Decarbonizing conference travel: testing a multi-hub approach

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Published Version

Open Access

To link to this article DOI: http://dx.doi.org/10.1175/bams-d-23-0160.1

Publisher: American Meteorological Society

BAMS
Essay

Decarbonizing Conference Travel

Testing a Multi-Hub Approach

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KEYWORDS:
Atmosphere;
Greenhouse gases;
Climate change;
Adaptation

ABSTRACT: As the global research enterprise grapples with the challenge of a low-carbon future, a key challenge is the future of international conferences. An emerging initiative that combines elements of the traditional in-person conference and a virtual conference is a multi-hub approach. Here we report on a real-world trial of a multi-hub approach, the World Climate Research Programme/Stratosphere-Troposphere Processes and their Role in Climate (WCRP/SPARC) General Assembly held in Qingdao–Reading–Boulder during the last week of October 2022 with more than 400 participants. While there are other examples of conferences run in dual-hub or hybrid online and in-person formats, we are not aware of other large atmospheric science conferences held in this format. Based on travel surveys of participants, we estimate that the multi-hub approach reduced the carbon footprint from travel by between a factor of 2.3 and 4.1 times the footprint when hosting the conference in a single location. This resulted in a saving of at least 288 tonnes of carbon dioxide equivalent (tCO_2eq) and perhaps as much as 683 tCO_2eq, compared to having the conference in one location only. Feedback from participants, collected immediately after the conference, showed that the majority would again attend another conference in a similar format. There are many ways that the format of the SPARC General Assembly could have been improved, but this proof of concept provides an inspiration to other groups to give the multi-hub format a try.

https://doi.org/10.1175/BAMS-D-23-0160.1
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In final form 15 November 2023

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Academic discourse requires international collaboration. Close communication between natural scientists and social scientists from all over the world brings fresh perspectives and approaches together to address some of the complex problems that the world faces. One of the problems is the need for a more sustainable approach to every aspect of everyone's working and personal lives.

For many researchers, particularly those working on climate change and sustainability, the high footprint associated with in-person travel to international scientific conferences presents an urgent ethical dilemma. Frequent work travel means that the personal travel carbon footprint of many researchers exceeds the global average (Le Quéré et al. 2015; Higham et al. 2019). Most recent estimates suggest that a very small proportion of the world population, around 2%–4%, flies each year (Gössling and Humpe 2020). Even in high-income countries, in a typical year, most of the population does not take a flight. Perversely, climate scientists fly more often than researchers from any other discipline (Whitmarsh et al. 2020). In addition, recent work found significant emission differences depending on scientific seniority and scientific fields (Hölbling et al. 2023).

This is not simply an ethical issue for researchers. There is evidence from randomized trials that the credibility of public advice from climate scientists can be negatively affected if those same scientists have a large personal climate footprint (Attari et al. 2016). Scientific studies such as Wynes et al. (2019) show no clear connection between frequent flying of a scientist and their scientific success.

In this context, there is a pressing need to reduce travel related greenhouse gas (GHG) emissions of in-person conferences (Hamant et al. 2019) while retaining opportunities for sharing research and networking. Large scientific conferences typically have substantial carbon footprints. For example, the 28,000 attendees from over 100 different countries of an American Geophysical Union (AGU) Fall Meeting in 2019 are estimated to have emitted about 3 tonnes of carbon dioxide equivalent (tCO_2eq) per scientist (Klöwer et al. 2020) or the equivalent of 80,000 tCO_2eq in total. For perspective, in 2019, the United Kingdom had an estimated per capita CO_2 emission of 5.5 tCO_2 (Ritchie et al. 2020) for the entire year. Attending the AGU Fall Meeting results in emitting over half of that annual per capita emissions in just one event.

Given this backdrop, many climate scientists have called for a reduction of how much we travel to do our work (Kalmus 2016, 2017; Cobb et al. 2018; Langin 2019). As these articles make clear, part of this reimagining of the scientific enterprise involves the structure and format of scientific conferences. We need to ask ourselves: "Can we find solutions which reduce the GHG emissions of conferences without compromising their goals of fostering collaboration and exchange of ideas and knowledge?"

One possible solution is to move all conferences online, and the scientific community has participated in an unplanned experiment using this approach during the years of the COVID-19 pandemic. Fully virtual conferences open up the research enterprise to a more diverse and representative group of participants and can improve the conference experience (Skiles et al. 2022). Nonetheless, there is still some way to go before a fully virtual conference fully replicates the serendipity of the in-person experience.

Another common proposal is to move conferences to a hub model (Parncutt et al. 2021), where groups of scientists meet in regional hubs, thereby reducing the carbon intensity of travel for individual scientists. Hubs are linked together to provide opportunities for global information exchange and collaboration. Despite this being a common proposal, there are few examples that conference organizers can draw from which investigate if a multi-hub approach works in practical terms.

In this article, as proof of concept, we report on a recent conference that was organized as a multi-hub conference. The focus of this study is to assess the potential decrease in GHG emissions associated with academic travel. This is achieved by rethinking the traditional concept of a single-location conference. Therefore, we conduct a comparative analysis of travel emissions resulting from participants attending conferences, contrasting the multi-hub approach and the conventional single-location approach.

Description of the multi-hub conference approach

Why did we choose the multi-hub approach? The conference described in this article is the 7th General Assembly of the Stratosphere-Troposphere Processes and their Role in Climate (SPARC) project, which took place from 24 to 28 October 2022. It was held in three connected hubs in China, the United Kingdom, and the United States.

SPARC is one of six core projects of the World Climate Research Programme (WCRP), and it coordinates international research efforts to understand how chemical, physical, and dynamical processes interact with the Earth's climate system. SPARC has held a General Assembly every 4 years since 1996. The aim of the General Assembly is to bring the whole SPARC community together to discuss important new science and coordinate project activity for the next 4-yr cycle. The previous six meetings have taken place in Australia (1996), Argentina (2000), Canada (2004), Italy (2008), New Zealand (2014), and Japan (2018). Typically, between 250 and 400 people attend these conferences.

The idea for running the next General Assembly as an experiment in multi-hub format first came from an informal chat over lunch at a smaller SPARC meeting in Madrid in October 2019 (Saggioro et al. 2020). The lunch was led by early career researchers (ECRs) who asked pointed questions about the carbon footprint of the scientific enterprise and proposed some solutions. We took up this challenge and proposed a model for the conference which was shared with the SPARC community for comments (Charlton-Perez et al. 2021). Only a few responses ($n = 24$) to a survey of the community about formats for the conference were received. There was no consensus on the approach to try, with a roughly even preference for a multi-hub and single-site conference. Nonetheless, the co-chairs of the SPARC project were content for us to stage the event as a multi-hub conference. As far as we are aware, this would be the first climate science conference of this scale (300+ attendees) to be held in a multi-hub format. There was no roadmap, but we were excited for the challenge nonetheless.

How did the multi-hub event work? We were very fortunate to secure hubs for the conference spaced roughly 8 h apart, consistent with approaches to multi-hub conferences proposed in the literature (Parncutt et al. 2021). Our hubs were located at the First Institute of Oceanography in Qingdao, China (Asia Hub); the European Centre for Medium-Range Weather Forecasts in Reading, United Kingdom (Europe Hub); and the National Center for

Atmospheric Research in Boulder, Colorado, United States (Americas Hub). Although we had hoped that COVID-19-related travel restrictions would largely have subsided by the time of the conference, this proved not to be the case, and international travel was still severely restricted for the Asia Hub. In addition to the three hubs, participants could choose to attend the conference online. Including this online aspect in the plan meant that there was a fully virtual contingency plan if COVID-19 restrictions prevented travel to all hubs. Of the 414 participants, 162 attended online, 118 attended the conference in person in Boulder, 101 in Reading, and 33 in Qingdao.

While each day of the conference had a slightly different structure, the broad pattern of each day is shown in Fig. 1. At the beginning of each calendar day in Qingdao, a joint oral session with the hub in Boulder was held. In all joint sessions, presentations were given in both hubs, with a session chair in each location. Questions could be asked by participants in either hub or by the online audience, who were represented by an ECR as their "voice." Once this session had finished, the day would end in Boulder and the Qingdao hub would participate in a poster session, eat lunch, and catch up on talks from the previous joint session between Reading and Boulder which they had missed while they were offline. All talks were live streamed to the online audience, recorded, and made available on the online conference platform. At all hubs, recorded talks were played for the in-person audience in the main lecture hall on the large screens. These sessions were attended by the majority of the in-person attendees.

As the meeting in Qingdao moved to the afternoon, they would be joined by the Reading hub for the next shared oral session. This pattern was then repeated across the three hubs; Reading would move to poster sessions and recorded talks before joining Boulder for the next shared oral session. Truly, this was a 24-h conference, with at least one of the hubs in operation for every second from the beginning of the conference until the final day.

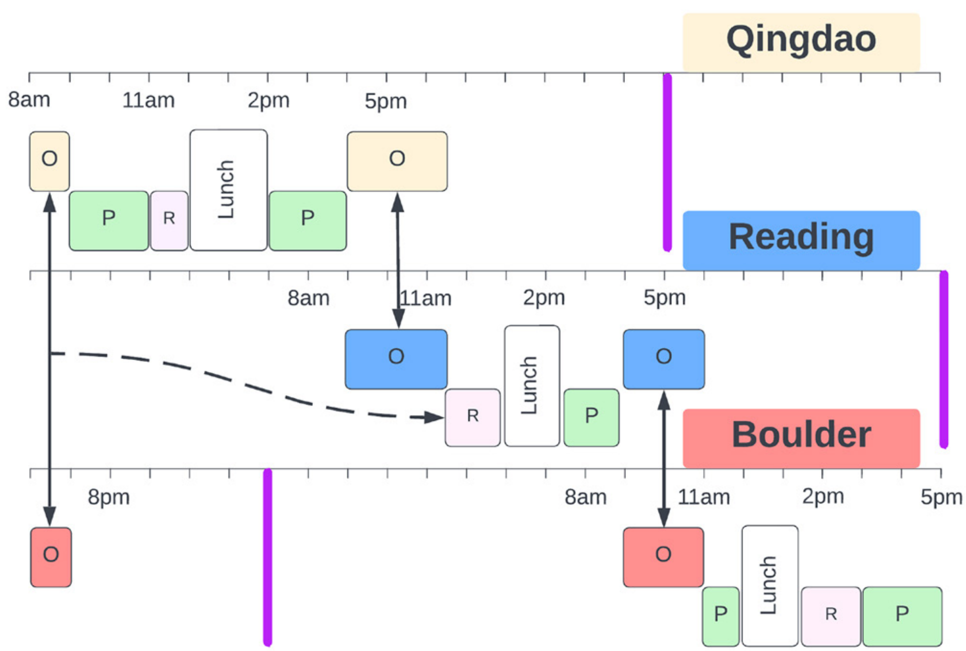

Fig. 1. Schematic structure of the three-hub conference model. Here we show an example 24-h period of the conference for the three hubs, Qingdao, Reading, and Boulder. Purple vertical lines mark the end of a local 24-h period. Each hub shows an example daily structure with oral sessions (O), poster sessions (P), and playing recorded talks (R), which took place while the hub was asleep. Black double-headed arrows indicate where oral sessions are joint between two hubs. The dashed line shows an example of how recorded talks feed into the recorded sessions; not all are shown for legibility. This structure is for illustration only and was varied day by day in each hub to accommodate local time zones and events, including the conference dinner.

Significant technical expertise, provided by all three hubs, was needed to make this pattern work smoothly. All talks were live-streamed using video conferencing software and multiple cameras and microphones in each hub. As soon as the talks had finished, the technical teams edited and uploaded talks to the dedicated conference microsite. The talks could then be viewed asynchronously by any of the participants. Posters, an integral part of previous SPARC General Assemblies, were presented both in person and online through a dedicated conference microsite. All posters were available on the microsite ahead of the conference, throughout the week, and thereafter.

Results

What was the travel carbon footprint? To estimate the carbon footprint of the travel associated with the conference, we asked participants when they registered to provide us with travel details to attend the conference.

For each participant and their associated travel to one of the three hubs, we gathered information on the starting location (airport or train station), the destination hub, and the main mode of transport regarding the longest travel distance (e.g., plane, car, bus, or train). While the registration form only required the participant to supply their main mode of transport, for flights, we calculated the GHG emissions based on the entire travel, i.e., transport to/from airports are included in the emissions estimates based on reasonable assumptions. Travel of the longest distances and associated GHG emissions were calculated using a mobility-service app developed at the Wegener Center of the University of Graz, Austria, together with emissions factors provided by Mobitool (Mobitool 2021). These emissions factors evaluate the environmental impacts of different travel modes in terms of all relevant GHG emissions consistent with the IPCC (2007), such as carbon dioxide, methane, and nitrogenous dioxide, based on life cycle assessments (LCA). These greenhouse gas equivalents, calculated for global warming potential over 100 years (GWP100), are specified per person and kilometer traveled, and are given in $gCO_2eq\ pkm^{-1}$ (where pkm is person kilometers).

The service works with real travel distances, using train maps and street maps for trains, cars, and buses. For trains, due to different degrees of electrification and sources of energy in the respective countries, emission factors depend on the countries that the traveler crossed. For flights, Mobitool uses the great-circle distance to calculate the travel distance and adds the uplift factor of UF = 1.08 (Bramwell et al. 2017). The uplift factor accounts for takeoff and landing, as well as stalling phases. The tool also distinguishes between short- and long-haul flights (smaller or greater than 3,600 km), due to the higher energy demand in the landing and takeoff phase for short-haul flights. A radiative forcing index (RFI) of RFI = 2.0 (Fuglestvedt et al. 2010; Jungbluth and Meili 2019; Lee et al. 2010) is used in the GHG emissions estimate for flights, considering the increased warming impact at flight altitudes.

To give an example, the emissions of an individual flight were calculated as follows:

$$E\left(\text{kg}\,\text{CO}_2\text{eq}\right)=\text{dist}\left(\text{km}\right)\times\text{EF}_{\{1,2\}}\left(\text{kg pkm}^{-1}\right)\times\text{UF}\times\text{RFI}, \tag{1}$$

where E (kg CO_2eq) are the GHG emissions of the individual flight in kilogram CO_2 equivalents, dist (km) is the total distance of the return flight given in kilometers, and $EF_{\{1,2\}}$ (kg pkm^{-1}) is the respective emission factor of the travel mode "flight" given in kilogram per person kilometer, distinguishing between short- ($EF_{\{1\}}$) and long-distance ($EF_{\{2\}}$) flights. Furthermore, the UF and RFI are applied. For car, bus, and train travel the calculation is done in the same way, but without the uplift factor and radiative forcing index, and with different emission factors for the respective travel mode.

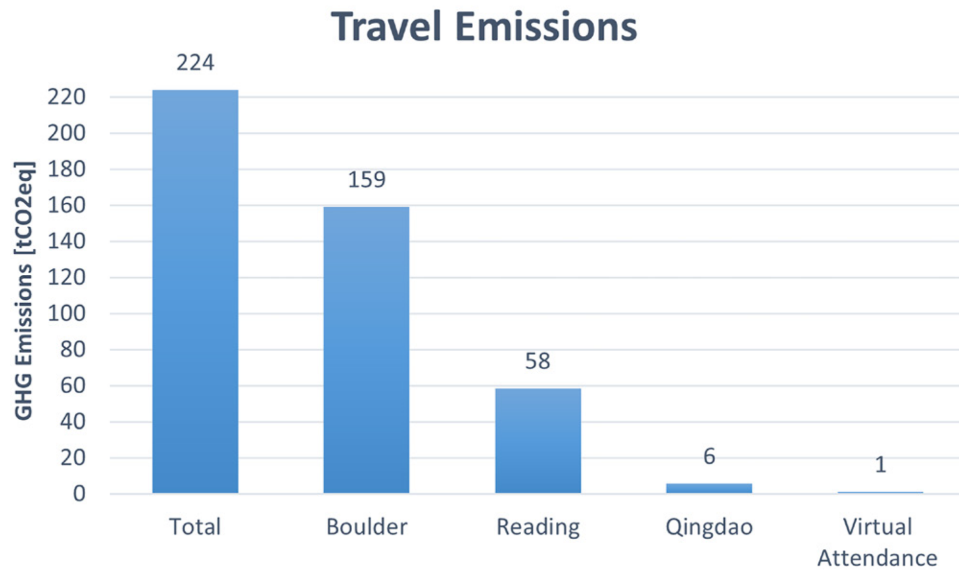

Fig. 2. **GHG emissions (tCO_2eq) because of travel to the SPARC multi-hub conference and the individual contributions for three conference venues of Boulder, Reading, and Qingdao and virtual attendance.**

Using this equation, total travel emissions for the conference of 223 tCO_2eq were estimated, with individual contributions for each hub of 159, 58, and 6 tCO_2eq for Boulder, Reading, and Qingdao, respectively (Fig. 2). For the 252 in-person participants at the conference this is an average travel carbon cost of 885 kg CO_2eq per attendee.

Estimating the additional carbon emissions generated by online participants is challenging as it depends on different factors, such as video on, video off, the energy generation source in the respective country, the video quality, or the connection technology (Obringer et al. 2021). To provide an estimate of the emissions caused by attending the conference online, it is assumed that the 162 online participants attended the conference for 5 h day^{-1} across the full 5 days of the conference and an emissions factor of 157 g CO_2eq h^{-1} was used for "video on" teleconferencing (Obringer et al. 2021). The respective study includes storage and data transmission given in CO_2 equivalents in the estimation of the GHG emissions (Obringer et al. 2021). The results indicate that additional emissions from online participants would not exceed 1 tCO_2eq for all online participants. Across all participants (in person and online), the conference therefore reduces its average footprint to 541 kg CO_2eq per attendee.

Across the three hubs, there were significant differences in accessibility of each venue by lower carbon transport modes (Fig. 3). In Reading, accessible by train from several different European countries, the journeys to the conference site comprised a nearly equal count of trips by plane ($n = 47$) and by train ($n = 45$). However, emissions of CO_2eq resulting from plane travel were 50 times greater than those from train travel. In Boulder, no participants traveled by train as this transport mode was not available, but the reduction in long-haul flights still resulted in substantial reductions in the carbon footprint if compared to a single-site conference (see details below).

As an estimate of the total emissions saved by holding the conference in the multi-hub format, we produced three "what if" scenarios, assuming a single-site conference at one of the three hubs (Fig. 4). In these scenarios, we assumed that any travelers who attended the conference via low-carbon transport would continue to do so, but that all intercontinental travelers would fly. This approach leads to a total number of 209 flights to the single hub Boulder, 198 flights to the single hub Reading, and 227 flights to the single hub Qingdao. The estimate shows that the multi-hub model reduces the travel carbon footprint by 65%, 56%, and 75% or by a factor of 2.9, 2.3, or 4.1, relative to a single-site conference in Boulder, Reading, or Qingdao, respectively.

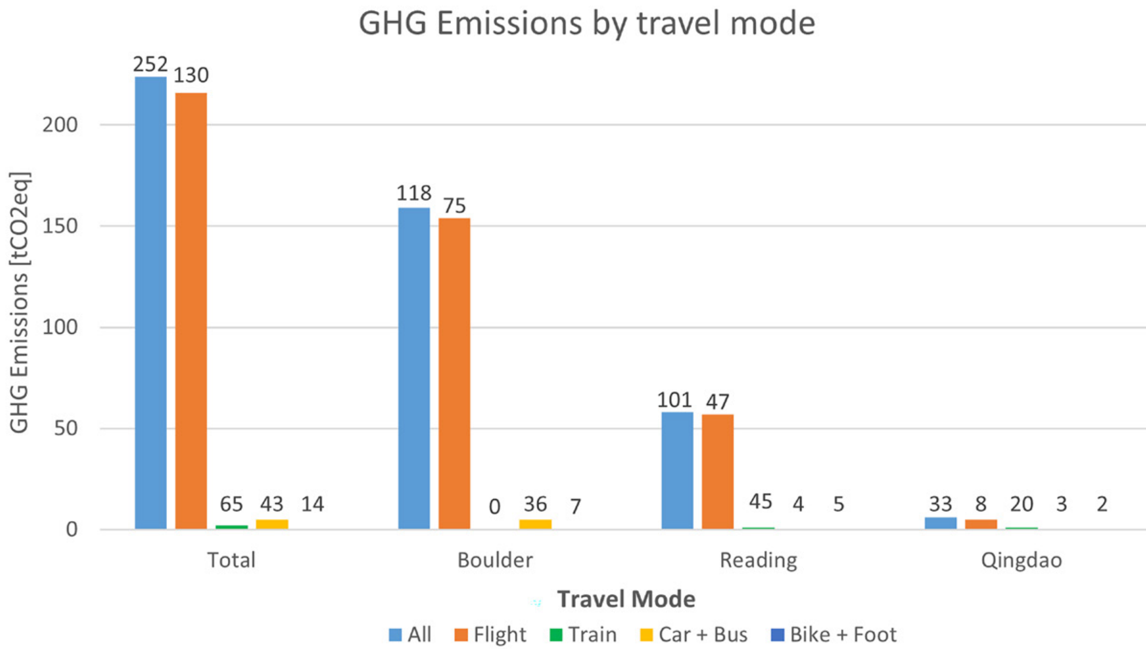

Fig. 3. **GHG emissions (tCO_2eq) for the three individual hubs, illustrated according to the main transport mode, i.e., transport mode for the longest distance. The number of trips in the respective travel mode is shown as a number at the top of each bar. Since emissions are given in tCO_2eq, sometimes a rather small number of trips led to less than 1 tCO_2eq, and if was reasonable, rounded to 0 tCO_2eq. However, it is noted that this was only rounded for presentation purposes, the individual calculations were performed with more significant figures. Emissions from biking or walking are not included in the overall GHG travel footprint and are only included here to indicate how many people walked and biked to the conference location as a choice of their main transport mode.**

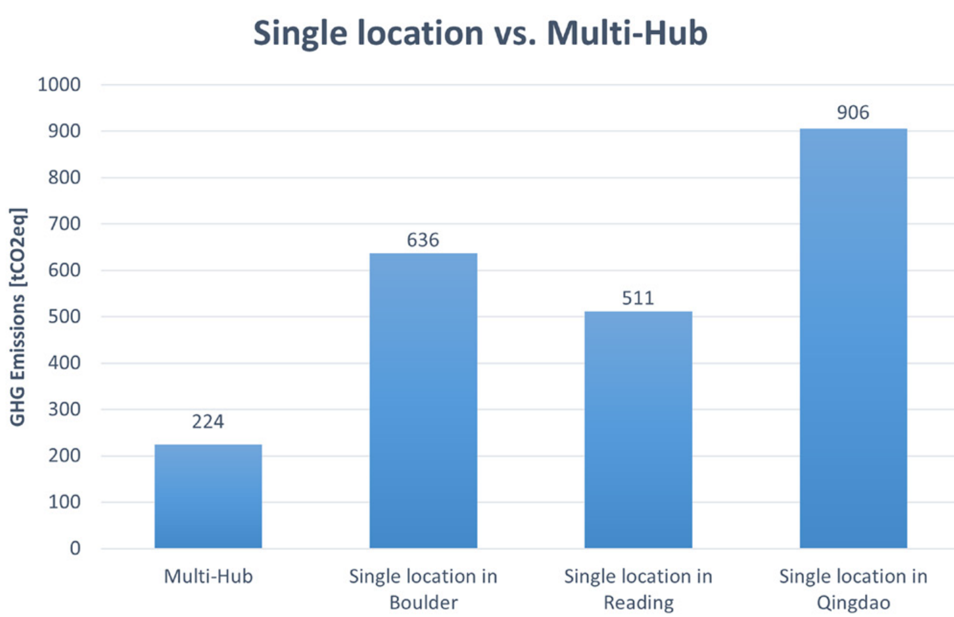

Fig. 4. **Comparison of the multi-hub model to the standard one-hub conference model. Total estimated emissions are given at the top of each bar. The general assumption was made that all cross-continent trips to an individual hub were done using planes.**

What did those who attended the conference think? Clearly the conference achieved one of its aims in reducing travel GHG emissions compared to a single-site conference. To understand if this came at too high a cost to the aims of the conference, we asked participants to complete an online survey at the end of the conference, with results for 122 of the

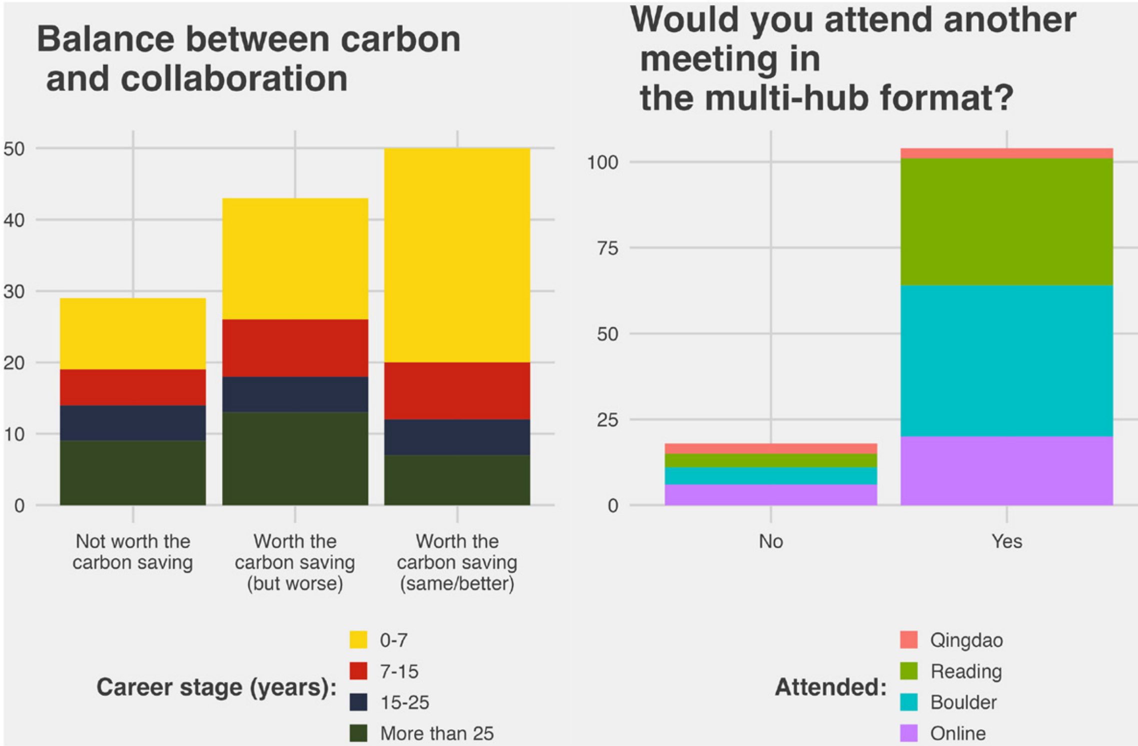

Fig. 5. Feedback on the conference received from participants (*n* = 122, 30% of those registered). (left) Answers to the question, "Thinking about the balance between the carbon footprint of the GA and the importance of the conference for your scientific networking and development, would you say the conference (compared to a traditional single site conference), was ...." Respondents were given three choices: not worth the carbon saving because the experience was worse, worth the carbon saving even though the experience was worse, or worth the carbon saving because the experience was similar or better. (right) Answers to the question, "Would you attend another conference in a similar format?" Responses are categorized by the hub (or online) where the participant joined from.

participants reported in Fig. 5. The responses are grouped based on the career stage identified by the individuals, giving the number of years they had worked in science (excluding graduate school). Specifically, 47% of the respondents were in the early stages of their careers (0–7 years post-PhD), 17% had been working in their field for 7–15 years after earning their PhD, 12% had accumulated 15–25 years of experience, and 24% of the respondents had more than 25 years of experience in their careers. With a response rate of 30%, this survey might not represent the views of the majority of the participants and could potentially be biased (nonresponse bias) toward the views of the ECRs. While the survey may not fully represent the opinions and characteristics of all attendees, the survey results still have value and provide insights as outlined below. In future, this potential bias could be mitigated by providing an incentive to fill in the survey or to hand out the survey to a random sample of participants. However, even implementing these additional measures, achieving a completely representative sample can be challenging, especially in voluntary online surveys.

When explicitly asked if the reduction in carbon was worth the carbon saving, only 23% of the respondents said that it was not. The majority of those who responded said the emission saving was worthwhile even though the conference was worse than a single-site conference (34%) or that the multi-hub format was the same or better (41%). Within these categories, this judgment was similar across career stages, although a significant majority of the ECRs said the conference was the same or better. Undoubtedly many of these researchers may not have attended many similar scientific meetings, particularly through the pandemic, and so this may be reflected in their opinion. We also asked participants if they would attend another conference in the multi-hub format, with the responses also shown in Fig. 5. While a majority of online participants and those at Reading and Boulder expressed their willingness to attend another multi-hub conference, the results from the Qingdao responses presented a less clear picture. Half of the respondents would not attend, while the other half would attend another multi-hub conference. However, as stated above, the limited number of survey responses received does not allow for the formulation of a comprehensive view for all participants and results need to be carefully interpreted. Furthermore, Qingdao faced the additional challenge of short-notice travel restrictions due to COVID-19, which might have additionally added to the more negative perception of the conference, given that the number of in-person attendees was significantly reduced. The results suggest that there needs to be a critical mass of attendees at a given location to make the conference experience satisfactory or comparable to a fully in-person meeting. Originally, Qingdao was planned as an Asia hub, however, due to the COVID-19-imposed travel restrictions, only local attendees could gather at that location. This was beyond the control of the organizers.

This analysis, and further analysis of other questions in the survey, gave a clear indication that the conference also met the aim of enhancing collaboration. There are, of course, important caveats to the survey results which it is important to note. There will be some bias in the responses to the survey because only those who attended the conference participated; those who did not attend because of the new format had no opportunity to respond, and so the survey may have a positive bias because of this effect. Similarly, although the survey was anonymous, those with strongly negative views might not have felt comfortable expressing those to the conference organizers through the survey. As pointed out by one of the reviewers of the paper, the true test of a multi-hub format might be multiple surveys over a series of annual or multi-annual events. There would of course be many other confounding factors in this kind of approach and a more substantive shift to recurrent multi-hub approaches.

There was also a rich and varied response to free-text input questions suggesting several ways the format could be improved, including

- making sure the online audience could appear in the poster room through attendance on screens and/or with webcams;
- reducing the number of sessions to make the conference days shorter (perhaps with a break in the middle of the day); and
- providing dedicated quiet sessions and online tools to enable collaboration and personal connection with online poster presenters and researchers from different hubs.

What did we learn? Most importantly, we were able to demonstrate that a multi-hub conference can work with the technology available to most research organizations. We found a compromise between GHG emissions, collaboration, and connection.

For anyone else wishing to organize a similar conference, we suggest the following:

- Invest in professional, high-quality technical support. Solving problems as they occur and keeping the conference flowing requires deep knowledge and skills most scientists do not have.
- Invest in required technology. The multi-camera setup in each hub gave a sense of immediacy and cross-hub conversation that a fuzzy camera on a laptop could not replicate.
- Do not underestimate the work for the local organizers. Everything needs to happen three times, often in slightly different ways. Finance, visas, and travel are all different between the three hubs, and there is some additional financial exchange rate risk. We were again lucky that the SPARC project office could support the conference, but consider costing a full-time coordinator into the conference fee.

We were fortunate to have support from hosting organizations and sponsors to keep costs low and fund technical staff and equipment. Nonetheless, making each individual hub smaller opened more possible venues for the conference, with lower venue costs making this possible even without similarly generous hosts.

We underestimated how important playing the recorded talks in the main lecture hall was. A large proportion of attendees were present for all the recordings and even clapped when the recorded talks finished. Having the opportunity to share the talks with others at the conference and immediately discuss them is something that online conferences really struggle to replicate.

Furthermore, we should have invested more time in producing closed captions for the talks, which would have been beneficial for both online and in-person participants.

Some things went better than expected at the beginning and these include the following:

- Curiously, the hybrid (online plus onsite) experience was better for many online attendees than a purely online conference. Even viewing the interaction at a distance seemed to keep the attention of the online audience. The reduced fee for the online audience was appreciated.
- The reduced travel time and travel costs opened the conference to many more people than might otherwise have attended. Conferences in this format have the potential to be more equitable for those with lower amounts of research funding and caring responsibilities. Future evaluation of multi-hub conference formats should explore with both pre- and post-event audience engagement if this does make them more inclusive. Decentralizing the conference could potentially have increased travel to the multiple local hubs, diminishing the overall reduction in the emissions savings compared to a single-location conference—a rebound effect on emissions. To assess this potential rebound effect a comprehensive analysis and case study is required, which, however, is beyond the scope of this study.
- On a similar theme, having hubs in different parts of the world imposed a discipline on the organizers to think about ensuring there were talks presented live in each hub. This meant that the range of voices we heard from, with different nationality, gender, career stage, and other characteristics, was wider than might have been the case in a single-site conference.

There were certainly parts of the format which were suboptimal. Interaction between poster presenters and participants from different hubs and for online poster presenters was lower than we had hoped. This could potentially be improved upon by splitting poster sessions into both online and in-person sessions. However, the disadvantage might be that the already long conference days are even extended further. More thought will need to be given on how best to organize poster sessions across multi-hub conferences, maybe with the help of some advanced technological setup. The format also necessitated long conference days, particularly in the Boulder hub, but this could have been reduced by a switch to the number of oral presentations. Collaborative discussions in the breaks were limited to those among attendees of an individual hub. If we were to organize a similar conference, we would consider ways to restructure the program and provide innovative solutions to address these two issues.

If anyone is considering trying similar experiments for their scientific conferences, the organizers would be happy to share their data and experience. Please contact the corresponding author.

Acknowledgments. We thank the many colleagues who helped us to organize the meeting to allow us to conduct the multi-hub experiment. These included our scientific organizing committee members and especially staff at CLIVAR (Qian Zhao), FIO (Fangli Qiao, Li Li), ECMWF (Karen Clarke, Inna Polichchuk, Tim Stockdale), UCAR/NCAR (Elizabeth Faircloth, Kelvin Tavarez, Keila DeBellis), and our technical team at Glasgow (Emma Thivy, Jimmy Thew). We also thank the SPARC SSG and in particular co-chairs Neil Harris, Seok-Woo Son, Karen Rosenlof, and Amanda Maycock for allowing us the opportunity to try out this meeting format. We would also like to thank Sabrina Zechlau from the SPARC IPO for her support in putting together this SPARC General Assembly. This work was supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement 1852977.

Data availability statement. All data generated during this study and presented in this paper can be obtained from the corresponding author.

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