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ORIGINAL RESEARCH ARTICLE

How can we reduce the climate costs of OHBM? A vision for a more sustainable meeting

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ABSTRACT

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SUMMARY

Climate change threatens the future of humanity. It will also significantly impede our ability to conduct science, by destabilising societies globally. Aviation, including travel to scientific conferences, generates a huge carbon footprint. This must be addressed if we are to limit global warming to the 1.5–2°C mandated by the Paris agreement of the 2015 UN Climate Change Conference, and time is running very short: we are already at 1.2°C of warming. This also means we must urgently transform the way we attend conferences. Although OHBM is only one medium-sized society, it is crucial to recognise that collective action has the power to change social norms, in science, and society more broadly. This has far-reaching consequences beyond the direct carbon savings of updating the meeting format.[1]

In this report, authored by the Sustainability and Environment Action Special Interest Group (SEA-SIG), we analysed the carbon footprint of previous Organization for Human Brain Mapping (OHBM) meetings. On average, attendees travelling to an in-person meeting generate over 10,000 tonnes of carbon – as much as 1,250 average German residents would emit over the course of 1 year (mean of 8 tonnes in 2021). Virtually all these emissions are eliminated when we meet online instead. The location of in-person meetings also matters: setting the meeting in a place that requires more colleagues to fly long-haul very significantly increases climate costs by up to three times as much as the lowest-carbon locations.

We can do things differently, however. Hybrid meetings – accessible both in-person and online – are set to become the norm for academic societies around the world. Although driven by the COVID-19 pandemic, hybrid meetings should be here to stay, because of the many other benefits they bring to both accessibility and sustainability. There are also several other alternative meeting formats being explored by academic societies, such as a biennial meeting (every other year), and multiple regional hubs, in which attendees travel to their nearest geographical meeting location.

Using aviation carbon footprint modelling, we calculated the carbon savings that OHBM would make under these future meeting formats. We also determined the most climate-friendly locations for in-person aspects of future meetings and the least climate-friendly places. As a result, we recommend that all future OHBM meetings are fully hybrid. We furthermore recommend that OHBM transitions to a multiple regional hub model (with hybrid attendance also supported), in locations specifically chosen to minimise long-distance aviation. We do not advocate carbon offsetting as a suitable alternative to tackling real-time and long-term reductions in aviation emissions.

We conclude that updating the way OHBM meetings are run for a post-pandemic, climate-crisis era will save thousands of tonnes of carbon and send a crucial sign at a time of climate emergency. Furthermore, setting the meeting in locations that minimise the need for long-distance flying is critical. Finally, supporting colleagues to attend online and more locally will enhance accessibility, furthering the society's mission to provide educational forums for the exchange of groundbreaking neuroimaging research. Importantly, as a scientific community, we are in an ideal position to lead by example and experiment with new ways of sharing knowledge, including the way we attend conferences.

INTRODUCTION

We are in the midst of a climate crisis and we as scientists are not immune from the effects of climate change, from disruption to data collection as a result of extreme weather events, to wider interruption of normal life through societal disarray and conflict (1). Along with many other human activities, our scientific endeavours are driving climate change, including the carbon footprint of international conferences (2). **Travelling to conferences by plane generates a huge amount of carbon emissions:** up to 10.9 tonnes of CO_2e[2] for a return transatlantic flight from London to Sydney, per person (calculated using the Atmosfair flight emissions tool). To put this into perspective, the average annual carbon footprint for a citizen in the United States is 15 tonnes, and in Uganda, 0.1 tonnes.[3] Regarding individual carbon emissions, mobility (living car free) and specifically aviation (avoid only **one** transatlantic flight) are among the top 3 most impactful actions recommended by Wynes & Nicholas (3). This emphasises just how large the carbon footprint of aviation is, and why aviation accounts for approximately 96% of total conference emissions (4). Conference centre practices, such as avoiding single-use catering items, are also important sustainability issues but are dwarfed by the huge carbon costs of aviation.

Scientists are often not aware of the significant climate impacts of flying and what this is costing the planet – ultimately, endangering our individual safety and ability to carry on doing science. On the other hand, increasing numbers are acutely aware of the climate costs of travelling to scientific meetings, with a majority of OHBM members in a 2021 meeting feedback survey stating that the carbon footprint of travel was important in their decision to participate.

In this report, we outline why scientists travelling to conferences by plane is such a problem. We then use Organization for Human Brain Mapping (OHBM) annual

[1] Please note that the recommendations expressed in this report are suggestions by SEA-SIG, and are not necessarily reflective of all OHBM members' opinions.

[2] CO_2e = Carbon dioxide equivalent, which measures greenhouse gas emissions in terms of the most common greenhouse gas, carbon dioxide. Other greenhouse gases emitted by aviation and incorporated in CO_2e include nitrous oxide

[3] Calculated using World Bank data on annual CO_2e per capita for high and low-income countries.

meetings as a case study to demonstrate the environmental effect of scientific conferences. This is done by calculating how much carbon has been emitted at previous OHBM meetings and how much carbon we could save under future alternative meeting scenarios. We also discuss practical considerations regarding the implementation of alternative meeting models, and intersectional issues around accessibility, inclusivity, and diversity. Finally, we present a concrete vision for more sustainable annual meeting formats that would enable us to address our climate responsibilities, while enabling us to connect deeply and meaningfully internationally and at all career levels.

WHY IS AVIATION A PROBLEM?

Aviation has a large contribution to global warming relative to the number of people that regularly fly. Airplanes emit huge amounts of greenhouse gases high up in the atmosphere causing both CO_2 and other warming effects. There are currently no alternatives to fossil-fuelled planes for rapid mass international transport, and no technological developments for sustainable alternatives near the horizon (5). To date, aviation is responsible for 4% of human-induced global warming (5). However, this statistic masks the fact that the majority of flying is done by a small minority of individuals: the vast majority of the world's population has never been on a plane, while less than 1% of the world's population emits more than 50% of aviation's carbon (6). Even within academia, it is a small percentage of privileged power-holders who fly the most: while there is no correlation between number of flights and career success as measured by publication citations, there is an association with demographics – it is senior men who take the most flights (7), and the majority of those flights are usually to conferences (8). Younger researchers are doubly disadvantaged: not only do they fly less, they are the generation most at risk from climate change, and they will live with its effects for longer.

Although the contribution of attendees flying to scientific meetings is a small percentage of total global aviation emissions, this footprint is disproportionately large relative to the average citizen: if every human flew as much as academics do, the planet would be even further along the risky path towards 1.5°C of warming that the Intergovernmental Panel on Climate Change tells us we should not cross. Already we are at 1.2°C of warming over preindustrial temperatures. Time is therefore running very short to decarbonise every aspect of our societies, from energy generation to land use and transport. This imperative must also include reducing the amount of carbon pollution produced by people attending scientific conferences. Importantly, there are also far-reaching impacts of changing conference formats beyond the direct carbon savings, by changing social norms on the importance of addressing our environmental footprints. These social norms will percolate through science, and society more broadly, but if we as academics don't act on the insights of our colleagues in climate science, then how can we expect others to do so?

CARBON EMISSIONS FROM PAST OHBM MEETINGS

Using modelling developed by author M.K. (and guest climate science expert at the 2021 SEA-SIG symposium), we calculated the carbon footprint of the previous three in-person OHBM meetings. **This was 12,254 tonnes [CO_2e] for Rome 2019, 10,200 tonnes [CO_2e] for Singapore 2018, and 8,326 tonnes [CO_2e] for Vancouver 2017**[4] (***Figure 1***). Notably, Singapore 2018 emitted more CO_2e than Vancouver 2017, despite fewer attendees (2,038 attendees in Singapore vs. 2,775 in Vancouver), because the location required more people to fly long-haul. Rome 2019 has the highest footprint of the three most recent in-person meetings, in part because we had the highest ever number of attendees (3,886), and in part because many of these took long-haul flights. We also calculated the footprint of Honolulu 2015, to confirm the detrimental effect of locating the meeting in places that require the majority of attendees to take long-haul flights: this generated even higher emissions than Rome 2019, despite fewer attendees (14,277 tonnes CO_2e, 2,897 people).

These numbers demonstrate that:

1. The carbon footprint of previous in-person OHBM meetings is very substantial – the emissions of Rome 2019 are equivalent to the entire carbon footprint of 50,000 people in a low-income country (e.g., Uganda) over 1 year.[5]
2. Location matters – setting the meeting in a place that requires more attendees to take long- haul flights significantly increases its carbon costs (e.g., Honolulu).
3. Number of in-person attendees matters – the more in-person attendees, the more people fly, and the higher our emissions.

These numbers therefore also tell us that:

1. Reducing the carbon footprint of OHBM meetings will save thousands of tonnes of carbon;
2. Setting the meeting in locations that minimise the need for long-distance flying is critical;
3. Offering participants the ability to attend online rather than in-person is crucial, especially for those who would travel the furthest.

[4] Following Klöwer et al. (10), we calculated CO_2e emissions in three categories: 200 g CO_2e/km/person for short-haul (<1,500 km), 250 gCO_2e/km/person for long-haul (between 1,500 and 8,000 km), and 300 gCO_2e/km/person for super long-haul flights (>8,000 km).

[5] Calculated using World Bank data on annual CO_2e per capita for low-income countries. The same amount of emissions are also equivalent to the energy usage of a town of 1,500 people in the United States over 1 year, calculated using the Environmental Protection Agency Greenhouse Gas Equivalencies Calculator. US homes have the largest energy usage of all countries.

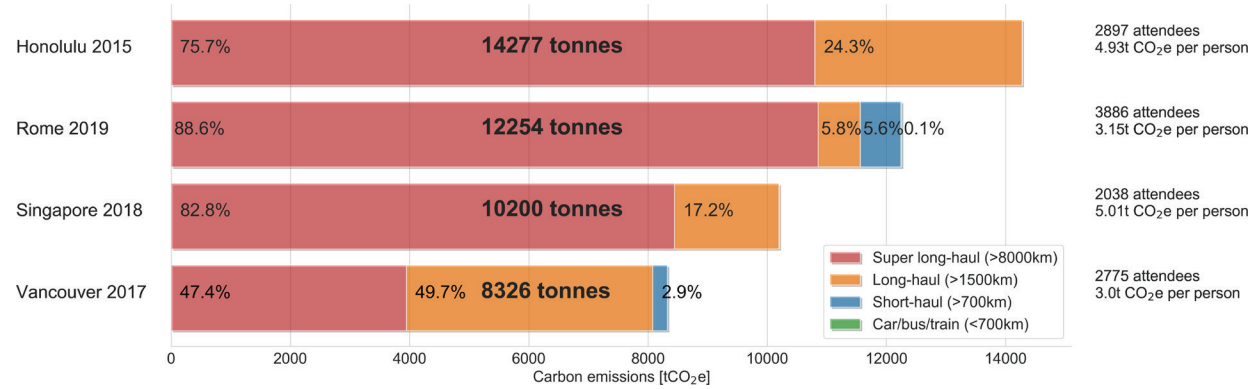

Fig 1. Carbon footprint of the most recent in-person OHBM meetings. Data on attendee home location were at the country level rather than city, so we assumed participants travel from the capital city of their given country. Note that the total emissions include both direct CO_2 emissions and non-CO_2 climate effects of other gases and aerosols emitted by jet engines (such as nitrous oxide), the effects of which are most significant at high altitude (and which longer-haul flights spend more time in). Calculated using modelling developed by author M.K. See sections 4.5–4.6 of M.K.'s analysis of the AGU2019 conference for further details of modelling assumptions.

Furthermore, individual attendee's carbon emissions vary significantly, depending on how far they are travelling. The minority who have to take the longest-haul flights have disproportionately large footprints relative to other attendees (***Figure 2***). This is not only due to the obvious fact that longer-haul flights burn more fossil fuel, as the plane is in the air for longer, but also due to non-CO_2 gases and aerosols emitted by jet engines, such as nitrous oxide. These have a larger impact on climate at high altitude, which longer-haul flights spend more time in (5, 9). **Supporting those who are furthest away to attend online, or to travel to a geographically nearer regional hub, would save substantial amounts of carbon.**

REDUCING THE CARBON FOOTPRINT OF FUTURE OHBM MEETINGS

The COVID-19 pandemic forced academic societies around the world to hold their meetings online. While the online OHBM meetings in 2020 and 2021 were somewhat mixed experiences – with different implications for different career stages and geographies – they saved **99.99% of emissions from an in-person meeting** (10), approximately 19,000 tonnes of CO_2e over 2 years (based on our calculations for Vancouver 2017: 8,800 tonnes, and Singapore 2018: 10,200 tonnes). Cumulatively, the 2020 and 2021 meetings were attended by 7,282 delegates, none of whom had to take a flight. Furthermore, the increased attendance of around 1,000 people compared with in-person meetings demonstrates the improved accessibility of meeting online.

Nevertheless, there are real disadvantages to online meetings, with early career researchers in particular being most affected by a lack of effective opportunities to present their work and build connections in the fully online arena.

Happily, **there are now plentiful options for various meeting formats that reduce the carbon costs of flying to them** [see ***Figure 3***; (1, 10)]. For many academic societies, the COVID-19 pandemic has precipitated exploration and uptake of these possibilities. We now outline these options below, along with context from the experience and opinions of OHBM members.

Hybrid

Hybrid meetings enable speakers and attendees to choose whether to join in-person or online. Hybrid meetings can include livestreaming of talks from the in-person venue, including the possibility for online attendees to ask questions to in-person speakers; recording of talks for those in different timezones to watch back; and individual 'poster rooms' enabling one-to-one video chats. OHBM's first ever hybrid meeting took place 2022 in Glasgow. Although as a medium-sized society, we did not have capacity to fully hybridise all elements of the meeting program in one year, OHBM 2022 was a critical foundation on which to build and continue improving our hybrid offering at future meetings. The investment made in 2022 by the organization's leadership will help inform plans for future OHBM meetings. We also continue to grow our experience of the hybrid format through other conferences and societies of which we are members in addition to OHBM, experience that can be brought to bear on minimise OHBM's hybrid offering.

The carbon savings of hybrid meetings are substantial. Klöwer et al. (10) showed that if the 17% of attendees at the 2019 American Geophysical Union meeting who travelled the furthest had had the chance to attend online instead, the meeting's carbon footprint would have been cut by 39%, saving many thousands of tonnes of CO_2e. We also note that those travelling the furthest distance face the greatest financial cost, which can be a significant barrier for those in low- and middle-income countries, and early career researchers. This again illustrates the importance of hybrid conference models in terms of improved accessibility [see section 6, INTERSECTIONALITY: ACCESSIBILITY, INCLUSIVITY, AND DIVERSITY, for more (11, 12)].

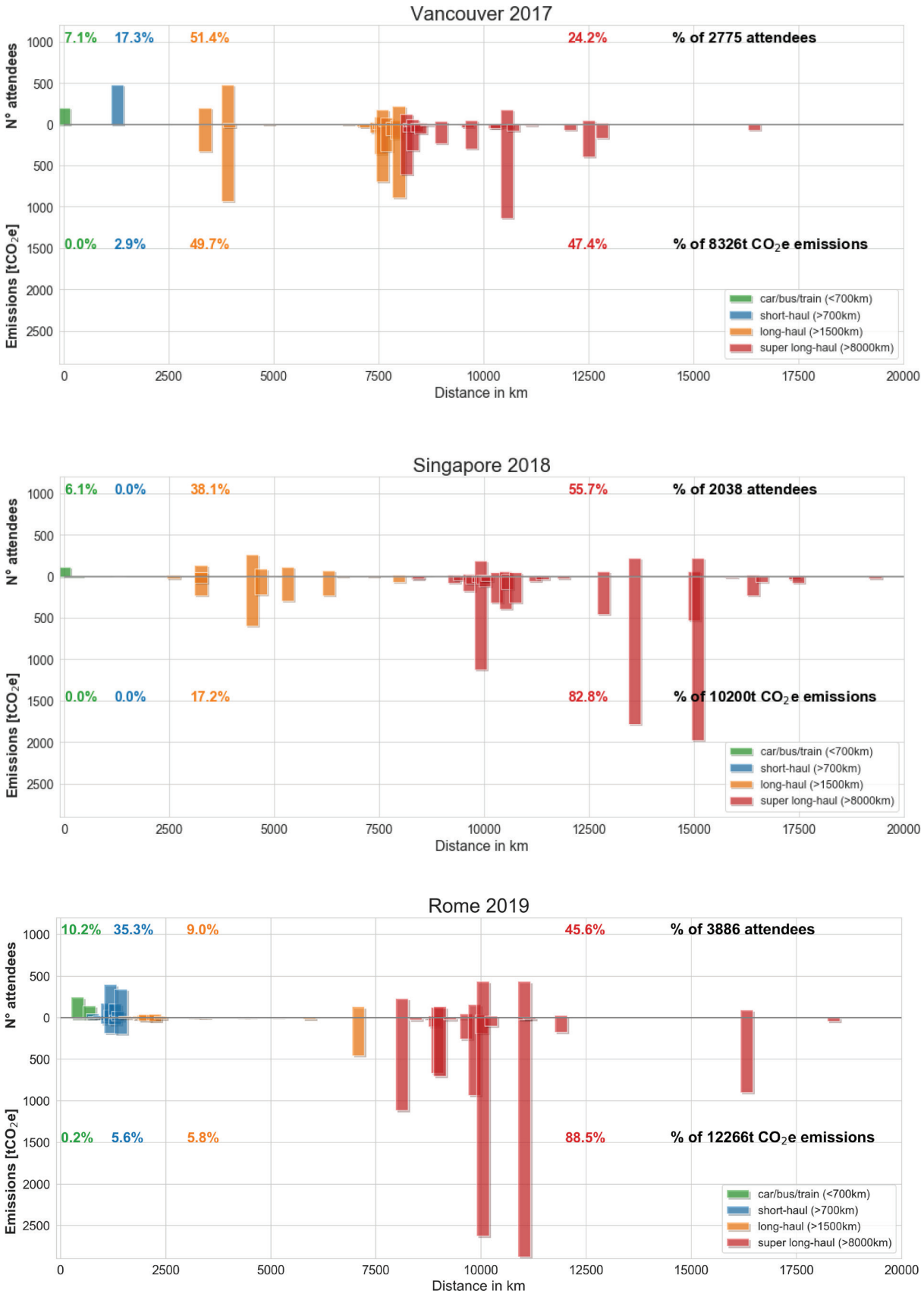

Fig 2. Contrast between the number of attendees and corresponding carbon emissions from the last three in-person meetings, depending on mode of travel and distance. For Vancouver 2017, even though only 25% of the attendees took super-long-haul flights, their travel was associated with nearly half of the emissions. In a similar vein, for Singapore 2018 and Rome 2019, the ~50% who took super-long-haul flights generated the majority of emissions. We assumed participants travelling <700 km did so by car/bus/train, rather than flying. Calculated using modelling developed by author M.K.

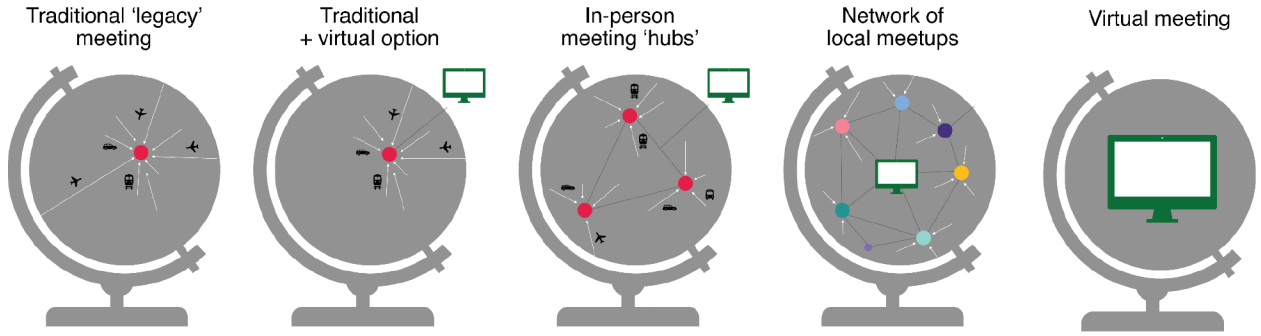

Fig 3. Alternative formats for scientific meetings, from traditional 'legacy' in-person only meetings, to hybrid, hubs, local meetups, and fully virtual. Reprinted from Rae et al. (1), Brain and Neuroscience Advances (SAGE Publishing).[1]

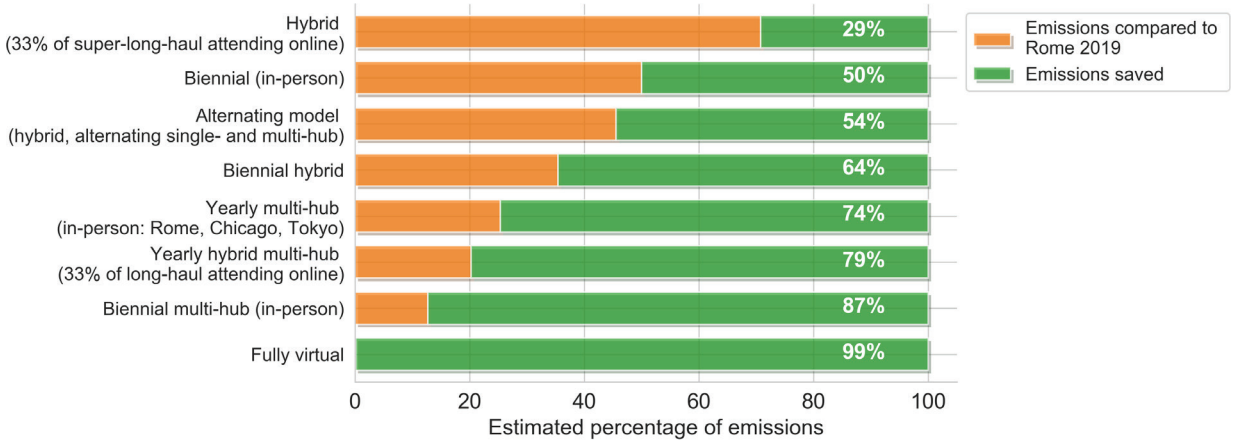

Fig 4. Comparison of how much carbon is saved by alternative meeting models in comparison to Rome 2019. 'Hybrid meeting' in each scenario assumes that 33% of super-long-haul flyers (distance >8,000 km) attend online. A hybrid meeting where we would be able to cut 33% of only the super-long-haul flights already saves nearly 30% of the total conference emissions. In the multi-hub scenario, only 42 super-long-haul flights need to be taken, saving 74% of emissions.

We calculated that a hybrid meeting would cut the carbon footprint of OHBM meetings by 29%, if only 33% of those who would otherwise have to take a super-long-haul flight (>8,000 km) attend online, with everyone else in-person (***Figure 4***). Of course, the more people who attend online (especially those who would otherwise travel the furthest), the more we reduce our emissions. ***Figure 4*** displays more alternatives: particularly, **we would save nearly 80% of emissions if we held a hybrid multi-hub meeting every year and nearly 90% of emissions if we switched between in-person hubs and online on a biennial basis.**

The appetite amongst OHBM attendees for hybrid meetings going forwards is strong. In a 2021 annual feedback survey of OHBM members, the majority of respondents indicated that a hybrid meeting was their first preference for future meeting formats, over solely in-person or solely virtual meetings (***Figure 5***). Although the response rate to the survey was small, at 59 individuals (3% of members), it seems likely that there is now expectation amongst members for hybrid meetings. A second feedback survey after the 2021 OHBM meeting, which also includes non-members, revealed similar support for hybrid meetings amongst attendees (147 responses, 5%; ***Figure 6***). This suggests that the pandemic-induced switch to hybrid is something that OHBM attendees want to retain long term, even in a post-pandemic world. Thus, the COVID-19 pandemic is not the only factor influencing attendees' wishes to flexibly access OHBM meetings without necessitating in-person attendance.

Hybrid meetings would not only significantly reduce our carbon footprint but would also boost accessibility. There are further benefits for the OHBM community, including increased attendance (as noted above, registration increased by approximately 1,000 for the 2020 online meeting), more memberships (as more colleagues regularly attend every year), higher engagement with the society (as more colleagues remain members long term), and potentially more online content throughout the year as well.

Practical considerations – hybrid

Beyond the climate costs, we note that there are many other practical considerations for different conference formats. Here, we consider aspects to consider and potential solutions for each potential meeting format (see ***Table 1*** for hybrid).

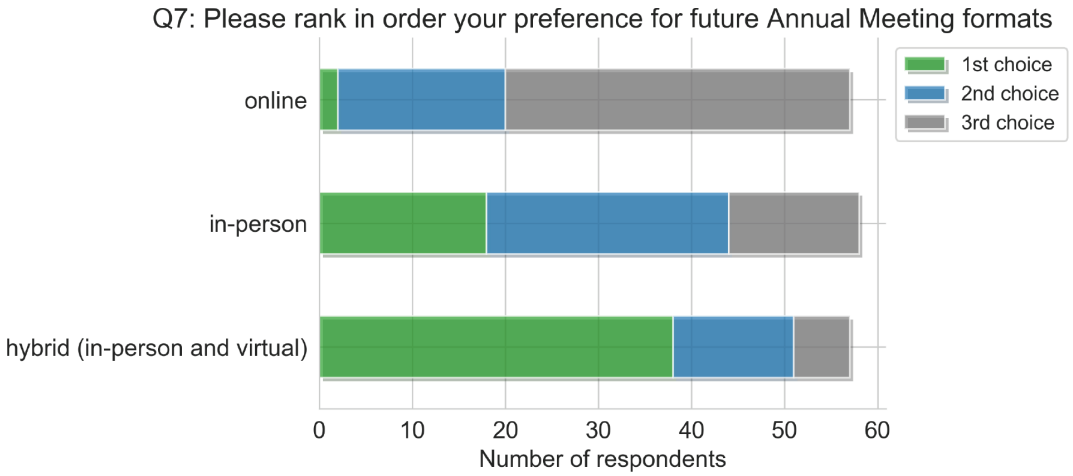

Fig 5. In the 2021 annual feedback survey, there was a strong preference for hybrid to be the default meeting format for future OHBM meetings amongst those that responded (3% of members).

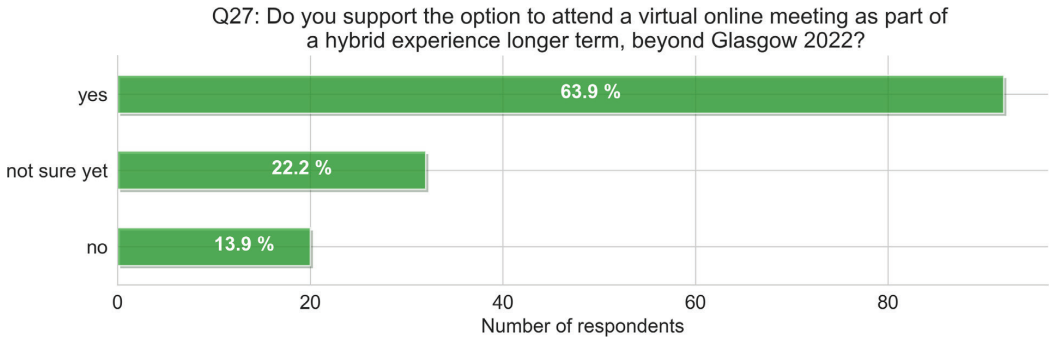

Fig 6. In the 2021 meeting attendee survey, there was a majority preference for hybrid OHBM meetings in the future amongst those that responded (5% of attendees).

Table 1. Potential issues and solutions for hybrid conferences.

Hybrid – Issue	Hybrid – Potential solutions
Lots of work for organisers (Technology Task Force, Program Committee, Executive Office, SIGs, and others)	• Many other societies are also developing hybrid platforms and approaches • Utilise insights from fellow societies • We will build capacity and expertise year on year
Traditional poster sessions more challenging, with disproportionate impact on ECRs	• Short pre-recorded presentations with live Q&A, which has worked well for other hybrid conferences; enables ECRs to retain opportunity to practice presentation skills • Virtual space has possibility to add direct link to preprint and other resources (see Neuromatch) • Dedicated virtual poster session with both virtual and in-person attendees
Facilitating real-time interactions across timezones, rather than simply streaming recorded material, is challenging or even impossible	• Hybrid hubs (see below) would ensure there is live activity during all timezones • Use insights from other academic societies • Being able to reach out online / through chat might reduce the barrier for contacting fellow researchers • Vary the timings of key events throughout the week, so that interactions are feasible for as many different timezones as possible across the conference
More work for presenters to pre-record talks, upload posters and be present both in-person and potentially online	• Here, more work results in more impact: attendees can catch up with sessions they have missed whenever they have time • Having all content available virtually (including contact information and other resources) makes reaching out to fellow researchers easier
Online attendees may miss out on social interactions and networking opportunities compared to in-person attendees	• Dedicated online networking events with engaging activities • Virtual networking rooms are opened up prior to the conference, to encourage all participants to engage in online interactions • A dedicated space at the venue for interactions with online participants
Technical issues may impact online experience of the conference	• We can build on the experience and lessons learned from the last two virtual OHBM meetings • Sharing insights with other societies to find the best options for online conferencing • Using the breadth of expertise within the OHBM community to problem-solve when issues arise
Potentially higher cost from conference venue of providing genuine hybrid (two-way) interactions	• Adjust registration fees (online, and in-person) to ensure equal access to all meeting aspects • Conference venues will continue to adapt their hybrid offering and pricing structure as hybrid becomes the norm globally • Work with fundraising committees to identify revenue-raising routes specifically for hybrid (e.g., NSF federal funding program for US-based students)

Hub

Many additional models can be considered beyond or in addition to the hybrid format. Hub meetings enable speakers and attendees to join the meeting from their local regional 'hub.' This option significantly reduces the need for participants to take a long-distance flight, and thus, substantially cuts carbon costs, while permitting face-to-face interaction. For example, three 'hubs' in the Americas, Asia/Oceania, and Europe would enable OHBM attendees to avoid many of the inter-continental flights we would otherwise be forced to take to attend in-person. **By switching to three hubs, the carbon footprint of OHBM meetings would be cut by a remarkable 74%** (***Figure 4***). This large saving comes primarily from the fact that hubs substantially reduce the number of the longest distance flights.

Hub meetings are potentially an ideal balance of enabling scientists to interact in-person with colleagues at one's own local hub, and virtually with colleagues at other hubs through live streaming, while making significant carbon savings. Furthermore, hub meetings could bring valuable accessibility benefits, by enabling those with family commitments to more easily travel to an in-person meeting every year, as they have shorter distances to go. Hubs could also be hosted in smaller cities, leading to less demand on hotels, and potentially becoming more affordable for lower income groups and early career researchers, as also flight prices scale with distance.

In addition to more formal hubs, organised by the host society in predetermined locations, we can consider more informal 'meetups' or 'hublets' that attendees self-organise (***Figure 3***). This may take more of a 'watch party' format, with sessions streamed one-way, rather than full dual-interaction. Nevertheless, this has already been effective in bringing together participants at the 2021 NeuroMatch online conference, who came together in 12 local meetups to watch talks, and enjoy more intimate social and networking events. Trialing local meetups could precipitate subsequent organisation of a more formal hub approach in future years.

However, consultation with the wider membership will be critical in planning for hub meetings going forwards (See Table 2 for discussion of practical considerations for hub meetings).

Biennial

Biennial meetings occur every 2 years, instead of annually. Some academic societies already meet biennially and have done so for many years (e.g., the Resting State Brain Connectivity meeting; the British Neuroscience Association; BRAIN & BRAIN PET; and the International Conference of Cognitive Neuroscience (ICON), which occurs every 3 years). Biennial meetings save time away from the laboratory, and save scientists' limited finances.

Table 2. Potential issues and solutions for a hub OHBM meeting.

Hub – Issue	Hub – Potential solutions
Lots of work for organisers, with multiple teams needed for multiple hubs	• Establish a list of preferred locations that are re-visited regularly, so that organisers already have familiarity with the venue *(note that Klöwer et al (10) suggested the AGU meeting should always be in Chicago, Paris, and Tokyo, annually)* • Coordinate with fellow academic societies with whom there are shared close interests (e.g., ISMRM, CNS, or ICON in the case of OHBM) to generate critical mass at each hub • Involve more early career researchers in local organisation committees as a career development opportunity • Organisational costs and work are reduced if a biennial hub meeting model is used
Potentially increased costs for venue hire	• Increased venue hire costs could be offset by increased attendance, because more colleagues register for the meeting when they do not have to undertake inter-continental travel • Make use of smaller conference venues, such as on university campuses or a set of rooms within a commercial venue, rather than hiring the whole conference centre
A single society may not be big enough to generate critical mass at three locations	• Collaborate with fellow academic societies with whom there are shared interests to generate critical mass at each hub (e.g., either joining the meetings, or running two in close temporal proximity) • Make use of smaller conference venues • Overall attendance should increase as travel costs (due to decreased distances) + other barriers (e.g., usually reduced visa issues on the same continent) are reduced
Traditional poster sessions more challenging, with disproportionate impact on ECRs	• Traditional in-person poster at local hub, with recorded presentation and scheduled live Q&A for colleagues at other hubs
Facilitating real-time interactions across hubs, rather than simply streaming recorded material, is challenging or even impossible	• Use insights from other academic societies • Being able to reach out online / through chat might reduce the barrier for contacting fellow researchers • Vary the timings of key events throughout the week so that interactions are feasible for as many different timezones as possible across the conference • Not all global conferences attempt to synchronise their hubs (e.g., a software meeting deliberately desynchronise, to convene in 3 locations at 3 different times of year, and provide some material in common across all, and some hub-specific activities: KUBECON)
Possibility of limited cross-continental networking and collaboration	• Attendees may choose to attend another hub instead of their nearest, as part of a longer overseas trip • Dedicated virtual poster session with both virtual and in-person attendees • Run smaller scale events throughout the calendar year that colleagues can opt in according to desired networking opportunities

Table 3. Potential issues and solutions for a biennial OHBM meeting.

Biennial – Issue	Biennial – Potential solutions
Financial implications of receiving registration fees only every 2 years (e.g., for paying Executive Office salaries)	• Alter registration fees • Meet online in between in-person years, charging more registration for in-person, and less for online, recouping costs on average
Career implications for ECRs who are only able to attend one conference meeting in a 3-year PhD	• Meet online in between in-person years • Organize smaller virtual seminars throughout the year, to give more opportunities for ECRs to present their work and network with peers and more senior researchers

They also significantly reduce carbon emissions: **meeting every 2 years instead of annually would instantly halve the carbon footprint of OHBM meetings (*Figure 4*).**

Relative to annual hubs, biennial meetings could reduce planning workload for those organising conferences, as there is only one meeting location to plan every 2 years. However, we note that reduced income from registration fees under a biennial model will have financial implications (which could potentially be addressed by raising registration fees on conference years). There may also be implications for early career researchers, who might only attend one conference during a typical 3 year training period.

It is also worth noting that **annual hubs would actually save more carbon than a biennial meeting in one location (74% versus 50%; *Figure 4*)**. However, combination formats are possible, such as a hybrid meeting 1 year, and fully online the next (See Table 3 for discussion of practical considerations for biennial meetings).

Combinations

Although we have so far discussed hybrid, hubs, and biennial meetings separately, one can of course combine multiple models. Combinations of the above would cumulatively generate the biggest carbon savings. Combinations could be applied to an individual meeting, or implemented in an alternating manner over several meetings. For example, a hybrid hub meeting with just 33% of those who would take long-haul flights attending online and the remaining participating in-person saves 79% of the carbon of a fully in-person annual meeting in one location, while **a staggering 87% of carbon emissions are saved if one were to alternate biennially between an in-person hub meeting 1 year, and fully online the next (*Figure 4*).**

Summary of alternative models

SEA-SIG recommends that all OHBM meetings from 2022 onwards offer hybrid attendance. In addition, **we recommend continuing to expand and improve the hybrid experience year on year, ensuring that by 2024, all aspects of the program can be fully accessed and engaged with online.** To achieve this, we suggest making use of expertise and experience from other societies.

Furthermore, SEA-SIG recommends that OHBM meetings transition to a hub model, also including hybrid offering. Both hybrid hub and hybrid biennial models save significant CO_2e (***Figure 4***). A hybrid biennial model is a viable option to reduce CO_2e, however, **SEA-SIG recommends a hybrid hub model over hybrid biennial, as hybrid hub saves more emissions.**

THE IMPORTANCE OF LOCATION

Even were none of the above options to be pursued, simply **setting in-person meetings in a location that minimises the need for attendees to fly long-haul would substantially reduce conference emissions.** Klöwer et al. (10) demonstrated that moving the 2019 American Geophysical Union meeting from San Francisco to Chicago would have saved 12% of emissions, because fewer attendees would have needed to take long-distance flights. In the case of OHBM, the 2015 conference in Honolulu required a long-haul flight for all 2,897 attendees, at a carbon cost of 14,277 tonnes CO_2e, which translates into 4.93 tonnes CO_2e emissions per person; significantly more than, for example, Vancouver 2017 with 3.0 tonnes CO_2e per person (***Figure 1***).

As well as carbon emissions, the location of an in-person meeting also influences how many people attend from different regions. Historically, most of those attending OHBM meetings are located in the northern hemisphere, but the numbers (***Figure 7***) also show that many people decide to travel to a meeting or not depending on the distance. A substantial reduction in OHBM attendance can be seen for people on years that the in-person meeting is not on their continent, with this being the case for all geographical areas. For example, in the case of attendees from China, we see that the total numbers are highest in Singapore and decreased by 14% (Rome), 39% (online), and even 100% for Vancouver (perhaps due to travel restrictions). The strongest variance in attendance can be seen for the United States, where attendance of the online event nearly doubled compared with Vancouver. From this, we infer two main conclusions:

1. It is important to offer in-person options (hubs) that are more accessible for everybody with respect to travel restrictions or the need to travel long distance.
2. Hybrid options will increase attendance, as also undergraduate students or labs without sufficient funding can attend, enlarging the overall pool of possible attendees.

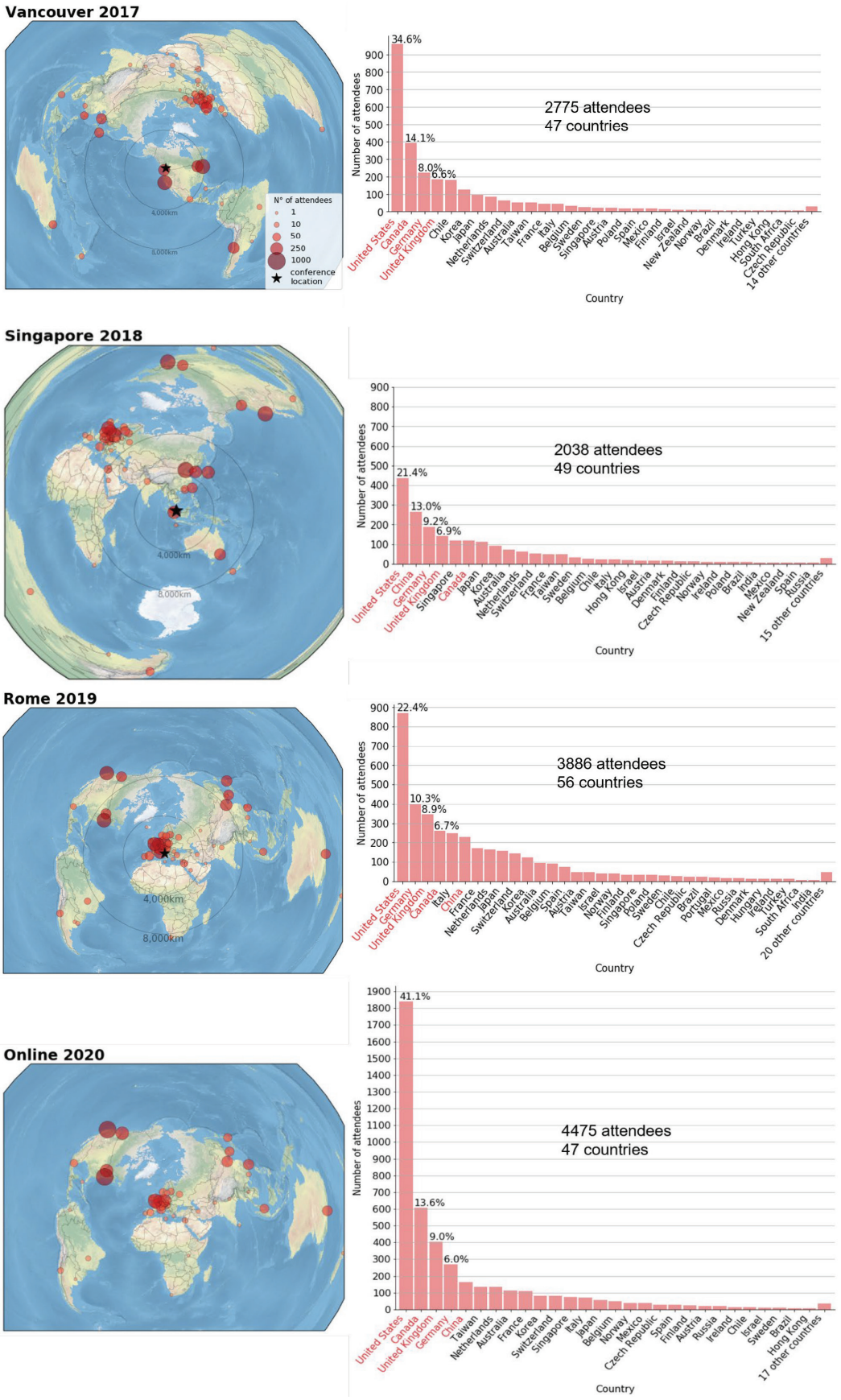

Fig 7. Most historical OHBM meeting attendees come from the northern hemisphere. But the percentages as well as total number of attendees vary depending on the meeting location. Note that the maps are centred on the meeting location for 2017–2019 respectively. An equidistant map projection is chosen such that distances relative to the map centre are proportional to great-circle distances, i.e. shortest flight routes.

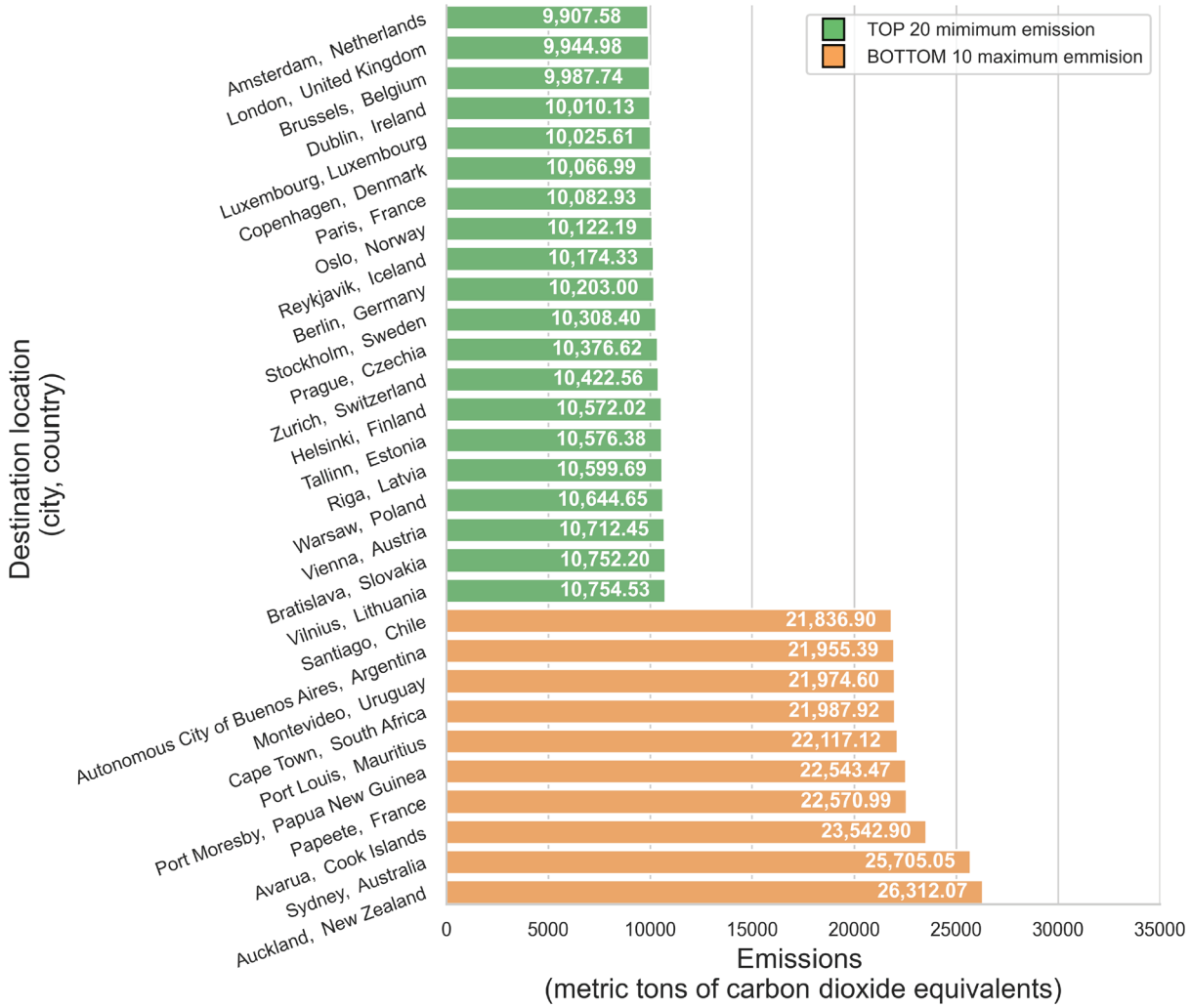

Fig 8. The top twenty most and ten least climate-friendly locations for future meetings, according to historical OHBM attendees' geographic location (average calculated across 2017, 2018, 2019), per country (dividing attendee locations in United States and Canada into East and West Coast). Calculated using the Travel Carbon Footprint Calculator. We defined the list of potential locations according to the footprint calculator's list of 'large airports in all continents' but did not check if locations have a suitable conference venue. The emissions estimates include both direct CO_2 emissions; and non-CO_2 climate effects of other gases and aerosols emitted by jet engines (such as nitrous oxide), the effects of which are most significant at high altitude (and which longer-haul flights spend more time in).[6]

The fact that attendees frequently modulate their in-person attendance according to location highlights the critical importance of a hub approach for inclusivity. As we see in section 7, RISKS OF NOT UPDATING MEETING FORMATS, below, 60% of 2021 meeting attendee survey respondents stated that the carbon footprint of OHBM meetings was important in their decision to participate. But the decision may also depend on visa and other accessibility issues, care work responsibilities (e.g., parenting), and available funding. To not further deepen these inequities, we cannot stress enough the need for an equivalent hybrid option, as well as a hub model. It should be made possible for everyone to attend (online or in-person) without having to travel long-distance (see section 4 above).

Looking ahead, the setting of OHBM2025 in Brisbane will increase carbon emissions significantly, and likely also reduce in-person attendance, given the large number of attendees who would have to fly super-long-haul. Australia ranges among the less favourable locations when we calculate emissions based on average historical attendance across 2017–2019 (see ***Figure 8***). Prioritising the locations of future in-person meetings at transport hubs that minimise the requirement for long-haul flights will go a long way to preventing unnecessary emissions. Given the data in ***Figure 7***, it is very important to consider inclusivity for colleagues who are based in places that make it harder to travel to OHBM meetings

[6] High altitude effects are derived using a multiplication factor of 2 (ADEME, MY-CLIMATE, and DEFRA settings in the Travel Carbon Footprint Calculator). High altitude effects in Figures 1 and 2 [using (10)] were derived with a factor higher than 2 for distances larger than 1,500 km: factor = 2.5 for 1,500–8,000 km, factor =3 for >8,000 km. This means CO_2e in Figure 7 is slightly lower than were the same factors applied as in Figures 1 and 2, especially for the 'least climate-friendly' destinations. Train travel is assumed for distances <700 km.

when the location is not near them. However, we must also recognise the context of the climate emergency we are living in. Setting the meeting in only one location that requires the majority of attendees to take long-haul flights (e.g., as for Honolulu 2015) is a serious neglect of our climate responsibilities. Offering a genuinely interactive and quality online experience for colleagues across all geographical locations, along with the option to travel to a nearer regional hub, will be critical in balancing inclusivity and sustainability.

We also note that setting the meeting in a perceived desirable 'holiday' location can help increase registration, as well as foster an even more enjoyable OHBM experience. There are many attractive destinations that also fulfil the criteria of being in a more climate-friendly location (***Figure 8***), so these aims do not need to be mutually exclusive. However, we should avoid holiday destinations that do not align with also being a more sustainable meeting location.

To help identify suitable locations that minimise long-distance aviation, we used the Travel Carbon Footprint Calculator (13). By entering the locations of the likely attendees – using the average of the attendees' locations from previous meetings (2017–2019) – **we identified the most climate-friendly meeting locations from amongst a short-list of potential cities** (defined according to the footprint calculator's list of 'large airports in all continents,' ***Figure 8***). Cities in Central and North Europe, for example, Amsterdam, Stockholm, Paris, range amongst the most optimal, followed by cities in North America on the East Coast, such as Toronto (11,380 tonnes) or New York (11,300 tonnes). Locations in South-East Australasia, however, are the least sustainable options, with Sydney generating 2.6 times as many emissions as Amsterdam. In general, locations in Europe and Northern America are the most optimal, because this is where many historical attendees are from. As the attendees' locations will hopefully become more diverse in the future, the calculation will need revising regularly. *This is why offering colleagues across all regions online attendance as a genuine quality option in a hybrid meeting is critical. In addition, this illustrates the value of a hub model that permits inclusive in-person attendance in all major geographic regions, while minimising long-haul aviation.*

In making use of this information to guide future locations, it is likely important to communicate to society members the role that the carbon footprint of meeting locations played in the choice. In addition to using this information to set locations for the annual meeting, societies can also guide which city it selects for other gatherings, such as strategic retreats, according to likely travel footprint.

Although the critical driver of a meeting's carbon cost is how many attendees travel long-distance, **there is also an additional benefit of attendees who are closer to the meeting location travelling by train** instead of short-distance plane. Particularly within Europe, distances up to 1,000 km can be reached by train within 1 day of travel. As an illustration, for a conference in Glasgow, an attendee travelling from Paris can save 200 kg of carbon if they take the Eurostar and onward train from London to Glasgow, instead of flying (***Figure 9***). This journey takes approximately 9 hours, during which attendees can work in comfort and even network en route. Conference organisers may wish to provide information and advice on train booking to attendees when arranging their conference travel. These communications will also help signal a commitment to sustainability and adjust social norms around travelling behaviours where feasible.

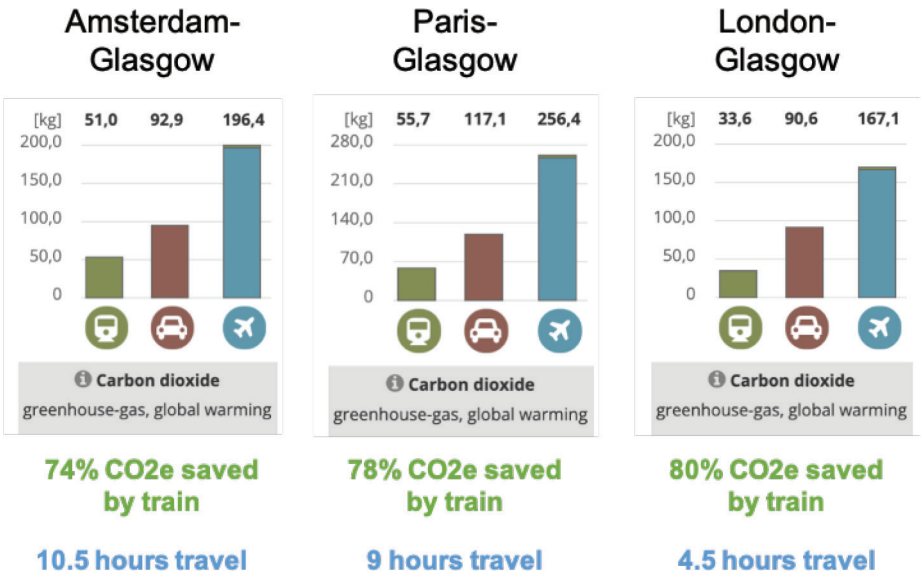

Fig 9. When travelling less than 1,000 km, taking the train instead of plane is feasible, and saves around 80% of the carbon emitted by flying. Route emissions and travel duration calculated using EcoPassenger.

In summary, **SEA-SIG recommends setting locations of future meetings in places that minimise long-haul aviation** and **making use of travel footprint tools to determine the most climate-friendly locations**. We also **recommend communicating the setting of locations with carbon footprint in mind to OHBM members** and **encouraging attendees to travel by train where possible**.

INTERSECTIONALITY: ACCESSIBILITY, INCLUSIVITY, AND DIVERSITY

All meeting formats offering an online component remove significant barriers that have long affected traditionally under-represented groups, including practical (e.g., caregiving duties), legal (e.g., visa requirements), economic (e.g., registration fees and travelling cost), and physical (e.g., accessibility) hurdles. Overall, online spaces provide a unique opportunity to ensure access and active participation (11, 12, 14), potentially leading to three main advantages.

First, removing international travel requirements and lowering the registration cost opens the door for historically under-represented groups, including those with caregiving responsibilities and disabilities, thus breaking current power imbalances (the so-called rich-club phenomenon). Second, trainees and ECRs face significantly more entry barriers (e.g., having to pay upfront, out-of-pocket high registration fees associated with in-person venues). Third, online attendance increases participation of attendees from low- and middle-income countries, where brain research equipment (e.g., open source EEG devices) is becoming cheaper and more accessible to a wider range of researchers. This benefits the field as a whole, leading to experiments with more diverse participants, but such researchers face barriers to attending in-person conferences such as visa issues and institutional support for travel (15).

However, many technical aspects to fully online or hybrid meetings are at the same time more challenging for those in low and middle-income countries (e.g., access to reliable wifi), those with caring duties (e.g., scheduling conflicts), those in countries with geopolitical restrictions (e.g., access to gmail), and those that don't speak/read/write fluently in English (as nonverbal cues are lacking) (11, 16). Similarly, the disparities in networking opportunities might be exacerbated (rather than solved) by online spaces: trainees and ECRs not belonging to 'rich-clubs' might paradoxically receive even less visibility, as without the random interactions of a bustling poster hall, online participants are likely to be drawn to virtual posters aligned to more prestigious groups or universities. However, one potential technical solution is biosemantic matching algorithms, which populate schedules with suggested matches to your interests and identify other attendees with similar interests to meet over structured networking and social events, such as Neuromatch's algorithmic 'speed-dating.'

While we believe that the balance is overall in favour of (at least partially) virtual scenarios, accessibility, inclusivity, and diversity need to be explicit goals of any meeting format, and detailed analyses need to be performed well in advance, case by case, to acknowledge the needs of the community members and address them. This includes reaching out to communities who may have historically not participated due to the above barriers, to identify how such barriers can be reduced (11). A growing body of checklists and recommendations can help in this endeavour (see Accessible Virtual Conferences and Association for Computing Machinery Best Practice Virtual Conference guide).

In summary, **an assessment of inclusivity and accessibility issues for alternative meeting models, including hybrid, hub, and biennial,** should be conducted to quantify the benefits and costs that may arise for different populations.

RISKS OF NOT UPDATING MEETING FORMATS

Organisational burdens aside, it is important to consider the implications for a scientific society of not taking action to reduce the climate costs of conferences. In the 2021 OHBM meeting feedback survey, 60% of respondents rated the carbon footprint of the conference as important in their decision to participate, with 20% stating that it was critically relevant (***Figure 10***, although the sample size was small, at n = 128). We anticipate this figure will rise year on year, as people become ever-more aware of the climate crisis in their own lives and the contribution aviation plays in this. If we do not change how we meet, for both sustainability and inclusivity reasons, we run the risk of a steady attrition in attendees, because the meeting, and society as a whole, does not align with members' values. Other academic societies are facing similar scenarios, including the biggest neuroscience society in the world, SfN, who were petitioned by over 1,200 members to reduce the footprint of their meeting. If we do not change how we meet and show leadership in this area, we risk a steady attrition in attendance as attendees will choose meetings of societies whose values and preferences align with theirs. Furthermore, we are living through a time of social change with accessibility of science by under-represented groups under the spotlight (11).

It is crucial to recognise that by changing conference formats, there are important impacts on social norms beyond the direct carbon savings. If we do not do so, we lose this essential opportunity to lead by example and enable broader societal change. This is a unique moment in history to reshape academic conferences for a post-pandemic, sustainable, and accessible world.

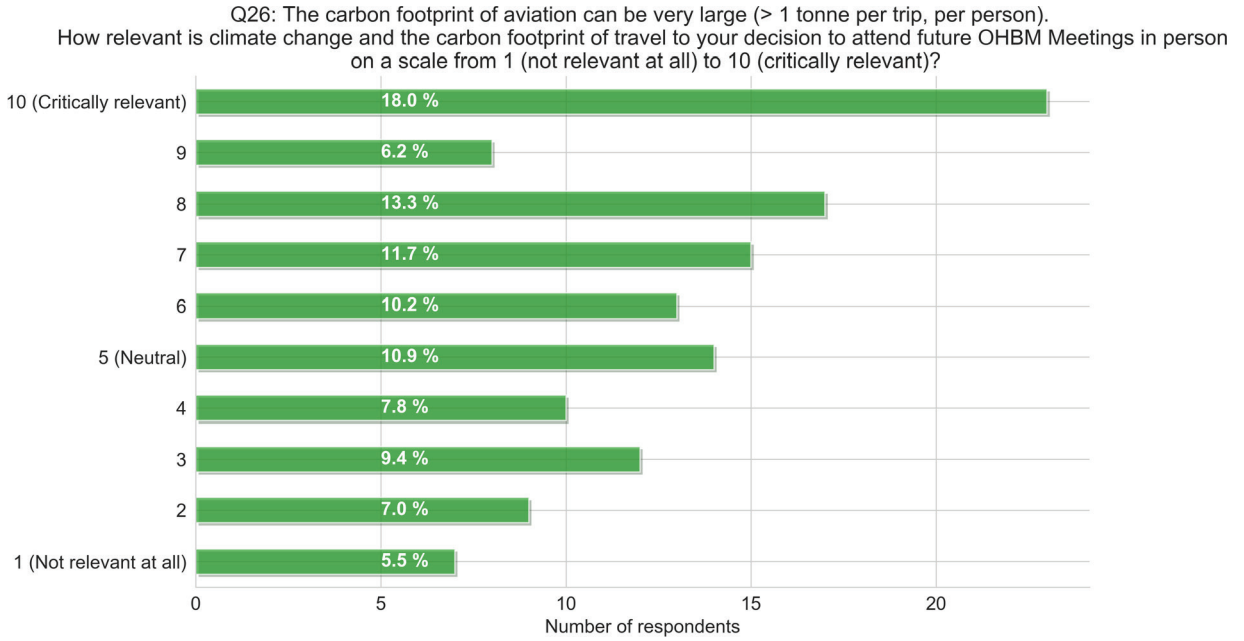

Fig 10. In the 2021 meeting attendee survey, 59.4% stated that the carbon footprint of OHBM meetings was important in their decision to participate (6 or more on the scale). 18% said it was critically relevant. This is certain to grow.

THE QUESTION OF CARBON OFFSETTING

It is sometimes asked, 'why can't we just offset our emissions and keep flying as we have done?' The concept of offsetting refers to schemes often offered by the aviation industry (and other polluting sectors) for consumers to pay for an activity that will reduce carbon in proportion to that emitted by their flight, and specifically, an activity that would otherwise not have happened – thus making the flight 'carbon neutral.' Offsetting schemes offered include a range of activities, from providing more efficient cookstoves in Africa to planting trees.

Unfortunately, offsetting is not an appropriate solution **to the huge carbon cost of flying** (2), for the following reasons:

- It is widely acknowledged that the carbon offsetting industry is poorly regulated, with no guarantee that the offset activity happens at all, sustains long-term, mitigates the emitted carbon, or that the activity would not have happened anyway.
- Offset schemes involving tree planting absorb carbon slowly over many years, while in the interim, the carbon emitted from the flight remains in the atmosphere. In addition, the amount of carbon absorbed by one tree over its lifetime is smaller than one might think: we calculated that to offset the carbon emitted by Rome 2019, 200,000 trees would need to be planted.[7] In addition to the required land use (approximately 2,600 hectares for 200,000 trees), which is a major limiting factor for this kind of offsetting, trees need about one century to reach maturity and long-term offset in times of increasing wildfires cannot be guaranteed[8].
- Mass reforestation and restoration of carbon sinks such as peatlands needs to happen in addition to, not instead of, real-time emissions reductions.
- Most of all, it enables a privileged few to avoid confronting the inconvenient truth that absolute emissions reductions are required across all areas of life, and that these emissions reductions cannot be put off for the future, or offloaded to somewhere, and someone else.

The climate scientist Kevin Anderson famously said in a 2012 (17) Nature editorial: 'Offsetting is worse than doing nothing. It is without scientific legitimacy, is dangerously misleading, and almost certainly contributes to a net increase in the absolute rate of global emissions growth.' The combination of the above issues with offsetting and the fact that non-fossil-fuel-powered planes are unlikely to be available for mass transport by 2050 means that in the short to medium term, reductions in passenger aviation are required.

Therefore, **carbon offsetting cannot be seen as a suitable approach to tackling real-time reductions in aviation emissions for conference organisers. Instead, they should look to support attendees to travel to a hub, travel by train, or attend online where possible.**

[7] Calculated using the Environmental Protection Agency Greenhouse Gas Equivalencies Calculator

[8] https://climate.nasa.gov/news/2927/examining-the-viability-of-planting-trees-to-help-mitigate-climate- change/

ADDITIONAL ASPECTS OF SUSTAINABILITY BEYOND AVIATION

In this report, we have focused on the climate costs of air travel to attend OHBM meetings, rather than sustainability aspects of what happens once attendees arrive at the conference centre and host city. This is because overwhelmingly, long-distance air travel has by far the largest environmental impact over conference centre practices and events during the conference.

However, it is important to note that there are indeed many aspects of sustainability that can be considered in the running of the in-person aspect of the meeting, from venue energy consumption and meat-free catering, to hotel choice and tourism (e.g., club night venue). In the case of the 2022 OHBM conference in Glasgow, organisers and OHBM's Sustainability and Environmental Action group provided information to attendees on topics such as ground travel to Glasgow, green award hotels, and cycling and walking within the city. Organisers also chose a world-leading sustainable conference venue, the Glasgow SEC.

It is also important that society members and conference attendees be informed of the ways in which organisers take steps to address the environmental impacts of in-person aspects of meetings. This may help create a culture in which sustainability is valued and prioritised. This can be done by mail outs from the Executive Office and also during opening and closing speeches from our leadership.

Therefore, **SEA-SIG recommends that colleagues across OHBM (e.g., SEA-SIG, Executive Office, leadership) continue to work together to minimise the environmental footprint of the in-person aspect of the meeting, including communicating to attendees what steps have been taken and why.**

LIMITATIONS AND FUTURE DIRECTIONS

We used data from recent in-person (2015, 2017–2019) annual meetings, as well as the 2020 online meeting, to calculate both carbon footprint and impact of geographical (or online) location in decision to attend. The location of attendees at the 2017–2019 meetings (across three major geographical regions of Americas, Asia/Oceania, and Europe) was also used to determine the most sustainable locations for future meetings. The data informing the suggested most 'climate-friendly' locations were therefore determined by historical annual meetings in which colleagues based in different regions (Americas, Asia/Oceania, Europe) choose to attend or not according to proximity. However, there are still some areas (e.g., South America) that were not proximal to the meeting location on any of the three rotations and thus likely under-represented in the analyses. In addition, we cannot know for sure the exact reasons that attendees modulate their attendance; though it is likely a combination of financial, visa, caregiver, and carbon factors.

It is also an important, though possibly hypothetical, question of what the full potential OHBM attendeeship might be if financial, political, cultural, and related inclusivity issues were less of a barrier. To develop better insights, SEA-SIG have collaborated with the OHBM Executive Office and are collaborating with the inclusivity working group to add demographic questions to the meeting registration form, which was used to identify where previous attendees travelled from. Looking forward, these additions to the registration data will enable us to examine in greater detail how demographic features (such as career status) interact with location (in a hub model or otherwise) to influence engagement with the meeting. Having established our analytical pipelines in the present analyses, we will be able to continue to explore how future locations (Montréal, Seoul, Brisbane) drive emissions but also attendance. Over the coming years, we will therefore build a deeper understanding of the interaction between sustainability and inclusivity for our global society.

We also note the fact that data on attendee home location were at the country level rather than city, and so we assumed participants travelled from the capital city of their given country. However, this means that for some geographically large countries, such as the United States or Canada, where attendees almost certainly travelled from a transport hub nearer their residence, the actual travel distance for attendees from these regions may be inaccurate by many hundreds of miles. Additionally, because the capital of the United States (Washington, DC) is on the Eastern Coast, and there are typically many attendees from the United States, this may bias the identification of lower carbon future locations to Europe (Washington, DC, closer) over Asia/Oceania (Washington, DC, farther away). However, we did separate the attendees from both the United States and Canada into West and East Coast, on a 50/50 split. Although a 50/50 split between the two coasts will inevitably not reflect the true geographical distribution of attendees, we hope this minimises bias towards Europe in the identification of lower carbon future locations. If future meeting registrations can obtain more precise home location for attendees, we can further reduce the risk of bias in the identification of lower carbon locations for future meetings.

RECOMMENDATIONS FOR A MORE SUSTAINABLE OHBM MEETING

SEA-SIG recommends that:

- All OHBM meetings from 2023 onwards offer hybrid attendance
- We continue to expand and improve the hybrid experience year on year, ensuring that by 2024, all aspects of the program can be fully accessed and engaged with online
- Furthermore, we should adopt a hub model (also including hybrid offering), favouring hybrid hub over hybrid biennial, as hybrid hub saves more emissions
- Set locations of future meetings in places that minimise long-distance aviation, making use of travel footprint tools to determine the most climate-friendly locations
- Communicate the setting of locations with carbon footprint in mind to OHBM members
- Encourage attendees to travel by train where possible
- Conduct an assessment of inclusivity and accessibility issues for alternative OHBM meeting models, including hybrid, hub, and biennial
- Do not advocate carbon offsetting as a suitable approach to tackling real-time reductions in aviation emissions, and instead support attendees to travel to a nearby hub, travel by train, or attend online where possible
- Colleagues across OHBM (e.g., SEA-SIG, Executive Office, leadership) should work together to minimise the environmental footprint of running the in-person aspect of the meeting, including communicating to attendees what steps have been taken and why
- Recognise that beyond the direct carbon savings of updating the meeting format, there are important implications for social norms

DATA AVAILABILITY STATEMENT

Attendance data for past conferences as well as the code to generate Figures 1, 2, 4 and 7 are available under https://osf.io/f85zx/.

FURTHER READING

- Kim Nicholas, Lund University: 'Data on academic flying' slide share
- FlyingLess blog and FAQ
- Most important 3 references (below) indicated by *

REFERENCES

1. Rae, C.L., Farley, M., Jeffery, K.J., & Urai, A.E. (2022). Climate crisis and ecological emergency: Why they concern (neuro)scientists, and what we can do. *Brain and Neuroscience Advances, 6,* 1–11. https://doi.org/10.1177/23982128221075430
2. Aron, A.R., Ivry, R.B., Jeffery, K.J., Poldrack, R.A., Schmidt, R., Summerfield, C., & Urai, A.E. (2020). How can neuroscientists respond to the climate emergency? *Neuron, 106,* 17–20. https://doi.org/10.1016/j.neuron.2020.02.019
3. Wynes, S., & Nicholas, K.A. (2017). The climate mitigation gap: Education and government recommendations miss the most effective individual actions. *Environmental Research Letters, 12*(7), 74024. https://doi.org/10.1088/1748-9326/aa7541
4. Gattrell, W.T., Barraux, A., Comley, S., Whaley, M., & Lander, N. (2022). The carbon costs of in-person versus virtual medical conferences for the pharmaceutical industry: Lessons from the coronavirus pandemic. *Pharmaceutical Medicine, 36,* 131–142. https://doi.org/10.1007/s40290-022-00421-3
5. Klöwer, M., Allen, M., Lee, D., Proud, S., Gallagher, L., & Skowron, A. (2021). Quantifying aviation's contribution to global warming. *Environmental Research Letters, 16*(10), 104027. https://doi.org/10.1088/1748-9326/ac286e
6. Gössling, S., & Humpe, A. (2020). The global scale, distribution and growth of aviation: Implications for climate change. *Global Environmental Change, 65,* 102194. https://doi.org/10.1016/j.gloenvcha.2020.102194
7. Wynes, S., Donner, S.D., Tannason, S., & Nabors, N. (2019). Academic air travel has a limited influence on professional success. *Journal of Cleaner Production, 226,* 959–967. https://doi.org/10.1016/J.JCLEPRO.2019.04.109
8. Wynes, S., & Donner, S.D., (2018). Addressing greenhouse gas emissions from business-related air travel at Public Institutions: A case study of the University of British Columbia. https://pics.uvic.ca/sites/default/files/AirTravelWP_FINAL.pdf
9. Lee, D.S., Fahey, D.W., Skowron, A., Allen, M.R., Burkhardt, U., Chen, Q., … & Wilcox, L.J. (2021). The contribution of global aviation to anthropogenic climate forcing for 2000 to 2018. *Atmospheric Environment, 244,* 117834. https://doi.org/10.1016/j.atmosenv.2020.117834

*10. Klöwer, M., Hopkins, D., Allen, M., & Higham, J. (2020). An analysis of ways to decarbonize conference travel after COVID-19. *Nature, 583*(7816), 356–359. https://doi.org/10.1038/d41586-020-02057-2

*11. Levitis, E., Gould van Praag C.D., Gau, R., Heunis, S., DuPre, E., Kiar, G., … & Maumet, C. (2021). Centering inclusivity in the design of online conferences – An OHBM-Open Science perspective. *GigaScience, 10*(8), giab051. https://doi.org/10.1093/gigascience/giab051

*12. Sarabipour, S., Khan, A., Seah, Y.F.S., Mwakilili, A.D., Mumoki, F.N., Sáez, P.J., … & Mestrovic, T. (2021). Changing scientific meetings for the better. *Nature Human Behaviour, 5*(3), 296–300. https://doi.org/10.1038/s41562-021-01067-y

13. Barret, D. (2020). Estimating, monitoring and minimizing the travel footprint associated with the development of the Athena X-ray Integral Field Unit: An online travel footprint calculator released to the science community. *Experimental Astronomy, 49,* 183–216. https://doi.org/10.1007/s10686-020-09659-8
14. Skiles, M., Yang, E., Reshef, O., Munoz, D., Cintron, D., Lind, M.L., … & Kumar, M. (2021). Conference demographics and footprint changed by virtual platforms. *Nature Sustainability, 5*(2), 1–8. https://doi.org/10.1038/s41893-021-00823-2
15. Velin, L., Lartgiue, J.W., Johnson, S.A., Zorigtbaatar, A., Kanmounye, U.S., Truche, P., & Joseph, M.N. (2021). Conference equity in global health: A systematic review of factors impacting LMIC representation at global health conferences. *BMJ Global Health, 6,* e003455. https://doi.org/10.1136/bmjgh-2020-003455
16. Niner, H.J., & Wassermann, S.N. (2021). Better for whom? Leveling the injustices of international conferences by moving online. *Frontiers in Marine Science, 8,* 146. https://doi.org/10.3389/fmars.2021.638025
17. Anderson, K. (2012). The inconvenient truth of carbon offsets. *Nature, 484,* 7. https://doi.org/10.1038/484007a

