Lett.* 16, 064038 .

Polvani, L.M., et al., 2018:, Significant weakening of Brewer-Dobson circulation trends over the 21st century as a consequence of the Montreal Protocol. *Geophysical Research Letters* 45, 401–409, 10.1002/2017GL075345.

RDA-NCAR Rocketsoundings, (https://rda.ucar.edu/datasets/ds855.0/), DOI: 10.5065/VGWG-KM15, (last access 31 May 2023).

Schrøder, T.M., C.O. Ao, and M. de la Torre Juárez, 2007: Sensitivity of GPS occultation to the stratopause height, *J. Geophys. Res. Atmos.* 112, 10.1029/2006JD007330.

Shine, K.P., J.J. Barnett, and W.J. Randel, 2008: Temperature trends derived from Stratospheric Sounding Unit radiances: The effect of increasing CO2 on the weighting function, *Geophys. Res. Lett.* 35, 10.1002/2017GL075345.

Sofieva, V. F. et al., 2017 : Merged SAGE II, Ozone_cci and OMPS ozone profile dataset and evaluation of ozone trends in the stratosphere, *Atmos. Chem. Phys.,* 17, 12533–12552, doi.org/10.5194/acp-17-12533-2017.

Sofieva, V. F. et al., 2021,: Measurement report: regional trends of stratospheric ozone evaluated using the MErged GRIdded Dataset of Ozone Profiles (MEGRIDOP), *Atmos. Chem. Phys.*, 21, 6707–6720, doi.org/10.5194/acp-21-6707-2021.

Solomon, S.C. et al., 2018: Whole atmosphere simulation of anthropogenic climate change, *Geophys. Res. Lett.* 45, 1567–1576, 10.1002/2017GL076950.

SPARC Rocketsoundings, (sparc-climate.org/data-centre/ data-access/rocketsonde/) (last access 31 May 2023).

Stober, G., V. Matthias, P. Brown, and J. L. Chau, 2014: Neutral density variation from specular meteor echo observations spanning one solar cycle, *Geophys. Res. Lett.* 41, 6919– 6925, 10.1002/2014GL061273.

United Nations Office for Outer Space Affairs (UNOOSA): Inter-Agency Space Debris Coordination Committee (IADC) Space Debris Mitigation Guidelines, September 200

Weatherhead, E.C., et al., 2017: How long do satellites need to overlap? Evaluation of climate data stability from overlapping satellite records, *Atmos. Chem. Phys.*, 17, doi.org/10.5194/acp-17-15069-2017.

Wing, R. et al, 2018: Lidar temperature series in the middle atmosphere as a reference data set – Part 2: Assessment of temperature observations from MLS/Aura and SABER/TIMED satellites, *Atmos. Meas. Tech.*, 11, 6703–6717, doi.org/10.5194/amt-11-6703-2018.

WOUDC Rocketsoundings, (woudc.org/data/explore.php) (last access 31 May 2023).

Zhang, S.-R. et al., 2016: Ionospheric ion temperature climate and upper atmospheric long-term cooling. *J. Geophys. Res. Space Physics*, 121(9), 8951–8968. doi.org/…971

Report on the National Workshop on Boundary Layer Exchange Processes and Climate Change (NoBLExClim-2023)

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Dates:
23-24 March 2023

Scientific organising Committee:
AVM (Dr) Ajit Tyagi, Dr.K.Krishnamoorthy, Dr. P.K. Pal, Dr. V.S. Prasad, Dr. John P. George, Dr. G. Pandithurai, Dr. Jagvir Singh.

Local Organising Committee:
Prof. A. Karthigeyan, Prof. P. Malar, Prof. Venkat Prasad Bhat, Dr. Arijit Sen, Dr. T. V. Lakshmikumar, Dr. Rohit Dhir, Dr. Debabrata Sarkar.

Meeting venue:
SRM Institute of Science and Technology, Chennai, India

Number Of Participants:79
Contact: **ksanjaym@gmail.com**
Conference Website:
https://www.srmist.edu.in/events/national-workshop-on-boundary-layer-exchange-processes-and-climate-change/

Sponsors:

To promote a better understanding of the exchange processes of the atmospheric boundary layer (ABL), the National Workshop on Boundary Layer Exchange Processes and Climate Change (NoBLExClim) was jointly organized at Atmospheric Observations and Modelling Laboratory (AOML), Department of Physics, SRM Institute of Science and Technology (SRMIST), Kattankulathur, India in association with the Ministry of Earth Sciences (MoES), Govt. of India, which has established a micro pulse lidar observation facility under a satellite meteorology cell project and the Science and Engineering Research Board (SERB), Govt. of India, which has provided radiosonde/ozonesonde facility under core research grant (CRG) project at SRMIST. The NoBLExClim workshop provided an excellent opportunity for the scientists and students to highlight the current status of the boundary layer processes and their impact on the weather and climate system and discuss futuristic plans and prospects.

The first NoBLExClim workshop was held at SRMIST from 23-24 March 2023 on the special occasion of World Meteorology Day, celebrated every year on 23 March. This year, "*The future of weather, climate, and water across generations*" is the slogan of the world meteorological organization for international cooperation in meeting the challenge of the stressed climate change situation. Our climate system has five major components: lithosphere, hydrosphere, cryosphere, atmosphere, and biosphere. Knowledge of all these components is required to address the complex climate system, which is possible only through collaborations. The ABL is the lowest layer of the atmosphere where the majority (~99 %) of the biosphere and human activities occur and is mainly governed by small-scale processes. Over the past few decades, several ground-based and space-borne instruments and numerical models have been developed to monitor the ABL. Despite this, several models still fail to simulate adequate ABL depth, which is essential to understanding the key parameters controlling the earth's climate. Recent studies indicate the role of the ABL on climate by regulating the vertical exchange of air masses. Thus, the present workshop was focused on the following sub-themes:

1. **Techniques**: Advancement in ABL measurement techniques, Boundary layer clouds, and Processes

2. **Exchange**: Surface Trace Gases, Exchange processes between the Boundary Layer andFree Troposphere, Role of the Asian Monsoon

3. **Aerosols**: Vertical distribution of aerosols and their transport, cloud-aerosols interactions

4. **Modelling**: Boundary Layer Parameterization, Simulations, and models

5. **Trends**: Long-term changes of the temperature, trace gases, moisture aerosols and cirrus clouds, climate change

The NoBLExClim Workshop included 50 oral and 11 poster presentations. It includes five keynote speakers and 11 invited talks, 23 oral talks, and 11 lightning talks. About 60 % of presentations were from early carrier scientists and students that were examined by expert panels. Three best poster presentations and two early carrier scientists were awarded. The workshop was organized in hybrid mode to enable the participants to join online. The workshop started with a formal inaugural function, including a lighting lamp followed by a welcome address by **Sanjay Kumar Mehta** (SRMIST, Kattankulathur) and the release of the abstract book by dignitaries on the dais **K Krishnamoorthy** (IISC, Bangalore) and **P. K Pal** (IIRS, Dehradun). The two-day workshop was divided into five oral sessions, one poster session, and one hands-on training session for the Lidar data analysis. Each oral session began with a keynote presentation followed by invited talks and presentations from early carrier scientists and students.

Techniques: Advancement in ABL measurement techniques, Boundary layer clouds, and Processes

The exchange between the ABL and free troposphere generally occurs over the coastal and mountainous regions. The diurnal evolution of ABL is the key characteristic of such an exchange process. The diurnal evolution of the ABL heights over a coastal station using observational and model simulations were presented by **D. Bala Subrahamanyam** (SPL, Trivandrum). The paper highlights the complexities in determining the ABL heights during a mesoscale sea-breeze circulation over the coastal regions. **Som Kumar Sharma** (PRL, Ahmedabad) described the investigation of the Atmospheric boundary layer in terms of both Scientific and Societal Perspectives. The monitoring of ABL during the national Lockdown period has been reported with continuous measurements of the Ceilometer. The characteristics of the atmospheric boundary layer over the coastal site, Kalpakkam, were reported by **C. V. Srinivas** (Indira Gandhi Centre for Atomic Research, India) using in situ instruments such as GPS Sonde, SODAR and Micro-meteorological observations.

Figure 7: *Participants at the National Workshop on Boundary Layer Exchange Processes and Climate Change (NoBLExClim) held in Chennai, India during March 23-24, 2023.*

Figure 8: *Top: Release of Abstract booklet of NoBLExClim workshop. Middle: Participants attending inaugural session of NoBLExClim workshop. Bottem: Presentations from the participants of NoBLExClim workshop.*

M. G. Manoj (CUSAT, Cochin) presented an overview of various methods of ABL height retrievals. It is crucial to understand the role of soil moisture and its interaction with the atmosphere in forming local thunderstorms. **Jiteshwar Dadich** (NARL, India) presented the soil-air interface solver estimation of evaporation losses from different soil types. Scaling surface drag in the atmospheric boundary layer using laboratory ideas was presented by **Abhishek Gupta** (Indian Institute of Tropical Meteorology (IITM), Pune). Diurnal variability of the coastal atmospheric boundary layer during different seasons over the tropical east coast region, Kattankulathur, was presented by **T. V. Ramesh Reddy** (Indian Institute of Technology (IIT), Kanpur). **Jaswanth Rathore** (IIT, Delhi) presented the ABL structure over Delhi-NCR using Ceilometer measurements. The boundary layer dynamics over the planar and the coastal regions of the Indian subcontinent were presented by **Shivali Kundan** (Central University of Jammu).

Exchange: Surface Trace Gases, Exchange processes between the Boundary Layer and Free Troposphere, Role of the Asian monsoon

The vertical distribution of aerosols and trace gases has been monitored regularly to understand the exchange process between ABL and FT. The role of the Atmospheric boundary layer for the temporal and vertical distribution of Aerosol and trace gases was presented by **M. Venkat Ratnam** (NARL, Gadanki). An overview of different probing and detection techniques of ABL, its influence on the temporal and vertical distribution of aerosol and trace gases, and a new understanding of various boundary layer processes was provided. **Amit Kesarkar** (NARL, Gadanki) presented the role of boundary layer dynamics in the development of convective instabilities and occurrences of thunderstorms over Gadanki. The results depict the shear-induced instability due to land-sea breeze also plays an important role in developing horizontal convective roles, modulation of boundary layer convergence, and advection of heat and moisture over this region. Turbulent humidity measurements in the convective boundary layer using water vapor Differential Absorption Lidar were presented by **Shravan Kumar Muppa** (India Meteorological Department, Delhi). **Seetha C J** (SRMIST, Kattankulathur) presented the Atmospheric boundary layer height during the transient monsoon conditions over the different stations in India. The influence of Atmospheric Boundary Layer height variations on trace pollutants over Kannur, Kerala, was presented by **Keerthi Lakshmi K A** (Sree Krishna College, Kerala). From the climate change perspective, the long-term changes in the PBL height have to be studied, and **Chetan** (University of Delhi) presented a talk on Long-term trends of planetary boundary layer height over Delhi, India, from 2007 to 2021. **Sachin K Philip** presented the thermodynamic structure and role of convection and advection for the formation and maintenance of different mixing lines over the coastal station in north east monsoon region, India (SRMIST, Kattankulathur). **Nanditha Subhash** (Savitribai Phule Pune University, Pune) presented the biosphere-atmosphere interaction in a semi-urban environment in Pune, India. The results provide a deep insight into the influence and extent of different meteorological parameters on biosphere-atmosphere exchange.

Aerosols: Vertical distribution of aerosols and their transport, cloud-aerosols interactions

The complexity, heterogeneity, and strong variability of their global distribution make aerosols difficult to study, and their radiative effects exhibit large spatial and temporal variations. Challenges facing the role of atmospheric aerosols in climate change was presented by **S. Ramachandran** (PRL, Ahmedabad). **Sanjay Kumar Mehta** (SRMIST, Kattankulathur) presented an overview of the micro-pulse lidar observations of the boundary layer, aerosols, and clouds over Kattankulathur. His study gives an insight into the coupling process from the ABL to the free troposphere and the vertical aerosol distribution, cirrus cloud occurrence, *etc*. Constraining estimates of black carbon (BC) emissions from open biomass burning using Lagrangian dispersion modeling were presented by **Akanksha Arora** (PRL, Ahmedabad). **A P Lingaswamy** presented the influence of black carbon aerosols on changing the atmospheric thermodynamics over a tropical coastal environment, Chennai. The fumigation effects of aerosols and their understanding from the collocated measurements of black carbon mass concentration and atmospheric boundary layer height were presented by **M. Ashok Williams** (SRMIST, Kattankulathur). **K. Janaki** (M.G.R. College, Hosur) presented the vertical distribution of Aerosols over Delhi before and after the lockdown period. This study gives an insight into the anthropogenic aerosol difference during and after the lockdown. **Rajitha J Rajan** (SRMIST, Kattankulathur) presented a microstructural analysis of aerosols over a suburban tropical coastal environment. Energy Dispersive X-ray (EDX) analysis of the samples revealed the presence of different elements such as C, O, Al, Si, S, K, Fe, Mg, Ca, V, Bi, Na, Cl, P, and Tc with a high concentration of carbon and oxygen and aluminum-silicate particles indicating the presence of carbonaceous aerosols and wind-born dust particles. Morphological characteristics and elemental composition of regional atmospheric aerosols over a semi-arid tropical station in south India have been presented by **Shaik Fasiha Begum** (Yogi Vemana University, Kadapa). Similarly, **A Ramanjula Reddy** (Yogi Vemana University, Kadapa) presented the analysis of fine particulate matter (PM2.5) over Kadapa, a tropical semi-arid region of India. **Jai Prakash** (Central University of Rajasthan) has presented a long-term analysis of the aerosols in Delhi using low-cost PM sensors. **Mohit Singh** (Indian Institute of Science and Technology (IIST), Trivandrum) has presented the mass absorption cross-section of black carbon for Aethalometer measurements at four sites in the Arctic. The possible role of entrainment mixing in reversing the Twomey effect over the eastern indo-gangetic plain during the winter season was presented by **Thejas K V** (IIST, Trivandrum). Satellite-based monitoring of the aerosol loading is crucial for understanding the transport process. **S. Gurusingadurai** (M.G.R. College, Hosur) presented the vertical distribution of Aerosol over Malaysia using the satellite data CALIPSO satellite data. Land Sea Breeze and Pollution Flux over the Tamil Nadu Coast were presented by **Akansha Maity** (SRMIST, Kattankulathur). **R. Shiva** (M.G.R College, Hosur) presented the seasonal distribution and variation of aerosol over Singapore using the CALIPSO satellite data. And finally, **Rajith K** (CUSAT, Cochin) presented the topic "Using the Parcel Model and Parameterisation to Study the factors affecting aerosol activation."

Modeling: Boundary Layer Parameterization, Simulations, and models

Jagabandhu Panda (NIT, Rourkela) gave a keynote lecture about the rainfall microphysical characteristics using boundary layer observations on polluted days at an industrial Tropical Indian Station During Monsoon. The results provide insight into a better understanding of the raindrop size distribution variability during the polluted days and to understand the aerosol-precipitation interactions on a micro-scale better. He has also discussed the explicit urban modification of the Atmospheric boundary layer and mesoscale weather over an island city during two

Figure 9: *Young participants during hands-on training session of MPL data utilization as part of the NoBLExClim workshop. Former Director General of Meteorology, Dr. Ajit Tyagi was also present.*

contrasting scenarios. Understanding boundary layer development during the convective seasons is more complex. **C. A. Babu** (CUSAT, Cochin) presented a lecture about the characteristics of the atmospheric boundary layer during different phases of the southwest monsoon. Similarly, **N. V. P. Kiran Kumar** (SPL, Trivandrum) showed the objectives such as Surface layer characteristics over a coastal station Thumba during the winter season and Integral turbulence statistics over Anantapur, a semi-arid location in peninsular India. Remote sensing instruments play a key role in understanding the lower atmospheric characteristics, especially the atmospheric boundary layer and aerosol characteristics. The design and development of Dial Lidar for tropospheric ozone profiling were presented by **M. Roja Raman** (Sathyabama Institute of Science and Technology, Chennai). The retrieval and validation of cloud condensation nuclei from satellite and airborne measurements over the Indian monsoon region were discussed by **A Aravindhavel** (IITM, Pune). The study estimates the height resolved cloud condensation nuclei from Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) using Optical Modelling of CALIPSO Aerosol Microphysics (OMCAM) algorithm and validated the results with airborne in-situ cloud condensation nuclei (CCN) measurements collected during the Cloud Aerosol Interaction and Precipitation Enhanced Experiment (CAIPEEX) at six locations over the Indian summer monsoon region. Finally, **Archana Sagalgile** (IITM, Pune) explored the impacts of South Asian anthropogenic aerosols on the low-level jet during monsoon using the chemistry-climate model.

Trends: Long-term changes of the temperature, trace gases, moisture aerosols and cirrus clouds, climate change

Sandeep Sukumaran (IIT Delhi) discussed the dry air intrusion index in his keynote lecture. The study was carried out over the period of 1981 to 2014 monsoon season, and it was reported that 34 monsoon break phases in July and August months during the analysis period were accompanied by a dry air intrusion. The results suggested that the bulk of the dry air transport occurs from the northern Arabian Sea, not the Middle East deserts. A mechanism is proposed for the dry air intrusion over India, in which the northern flank of the low-level monsoon jet carries unsaturated air from the northern Arabian Sea to continental India. **Anusha Andrews** (National Centre for Earth Science Studies (NCESS), Trivandrum) presented the microphysics of warm rain in lower tropospheric clouds using the in-situ observations from micro rain radar, optical disdrometer, and microwave radiometer over a tropical coastal station, Trivandrum, during June to July 2022. **Amit Kumar** (IITM, Pune) observed three-dimensional precipitation characteristics of tropical cyclones over the Arabian Sea during October, November, and December months between 2014-2019. **K. Bharghavi** (Yogi Vemana University, Kadapa) presented the comparative studies between CAPE and near-surface temperature and rainfall over Four Indian stations. **P. Lakshmi Bharathi** (Yogi Vemana University, Kadapa) showed comparative studies between CAPE and rainfall from East coastal states to West coastal states of India. **R. Vineeth** (IIT, Madras) presented the Influence of Urban micro-climate on precipitation variability over Chennai over the 8 years from 2014 to 2022 using high-frequency and fine spatially resolved precipitation data from the geostationary satellite INSAT 3D. **Saleem Ali** (SRMIST, Kattankulathur) presented the characteristics of cirrus occurrences over a coastal station, Kattankulathur, in the northeast monsoon Region. The study reported the single-layer cirrus occurrence showing a diurnal pattern with frequent occurrence in the late evening (~ 30%–40 %), whereas multilayer cirrus clouds occurrences in the early morning (~10% –20%). **Muhammed Abdul Basith KC** (SRMIST, Kattankulathur) presented the temporal variations in the occurrence characteristic of cirrus clouds during two contrasting seasons. **Dhwanit J. Mise** (IITM, Pune) presented a study on cloud morphology during southwest monsoon over a high altitude site in Mahabaleshwar using ceilometer observation. They observed three distinct layers of the cloud base height that undoes significant diurnal variation with lower altitude in the day and higher altitude in nighttime during May (Pre-monsoon Season) and October (Post-monsoon season).

Future directions:

As per suggestions from the advisory committee, the NoBLExClim workshop will be held every alternate year online and in physical mode during world meteorology day to enhance the collaborative effort for the future of weather, climate, and water across generations.

Acknowledgments

We acknowledge the support for the workshop from MoES, Govt of India and SERB, Govt of India and SRM IST, India.

The 5th TUNER meeting

T. von Clarmann[1], Nathaniel Livesey[2], Doug Degenstein[3].

[1]KIT/IMK, Karlsruhe, Germany; [2]NASA JPL, Pasadena CA, USA; [3] Univ. Saskatchewan, Saskatoon, Canada.

Dates:
18-20 April 2023

Organizing Committee:
Thomas von Clarmann
Sylvia Kellmann
Berfin Demirci
Esther-Salomé Prietzel

Meeting venue:
KIT/IMK, Karlsruhe, Germany

Number Of Participants: 15
Contact: thomas.clarmann@kit.edu

Conference Website:
https://www.imk-asf.kit.edu/english/4215.php

Sponsors:

The 5th working group meeting of the SPARC Activity "Towards Unified Error Reporting (TUNER)" took place at KIT/IMK (Karlsruhe, Germany) from 18-20 April 2023. This activity, lead by **N. Livesey**, **D. Degenstein**, and **T. von Clarmann**, aims at the unification of error characterisation of satellite data. Presentations covered retrieval, error estimation, validation and interaction with other programmatic activities. In particular, TUNER-compliant error analyses were presented for, *e.g.*, SCIAMACHY and MIPAS. TUNER-compliance implies, among other characteristics, separate reporting for errors resulting from different error sources, correlation information in various domains (time, altitude, geolocation between species, etc), and assignment to either the random or the systematic error budget (see, von Clarmann *et al.*, 2020). The main purpose of the meeting was to structure a tutorial paper that is meant to help data users to make the best possible use of data characterisation (*i.e.*, TUNER-compliant error bars, covariance information, averaging kernels) of satellite data. It has been decided that this paper shall be built around illustrative examples such as zonal averaging, time series and trends, calculation of zenith column amounts of trace gases *etc*. The point is that error components that act randomly in one application act systematically in other applications. For example, errors in mixing ratios of trace species due to uncertainties in spectroscopic data are of systematic nature in the context of trend estimation, while they behave as random errors when trace gas budgets involving multiple species from one instrument, such as NO_y or total chlorine, are calculated for one air parcel. Conversely, uncertain tangent altitudes affect trace gas budgets for one air parcel systematically, while in trend estimation this error source behaves randomly. Responsible scientists have been assigned to each of the example to be shown.

References:
T. von Clarmann, D. A. Degenstein, N. J. Livesey, *et al.*: Overview: Estimating and reporting uncertainties in remotely sensed atmospheric composition and temperature. Atmos. Meas. Tech., 13, 4393-4436, 10.5194/amt-13-4393-2020, 2020

Figure 10: *Participants of the 5th TUNER Meeting at KIT, Kalsruhe, Germany.*

A further issue of discussion was interaction of TUNER with other SPARC activities. LOTUS (Long Term Ozone Trends and Uncertainties in the Stratosphere) was identified as an activity which could particularly benefit from TUNER, because it uses, among other data sources, satellite data, whose uncertainties propagate directly onto estimated ozone trends. Controversial issues were: Shall trend estimated rely on merged data products or shall the original data be used? Is error-weighting adequate or not? How can instrumental drifts be determined?

Passing away of Jean-Pierre Pommereau

Florence Goutail[1]

[1]LATMOS, France

Figure 11: *Jean-Pierre Pommereau in 2015, during the installation of a Mini-SAOZ in Arosa, Switzerland.*

Jean-Pierre Pommereau passed away on Monday May 29, 2023 at Saint-Jean de Luz, France. He would have turned 80 years next August.

Jean-Pierre has spent his entire career at CNRS, France, in the field of atmospheric research. An enthusiastic and energetic researcher, he was first interested in nitrogen oxides in the stratosphere and led several international balloon measurement campaigns, then within the framework of a European EUROTRAC pollution measurement project he embarked with Florence Goutail in the development of the SANOA long-range remote sensing spectrometer.

Following the discovery of the ozone hole in 1987, a new spectrometer was developed, the fully automated SAOZ, which could perform ozone and nitrogen oxide measurements from the ground or from a balloon. Since then, around thirty instruments have been built and distributed around the globe and more than 120 balloon flights have been carried out from various launch centers in the northern and southern hemispheres. The SAOZ and its descendant the Mini-SAOZ are part of the NDACC international atmospheric monitoring network.

Jean-Pierre has organized and coordinated numerous international campaigns: MAP-Globus, CHEOPS, EASOE, SESAME, HIBISCUS. He has been part of many French and international committees (European Ozone Science Panel, NDSC/NDACC Steering Committee, IO3C). His expertise has been requested at the French level by PAMOY, PNCA, INSU-CSOA, CNES, IFRTP and at the international level by the EEC, ESA, NERC (GB), Canadian, Finnish and Spanish national agencies, International Science Foundation and within the framework of France-Australia-New Zealand and Franco-Russian cooperation. He was also part of the expert panel (Scientific Advisory Committees) for the GOME/ERS2 and SCIAMACHY/ENVISAT satellite instruments.

About fifty students have benefited from his advice and more than a dozen have completed a university thesis under his supervision.

Figure 12: *Jean-Pierre Pommereau with 3 colleagues (Florence Goutail, Sophie Godin-Beekmann, Andrea Pazmiño) during the Montreal Protocol 20th Anniversary, Symposium, Athens, Greece, 23-26 September 2007.*

Figure 13: *Jean-Pierre Pommereau during the 4th DOAS workshop, Hefei, China, 30 March to 3 April, 2008.*

SPARC meetings

30 August - 01 September 2023
FISAPS meeting
Boulder, Colorado, USA

03 - 5 October 2023
CCMi Workshop
Toulouse, France

11 - 13 October 2023
SSiRC ISSI Team meeting
Bern, Switzerland

09 - 13 October 2023
DynVar/SNAP join meeting on: "The Role of Atmospheric Dynamics for Climate and Extremes"
Munich, Germany

SPARC related meetings

25 - 29 September 2023
ICRC-CORDEX 2023
Trieste, Italy

10 - 11October 2023
EE11 User consultation meeting
Bucharest, Romania & online

23 - 27 October 2023
WCRP Open Science Conference
Kigali, Rwanda

11 - 15 December 2023
AGU Fall meeting
San Francisco, USA

28 January - 1 February 2024
AMS Annual Meeting
Baltimore, USA

Find more meetings at: www.sparc-climate.org/meetings

Publication details

Editing
Sabrina Zechlau & Mareike Heckl
Design & layout
Brigitte Ziegele & Sabrina Zechlau
Distribution & print (on demand)
DLR - IPA, Oberpfaffenhofen

ISSN 1245-4680

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