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PAPER

Astronomy's climate emissions: global travel to scientific meetings in 2019

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Background

- Previous assessments:
  - Conference travel: ~17 – 47% of carbon footprint in astronomy
    (Stevens et al. 2019,2020, Jahnke et al. 2020, Burtscher et al. 2020,2021)
  - Astronomy worst among the sciences for conference travel

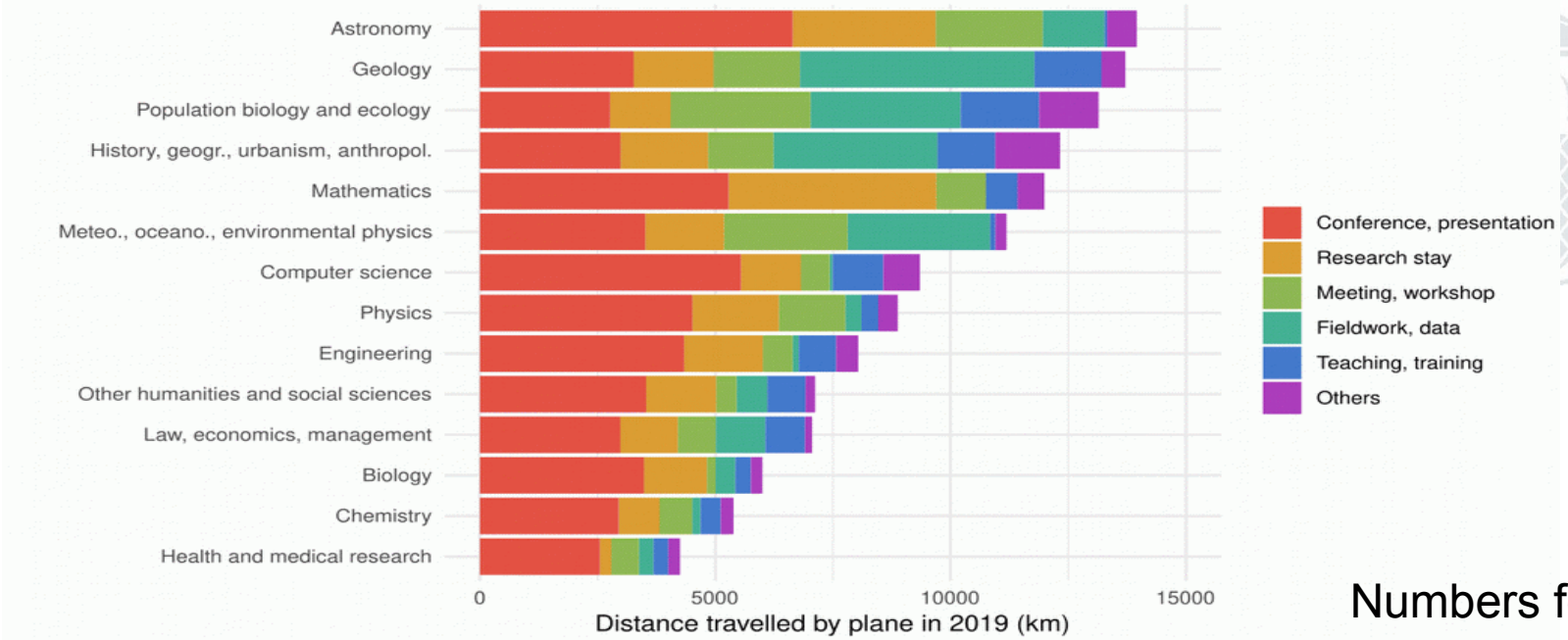


Fig 3. Average distance traveled by plane in 2019 by discipline of respondents.

Numbers for France:
Blanchard et al. (2022)

  - Background
    - Traditionally small and very international community
    - Observatories in remote places


ASTRONOMERS
FOR PLANET EARTH
NASA, Apollo 8, Bill Anders
Processing: Jim Weigang

Goal

Global statistics for our field:

- Collect all information for known conferences:
  - Canadian Astronomy Data Centre, exoplanet.eu, additional meetings in Indian, Russian, Japanese, Australian community and known to A4E members
  - Public information & request for anonymized data from meeting organizers

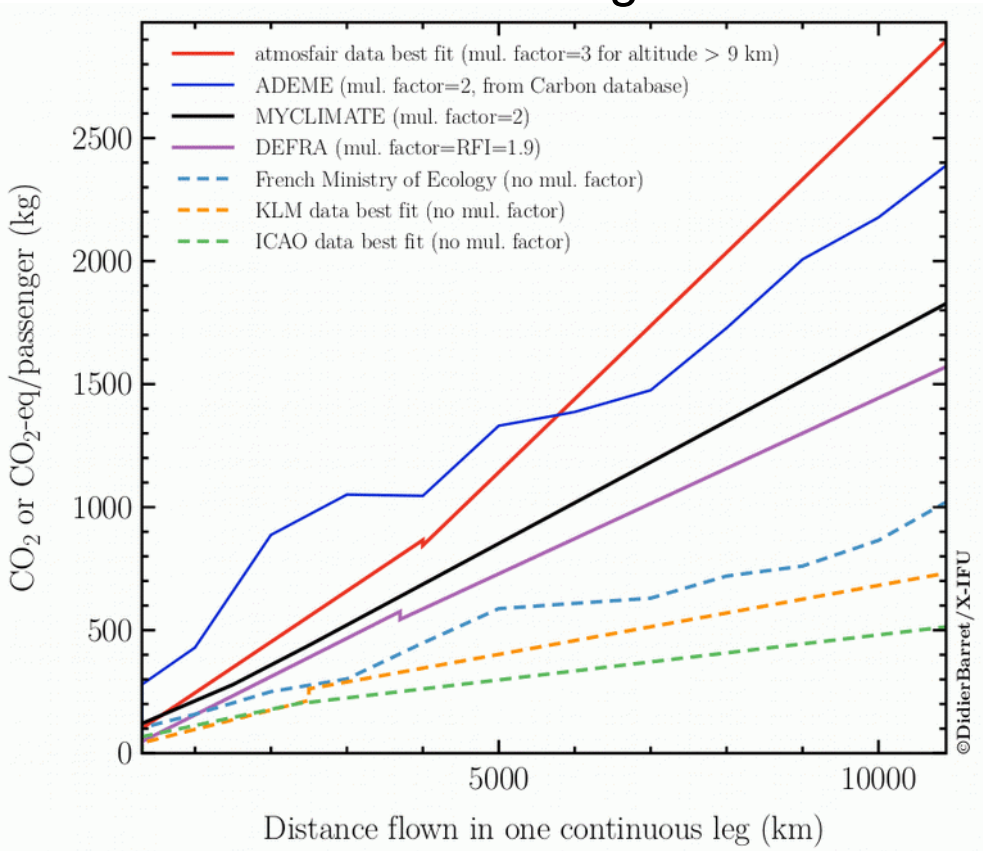
Conference venue location	Number of meetings	Cumulative travelled distance [km]	Cumulative CO_2e emissions [t]	Mean number of participants	Mean emission per participant [tCO_2e]	Mean local participants [%]
CONFERENCES						
World-wide	258	2.16×10^8	36254	128^{+33}_{-86}	1.1 ± 0.6	21 ± 18
Africa	3	3.13×10^6	515	93 ± 80	1.9 ± 0.4	9 ± 8
Asia	49	3.10×10^7	5125	91 ± 54	1.1 ± 0.7	26 ± 20
Europe	124	9.76×10^7	16315	127^{+37}_{-87}	1.0 ± 0.5	17 ± 14
North America	59	6.50×10^7	11074	176^{+64}_{-129}	1.2 ± 0.6	22 ± 18
Oceania	18	1.62×10^7	2694	83 ± 55	1.6 ± 1.2	24 ± 21
South America	5	3.08×10^6	531	132 ± 115	0.8 ± 0.8	40 ± 28
SCHOOLS						
World-wide	42	1.05×10^7	1786	54 ± 27	0.7 ± 0.4	23 ± 21
Africa	1	1.99×10^5	33	70	0.46	16
Asia	12	2.48×10^6	435	53 ± 21	0.65 ± 0.27	25 ± 22
Europe	18	4.01×10^6	690	53 ± 24	0.69 ± 0.33	20 ± 17
North America	6	2.02×10^6	340	59 ± 45	1.10 ± 0.28	20 ± 17
Oceania	3	2.10×10^5	36	32 ± 21	$0.23^{+0.35}_{-0.18}$	49 ± 41
South America	2	1.53×10^6	252	87 ± 42	1.3 ± 0.5	32 ± 14

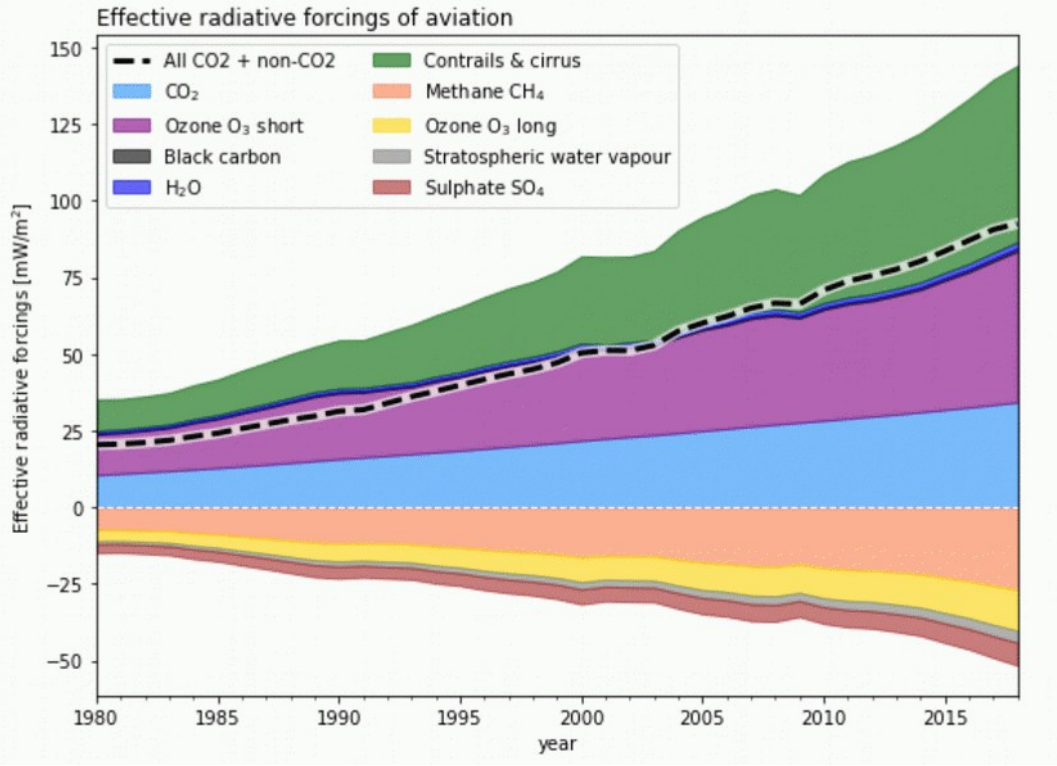
  - 300 meetings with complete information, 62 with extrapolated data (15% of trips, 9% of emissions)

Method

Greenhouse effect of flights:

- CO_2 emission provide only a minor contribution, contrails and O_3 have bigger impact
- Significant variation depending on time and location of flight





Klöwer et al. (2021)

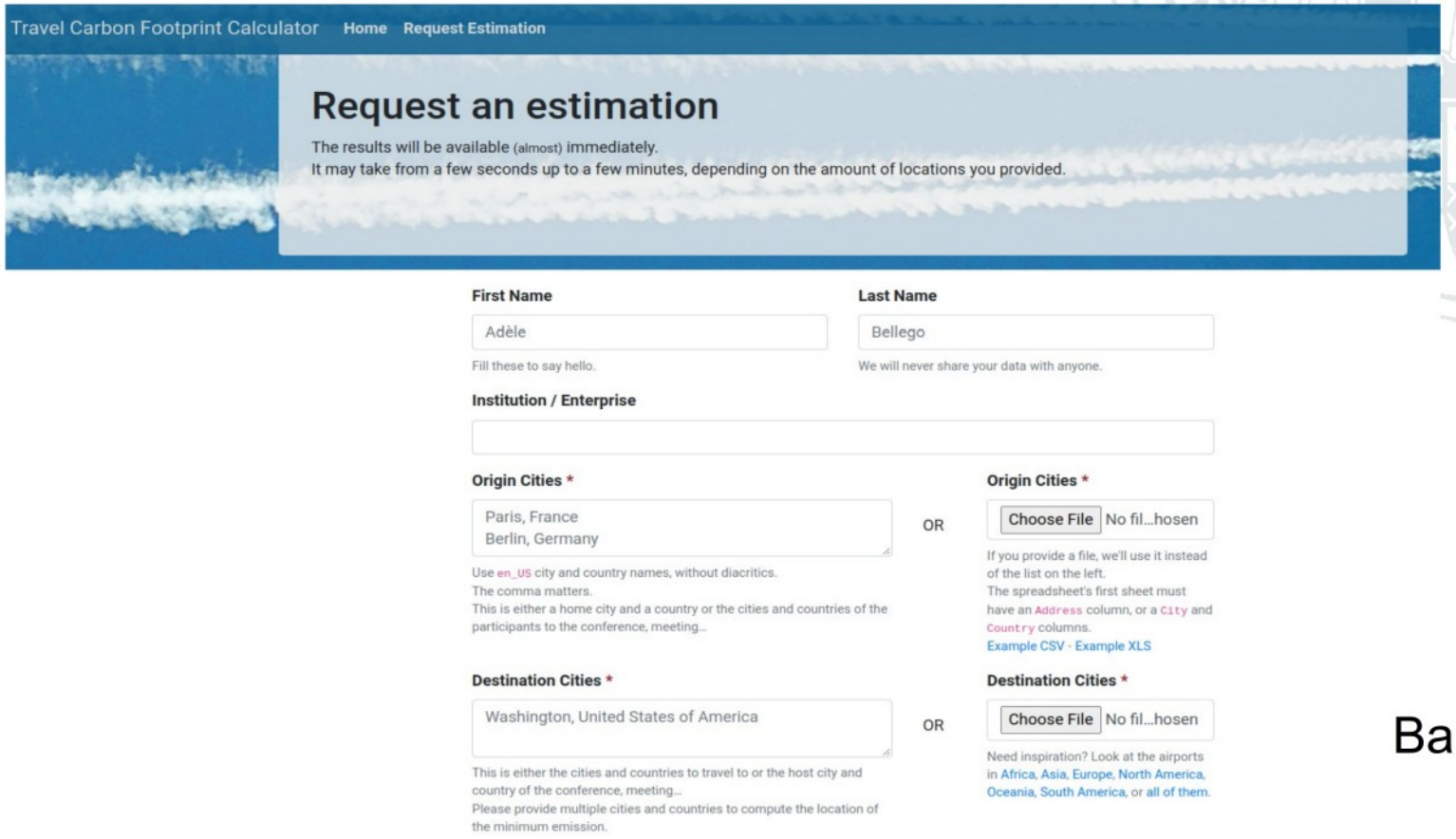
- We used a conservative correction factor of 1.95 (total vs. direct CO_2)

Barret et al. (2020)

Method

Practical implementation:

- **Travel Carbon Footprint Calculator** by Didier Barret:
  https://travel-footprint-calculator.irap.omp.eu/



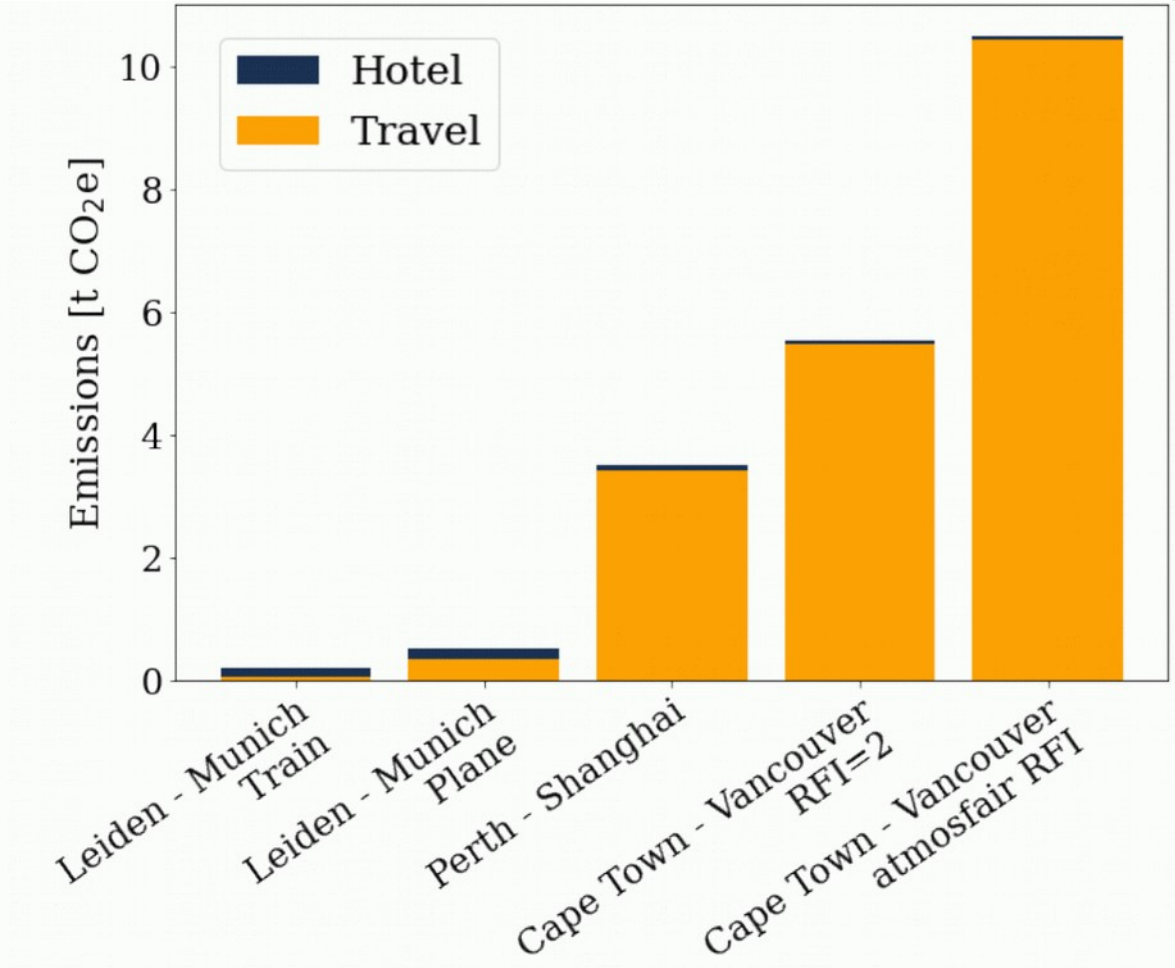
Barret et al. (2020)

- Assumes 5% longer path for flights than the great circle distance
  - 40% for trains

Method

Comparison to hotel costs:

- Based on tables by atmosfair gGmbH, Germany, “VDR Standard Part III”: *https://www.atmosfair.de/en/standards/emissions_calculation/co2_reporting_for_companies/vdr_standard_methodology*



- Trains and hotels provide an almost negligible contribution to the conference related emissions

Results

Global numbers

Number of meetings	362
Total CO_2e emissions	42.5 ± 0.4 kt
Traveled distance	1.5 AU
Mean emission/meeting/person	1.0 ± 0.6 t CO_2e
Meeting participations per astronomer	1.4

Compare: Average carbon footprint of individuals living in Germany: ~11.2 t CO_2e/year

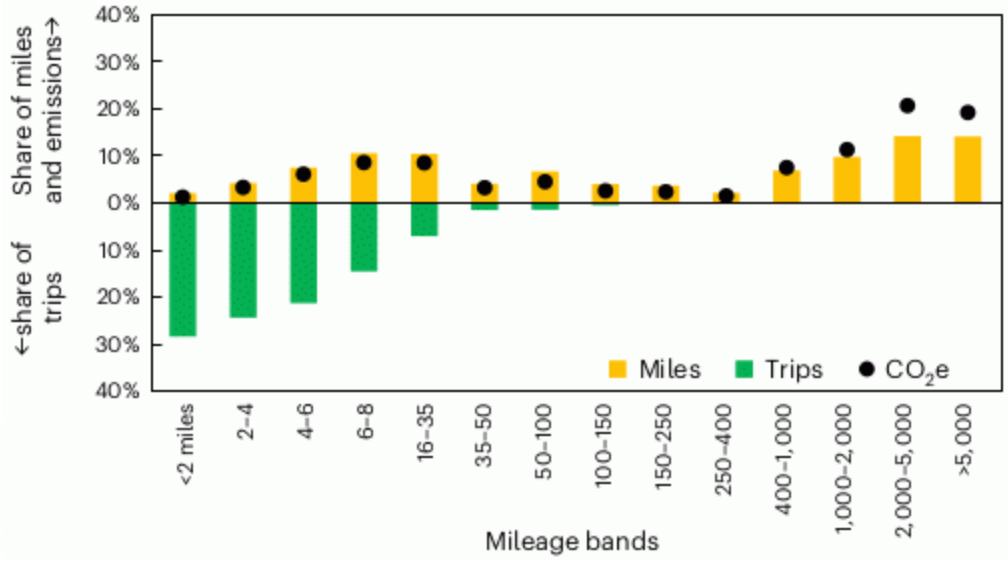
Trips per astronomer assumes 30000 astronomers world wide, Based on IAU extrapolations (Knödlseder J., et al., 2022, Estimate of the carbon footprint of astronomical research infrastructures. Nature Astronomy, 6, 503)

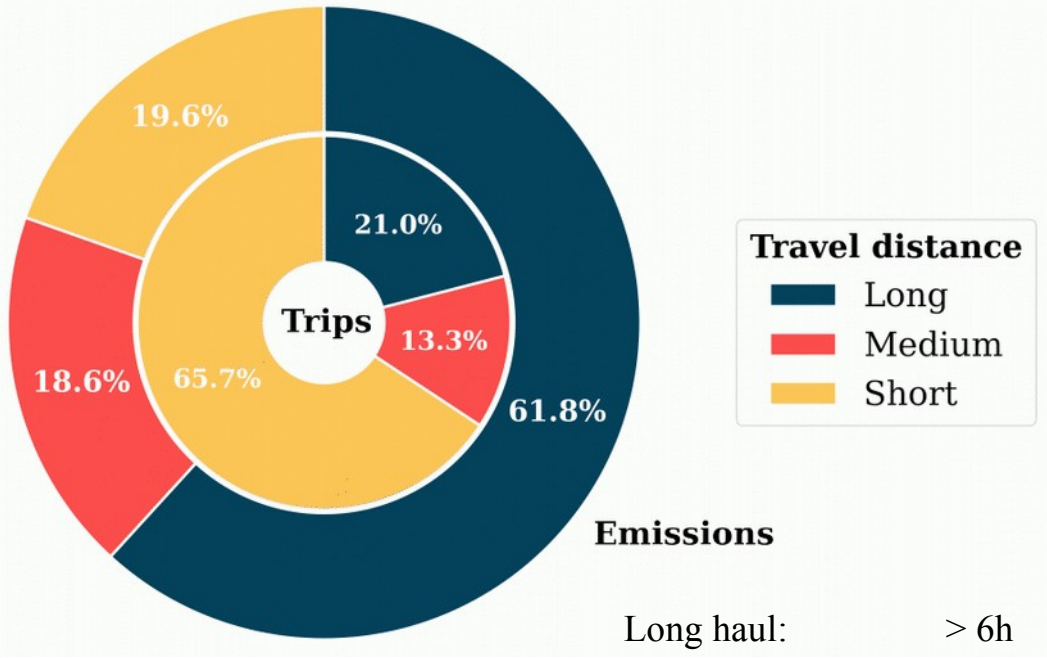
Results

Global numbers

- Total CO_2e emissions: 42.5 ± 0.4 kt

- Main contribution:
  - long-distance flights
  - Consistent with British transportation statistics (Wadud et al. 2024):



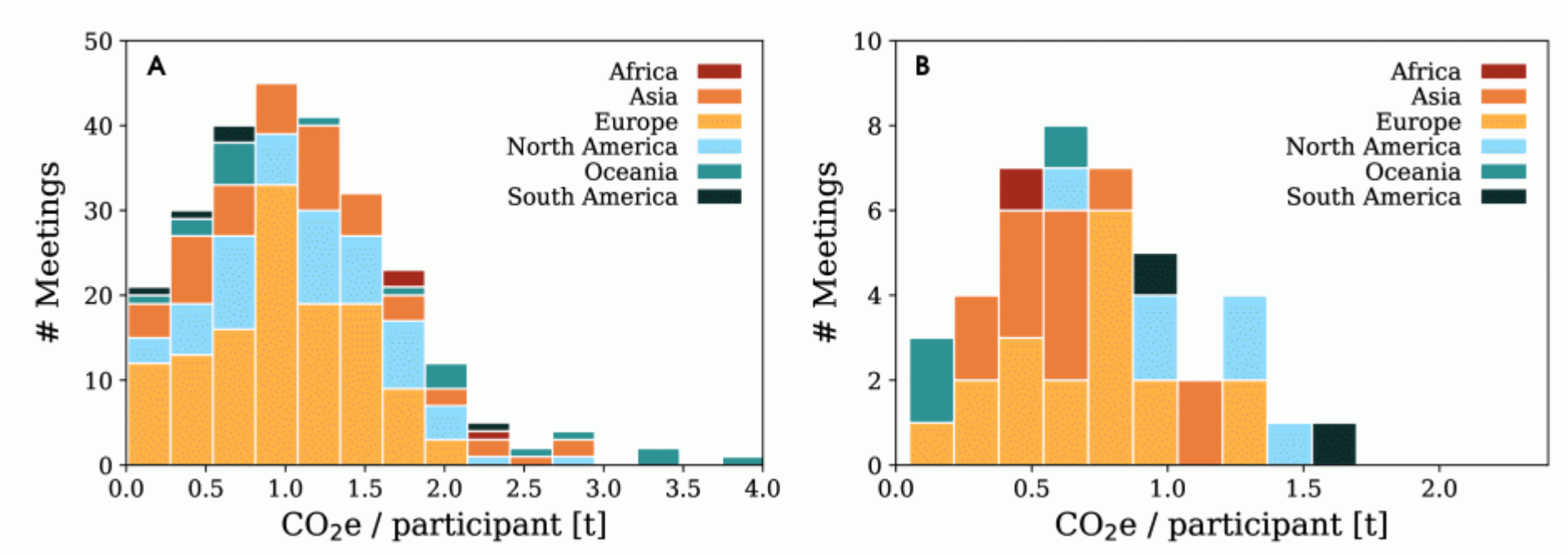


Long haul: > 6h
Medium Haul: 6h > t > 3h
Short houl: < 3h

Results

Conferences vs. schools

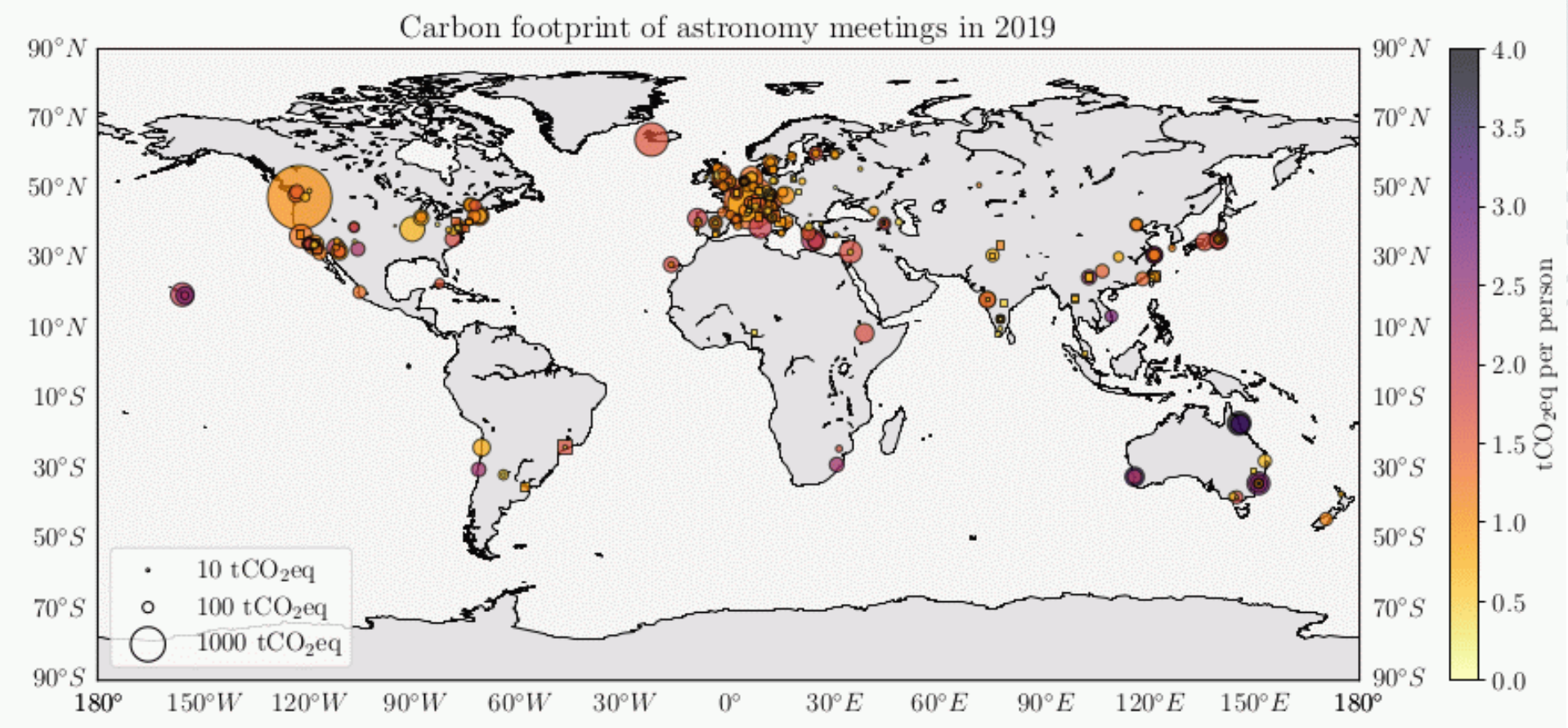
- 307 conferences (49 with incomplete data)
- 55 schools (13 with incomplete information)



- CO_2e per conference participation 1.1t, for schools only 0.7t
- schools in Asia significantly more local

World-wide distribution

Conference places

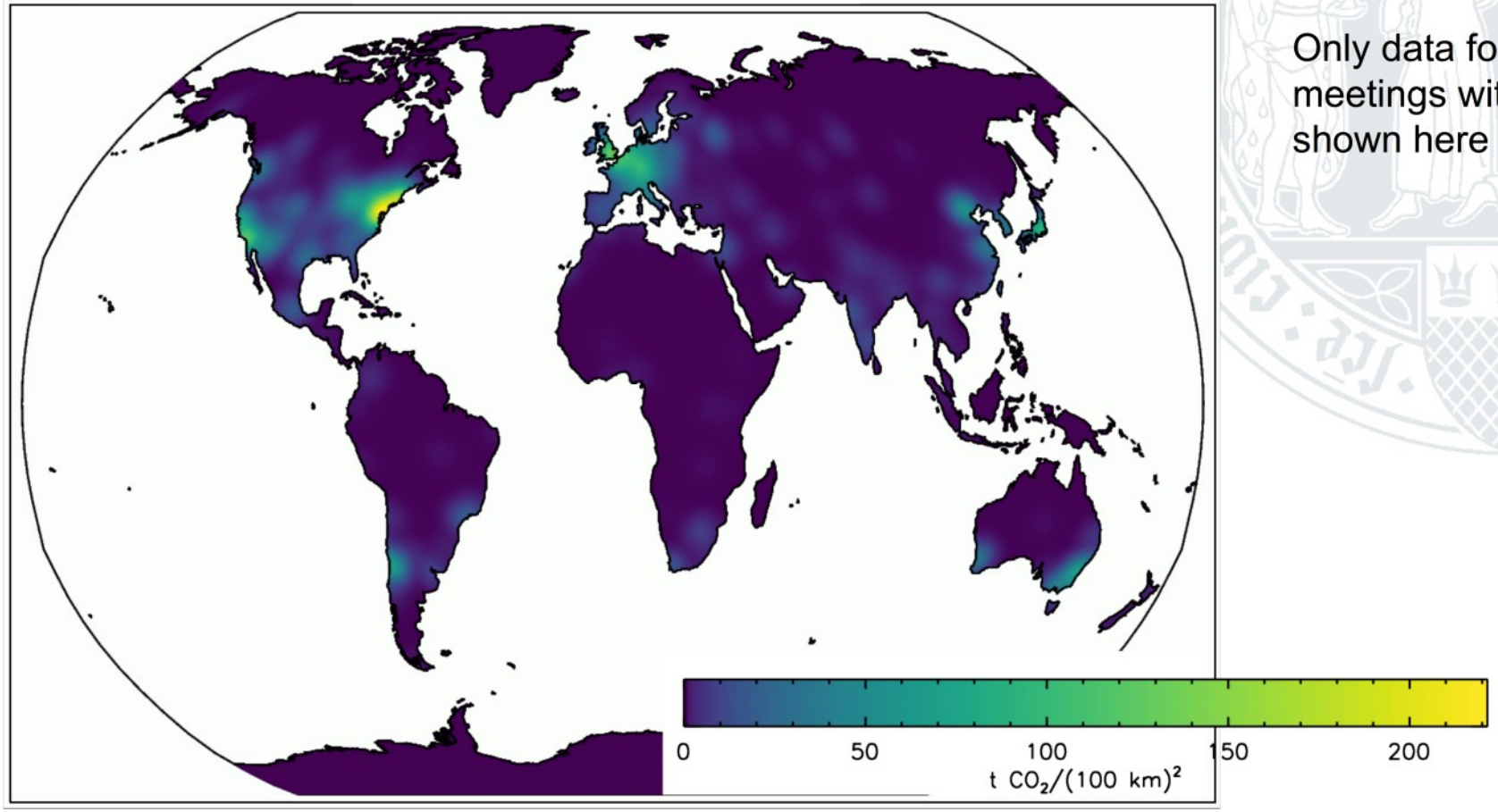


- Dominated by Europe (47%) - peaks in Geneva and Lyon
  - extreme in US from AAS meeting in Seattle

Very high CO_2e intensity for meetings in Australia, Reykjavik, Hawaii

World-wide distribution

Origins of conference participants (by accumulated eCO_2 emission)

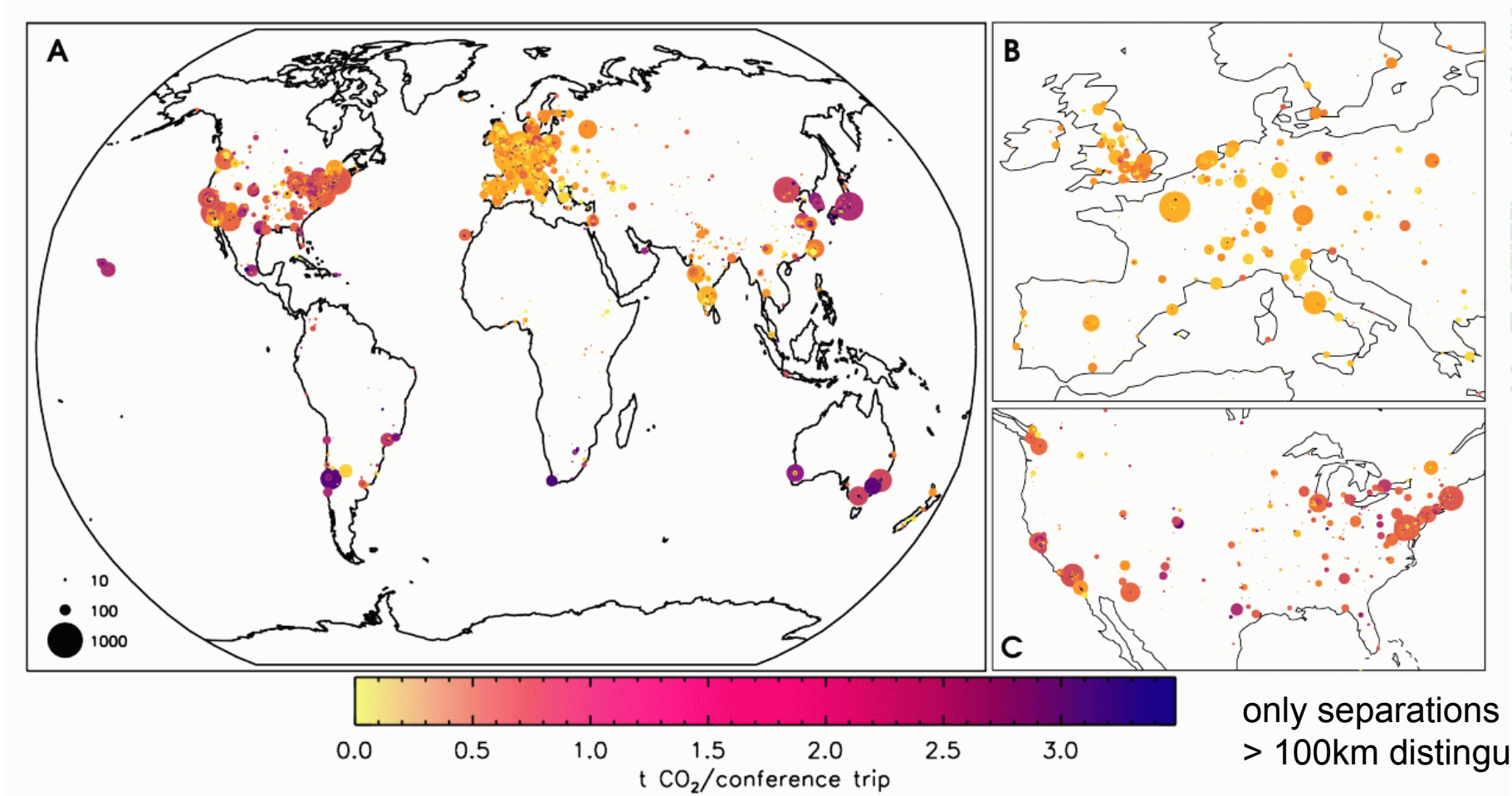


Only data for the 300 meetings with full information shown here

- Highest concentration of emissions at the US East coast (Baltimore, Cambridge)
- Widely spread over Europe
- Australia not high due to low number of participants

World-wide distribution

Origins of conference participants (by numbers and eCO_2 intensity)

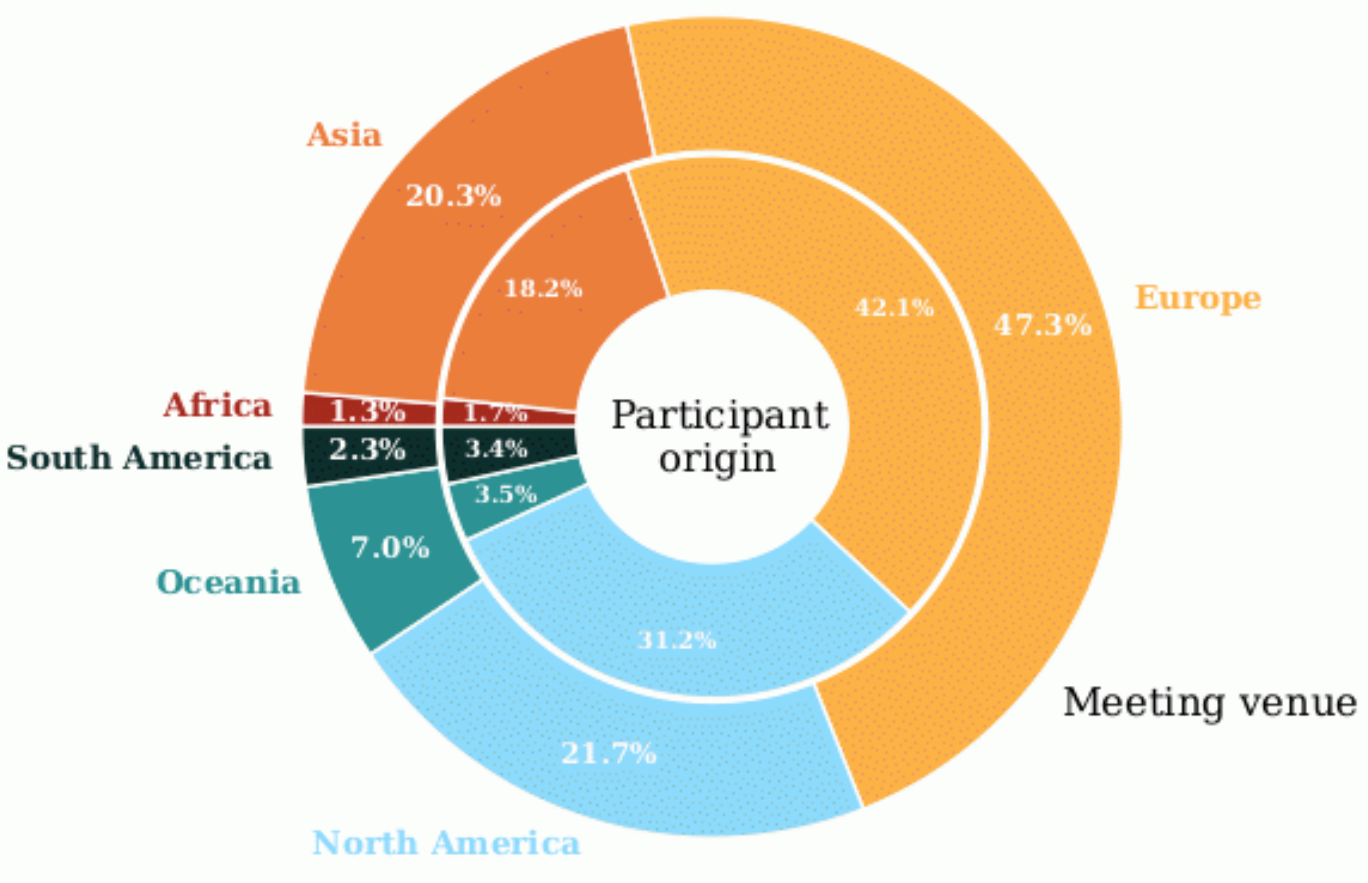


only separations
> 100km distinguished

- Most participants from Europe and the US East coast
- European participants profit from the on-average shorter distances
  - Mosts European attendants from Paris, but Heidelberg & Rome also significant

World-wide distribution

Comparison of places and participants

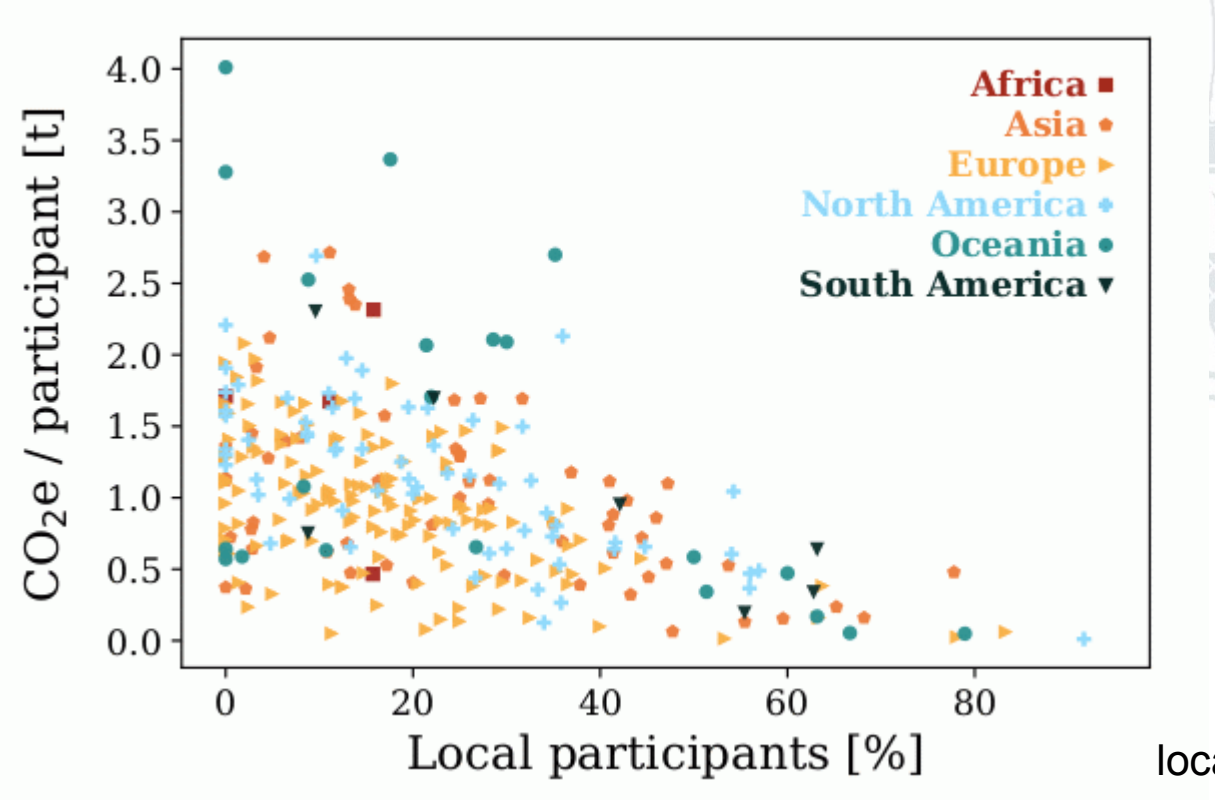


- Most meetings and participants from Europe
- Relatively more outgoing trips from North America, more incoming ones to Asia and Oceania

Problem

Conference tourism

- Conferences in nice places without local astronomers



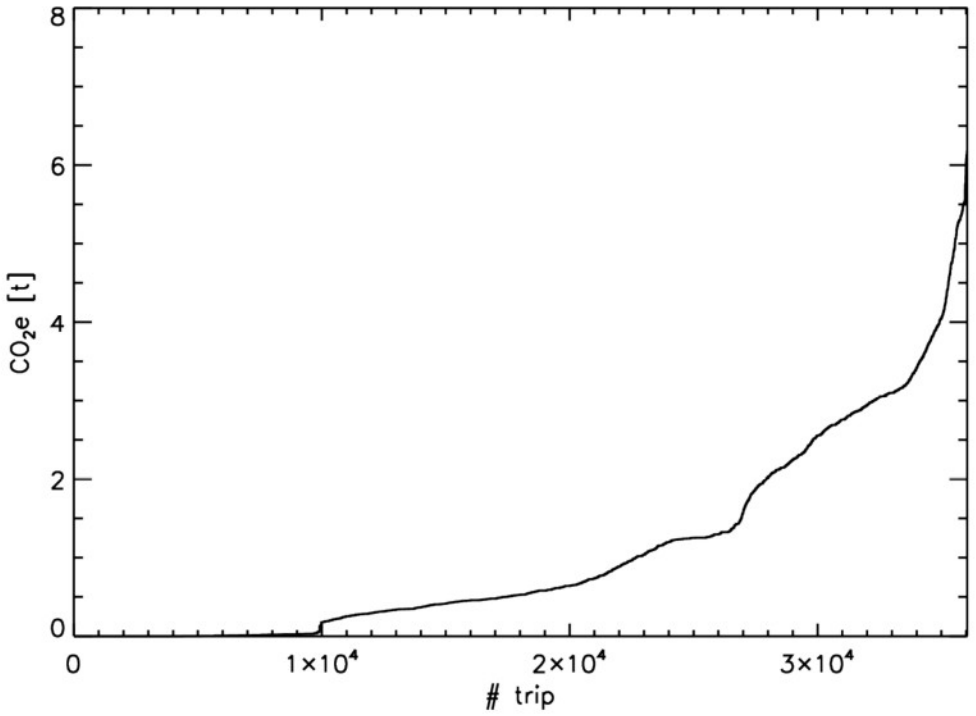
local = within 100km

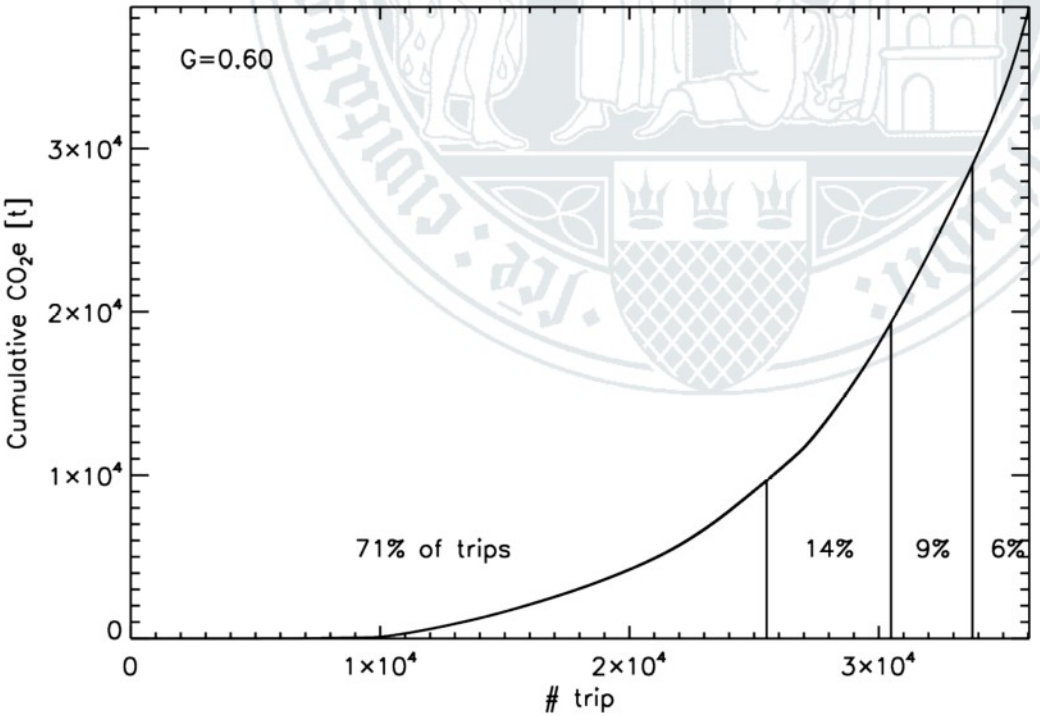
- Global trend of increased emissions with fewer local participants
  - Significant only if locals increase to > 35%
  - Even meetings with very few locals can have low average emissions

Shape of distribution

Few long trips dominate the sum

- About 10000 local participants produce no CO_2





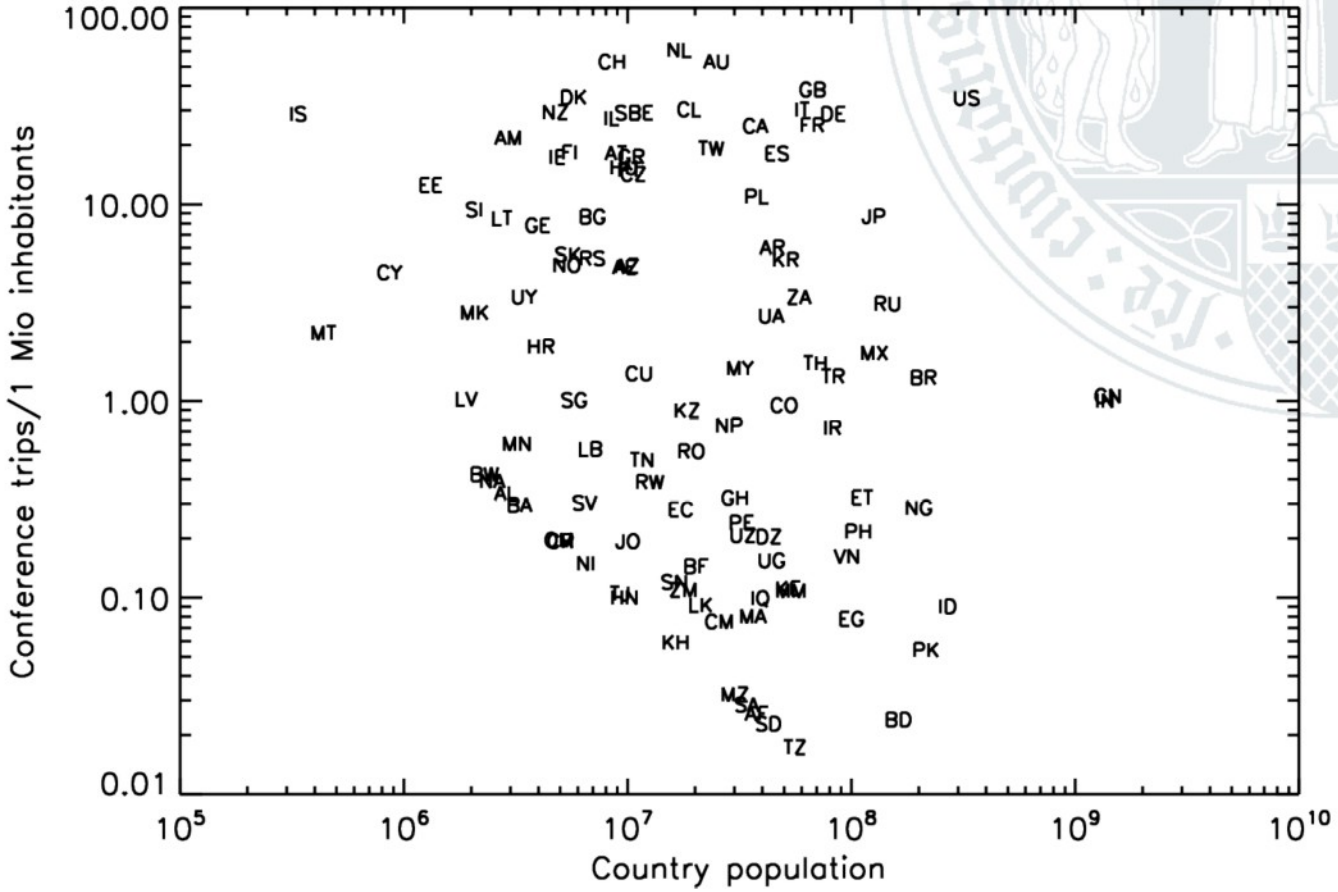
- 71% of all trips produce only 25% of the emissions
  - the 6% of long-distance trips produces another 25%
  - Very skewed distribution

Gini coefficient: $$G = \frac{\sum_{i=0}^{n} \sum_{j=0}^{n} |x_i - x_j|}{2n \sum_{i=0}^{n} x_i}$$

Social and economic exclusivity

Participation in conferences

- No correlation with population



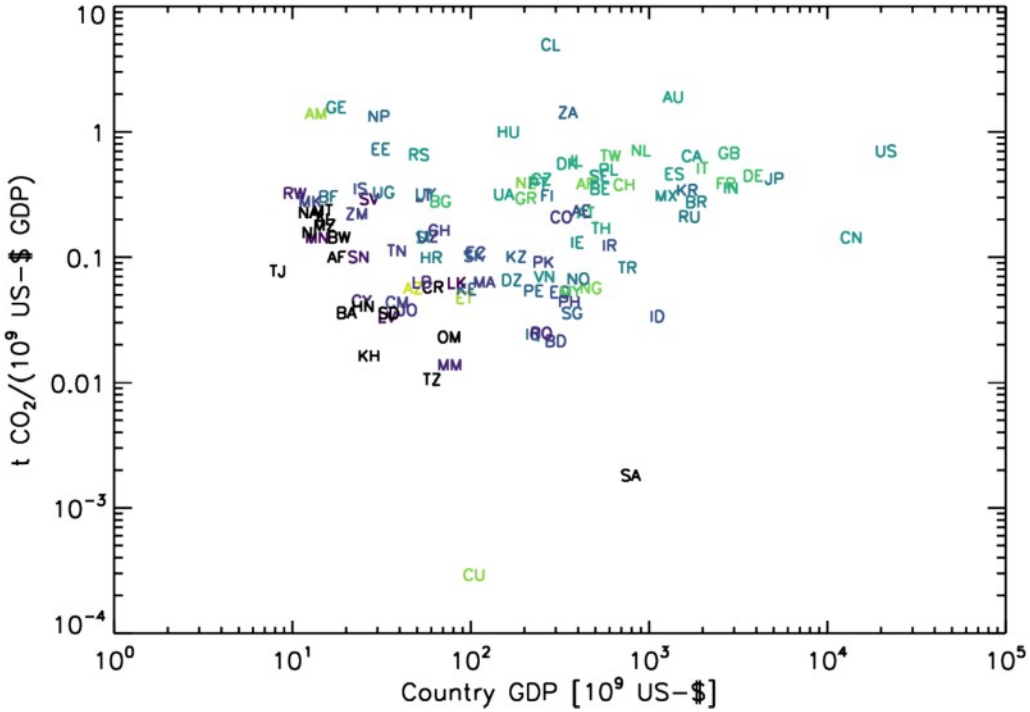
- Mirrors the national role of astronomy
  - budget spent for science and astronomy

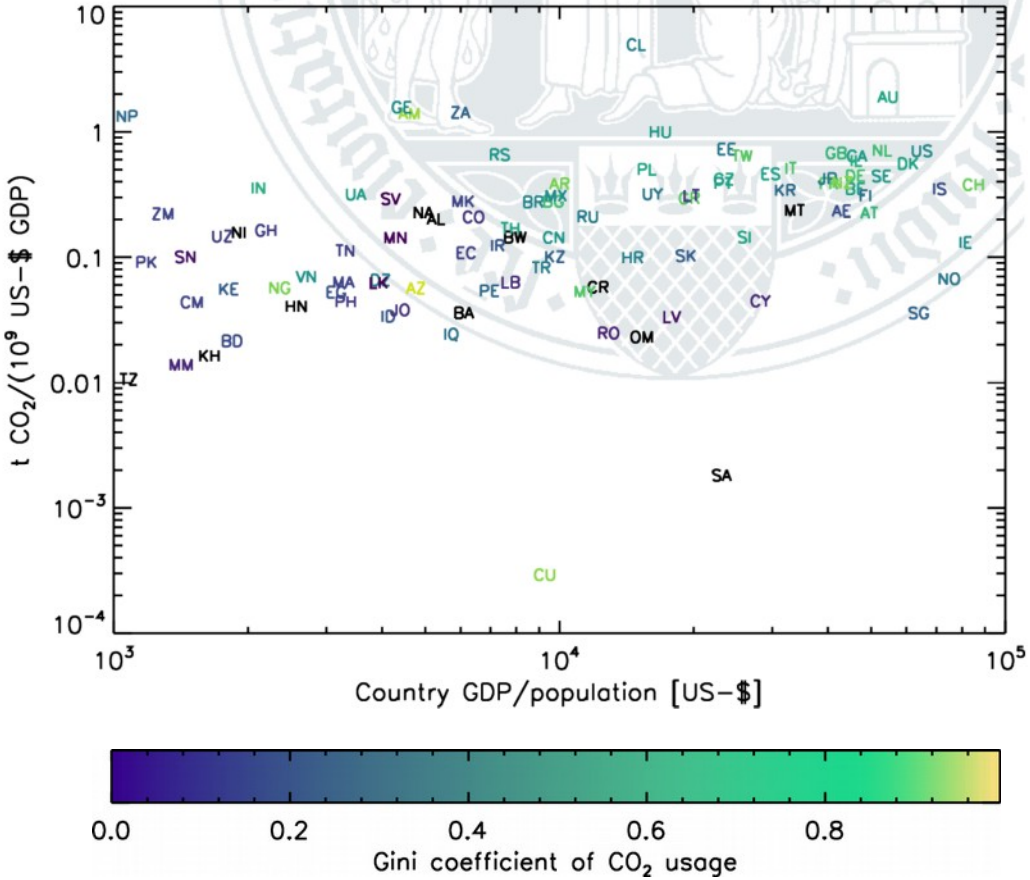
numbers on population and GDP in 2019 from the UN Department of Economic and Social Affairs, Statistics Division: *https://unstats.un.org/unsd/snaama/Basic*

Social and economic exclusivity

Participation in conferences

- Reflects budget spent for astronomy





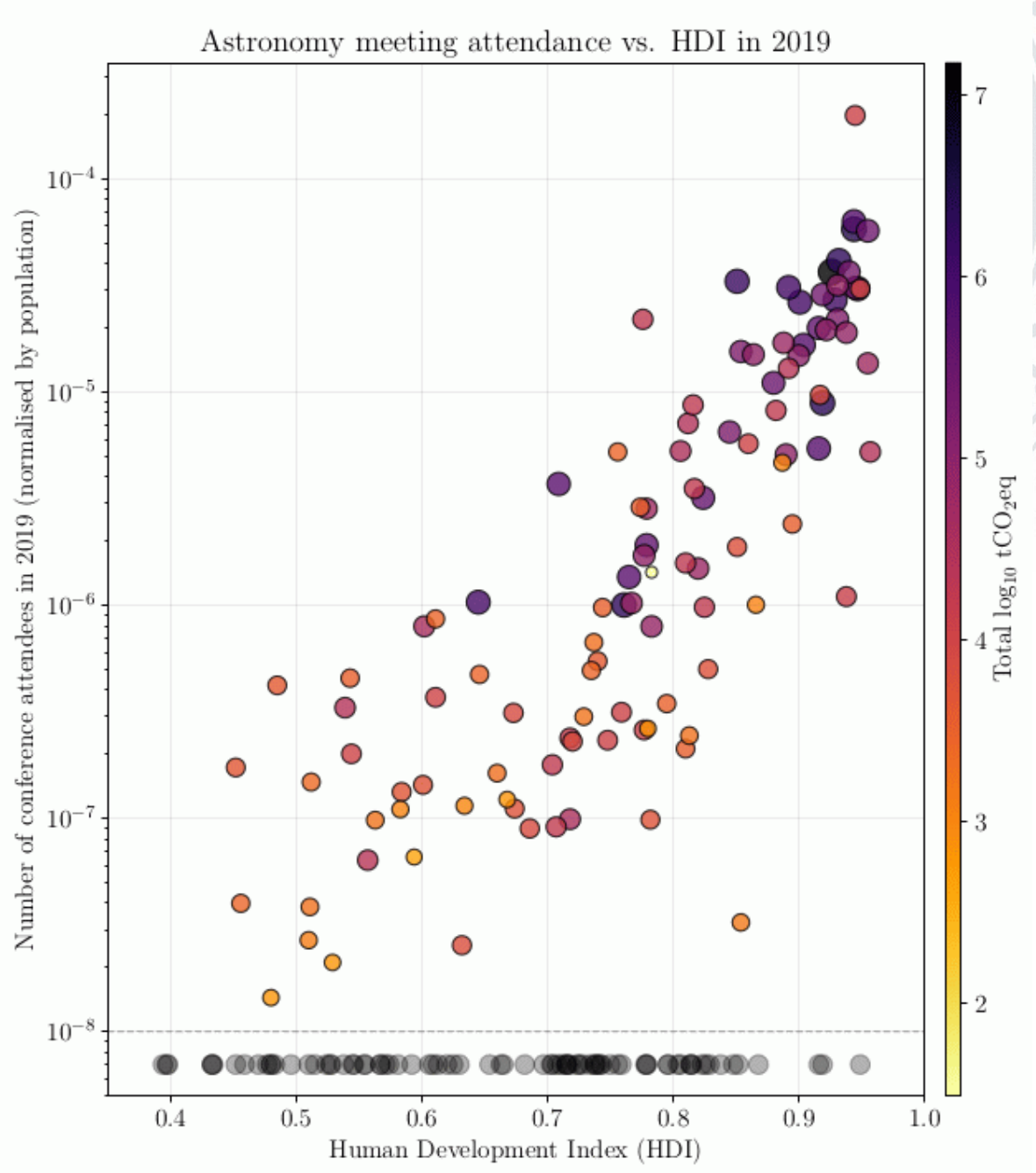
- Mirrors the national role of astronomy
  - discriminates against remote places like Chile

Social and economic exclusivity

Participation in conferences

- Reflects budget spent for astronomy

- Astronomers from less wealthy countries are excluded from meeting participation by lacking financial resources!



Social and economic exclusivity

Participation in conferences

- Criteria identified as major exclusions causes
  - Financial costs for in-person participation (transportation, accomodation, conference fees): ~ 500-3000 €
  - Visa processes (mainly discriminating against astronomers from African and Asian countries)
  - Time constraints from care-taking obligations (often more discriminating against female astronomers)
  - Other family issues*
  - Physical disabilities
  - Work responsibilities (lecture times, …)*
  - Neurodivergency*

* not mentioned in our paper but contained in the AAS Climate Change Task Force Report (Rector et al. 2024)

→ Making meetings more integrative reduces their CO_2 footprint as a side effect

Possible solutions

Different approaches depending on main aims of the meeting:

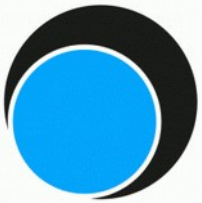
- Hub-model
  - Example: AAS meeting in Seattle, 3,396 participants, 3462 t CO_2e
    - 2-hub model: Los Angeles + Baltimore → 1377 t CO_2e
    - 3-hub model. Los Angeles + Baltimore + Amsterdam → 1201 t CO_2e
- Pure online meetings
  - Working examples: Cosmology From Home
  - Cheap but needs careful setup – interactive and persistent, synchronous and asynchronous elements required
- Hybrid meetings
  - Can allow for equal-footing participation of everyone when carefully planned
  - Rich experience available by now – collected e.g. at TFOM
  - Problems:
    - Expensive, in particular for large meetings
    - Tendency to always invite the same “big shots” that only call in for their talks

Hybrid meetings

Conference setup is reusable:

- Do not re-invent the wheel for every conference
- Example:
  ASA meeting
  in June 2024

Recommendations



ASTRONOMERS FOR PLANET EARTH

Updated October 2023

Statement on Conferences and Meetings

For all meetings, regardless of their format:

1. Clearly **define the purpose** of the event and weigh its importance to choose the best-suited format and tools corresponding to your aims.

2. **Regularly experiment with new tools and approaches** to build awareness of new solutions. To this end, The Future of Meetings team offers advice and technical help to organizers. An example is to divide large, international meetings into several synchronous regional hubs.

3. Provide **means of interaction, networking and socializing that are accessible and inclusive**. A4E offers guidelines to this end.

4. To enhance global accessibility independent of bandwidth and timezone, take **recordings** and provide them in a timely manner along with asynchronous communication channels.

5. Determine a **code of conduct and points of contact** in case of any related concerns or violations for each event, see eg the A4E Symposium code of conduct.

6. **Perform evaluations** to quantify the satisfaction of the audience and to measure the success of the intended purpose of the event (point 1). Sharing the corresponding outcomes with attendees is encouraged.

Recommendations

ASTRONOMERS FOR PLANET EARTH

Updated October 2023

Statement on Conferences and Meetings

If it is concluded that an in-person component is required:

7. **Virtual participation should be granted** to attendees and speakers who are not able or willing to travel to the venue. This not only covers scientific content but also networking and socializing. A digital-first approach is recommended for good interaction.

8. The meeting **venue should be chosen to minimize the environmental impact** of the event[10]. Choices in partial disagreement with this need to be well justified, see point 1. A statement about the location is recommended for transparency.
    - For instance, events taking place in developing countries may increase participation from underrepresented parts of the community. To reach this goal they should include a clear list of aims, involve the local community, and establish networking and long-term collaboration with these communities.
    - Some venues have particular benefits for team-building etc. but choosing a remote venue solely for its touristic assets is not acceptable.

9. **Priority for face-to-face interaction** (including funding allocation to facilitate travel) should be given to early-career researchers, and those from traditionally underrepresented groups and countries, as the demographic who should benefit from networking, with some caveats to allow for a fair allocation of funding. Senior people in attendance should ensure to be available for junior researchers.

10. Whenever possible **multiple events should be made compatible** for overlapping audiences, i.e. organizers are encouraged to cooperate so that events take place over several weeks in the same area.

Questions

We need an open discussion:

- Do we accept that astronomy continues to have a CO_2 footprint per astronomer well above that of other science disciplines?
- How much effort are we willing to invest to allow for the inclusion of ALL astronomers into our meetings?
- What level of personal conference/workshop travel is needed to maintain a fruitfully collaborating international community?
- How can we shift the narrative on a conference participation – slower travel, night trains, longer stays?
- How can we compensate the environmental impact of the remaining flights?