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# Like diamonds in the sky? Public perceptions, governance, and information framing of solar geoengineering activities in Mexico, the United Kingdom, and the United States

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**ABSTRACT**

Solar geoengineering (also known as solar radiation modification) is garnering more attention (and controversy) among media and policymakers in response to the impacts of climate change. Such debates have become more prominent following the first-ever field trials of stratospheric aerosol injection (SAI) in 2022. How the lay public perceives solar geoengineering remains unclear, however. We use nationally representative samples ($N = 3013$) in Mexico, United States, and United Kingdom to examine public perceptions of risks and benefits, support, and policy preferences. We also employ an information-framing design that presented individuals with media-style reports on SAI activities differing along three dimensions: location, actor, and scale and purpose. Support for SAI is found to be generally higher in Mexico; perceptions of risks and benefits do not differ between countries. Information about SAI activities has a limited effect. There is evidence that activities conducted by universities receive more support than those by start-up companies.

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## 1. Introduction

How will publics around the world perceive solar geoengineering? Heatwaves, wildfires, more intense cyclones, droughts, and other devastating outcomes of global heating come more into the public eye with every passing year. In some academic and policy circles, the prospect of trying to reduce how much

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sunlight reaches the Earth's surface has been taken up (National Academies of Sciences 2021, Intergovernmental Panel on Climate Change IPCC 2022, United Nations Environment Programme 2023).

Battlelines over different technology pathways are increasingly forming. There have been calls among scientists for a ban or non-use agreement of some kind, highlighting severe deficiencies for governance and substantial environmental, societal, and justice-related risks (Biermann *et al.* 2022). Others have called for more 'balanced research' of solar geoengineering (also known as solar radiation modification, SRM) given the risks of climate change, insufficient pace of emission reductions, and the need to fully evaluate which, if any, proposed options can be counted on (Wieners *et al.* 2022, American Geophysical Union 2023).

At a country level, the Biden administration in the United States released in June 2023 a congressionally mandated report outlining an initial research plan into and initial governance framework for solar geoengineering (OSTP 2023). Its broad aims include assessing social and environmental impacts of any such deployment and exploring possible research collaborations at an international level. Around the same time, the European Union inserted reference at the end of its 'Outlook on the climate and security nexus' on the importance of assessing climate intervention techniques using the precautionary principle (European Commission EC 2023). Notably, both research and deployment were stressed as requiring an internationally agreed governance framework.

The question of how SAI research, development, and deployment should be managed, as well as how publics around the world may respond, remains something of an open question. Recent events have, however, rendered these questions less hypothetical. Though only becoming public knowledge recently, Temple (2022, 2023) revealed that two separate groups conducted small-scale field trials of SAI. The first, from Make Sunsets (a Silicon Valley start-up), involved the release of two balloons in April 2022 in Mexico (without government authorization). Along with concerns over the expertise of those involved (De La Garza 2023), criticism focused on ongoing commercialization attempts of Make Sunsets, in the form of 'cooling credits'. The second, by a British researcher with the firm European Astrotech, took place in England in September 2022 and, unlike Make Sunsets, provided prior notice, obtained flight permits, and generally adhered to common research standards (Temple 2023). Still, the project's acronym (*SATAN*, Stratospheric Aerosol Transport and Nucleation) and comments to the press (Temple 2023) betrayed the desire to be provocative. Both trials elicited media attention and were denounced by researchers and critics of geoengineering alike; after becoming aware of Make Sunsets, Mexico banned future solar geoengineering experiments, becoming the first to do so. It is unclear how much the public is aware of these events.

This article examines one neglected aspect of social perceptions of climate interventions, solar geoengineering in the form of stratospheric aerosol injection (SAI). The study employs an information-framing design to explore how permutations of SAI research and deployment activities might affect public perceptions. Focusing on three countries central to the SAI trials, one in the global South (Mexico), two in the global North (United States, United Kingdom), we use nationally representative samples of over 1000 adults in each to explore how perceptions of SAI vary in general and in response to different information texts. Drawing on details of the recent trials, participants were randomly presented one of the nine information texts (designed to appear like newspaper articles). Besides the control which only gave background information on SAI, texts considered differences on three dimensions: location (Mexico, United Kingdom), actor involved (university, start-up), and scale and purpose (small-scale test with one balloon for research purposes, large-scale with hundreds of balloons and intent to commercialize). We thereby considered how much these aspects influence public perceptions in the three countries. As one of the few studies to jointly examine perceptions in the Global North and Global South (Carr *et al.* 2013, Winickoff *et al.* 2015, Biermann and Möller 2019, Baum *et al.* 2023), we also contribute to the limited literature on public and stakeholder perceptions in the Global South.

Three primary objectives were the focus of the present study. First, in the wake of the first-ever SAI field trials, we aimed to gain insight on where public perceptions stand, for overall support, perceived risks and benefits, and policy preferences. Except Sugiyama *et al.* (2020) and a separate survey into 10 climate-intervention technologies by Baum *et al.* (2023), we are not aware of other quantitative studies examining public preferences for SAI governance. The increasingly fraught debate within academic and policy circles (Biermann *et al.* 2022, Wieners *et al.* 2022, American Geophysical Union 2023) makes public input on this topic of increasing interest.

Second, given the paucity of public-perceptions research engaging the Global South (Visschers *et al.* 2017, Carr and Yung 2018, Sugiyama *et al.* 2020, Baum *et al.* 2023, Hussain *et al.* 2023), there is an essential gap in our understanding of how publics in the Global South perceive solar geoengineering. We thus employed a nationally representative sample of 1004 Mexican adults, the first time this country is examined in the climate-intervention literature and given its status as the site of the first-ever SAI field trials. Doing so facilitates a contrast between this country and counterparts in the Global North, regarding determinants of individual perceptions and the influence of different types of information.

Third and finally, we undertake a richer examination of how the characteristics of SAI-related activities influence public perceptions. Though a few studies establish variations in acceptance related to the scale of activity

(research activities versus immediate deployment of SAI; Merk *et al.* 2015, Baum *et al.* 2023), this is yet to be accompanied by investigation of how the type of actor may matter. This contrasts frequent concerns expressed about 'rogue' non-state actors experimenting with or deploying SAI with no regulation or oversight (Victor 2008; for opposing perspective, Smith and Henly 2021). The same is true for location, given the not-unreasonable concerns that it may be developing countries or indigenous lands used as testing sites for solar geoengineering (Sovacool *et al.* 2022, Okereke 2023, Oksanen 2023). Examining how much each of these traits of SAI activities influence public perceptions, and if this varies across countries, thus provides insight into how well-founded such criticisms are at present.

## 2. Current research: risks, publics, and media coverage

### *2.1 Risks and governance of stratospheric aerosol injection*

How the lay public perceives solar geoengineering remains unclear, despite being researched in one form or another for more than a decade. Indeed, some of the earliest research into public perceptions of climate-intervention techniques focused on solar geoengineering (Mercer *et al.* 2011, Pidgeon et al. 2012, 2013). Principally, this involved the Stratospheric Particle Injection for Climate Engineering (SPICE) project in the United Kingdom. Stratospheric aerosol injection (SAI) proposes the intentional dispersal of small particles at high altitudes (in the stratosphere) to reflect sunlight back into space. Patterned after the cooling effects of volcanic eruptions, sulphates are the most common particles explored (Rasch *et al.* 2008), though alumina, calcites, salt and diamonds have been considered (Keith *et al.* 2016). SPICE was ultimately cancelled – amidst a patent row, discomfort among the public, and concerns such a project would be 'somewhat premature' without an effective governance framework (Pidgeon et al. 2012, 2013). Little has changed in the intervening decade, on the issues of governance or in-field trials. A planned trial in northern Sweden, led by Harvard University, was indefinitely postponed following criticism activities would take place on indigenous Sámi lands, without their approval. As such, there are no field trials from which insights can be gained, whether on technical performance, adverse consequences, or public acceptability – until recently.

Research has provided numerous insights into SAI, even if chiefly hypothetical. Understanding of the risks of SAI continues to grow, including potentially adverse impacts on monsoons and precipitation patterns (Da-Allada *et al.* 2020, Krishnamohan and Bala 2022, Tracy *et al.* 2022); ecosystems disruption and threats to biodiversity (Trisos *et al.* 2018, Tracy *et al.* 2022); shifting incidence and range of diseases like malaria (Carlson *et al.* 2022); delays to recovery of the ozone layer (Tilmes *et al.* 2022); and an

inability, at best, to counteract climate-related damages to agricultural production (Proctor *et al.* 2018, Fan *et al.* 2021). How the extent and inequality of risks (and benefits) depends on the amount of cooling pursued is also the subject of research (Irvine *et al.* 2019, Intergovernmental Panel on Climate Change IPCC 2022).

Growing attention is also being devoted to examining the key actors, networks, and discourses around solar geoengineering, much of which has appeared in this journal (Felgenhauer *et al.* 2022, Sovacool *et al.* 2023). There is consideration of the extent to which solar geoengineering could be employed in the service of ecological security (Thiele 2019, McDonald 2023) and human rights (Svoboda *et al.* 2019) or identifying inadequacies in (de facto) governance that may cause such objectives to fall short (Rabitz 2019, Gupta and Möller 2019). Other research explores a potential, crucial role for the public and other stakeholders (Conca 2019, Stephens *et al.* 2022), with implications for the nascent governance of solar geoengineering, not least in the United States (Jinnah and Nicholson 2019, Lin *et al.* 2022, Stephens *et al.* 2023). Contrary to the (implicit) tendency towards expert-led governance, such research underscores the need for a wide-ranging, public-informed dialogue into the risks, uncertainties, and variety of implementation pathways for solar geoengineering.

### 2.2 Public perceptions of stratospheric aerosol injection

A vibrant literature on public perceptions of SAI (along with other solar geoengineering and/or carbon dioxide removal approaches) is developing. Using surveys (Corner and Pidgeon 2015, Merk *et al.* 2015, Visschers *et al.* 2017, Braun *et al.* 2018, Raimi *et al.* 2019, Jobin and Siegrist 2020) and focus groups (Corner *et al.* 2013, Pidgeon *et al.* 2013, Asayama *et al.* 2017), several illustrative findings have emerged. First, there is a lack of familiarity with solar geoengineering, typically greater than for carbon dioxide removal. This is unsurprisingly coupled with lack of knowledge and uncertainty about the extent to which SAI should be relied upon (Merk *et al.* 2019, Klaus *et al.* 2021). Second, publics are less positive about SAI (and solar geoengineering) than other solutions, notably climate mitigation and the pursuit of emission reductions or use of carbon dioxide removal (Pidgeon *et al.* 2012, Merk *et al.* 2019, Cherry *et al.* 2022, Baum *et al.* 2023, Bellamy 2023). Reasons for this are only sketched but include possible environmental impacts, risks of heightened geopolitical conflict, a perceived failure to address the 'root cause' of climate change (emissions), and concern over tampering with nature (Visschers *et al.* 2017, Jobin and Siegrist 2020, Klaus *et al.* 2020, Fenn *et al.* 2023). However, and thirdly, factors are identified that may increase support for SAI: the perceived urgency and seriousness of climate change (Corner and Pidgeon 2015, Merk *et al.* 2016, Visschers *et al.* 2017, Raimi *et al.* 2019,

Klaus *et al.* 2020), trust in industry, scientists, and political institutions (Merk *et al.* 2015, Braun *et al.* 2018, Jobin and Siegrist 2020, Fenn *et al.* 2023); and viewing science and technology as a solution for climate change (Mercer *et al.* 2011). The perceived relationship between climate mitigation and SAI, whether undercutting such efforts or acting in a complementary fashion, is also influential (Merk *et al.* 2016, Visschers *et al.* 2017, Cherry *et al.* 2022, Fenn *et al.* 2023).

Members of the lay public have also proven responsive to how information is presented. This literature remains small, around 10 studies in total, but provides several insights. For instance, Corner and Pidgeon (2015) established that framing SAI as 'natural', by imitating effects of a volcano, cultivated more positive perceptions. Asayama *et al.* (2017) also found that reference to the 'climate emergency' motivated Japanese publics to become more accepting ('willingly or reluctantly') of solar geoengineering research. However, Mahajan *et al.* (2019) failed to find any difference in acceptability when SAI was (briefly) described as natural. In total, the studies highlight the need for caution regarding how SAI is presented to the public.

This also includes the extent to which SAI is presented as a solution to climate change, one that may diminish the importance of mitigation (Merk *et al.* 2016, Raimi *et al.* 2019). Increasing the length and detail of information on SAI is also shown to adversely influence perceptions. Braun *et al.* (2018) found that only providing more information on SAI (on potential benefits and risks) tended to decrease acceptance. Both Klaus *et al.* (2021) and Bolsen *et al.* (2022) have revealed how reading negative opinion statements on SAI had a similar effect – the latter also failed to identify a countervailing influence from reading positive statements. Even affording a chance to discuss SAI (in a citizen jury) and improve their knowledge caused individuals to become more negative (Merk *et al.* 2019). In sum, the more individuals are exposed to SAI, the more negative they become – unless strongly linked to natural processes or as a solution to climate change. A possible moderating factor may be source credibility, with Klaus *et al.* (2021) and Bolsen *et al.* (2022) showing that information from more credible sources, e.g. scientists, appears to significantly and positively influence on SAI acceptance.

### 2.3 Hypotheses on public perceptions of SAI activities

We ventured three hypotheses based on foregoing literature. First, we expected that acceptance of SAI would be higher in Mexico, being in the Global South, than in United States or United Kingdom. This hypothesis draws on cross-country studies that, while only a few, consistently found greater support for climate-intervention techniques in the global South (Visschers *et al.* 2017, Sugiyama *et al.* 2020, Baum *et al.* 2023). Reasons for this remain unclear, perhaps due to greater expectations and experiences of

climate harm (Baum *et al.* 2023), which is one of the driving forces for the present study. Second, we expected participants in Mexico would be less supportive and more negative of SAI activities undertaken in their country, especially if the actor was pursuing commercial interests (i.e. the Make Sunsets case). Third and similarly, we anticipated that SAI activities done by universities versus start-up firms would be perceived more positively and attract greater support. The last two hypotheses center on reactions to the recent SAI field trials in the media and by critics and researchers and consider the extent to which public perceptions might be similar or divergent.

## 3. Research methods: three nationally representative surveys on public perceptions

### 3.1 Participants

All data was collected between April and May 2023, with samples provided by a professional survey firm drawing on nationally representative panels of adults in Mexico, United States, and United Kingdom. Prior and informed consent was obtained from respondents before collection of survey data; data was delivered to researchers in a de-identified and anonymized form. After removing respondents failing to answer instructed response items correctly or with completion times 30% faster than the median in each country, we collected 3013 responses (1005 in US, 1004 in UK and Mexico). Median completion time was about 8.25 minutes in US and UK, 11.5 minutes in Mexico. Samples were representative vis-à-vis age, gender, region (in country), and broadly for educational attainment and household income (Table 1). Survey design was revised via pre-testing with a prior survey with a convenience sample ($N = 18$) and soft launches with about 50 participants in each country.

English and Spanish versions of the survey are available in Appendix II – the Spanish version was translated by a professional translator, with a list of keywords on solar geoengineering and climate change translated by a native-language expert. Participants in Mexico and United States could decide to take the Spanish or English version.

### 3.2 Procedure

Participants were first presented background information on climate change and its impacts. This text included the mention of proposed measures in the form of mitigation and adaptation to set the survey context and, crucially, ensure solar geoengineering was not presented as a sufficient or necessary

**Table 1.** Sociodemographic characteristics for samples in each country.

| Characteristic | | Mexico | United States | United Kingdom |
|---|---|---|---|---|
| Gender | Male | 49.70% | 48.36% | 46.61% |
| | Female | 50.10% | 50.45% | 52.99% |
| | Other | 0.20% | 1.09%[1] | 0.40% |
| Average age in years (standard deviation) | | 39.37 (14.00) | 44.55 (15.76) | 45.65 (15.48) |
| Geographic area | Rural area or village | 2.09% | 19.20% | 15.94% |
| | Suburban | 6.27% | 34.43% | 29.88% |
| | Small- or medium-sized city | 23.01% | 23.58% | 26.00% |
| | Large city | 68.63% | 22.79% | 28.19% |
| Educational attainment[a] | High-school degree equivalent (or less) | 21.72% | 30.05% | 21.91% |
| | Some postgraduate study | 15.93% | 23.88% | 30.68% |
| | Tertiary degree (or more) | 62.35% | 45.17% | 46.51% |
| Household income (monthly, gross) | Higher than median level | 47.80% | 37.02% | 51.69% |
| | Lower than median level | 49.21% | 56.22% | 35.96% |
| | Prefer not to say | 2.99% | 6.77% | 12.35% |
| Political views | Very liberal | 13.55% | 8.36% | 8.37% |
| | Liberal | 10.76% | 8.56% | 13.35% |
| | Slightly liberal | 14.84% | 12.44% | 19.22% |
| | Moderate | 35.66% | 33.73% | 30.98% |
| | Slightly conservative | 13.45% | 12.34% | 11.85% |
| | Conservative | 4.98% | 9.25% | 4.88% |
| | Very conservative | 3.88% | 10.55% | 3.39% |
| | Prefer not to say | 2.89% | 4.78% | 7.97% |
| Religiosity[b] | High | 25.20% | 27.46% | 14.55% |
| | Intermediate | 44.32% | 33.13% | 22.51% |
| | Low | 29.18% | 36.72% | 60.32% |
| | Prefer not to say | 1.29% | 2.69% | 2.59% |
| Prior awareness- SAI | Yes | 24.00% | 17.61% | 11.16% |
| | No or Don't know | 76.00% | 82.39% | 88.84% |

Note: [1]One person in United States opted to answer "Prefer not to say". [a]Does not add up to 100% because around 10 in each country answered "Prefer not to say"; [b]Low represents values of 1 to 2, intermediate 3 to 4, high 5 to 6.

solution. They were then randomly assigned to one of the nine information treatments, given our $2 \times 2 \times 2 + 1$ design. Every text aimed to resemble media articles on recent SAI field trials. Texts were created by systematically adapting selected words and phrases along three dimensions: location (Mexico, United Kingdom), actor (university, start-up) and scale and purpose (small-scale for research aims, large-scale and aim to commercialize) (example in Figure 1; all available in Appendix II). There was a 'control' text with the title 'Stratospheric aerosol injection' with a brief description of the technique, how it works, and potential risks.

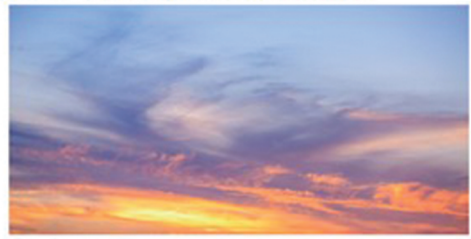
The remainder of the survey consisted of 32 questions, two instructed response items, and one open-ended question at the end. Table 2 presents all outcome and explanatory variables in the survey. Full details on survey procedure and materials can be found in the Appendix. Insights from the open-ended question on climate denial and criticisms of the government, particularly in the United States, are shared in Appendix I.

**Silicon Valley Start-up Deploys Vast Balloon Launch in Mexico to Tackle Climate Change**

Company also looking to sell "cooling credits" to earn revenue

By **Alyssa Harvey**

January 19, 2023



WASHINGTON, D.C. – In an effort to limit the negative impacts of climate change, Make Sunrises, a start-up founded in Silicon Valley, last month launched hundreds of balloons in the Mexican state of Baja California, near La Paz, to assess whether a new technique called *"stratospheric aerosol injection"* could be an effective solution. The company announced that they also want to offer "cooling credits" to companies and individuals as part of their activities to earn revenue.

By using planes or balloons to spray small particles (aerosols) into the upper atmosphere, stratospheric aerosol injection aims to change how much sunlight reaches the Earth, which could cool temperatures and mitigate climate change. For this idea to work though, it would need to be done continuously – if application of this technique were stopped, temperatures would rise once again, and probably very quickly (in the absence of emissions cuts). So far, as stratospheric aerosol injection is still being researched, it is not clear how it may affect weather and precipitation patterns around the world. And this strategy would not reduce overall greenhouse gas emissions or help address other impacts of climate change, like ocean acidification. Even so, the start-up and its CEO, Michael Conrad, have decided to pursue broad deployment in response to climate change, launching hundreds of balloons in Mexico in December of 2022. [...]

**Figure 1.** Example of headline presented to survey respondents.

### *3.3 Analysis*

Statistical analyses were conducted using SPSS v28.0, which included frequency distributions, normality of outcome variables using Shapiro-Wilk $W$ testing, comparison of group means via nonparametric testing (independent-samples Kruskal–Wallis $H$ testing for *balance of risks and benefits* and *support for development and deployment*, related-samples Friedman's two-way analysis of variance by ranks for *support for governance approaches*), and hierarchical linear regression (respectively for *perceived balance of benefits to risks* and *support for development and deployment*). Distributions of outcome variables were non-normal ($p < .001$), requiring use of non-parametric testing.

**Table 2.** Outcome and explanatory variables of survey instrument on stratospheric aerosol injection.

| Variables | Measurement scale | Item or factor used in regression analysis |
|---|---|---|
| **Outcome variables – SAI perceptions** | | |
| Balance of benefits to risks (adapted from Pidgeon and Spence 2017) | One 5-point continuous interval question | Numerical score. Values ranged from: 1= Risks far outweigh the benefits, 3=Benefits and risks are about the same, 5=Benefits far outweigh the risks. |
| Support for development and deployment (adapted from Pidgeon and Spence 2017) | One 5-point continuous interval question | Numerical score. Values ranged from: 1= Strictly oppose, 3=Neither oppose nor support to 5=Fully support, with "don't know" option available (coded as missing value). |
| **Outcome variables – SAI governance** | | |
| Support for governance approaches | Three 4-point continuous interval questions | Separate numerical scores for each option (national-level regulation and oversight; international ban or moratorium; public engagement campaigns). Values ranged from: 1= not at all, to 4=extremely important. |
| **Explanatory variables – effects of SAI information and familiarity** | | |
| Comprehension of article | One 4-point continuous interval question | Numerical score. Values ranged from: 1= not at all, to 4=completely. |
| Post-article change in concern over climate change | One 5-point continuous interval question | Numerical score. Values ranged from: 1=a lot more concerned, 3=not affected – neither more nor less concerned, to 5=a lot less concerned. |
| Familiarity with SAI | Multiple choice question | Binary variable: 0=No or Don't know; 1=Yes. |
| **Explanatory variables – values, beliefs, and motivations** | | |
| Moral obligation to help mitigate climate Change (adapted from Merk *et al*. 2016) | One 5-point continuous interval question | Numerical score. Interval values ranged from: 1= strongly disagree, to 5=strongly agree. |
| Mitigation deterrence of SAI | Four 5-point continuous interval questions | Average numerical score of all items (as there was only one factor). Values ranged from: 1= strongly disagree, to 5=strongly agree. |
| Climate mitigation in daily life (adapted from Merk *et al*. 2016) | One 5-point continuous interval question | Numerical score. Values ranged from: 0= never, 1=rarely, 2=from time to time, 3=often, to 4=always. |
| Aversion to tampering with nature (Wolske *et al*. 2019) | Five 7-point continuous interval questions | Average numerical score of all items (as there was only one factor). Values ranged from: 1= strongly disagree, to 7=strongly agree. |
| Trust in institutions and science (adapted from Jobin and Siegrist 2020) | Five 6-point continuous interval questions | Separate numerical scores for each group or institution (industry, universities and scientific research institutes, national governments, international institutions, NGOs). Values ranged from: 1=no trust, to 6=very high trust. |

(*Continued*)

**Table 2.** (Continued).

| Variables | Measurement scale | Item or factor used in regression analysis |
|---|---|---|
| Geopolitical and military risks | One 5-point continuous interval question | Numerical score. Values ranged from: 1=strongly disagree, to 5=strongly agree, with "don't know" option available (coded as missing value). |
| Perceived climate harm (adapted from Steentjes *et al.* 2017) | One 4-point continuous interval question | Numerical score. Values ranged from: 1= not at all, to 4=a great deal. |
| Personal experience with major natural disaster (in last 3 years) | Multiple choice question | Binary variable: 0=No or Don't know; 1=Yes. |
| Science and technology as solution to climate change (adapted from Steentjes *et al.* 2017) | One 5-point continuous interval question | Numerical score. Values ranged from: 1= strongly disagree, to 5=strongly agree, with "don't know" option available (coded as missing value). |
| Belief in climate change | Multiple choice question | Two Binary Variables: "Beliefs in climate change ("Yes but")", 0=No or Don't know (and Yes); 1=Yes, but natural processes have a larger effect; Beliefs in climate change ("Yes"), 0=No or Don't know (and Yes, but. . .); 1=Yes. |
| **Explanatory variables – demographic variables** | | |
| Age | One open-ended question | Numerical value. |
| Gender | Multiple choice question | Binary variable: 0=Female; 1=Male ("Other" and "Prefer not to say" coded as missing values). |
| Geographic area | Multiple choice question | Binary variable: 0=Rural or Suburban; 1=Urban (small to medium-sized city, or large city). |
| Region in country | Multiple choice question | Not included. |
| Educational attainment | Multiple choice question | Binary variable: 0=High-school degree equivalent or less; 1=More than High-school degree. |
| Monthly household income (gross) | Multiple choice question | Binary variable: 0=Lower than median level for country; 1=Higher than median level for country. |
| Religiosity | One 6-point continuous interval question | Numerical score. Values ranged from: 1= not at all, to 6=extremely, with "prefer not to say" option available (coded as missing value). |
| Political views | One 7-point continuous interval question | Numerical score. Values ranged from: 1= very liberal, to 7=very conservative, with "prefer not to say" option available (coded as missing value). |
| Ethnicity | Multiple choice question (select all that apply) | Dummy variables for specific ethnicities (country specific). |

We also created and assessed the significance of dummy variables related to (1) a country being in the *Global South*; and three aspects of SAI activities examined by information treatments: (2) location (*Global North versus Global South*); (3) actor (*University versus Start-up*); and (4) scale and purpose (*Commercialization versus Research*). These were included in the regression analysis.

## 4. Results

### 4.1 Comparing support, perceptions of risks and benefits, and familiarity across countries

As has been true for over a decade (Mercer *et al.* 2011, Mahajan *et al.* 2019), the public remains unfamiliar with stratospheric aerosol injection. Only 17.6% (530) of participants claimed to have previously heard about SAI. Of note, the proportion of those with familiarity was highest in Mexico (24.0%), followed by United States (17.6%), and then the United Kingdom (11.2%). Perhaps media coverage of the Make Sunsets trial has promoted greater awareness, though there may be a separate (cultural) explanation (e.g. Sugiyama *et al.* (2020) similarly identified a relatively high rate of familiarity among their student samples in three global South nations).

While acknowledging that the public is mostly unfamiliar with SAI, we note a general tendency toward supporting development and deployment of SAI ($M = 3.13$, $SD = 1.21$). This is contrasted by participants slightly assessing the risks of SAI to outweigh the benefits ($M = 2.70$, $SD = 1.16$). This inconsistency can be clarified by looking at country-level differences in these two factors (Table 3). Participants in the three countries do not differ in their assessment of the balance of risks and benefits, all indicating slightly more risks overall. Conversely, those in Mexico were significantly more supportive of the development and deployment of SAI ($p < .001$) than those in the United Kingdom and United States (which did not differ from one another).

**Table 3.** Country-level differences in mean values of perceived balance of benefits to risks, support for development and deployment of SAI, and support for governance approaches.

| | Mexico (*N*=1,004) | United Kingdom (*N*=1,004) | United States (*N*=1,005) |
|---|---|---|---|
| Balance of benefits to risks | 2.69[a] | 2.70[a] | 2.70[a] |
| (1–5 scale: 5=Benefits far outweigh the risks) | (1.22) | (1.07) | (1.18) |
| Support for development and deployment | 3.43[a] | 2.94[ba] | 2.99[b] |
| (1–5 scale: 5=Fully support) | (1.24) | (1.12) | (1.22) |
| Governance: national-level regulation and oversight | 3.44[1a] | 3.29[1a] | 3.16[1a] |
| (1–4 scale: 4=Extremely important) | (0.68) | (0.82) | (0.90) |
| Governance: international ban or moratorium | 2.78[2a] | 2.52[2b] | 2.55[2b] |
| (1–4 scale: 4=Extremely important) | (0.82) | (0.97) | (1.01) |
| Governance: engagement campaigns to consult public | 3.29[3a] | 3.23[1a] | 3.10[1b] |
| (1–4 scale: 4=Extremely important) | (0.74) | (0.85) | (0.91) |

Note: Standard errors in parentheses. Different letters denote significant differences ($p < 0.001$) across countries, according to independent-samples Kruskal-Wallis *H* testing. Different numbers denote significant differences ($p < 0.001$) between medians of governance approaches, according to related-samples Friedman's two-way analysis of variance by ranks testing. Responses for *balance of benefits to risks* used a five-point scale (1=risks far outweigh the benefits; 5=benefits far outweigh the risks), while *support for development and deployment* used a five-point scale (1=strictly oppose; 5=fully support) along with a "don't know" option. Responses for *governance* items used a four-point scale (1=not at all; 4=extremely important).

Taking these results together, the public in Mexico appears simultaneously appreciative of the risks of SAI and rather supportive of development and deployment. This is not the case in the United States or United Kingdom, where participants are less enthusiastic.

Regarding SAI governance, national-level regulation/oversight and public engagement campaigns were significantly preferred to an international ban or moratorium in every country ($p < .001$). Of these two, participants tended to assess national-level regulation and oversight as slightly more important – although this difference was only significant for the Mexican sample ($p < .001$). In total, publics in these countries assigned at least reasonable importance to all the governance approaches, though much less a restrictive approach, with the highest overall rating of importance attached to national-level regulation and oversight in Mexico.

### 4.2 Influence of information about SAI activities

To examine how information about SAI activities affected public perceptions, we assessed at an aggregate level the effects of the information treatments (by independent-samples Kruskal–Wallis $H$ testing). We failed to identify any significant differences for the treatments in terms of balance of risks and benefits ($p = .540$), support for SAI ($p = .407$), and importance of national-level regulation or oversight ($p = .144$) or public engagement campaigns ($p = .464$). Perceived importance of international bans or moratoria did significantly vary by information treatment ($p = .009$). However, when we conduct multiple-comparisons testing (using stepwise step-down method in SPSS), the chief differences emerge between the '*University* x *Global North* x *Trial*' condition, which resulted (mainly in Mexico and US) in greater perceived importance of a ban or moratorium ($M = 2.78$) relative to *Control* ($M = 2.51$) and '*University* x *Global South* x *Trial*' ($M = 2.55$) and '*University* x *Global North* x *Commercialization*' conditions ($M = 2.57$). It is not clear how to explain this result, since if we focus a country level, there are no significant differences between information treatments – for the perceived importance of an international ban or moratorium, this is broadly true for Mexico ($p = .092$) and United States ($p = .092$).

To better excavate any potential differences, we re-categorized the information treatments with dummy variables for each core dimension: location of activity, type of actor involved, and the scale and purpose of the efforts. Since publics in the countries may respond differently, we also examined if perceptions varied along these dimensions for each country separately. Starting with the United States, we failed to establish any significant difference for any outcome variable because of the three characteristics. In other words, whether the headlines and related texts described activities conducted by start-ups or universities, in Mexico or United Kingdom and for research

purposes or with the intent to commercialize had no influence on perceptions of risks and benefits, SAI support, or the perceived importance of any governance approach.

The lack of impact of the article information is not limited to the United States. We also failed to find any significant differences vis-à-vis perceived importance of the governance approaches or support for development and deployment of SAI for Mexico and United Kingdom. In total, the treatments did not seem to have a differential influence on such perceptions, suggesting the information provided was not ultimately perceived as relevant here.

Interestingly, our analysis yielded two significant results, one each for Mexico and the United Kingdom and both relating to the perceived balance of risks and benefits. For Mexico, we find that it was meaningful whether the SAI activity is conducted in Mexico or the United Kingdom ($p = .004$). Perhaps counterintuitively, participants in Mexico perceived activities to have a more positive balance of benefits to risks if conducted in Mexico ($M = 2.80$) vs. the United Kingdom ($M = 2.58$). There were no significant differences in relation to the type of actor or the scale and purpose of the activity.

For the United Kingdom, it was the type of actor which mattered, with activities undertaken by universities ($M = 2.78$) perceived significantly ($p = .033$) more positively than if start-ups were involved ($M = 2.63$). Where the activity was conducted or the nature of its scale and purpose did not make a significant difference.

## 4.3 Regression analysis

### 4.3.1 Determinants of support for development and deployment of SAI

We employed hierarchical linear regression analysis to examine the importance of information treatments vis-à-vis support for development and deployment of SAI and the perceived balance of benefits and risks (Table 4; see also Table A.2). While the information treatments did not play a role for the perceived balance of risks and benefits, the type of actor was influential for support of SAI. Across all countries, if the information described activities as being undertaken by universities rather than start-ups, this had a positive influence on support ($p = .043$). None of the other dummy variables were significant, however. We also note, looking at the standardized coefficients for the variables of significance (Table 5), which provide a basis for comparing the importance of the different factors, the effect of the type of actor is the lowest of any variable.

Using regression analysis, we identify several determinants of support for development and deployment of SAI. First, participants in the Global South (Mexico) were more supportive of SAI – this is true even after controlling for various other factors, though we highlight (Table 4, Column (1) versus (2))

**Table 4.** Coefficient estimates (unstandardized) of determinants of support for development and deployment of stratospheric aerosol injection (SAI) and perceived balance of benefits to risks.

| | (1) | Support of SAI (2) | Perceived Balance of Benefits to Risks (3) |
|---|---|---|---|
| Intercept | 3.489*** | 3.176*** | 3.772*** |
| | (0.057) | (0.240) | (0.244) |
| Country: Global South | 0.460*** | 0.136** | −0.098 |
| | (0.049) | (0.059) | (0.060) |
| *Information treatments* | | | |
| Global North versus Global South | −0.017 | −0.023 | −0.063 |
| | (0.047) | (0.047) | (0.047) |
| Commercialization versus Research | −0.027 | −0.040 | −0.045 |
| | (0.047) | (0.047) | (0.047) |
| University versus Start-up | 0.095** | 0.092** | 0.064 |
| | (0.047) | (0.047) | (0.048) |
| Moral obligation to help mitigate climate change | | 0.159*** | 0.112*** |
| | | (0.031) | (0.031) |
| Mitigation deterrence of SAI | | −0.281*** | −0.257*** |
| | | (0.032) | (0.033) |
| Climate mitigation in daily life | | −0.013 | 0.024 |
| | | (0.027) | (0.028) |
| Aversion to tampering with nature | | −0.094*** | −0.119*** |
| | | (0.021) | (0.021) |
| Beliefs in climate change ("Yes") | | 0.379*** | 0.109 |
| | | (0.115) | (0.117) |
| Beliefs in climate change ("Yes but") | | 0.228** | 0.015 |
| | | (0.111) | (0.113) |
| Perceived climate harm | | 0.025 | 0.050 |
| | | (0.033) | (0.033) |
| Personal experience with major natural disaster (in last 3 years) | | 0.009 | −0.037 |
| | | (0.051) | (0.052) |
| Science and technology as solution to climate change | | 0.143*** | 0.086*** |
| | | (0.022) | (0.023) |
| Geopolitical and military risks | | −0.126*** | −0.097*** |
| | | (0.024) | (0.024) |
| Familiarity with SAI | | 0.073 | −0.114† |
| | | (0.062) | (0.064) |
| Comprehension of article | | −0.017 | −0.058† |
| | | (0.034) | (0.034) |
| Post-article change in concern | | −0.009 | −0.159*** |
| over climate change | | (0.029) | (0.029) |
| Age | | −0.007*** | −0.002 |
| | | (0.002) | (0.002) |
| Political views | | 0.037** | 0.025 |
| ("Conservative") | | (0.016) | (0.017) |
| Educational attainment | | −0.088 | −0.121* |
| (0=Equivalent to HS degree or less) | | (0.062) | (0.051) |
| Trust in Industry | | 0.109*** | 0.065** |
| | | (0.021) | (0.021) |
| Trust in Universities and scientific research institutes | | 0.016 | 0.024 |
| | | (0.024) | (0.025) |
| Trust in National governments | | 0.041† | 0.014 |
| | | (0.022) | (0.022) |
| Trust in International institutions | | 0.060** | 0.033 |
| | | (0.022) | (0.023) |
| Trust in NGOs | | 0.005 | 0.019 |
| | | (0.022) | (0.023) |

(*Continued*)

**Table 4.** (Continued).

| | (1) | Support of SAI (2) | Perceived Balance of Benefits to Risks (3) |
|---|---|---|---|
| Observations | 3013 | 3013 | 3013 |
| Adjusted R-squared | 0.033 | 0.241 | 0.137 |

Note: *N*=3013; dependent variable is support for development and deployment of SAI in columns 1 and 2 and perceived balance of benefits to risks in column 3, coefficient estimates are unstandardized, standard errors in parentheses. ***$p \leq 0.001$, **$p \leq 0.01$, *$p \leq 0.05$, $^{\dagger}p<0.10$. See Table 2 for variables description. Results for socio-demographic characteristics not reported (i.e. gender, religiosity, household income, geographic area: urban versus rural/suburban) if the factor is not found to be significant.

**Table 5.** Standardized coefficient estimates (β) for determinants of support for development and deployment of stratospheric aerosol injection (SAI) and perceived balance of benefits to risks.

| | Support for SAI | Perceived Balance of Benefits to Risks |
|---|---|---|
| Belief that climate change exists ("Yes") | 0.144*** | n.s. |
| Moral obligation to mitigate climate change (1–5 scale; don't know) | 0.139*** | 0.102*** |
| Science and technology as solution to climate change (1–5 scale; don't know) | 0.135*** | 0.084*** |
| Trust in Industry and Corporations in field of climate technology | 0.130*** | 0.081*** |
| Belief that climate change exists ("Yes, but . . . ") | 0.081*** | n.s.* |
| Trust in International government institutions (e.g. United Nations) | 0.075*** | n.s.* |
| Country: Global South (versus Global North) | 0.054*** | n.s. |
| Political views (1–7 scale; prefer not to say) | 0.048*** | n.s. |
| Headline: University (versus Startup) | 0.038*** | n.s. |
| Mitigation deterrence of SAI (4-item factor, 1–5 scale; don't know) | −0.193*** | −0.184*** |
| Risks of geopolitical or military tensions (1–5 scale; don't know) | −0.111*** | −0.090*** |
| Aversion to tampering with nature (4-item factor, 1–7 scale) | −0.098*** | −0.130*** |
| Age | −0.085*** | n.s. |
| Post-article change in concern over climate change | n.s. | −0.125*** |
| Educational attainment (0=Equivalent to HS degree or less) | n.s.* | −0.051*** |

Note: Support assessed on 1–5 scale (1=Strictly reject to 5=Fully support), with "Don't know" option (coded as missing variable). Balance of risks to benefits assessed on a 1–5 scale (1= Risks far outweigh the benefits, 3=Benefits and risks are about the same, 5=Benefits far outweigh the risks). ***represents $p<.001$, **$p<.01$, *$p<.05$. Variables non-significant in either regression (perceptions of climate harm, personal experience with natural disasters, familiarity with SAI, religiosity) omitted. See Table 2 for variables description. N.s. stands for not significant.

how importance of being in a Global South country declined as more factors were included. Beliefs about climate change are also shown to be influential. Both those agreeing that climate change is occurring and the result of human activity and those who agreed while hedging (incorrectly) that 'natural processes have a larger effect' express greater support than those answering 'No' or 'Don't know'. However, the effect size is greater for those who

credited humanity's influence (Table 5: β = 0.144vs. 0.081). The extent that individuals believe in the existence of climate change thus corresponds to their level of support for SAI. Stronger beliefs in science and technology as a solution to climate change are similarly related to higher levels of support (β = 0.135). Conversely, one being averse to tampering with nature exercises a countervailing influence (β= −.098). Meanwhile, both perceptions of climate harm and personal experience with major natural disasters failed to have a significant impact on support for SAI – perhaps any explanatory power of such factors is manifested through, e.g. moral obligation to help mitigate climate change and science and technology as a solution to climate change.

Perceptions are similarly complicated regarding the relationship of climate mitigation and SAI. Those who expressed a stronger sense of moral obligation to mitigate climate change were also more supportive of SAI. Like the findings for climate beliefs, this signals a potentially positive relationship between climate mitigation and support for development of deployment of SAI. And yet, those perceiving SAI to have a mitigation-deterrence effect, by slowing development of renewables or encouraging continued use of fossil fuels, were much less supportive of SAI (β= −0.193). In fact, the size of the effect of this variable was the greatest of any determinant (besides perceived balance of benefits to risks). Thus, there was simultaneously present among survey participants both a positive and negative rationale linking climate mitigation and SAI.

Perceptions around the potential for adverse geopolitical consequences and the trustworthiness of actors were influential as well. Those envisioning SAI as promoting geopolitical or military tensions were less supportive (β= −0.111). Meanwhile, individuals expressed more support for SAI if they had greater trust that industry and corporations in the field of climate technology (β = 0.130) or international government institutions such as the United Nations (β = 0.075) would deliver solutions for climate change. Similar relationships could not be identified for scientific research institutes and universities, national governments and official agencies, or NGOs. With universities and research institutes rated as the most trusted institutions ($M = 4.42$), followed by NGOs ($M = 4.00$), this situates industry and corporations ($M = 3.56$) and international institutions ($M = 3.39$), their relevance as determinants is not because they are more trusted overall but rather from their being more trusted precisely by those also more likely to support SAI.

Socio-demographic characteristics only played a minor role for support of SAI (or perceived balance of benefits to risks; Table 4, Column (3)). Age and political views are the only factors that had a significant effect on SAI support. Notably, younger individuals and those who were more conservative are more likely to be supportive.

#### 4.3.2 Determinants of perceived balance of benefits to risks versus SAI support

Regression analysis was conducted with the perceived balance of benefits to risks as dependent variable to facilitate a comparison of the determinants. The factors most influential for support of SAI also tended to be influential for the perceived balance of benefits to risks (Table 5).

Conversely, neither beliefs about climate change nor a country's belonging to Global South had an impact for perceived risks and benefits. The latter makes sense since countries were broadly aligned in this regard (Table 3). No aspect of the information treatments had an influence either, in contrast to the importance of the type of actor for SAI support.

One variable was significantly predictive of just the perceived balance of benefits to risks: the post-article change in climate concern. Its effect size is indeed one of the largest, signaling that those becoming concerned about climate change after reading the article were also less positive of the benefit-risk balance. Though information treatments did not have a direct effect here, the significance of this variable identifies a potentially indirect path of influence.

#### 4.3.3 Country-level variation in determinants of SAI support

We conducted the same regression for each of the three countries to examine how determinants vary for each of the representative samples (Table 6). We firstly note, looking at the intercepts, how support for SAI remains higher in Mexico vis-à-vis United States and United Kingdom. To some extent, the findings of significance (or lack thereof) are consistent across the countries, notably for the variables with the strongest effects. The perceived mitigation-deterrence effect of SAI and the potential of geopolitical and military risks both exercise a negative influence on support for SAI, although the effect of the latter is smaller in Mexico (standardized coefficients: $\beta_{Mex}= -0.069$ vs. $\beta_{US}= -0.160$ or $\beta_{UK}= -0.117$). Meanwhile, beliefs in science and technology as a solution to climate change and trust in industry each have a reliably positive effect.

Once we look at a country level, however, none of the information-treatment dummy variables turn out to be significant. This includes the type of actor (university versus startup), which had been found to be significant at the cross-country level.

Beyond the commonalities, several notable differences emerge. For one, the moral obligation to mitigate climate change, while significant in Mexico and United States, is not influential for those in the United Kingdom. We also establish that aversion to tampering with nature has no bearing on support for SAI in the United Kingdom – and the importance of this variable differs notably for the Mexican and American participants ($\beta_{Mex}= -0.164$ vs. $\beta_{US}= -0.055$). Conversely, beliefs regarding climate change positively

**Table 6.** Cross-country comparisons of coefficient estimates (unstandardized) of determinants of support for stratospheric aerosol injection (SAI).

| | Mexico | United States | United Kingdom |
|---|---|---|---|
| Intercept | 3.691*** | 2.524*** | 2.359*** |
| | (0.527) | (0.379) | (0.421) |
| *Information treatments* | | | |
| Global North versus Global South | −0.092 | 0.003 | 0.007 |
| | (0.079) | (0.082) | (0.082) |
| Commercialization versus Research | −0.085 | −0.033 | 0.073 |
| | (0.078) | (0.082) | (0.083) |
| University versus Start-up | 0.125 | 0.032 | 0.122 |
| | (0.079) | (0.082) | (0.082) |
| Moral obligation to help mitigate climate change | 0.201*** | 0.186*** | 0.092 |
| | (0.050) | (0.054) | (0.059) |
| Mitigation deterrence of SAI | −0.293*** | −0.181*** | −0.334*** |
| | (0.048) | (0.060) | (0.067) |
| Climate mitigation in daily life | 0.018 | −0.056 | −0.023 |
| | (0.046) | (0.047) | (0.055) |
| Aversion to tampering with nature | −0.173*** | −0.048*** | −0.055 |
| | (0.037) | (0.034) | (0.038) |
| Beliefs in climate change ("Yes") | 0.672† | 0.423** | 0.399** |
| | (0.358) | (0.166) | (0.200) |
| Beliefs in climate change ("Yes but") | 0.601† | 0.052* | 0.405** |
| | (0.362) | (0.152) | (0.195) |
| Perceived climate harm | −0.037 | 0.018 | 0.089 |
| | (0.056) | (0.056) | (0.060) |
| Personal experience with major natural disaster (in last 3 years) | 0.057 | −0.023 | −0.048 |
| | (0.089) | (0.089) | (0.093) |
| Science and technology as solution to climate change | 0.136*** | 0.169*** | 0.123** |
| | (0.050) | (0.042) | (0.041) |
| Geopolitical and military risks | −0.076** | −0.184*** | −0.127** |
| | (0.037) | (0.043) | (0.045) |
| Familiarity with SAI | 0.185** | −0.127 | 0.161 |
| | (0.093) | (0.112) | (0.132) |
| Comprehension of article | 0.062 | −0.069 | −0.080 |
| | (0.055) | (0.061) | (0.063) |
| Post-article change in concern over climate change | −0.054* | 0.009* | 0.092 |
| | (0.041) | (0.055) | (0.066) |
| Age | −0.012*** | −0.004 | −0.007** |
| | (0.003) | (0.003) | (0.003) |
| Political views | −0.023 | 0.077** | 0.094** |
| ("Conservative") | (0.027) | (0.028) | (0.034) |
| Gender | 0.174* | −0.089 | 0.030 |
| (1=Male) | (0.084) | (0.087) | (0.087) |
| Geographic area | −0.251† | 0.006 | 0.025 |
| (1=Urban) | (0.150) | (0.086) | (0.087) |
| Trust in Industry and corporations | 0.090** | 0.100** | 0.141*** |
| | (0.033) | (0.038) | (0.039) |
| Trust in Universities and scientific research institutes | −0.037 | 0.002 | 0.067 |
| | (0.042) | (0.042) | (0.044) |
| Trust in National governments | 0.021 | −0.037 | 0.103** |
| | (0.031) | (0.044) | (0.046) |
| Trust in International institutions | 0.089*** | 0.105** | 0.027 |
| | (0.034) | (0.044) | (0.045) |
| Trust in NGOs | 0.003 | 0.038 | 0.012 |
| | (0.038) | (0.040) | (0.040) |
| Observations | 1004 | 1005 | 1004 |
| Adjusted R-squared | 0.241 | 0.210 | 0.240 |

Notes: dependent variable is support for development and deployment of SAI, coefficient estimates are unstandardized, standard errors in parentheses. ***$p \leq 0.001$, **$p \leq 0.01$, *$p \leq 0.05$, †$p<0.10$. See Table 2 for variables description. Results for socio-demographic characteristics not reported (i.e. religiosity, educational attainment, household income) if the factor is not found to be significant.

influence SAI support in United States and United Kingdom, but not Mexico. In addition, it is trust in national governments and official agencies that turns out to matter in United Kingdom, having a positive effect on support. In Mexico and United States, it is rather trust in international institutions. Trust in such groups and institutions thus emerges as a distinguishing factor for support of SAI.

Lastly, the sociodemographic characteristics making a difference for SAI support vary between the countries. In Mexico, we identified both younger individuals and males as being more likely to support SAI – there is also a tendency ($p < .10$) for those not living in urban areas to be more supportive. Those in Mexico already familiar with SAI also expressed greater support. Younger individuals in the United Kingdom (not United States) were also more willing to support SAI. In the United States and United Kingdom, there was also a linkage between more conservative political views and support for SAI.

## 5. Discussion and conclusion

Following the first SAI field trials in 2022, our survey pursued insights on public perceptions of this contentious climate-intervention technology. Using nationally representative samples ($N = 3013$) in United States, United Kingdom, and Mexico, we effected, to our knowledge, one of the first-ever explorations (along with Bolsen *et al.* 2023) of how public perceptions of risks and benefits and overall support may be influenced by media-style reports about different types of SAI activities. Whereas Bolsen *et al.* (2023) focus on the types of benefits and/or risks which are present in media reports, the current research offers complementary insights by examining perceptions of SAI activities, which differ in terms of location, type of actor, and the scale and purpose of the efforts.

In relation to our three hypotheses, first, we provided evidence that SAI support seems to be higher in Mexico vis-à-vis the United States and United Kingdom. Though there are few studies that enable such a comparison (Visschers *et al.* 2017, Sugiyama *et al.* 2020, Baum *et al.* 2023), this finding reinforces research demonstrating that publics in the Global South may be more supportive of solar geoengineering. One interesting addendum here is that publics in the three countries did not differ in their perceptions of benefits and risks. This finding echoes Visschers *et al.* (2017), where China was compared to Western countries. This highlights an ostensible divergence between support for SAI and perceptions of benefits to risks, one not apparent in the Global North. Indeed, while the mean values for perceived benefits and risks lean slightly negative (for all countries), the mean for support of SAI is positive in Mexico (only).

We deduce that the public in Mexico is willing to offer tepid support for SAI, even if presently of a hypothetical nature. This does not, however, indicate that support is somehow indicative of 'acceptance' nor that participants are inattentive to possible risks. For one, participants in Mexico were more likely to reject SAI due to concerns about tampering with nature while also being cautious about potential mitigation-deterrence effects and geopolitical and military risks (Table 6). Instead, for reasons needing to be understood better, the public in Mexico seems to be assuming an open-minded stance at present. Drawing on determinants of SAI support (Table 6), we conclude that this could result from beliefs in a moral obligation to help mitigate climate change and of science and technology as a solution, greater expressed familiarity with SAI, and the younger age of the sample (and national population). In any case, in line with Bellamy's (2023) rejoinder to calls for an international ban or moratorium (e.g. Biermann *et al.* 2022), there is tentative evidence for a 'public mandate for researching, if not necessarily deploying, all available options.' It is worth remarking that, of the governance approaches presented, an international ban or moratorium consistently and clearly received the least support (Table 3).

Regarding our second hypothesis, we failed to find any indication that SAI activities being undertaken in their country would adversely impact perceptions and support among the Mexican public. Overall, there is limited evidence that individuals were at all influenced by changing the details of the SAI activities – this holds true for Mexico and when considering all the countries together. Of the few findings of significance, one indicates that those in Mexico envisioned a more positive balance of benefits to risks if the activity was conducted in Mexico – the opposite of what we had hypothesized (though support was not affected here). We made our supposition, in part, given the reaction by experts and media to the Make Sunsets trial (Temple 2022, Keith 2022, De La Garza 2023), particularly the decision by the Mexican government to ban future experiments on solar geoengineering. Broader criticism about using countries in the Global South as a 'climate laboratory' (Okereke 2023) was also relevant here. Although anecdotal, there were a few comments from participants in Mexico to the open-ended question at the end of the survey that underscored such concerns (examples in Appendix I). In any case, it appears that the concerns expressed within the media and by researchers and critics of geoengineering are not necessarily reflective of the views held by the public.

Nonetheless, we surmise that the broad public in Mexico perceives there to be possible benefits from having SAI activities conducted on their own territory. There is correspondence here, for instance, with research showing a preference (in Germany) for afforestation or direct air capture programs that occur domestically (Merk *et al.* 2023b) and (in several European

countries) for carbon capture and storage programs fully operating domestically (Merk *et al.* 2023a). Merk *et al.* (2023a) explain the latter result in terms of individuals' sense of responsibility to reduce the greenhouse gases emitted by their own countries. As we found that the moral obligation to mitigate climate change also exerts a positive impact on support for SAI in Mexico (and United States), a similar effect may be present here. Participants may also have predicted more benefits for themselves if activities are undertaken in their own country. Also relevant is that the most positively rated pairing of country and governance approach entails the use of national-level regulation and oversight in Mexico. Perhaps the more positive assessment of benefits and risks should thus be seen in tandem with a strong regime of national regulation and oversight – plus international collaboration, as also stressed by the Mexican government after Make Sunsets. Together with the strong support in Mexico (and United Kingdom and United States) for public engagement campaigns, such insights help us to begin sketching conditions for support of the development and deployment of SAI.

Third and finally, we were able to offer some support for the hypothesis that SAI activities by universities would be viewed distinctly than those by start-up firms. Though we found no such effect for perceptions of benefits and risks, there was a generally positive influence on support for SAI if universities were involved (Table 4). Of the three different dimensions explored (i.e. location, scale and purpose, actor), it is the type of actor that seems to play the most important role. This conclusion must be strongly qualified, though, given that we could not identify any such effect for any of the countries on their own. We propose that its emergence at an aggregate level may reflect its importance for sub-populations that are not necessarily citizens of any one country. Less optimistically, the greater power afforded by a larger sample size may have been needed to uncover what is otherwise a small effect (Table 5). Still, this points to one important avenue for future research on public perceptions of solar geoengineering activities.

It is, however, crucial to reiterate that information treatments failed to have much of an influence on public perceptions. Just two of the possible 45 relationships between one of the dimensions of SAI activities (type of actor, location, scale and purpose) and the outcome variables (balance of benefits to risks, support of SAI, support for governance approaches) are significant (Section 4.2). In total, we are left to conclude that the information treatments were generally lacking in effectiveness or, given the still-hypothetical nature of solar geoengineering, that provision of a rather short text on a probably unfamiliar topic was not enough to engage individuals (not least in an online setting). Looking to the future, this potentially leaves public perceptions of solar geoengineering highly malleable as understanding and coverage of these options evolve.

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## Author contributions

The study was conceived by C.M.B. The detailed design and materials were developed by C.M.B., with feedback by L.F., S.L., and B.K.S. L.F. assisted C.M.B. with data collection. C.M.B. analyzed the data and wrote and revised the paper with contributions from L.F., S.L., and B.K.S.

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No potential conflict of interest was reported by the authors.

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