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Public perception of climate engineering in Japan: Results from online and classroom surveys

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Abstract:

Despite the global reach of climate engineering, previous studies on perception of this technology were mostly limited to the Western countries. Here, we present the results of an online survey conducted in March, 2011, in Japan. Each of approximately 4000 respondents read a short article, which was randomly chosen from four kinds prepared with slightly different framings. Common across respondent groups with different articles were cautious attitudes toward the deployment of stratospheric aerosol injection and strong support of research. The high level of support for research can be explained by trust in university researchers and international organizations. Two follow-up classroom surveys (conducted in 2012 and 2014) showed that university students, who learned more about the technique's limitations in a short lecture, also expressed endorsement for investigation. Nevertheless, in one survey where indoor research was distinguished from outdoor studies, the overall support level decreased, with the former preferred to the latter. Our results only capture a snapshot of the public perception, which will change along with the public debate on climate engineering research.

Keywords:

geoengineering, solar radiation management, climate change, public opinion, public awareness

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1. Introduction

1.1. Climate engineering and upstream engagement

In response to an increased interest in the controversial option called climate engineering, many analysts are calling for global public engagement (Corner et al. 2012; Carr et al. 2013). Climate engineering, or geoengineering, is a catch-all phrase to describe a set of techniques to intentionally intervene in the global climate system to counteract climate change (Royal Society 2009; IPCC 2012; NRC 2015). Stratospheric aerosol injection, a proposal that belongs to the category of solar radiation management (SRM), is receiving particular attention. Modeling studies are beginning to demonstrate benefits and risks of this technique (Kravitz et al. 2013).

The concept is new and people have only a vague idea about these technologies. However, based on the lessons from past emerging technology controversies, it is desirable to engage the global public from the early, upstream stage of research (Wilsdon and Willis 2004; Carr et al. 2013).

As reviewed by Corner et al. (2012) and Scheer and Renn (2014), initial attempts have been made to engage a small part of the public in workshops, and to evaluate their opinions in public surveys (Royal Society 2009; Ipsos-MORI 2010; Leiserowitz et al. 2010; Spence et al. 2010; Mercer et al. 2011; Parkhill and Pidgeon 2011; US GAO 2011; Bostrom et al. 2012; Pidgeon et al. 2012; Corner et al. 2013; Pidgeon et al. 2013; Merk et al. 2015)[3] (Hereafter we refer to Mercer et al. 2011 and Merk et al. 2015 as M11 and M15, respectively). The preliminary, general findings are that the awareness of climate engineering is low, and that when given some information, the public distinguishes between SRM and CDR (carbon dioxide removal), with a more favorable view toward CDR (Corner et al. 2012). In addition, some surveys indicate that a majority of the public is open to research into such techniques, although they express reservations about potential harms (M11; US GAO 2011; Pidgeon et al. 2013; M15).

Although SRM is global in its reach, such endeavors have been mostly limited to the West, particularly the United Kingdom and the United States of America (Royal Society 2009; M11; US GAO 2011; Pidgeon et al.

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[3] Not all studies listed here are independent. For example, part of the paper by Pidgeon et al. (2012) is dedicated to a detailed analysis of the results of Spence et al. (2010).

2012; Pidgeon et al. 2013), and more recently Germany (M15). The SRMGI (Solar Radiation Management Governance Initiative) (2011) has been reaching out to emerging and developing countries, including China (Edney and Symons 2013) and Africa (http://www.srmgi.org/events/, accessed 12 April, 2013). Bostrom et al.'s (2012) international survey comparison included one conducted in Bangladesh. A wider geographical coverage is warranted as it could bring different cultural perspectives and "open up" the discursive space (Stirling 2008).

1.2. Research and public opinions

There is a growing chorus for initiating a serious research program on climate engineering, including a possible field test on SRM (NRC 2015; Long et al. 2015). As NRC (2015) clarifies, the publics' perspectives are vital for discussing the governance arrangement surrounding the new research projects. It is therefore crucial to obtain a multitude of perspectives from various geographical areas since the perception and understanding of environmentalism and science differ from country to country.

For instance, according to the results of the International Social Surveys Program, compared to Americans and Germans, the Japanese are inclined to believe in the possibility of science and technology in solving environmental problems (Franzen and Meyer 2010; Franzen and Vogl 2013). This is perhaps due to the high degree of deference endowed to scientists in general, and the association between traditional and environmental values (Pierce et al. 1987; Aoyagi-Usui et al. 2003).

The Japanese public might therefore support climate engineering research if it were promoted by such a trusted source as scientists or international organizations. The "legitimization" of climate engineering by the IPCC (Stilgoe 2015) could be a first step in this direction, since the IPCC is characterized by mainstream newspapers as a pure scientific authority, reflecting the Japanese context (Asayama and Ishii 2014).

Many fields in science (excluding controversial ones like nuclear science and technology) continue to enjoy public trust, as illustrated by the enthusiastic news coverage of the Nobel prizes awarded to Japanese scientists, even after the Great East Japan Earthquake, tsunami, and accidents at the Fukushima Daiichi nuclear power plant on March 11th, 2011 (hereafter we use 3/11 to denote this collective tragedy). Also, by analyzing the surveys conducted before and after 3/11, Kosugi (2013) found that although the perceived risk of nuclear power increased among not only the Japanese public but also nuclear energy experts, the attitude of the public toward science and technology in general has not changed materially since 3/11.

1.3. Current level of interest and awareness in Japan

Before discussing the details of our survey, it is instructive to glance at the current level of awareness and interest in Japan. Fig. 1 shows the time evolution of the coverage of climate engineering by news, blogs, and academic papers in Japan. In contrast with the rising trend the English-speaking areas (M11), the media coverage of climate engineering in Japan is low. *Chikyu kogaku* (earth engineering) in Japanese sometimes means civil engineering, which accounts for a steady coverage over the entire period.

Very few academic papers have been authored. The data here indicate the number of publications in the Japanese language, but the articles in English written by Japanese authors are scarce. For example, the reference lists of Royal Society (2009) and NRC (2015) contain no paper with a Japanese first author.

In this paper we present results of three surveys: an online survey in Japan, and two classroom surveys at Hokkaido University. To our knowledge, it is the first of its kind outside the Western society. We particularly focus on support for climate engineering research. The rest of the paper is organized as follows. Section 2 describes the method used in the three surveys conducted, along with the limitations of the present study. Section 3 discusses results from the three surveys. Section 4 presents discussion and conclusions.

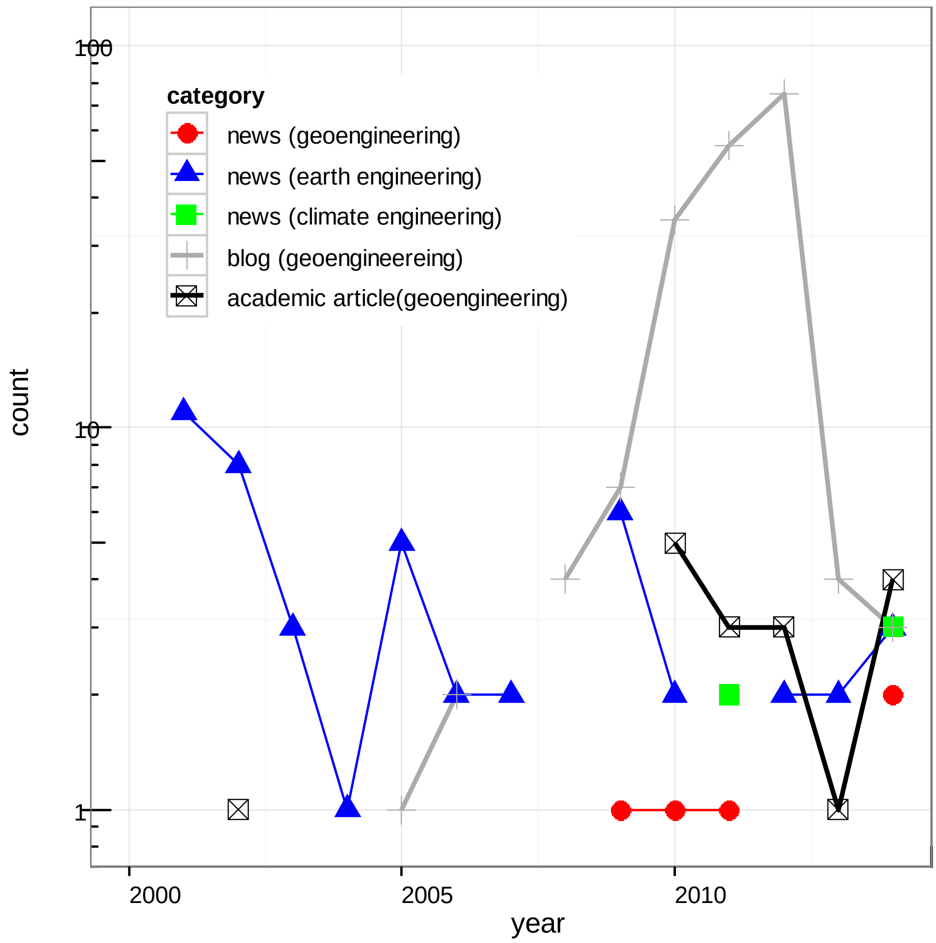

Fig. 1. Number of news articles, blog entries, and academic articles over the period 2000-2014 in Japan. All searches were conducted in April-May, 2015. The searched newspapers were *Asahi Shimbun*, *Yomiuri Shimbun*, and *Mainichi Shimbun*, which were analyzed by Asayama and Ishii (2014). The queries were conducted with three keywords: *jioenjiniaringu* (geoengineering), *chikyu kogaku* (earth engineering), and *kiko kogaku* (climate engineering). The count of blog articles was estimated with a Google search with a query "*jioenjiniaringu* (geoengineering)." Japanese academic articles have been identified with the CiNii service provided by the National Institute of Informatics (http://ci.nii.ac.jp/), with the same query as the blog search. Some articles matched with the query only in the author affiliation, and we have excluded them in the count. We also manually adjusted for double-counting. As the vertical scale is in logarithm, years with a zero count are neglected.

2. Methods

2.1. Internet, national survey in March, 2011

The first survey was conducted on the 8th and 9th of March, 2011, just before 3/11. It was administered to a sample chosen from the national panel maintained by Macromill Inc. of Japan. As the survey involved questions on political and religious views, a prescreening question was sent to 55,900 people from the 4th to the 7th of March. 17,282 people responded, indicating interest in participating in such a survey. After the prescreening, the survey instrument was sent to 8,358 people on the 8th and 9th until we received 4,128 responses with a response rate of 49.4%.

The sample was chosen so that the male-female ratio of the sample is 50:50. The respondents are 20 years or older, and the age distribution is uniform for each of four age blocks: 20-29, 30-39, 40-49, and 50 or older. The respondents were younger and had higher education backgrounds than the nationally representative sample. We excluded respondents who likely used internet materials while answering open-ended questions, retaining 4013 entries. See the Supplementary Material Section 1, Table S1 for the general characteristics of the sample.

Each subject read a short article about climate engineering before answering questions on climate engineering. We developed four kinds of messages with different framings, and randomly assigned them to each subject. The survey's structure is shown in Table 1.

Table 1. Overview of the online and in-class surveys.

	Online survey	In-class surveys at Hokkaido University
Date	March 8-9, 2011	January 26, 2012 / February 3, 2014
Respondents	Sample from a national panel maintained by a firm, Macromill Inc.	Students enrolled in the course “Earth and Planetary Science” and mostly composed of freshmen majoring in science/engineering (2012); Students in enrolled in the course “Introduction to Meteorology” and who are mostly freshmen and sophomores in various majors (2014)
Sample size	4013	143 (2012) / 127 (2014)
Questions	Image about climate change Awareness of climate engineering Concern about climate change (Article) Question on the presentation of article Impression of climate engineering Trust in information sources Concern about climate change (repeated) Post-materialist & attitude toward science Socio-demographic	Image about climate change Concern about climate change (Article) Question on the presentation of article Impression of climate engineering Trust in information sources Post-materialist & attitude toward science Socio-demographic (There is a slight difference in the survey instruments in 2012 and 2014 in (1) the information material, (2) the question on research support, and (3) the question on social values.)
Information material (See Table 2 for parts of the article)	Randomly chosen out of the four kinds: M1 M2 M3 M4	Only one type: M4

The questions were constructed based on previous surveys reported in the literature (M11; Inglehart 1971; Ohe and Ikeda 2005; Leiserowitz 2006). The SRM questions were mainly adapted and modified from those of M11; they kindly shared a draft version of their survey instrument with us. There is one key difference between the present study and M11, which is about terminology. M11 used SRM, while we used climate engineering in our survey instrument.

To construct the four kinds of messages, we considered positions expressed in various forums, ranging from a strong criticism (ETC Group 2010) to cautious support (Caldeira and Keith 2010) to an optimistic appraisal (Teller 1997). Such a vibrant, public discussion is absent in Japan, and we produced the four kinds of explanations by ourselves. We composed three components for information materials: (a) a basic description, (b) additional justification for climate engineering in light of the risk of dangerous climate change and climate emergency, and (c) risks associated with climate engineering. We then produced four types as follows:

- M1 (“basic”): (a);
- M2 (“dangerous climate change”): (a) + (c);
- M3 (“side effects”): (a) + (b); and
- M4 (“all”): (a)+(b)+(c).

Though there are four types of articles, the range of viewpoints is fairly narrow, as it does not include a very optimistic support or strong criticism.

For details of the survey instrument and information materials (including the original Japanese version), see the Supplementary Materials Sections 8, 9, and 10.

2.2. Classroom survey of university students in January 2012

Climate engineering is a novel idea, and it is difficult to explain it to a respondent in a short period of time. The online survey respondents may not grasp the idea sufficiently. A follow-up, in-class survey was therefore performed.

The second survey was conducted on January 26, 2012, on the Sapporo campus of Hokkaido University. It was administered to students in the course “Earth and Planetary Science,” mainly targeted at freshmen, who were mostly at the age of 18-19 and in a science/engineering major (convenience sampling).

The course, which consists of 15 sessions of 1.5-hour lectures, covers a wide range of introductory materials related with earth and planetary sciences, including the origin of the solar system, introduction to meteorology and climate science. The last three lectures touched on global climate change.

The first of the three-part series discussed the paleoclimate and natural climate variability such as the El Niño-Southern Oscillation (ENSO). The second was devoted to the science of climate change, covering anthropogenic greenhouse effects, past observations of the climate, and the use of global climate models for detection, attribution, and projection of climate change. Most discussions reflected the contribution of the IPCC Working Group I to the Fourth Assessment Report (IPCC 2007a).

The survey was conducted during the last class. Prior to the survey, a 30-minute lecture on mitigation, adaptation, and climate engineering was given. The descriptions of mitigation and adaptation followed a rather dry text of the IPCC assessment reports. Presentations on climate engineering covered both SRM (stratospheric aerosol injection and marine cloud brightening) and CDR (ocean iron fertilization and direct air capture). The class materials discussed the mechanisms underlying each method, potential efficacies and side effects, including possible stratospheric ozone destruction in the case of stratospheric aerosol injection. They also mentioned various social problems such as moral hazard and "playing God." Since the course is about science (not engineering) and emphasizes systems thinking, we would expect the students to be supportive of research but against the manipulation of nature.

Because the subjects became fairly knowledgeable about climate engineering before the survey, we utilized only the fourth article (M4) and excluded questions about awareness of climate engineering. Otherwise, the survey instrument was mostly identical to that of the internet survey. The attendance of the day of the survey was 176. 143 students completed questionnaire surveys, with a response rate of 81%.

2.3. Classroom survey of university students in February 2014

A third survey, similar to the second one, was conducted on February 3, 2014. The survey instrument was distributed to the students enrolled in Introduction to Meteorology, which was intended for undergraduates interested in the subjects. The enrolled students were mostly freshmen and sophomores, and many of them were non-science majors. It covered topics such as descriptive meteorology of Japan, meteorological observation networks, numerical weather prediction, stratospheric ozone depletion, and climate change. The last class dealt with human responses to climate change, and presented an updated version of the contents used in the previous in-class survey.

The survey instrument was almost identical to the previous one except for three points: (1) The question on research acceptance was divided into one on indoor research and another on outdoor, field experiments; (2) The information material was augmented with a statement on the social concern such as unilateral deployment and ethical issues and a mention of stratospheric ozone destruction; and (3) the question on social values was changed from the Inglehart post-material index to the New Ecological Paradigm (Dunlap et al. 2000), following M15.

The attendance of the day of the survey was 151. 127 students completed questionnaire surveys, with a response rate of 84.1%.

2.4. Study limitations

There are many deficiencies with our study. Because our method is an opinion poll, it precludes nuanced answers (Fischhoff and Fischhoff 2001) and might result in distorted outcomes through framing effects (Slovic 1995) such as “naturalness” (Corner et al. 2013; Macnaghten and Szerszynski 2013). Moreover, we did not carefully mention the timescale of the ice sheet melting, which is expected to take hundreds of years (Lenton et al. 2008), implying the urgency of the climate problem.

Owing to the issues mentioned above, we mainly focus on the findings robust to the framings.

3. Results

This section describes the results of the three surveys. We mainly discuss the online survey, complementing discussions with the classroom surveys. When we refer to a question by a question number, we utilize that of the online survey, unless otherwise noted. For the correspondence of questions between the three surveys, see the Supplementary Materials Section 7, Table S14. An “S” in a question identifier indicates a subquestion; Q20S1 means Subquestion 1 of Q20, for example.

3.1. Prior knowledge about climate engineering

The prior recognition was low among subjects in the online survey except for earth engineering. Of the responses to Q5 “Have you heard of geoengineering (*jioenjiniaringu*)?,” 5.1% were “yes”, 79.5% “no,” and 15.4% “unsure.” For responses to Q7 (earth engineering or *chikyu kogaku*), 28.0% were “yes,” 58.4% “no,” and “13.6%” unsure. And of responses to Q9 (climate engineering or *kiko kogaku*), 9.7% “yes,” 77.4% “no,” and 12.9% “unsure.” Although not directly comparable because of differences in survey designs, M11 report that 20% and 24% of respondents in their survey answered that they had heard geoengineering and climate engineering, respectively. The difference probably has to do with a lower level of mass media reporting in Japan.

Some caution is in order about the term *chikyu kogaku* (earth engineering). In Japanese, this phrase is often used to indicate civil engineering, not climate engineering. Kyoto University, for example, has a department of *chikyu kogaku*, which is concerned with civil engineering (http://www.s-ge.t.kyoto-u.ac.jp/ja, accessed 23 April 2013; although they use *chikyu kogaku* in Japanese, they use global engineering when translating into English). This term was included in the survey because the official translation of IPCC report employed this term as a translation of geoengineering (IPCC 2007b), and popular articles continue to use it (for instance, see the Japanese translation of Fleming 2010). This might explain why 28% of respondents (substantially a larger fraction than the cases of geoengineering and climate engineering) answered that they had heard of this term.

The official translation of the newly released IPCC report has changed its choice of word from *chikyu kogaku* to *jioenjiniaringu* (IPCC 2013).

We categorized responses to open-ended answers into climate engineering and other groupings, following M11. The first author coded each response with several iterations, using extensive computer-aided keyword sorting.

A majority of respondents gave incorrect descriptions, most of which are various kinds of science and engineering, while 5-12% of respondents correctly described it (see the Supplementary Materials Section 2, Table S2). About 40-50% of respondents stated “Don’t know” or left the answer box blank. Consistent with M11, climate engineering has an informational value, with 12% of the responses matching a correct definition. Some respondents saw climate engineering as an act of hubris or arrogance against nature, although the number of such responses was small.

3.2. Attitudes toward climate engineering

The survey participants answered their impression about climate engineering after reading the articles. The impressions did change with the framing as intended. Majorities felt that the article mentioning side effects was neutral but a significant fraction of the subjects thought that the articles were supportive of climate engineering (see the Supplementary Materials Section 3, Table S4).

The respondents displayed strong support for climate engineering research in both online and in-class surveys as shown in Table 2, which includes statistics from M11 and M15 for comparison. 85% of the online respondents and 93% of the 2012 students either agreed or somewhat agreed with the need for research. The very high degree of support might have been due to the vagueness of the question on research. The 2014 survey decomposed the question on research into two. 83% of the students agreed or somewhat agreed with the support for indoor research, and 62%, for outdoor research. On the other hand, many respondents were cautious about deployment. The fractions of the respondents who agreed or somewhat agreed on immediate deployment were 37%, 21%, and 16% for 2011, 2012, and 2014 surveys, respectively. (A fuller picture on the cautious attitude of respondents is depicted in the Supplementary Materials Section 4, Table S5.)

Table 2. Attitudes toward climate engineering research and deployment (all respondents with the four article types included for the online survey). The format is mean ± standard deviation. M11 used the term SRM rather than climate engineering. The response scales are 1 (”disagree”), 2 (“somewhat disagree”), 3 (“somewhat agree”), and 4 (“agree”), so that 2.5 corresponds to the middle ground. The questions posed to the respondents are as follows. Never: (Q20S5) Do you think that climate engineering should never be used, no matter the situation? Immediate: (Q20S4) If climate engineering was possible today, what would you think about using it immediately? Emergency: (Q20S3) What do you think about using climate engineering to stop a climate emergency? Research: (Q20S2) Do you think scientists should study climate engineering? Lab: (Q14S2 of the 2014 survey) Do you think scientists should study climate engineering with theoretical calculations, computer simulations, and indoor experiments? Field: (Q14S3 of the 2014 survey) Do you think scientists should conduct climate engineering experiments in the natural environment to examine its efficacy and side effects?

Source	This study			M11	M15
Geography	Japan			USA/Canada/UK	Germany
Year and format	2011 Online	2012 Classroom	2014 Classroom	2010	2012
Never	2.0±0.83	1.7±0.77	1.7±0.83	2.34±0.10	2.4±1.0
Immediate	2.3±0.94	1.9±0.97	1.7±0.81	2.23±0.94	1.9±0.95
Emergency	3.0±0.81	3.3±0.71	3.2±0.81	2.49±0.90	2.6±1
Research	3.4±0.71	3.6±0.63		3.08±0.80	
Field			2.9±0.96		2.4±1
Lab			3.3±0.85		3.1±0.91

Since direct comparison is difficult because of the difference in the information materials and the survey framework, it is more instructive to examine the overall patterns among M11, M15, and our study. Common across the studies are the support for research, compared to that of deployment, and the preference of indoor research over outdoor one. However, the Japanese are less inclined to flatly reject climate engineering. The lowest mean score was found for “deployment never” for the three Japanese cases (it tied with the support for immediate deployment in the 2014 survey), whereas the mean score was lowest for immediate deployment in M11 and M15. This might be because the Japanese are not used to categorically support or oppose a statement.

3.3. Framings and support for research

Given the high level of research support, to what extent is it dependent on the framing? Table 3 shows the effects of frames for the 2011 online survey, which randomly assigned each subject one out of the four different vignettes. The message M3, which emphasizes side effects of climate engineering, did affect the respondents’ attitudes, which became more negative about SRM for a few set of questions. On the other hand, adding the information on dangerous climate change did not contribute a statistically significant change.

Table 3. Changes in mean responses due to the randomized treatment. The results here are for the online survey only. The results are arranged in the increasing order of the difference between M3 and M1. The statistical test was performed using Student's *t* test. *: $p<0.05$, **: $p<0.01$; ***: $p<0.001$.

	Mean±SD	Differences			
Questions	M1	M2-M1	M3-M1	M4-M1	Sum of absolute values of changes
Q20S4: If climate engineering was possible today, what would you think about using it immediately?	2.40±0.96	-0.014	-0.231 ***	-0.124 **	0.369
Q20S1: Do you think that climate engineering should be used as a solution to global warming?	2.70±0.89	0.012	-0.130 **	-0.048	0.190
Q20S3: What do you think about using climate engineering to stop a climate emergency?	3.01±0.82	0.043	-0.066	-0.015	0.123
Q20S2: Do you think scientists should study climate engineering?	3.36±0.72	-0.012	0.003	0.012	0.028
Q20S5: Do you think that climate engineering should never be used, no matter the situation?	2.02±0.87	-0.045	0.049	-0.013	0.107

The question on research (Q20S2) is distinct from other questions as it is the least susceptible to the framing. Table 3 also exhibits the sum of absolute changes, and it is smallest for the question on research support. In fact, the accumulated difference is smaller by an order of magnitude compared to other questions. This is in sharp contrast to the attitude towards deployment. For example, the answers to the question on immediate deployment was the most responsive to framings.

3.4. Factors underlying support for research

The support for research was found to be high and stable irrespective of framings used, in contrast to questions on deployment. What then explains the variance of attitudes toward research? We thus conducted an ordered logistic regression (Table 4), in a way akin to that of M15. We have reduced the number of independent variables by aggregating similar parameters (see the Supplementary Materials Section 5).

The most important factors that explain support for research are trust in university researchers and the United Nations along with the attitude toward science, which is followed by the trust in religious leaders, the perception of climate change risks, and education. The trust in researchers and international organizations together with the attitude toward science are also found important for emergency deployment and unconditional rejection. The judgement on immediate deployment hinges on a different combination of factors, such as trusts in businesses, environmental organizations, religious leaders and friends, and how the respondents were worried about climate change.

Curiously, the post-materialism index and the message type (framing) did not significantly affect the responses, except for the influence of emphasis of side effects on immediate deployment.

Compared to the German survey (M15; see their Table 1), the survey participants in Japan highly regard the United Nations. In their results, the trust in international organizations was not identified as a statistically significant factor.

Table 4. Results of the ordered logistic regression of support for climate engineering. See Table 2 for the definitions of dependent variables. The results here are for the online survey only. *: p<0.05, **: p<0.01; ***: p<0.001.

	Predictands							
Predictors	research		emergency		immediate		never	
Trust in government	-0.054		0.074		0.167	**	-0.008	
Trust in business	0.001		0.074		0.219	***	-0.036	
Trust in environmental organizations	-0.003		0.09		0.192	***	0.011	
Trust in university researchers	0.335	***	0.23	***	0.17	**	-0.35	***
Trust in the media	0.106		0.029		0.046		-0.046	
Trust in the United Nations	0.268	***	0.319	***	-0.005		-0.276	***
Trust in religious leaders	-0.148	**	0.019		0.187	***	0.144	**
Trust in friends and family	0.017		0.062		0.224	***	0.023	
Science attitude index	0.353	***	0.256	***	0.106	*	-0.215	***
Bad impression index	0.059		-0.025		-0.178	***	0.025	
Understanding index	0.001		0.263	***	0.195	**	-0.186	**
Risk perception index	0.206	**	0.113		0.279	***	-0.054	
Action preference index	0.094		0.068		-0.046		0.047	
Policy preference index	-0.118	*	-0.09		0.138	**	0.18	**
Inglehart post-materialism index	0		-0.006		-0.077		0.036	
Dummy for sex (male=1)	0.105		0.211	*	0.235	*	-0.09	
Age	0.009	*	-0.009	*	0.005		0.008	*
Dummy for religiousness	-0.028		-0.021		-0.207		0.184	
Dummy for education	-0.283	**	-0.209	*	-0.035		0.036	
Dummy for M2	0.092		0.097		0.009		-0.142	
Dummy for M3	0.043		-0.084		-0.326	*	0.03	
Dummy for M4	0.022		0.058		-0.231		-0.046	
Sample size, n	1720		1649		1627		1577	
McFadden's R^2	0.594		0.564		0.566		0.557	

3.5. Trust in information sources

The preceding analysis has demonstrated that trust in scientists and trust in international organizations are the most important factors for support of research.

Based on Q22, the fractions of the respondents who trusted or somewhat trusted each source are as follows (in the descending order): (1) University researchers (78.9%); (2) The United Nations and international organizations (72.7%); (3) Friends and family (48.7%); (4) Private companies (46.6%); (5) Environmental protection groups (44.9%); (6) Government (23.5%); (7) The media (9.6%); and (8) Religious leaders (3.9%). (See the Supplementary Materials Section 6, Table S13 for the results of the classroom surveys.)

Scientists and international organizations rank very high as trusted sources of information in all the surveys. This is a factor underlying the strong support of research.

Compared to the English-speaking nations and Germany, however, environmental organizations were not favored as an information source in Japan. In fact, private companies are more trusted in Japan than environmental organizations (though neither of them is trusted by a majority). M11 reported that environmental organizations enjoyed the trust of about 60% of respondents or more, and the mean score was highest for such organizations in M15's results. In contrast, 45% of the online survey respondents and 35% of the 2012 students and 41% of the 2014 respondents indicated their support for such groups. Likewise, M11 showed that about 30% of respondents indicated trust for private corporations and the mean score was lowest for the firms involved, while our results show that 47% of the online survey respondents and 43% and 45% of university participants in 2012 and 2014, respectively, exhibited trust for private companies.

4. Conclusions and discussion

With an online survey and two follow-up classroom surveys, we have investigated the snapshot of the public perception on stratospheric aerosol injection, a climate engineering proposal. The awareness of this technology is low in Japan. The respondents expressed a high degree of support for research, though they were cautious about deployment. The research support was found to be related with trust in university researchers and international organizations.

Since our work is the first of its kind outside the Western societies, we below discuss wider implications of our findings.

4.1. Linguistic expressions of climate engineering

In the West, numerous expressions have been coined to describe similar concepts: geoengineering, climate engineering, solar radiation management (Royal Society 2009), climate remediation (BPC 2011), climate intervention, and albedo modification (NRC 2015). As with framings, the choice of words is important for public discussions.

In countries where English is not a mother tongue, these words are translated in many different ways, with implications for governance. In Japan, geoengineering is often translated into *chikyu kogaku* (earth engineering), which has a connotation similar to civil engineering. Similarly, in Chinese, the preferred phrase is *di chiu gong cheng* (earth engineering) (see the Chinese translation of Royal Society 2009).

Experts continue to invent new vocabularies, but so far little attention has been paid to global implications. This paper discovered that climate engineering is informative in Japanese. The future discussions should be more mindful about the linguistic aspects in non-English societies.

4.2. Trust in scientists and international organizations

In our three surveys, university scientists and the United Nations consistently ranked high as trusted sources of information, and such trust is found to be related with the support for research. This might have to do with the Japanese' tendency to believe in the ability of science and technology in solving environmental problems. In contrast, unlike Western countries, environmental organizations did not enjoy trust of citizens with regard to climate engineering, while corporations received a reasonable level of trust (though still less than 50%).

A possible explanation is that it is very rare for environmental organizations to make appearance in the mainstream media in Japan. This has been confirmed in the case of newspaper coverage of carbon capture and storage (CCS) (Asayama and Ishii 2013). And when they do, it is often about the anti-whaling movement that often attempts to block a research vessel. Asayama and Ishii (2014) showed that the influence of *Kisha Clubs* (reporters' clubs), which serve as a conduit of official reporting from the government, is significant in portraying the IPCC as a pure scientific authority. A similar force might be at play in the opposite sense characterizing environmental organizations.

Crucially, the publics in different countries trust different sources. The three Japanese surveys have identified scientists as trusted. Although the Japanese citizens trust both researchers and international organizations, citizens in other countries might differentiate indigenous scientists from those from outside. Understanding who is trusted in each country is a key to public engagement across multiple countries.

As Carr et al. (2013) enthusiastically noted, the time for global public engagement is now. More studies on non-Western constituents are greatly needed.

5. Acknowledgments

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Supplementary Materials to

Public perception of climate engineering in Japan: Results from online and classroom surveys

by Masahiro Sugiyama and Masatomo Fujiwara

1. Online sample characteristics

Table S1. Characteristics of the online survey sample (after exclusion of improper responses). Because of rounding, values do not necessarily add up to 100%.

Region	Hokkaido	4.9%
	Tohoku	5.1%
	Kanto (including Tokyo)	42.8%
	Hokuriku	2.9%
	Tokai	10.7%
	Kinki (including Osaka)	19.0%
	Chugoku	4.6%
	Shikoku	2.2%
	Kyushu	7.4%
	Okinawa	0.5%
Sex	Men	49.9%
	Women	50.1%
Age	20-29	25.2%
	30-39	25.2%
	40-49	24.9%
	50-59	16.4%
	60-	8.2%
Education	Elementary school / Junior high school	1.2%
	High school	23.5%
	Vocational school / two-year college / college of technology	23.1%
	University/Graduate school	50.6%
	Other / Would rather not answer	1.6%

2. Three terms (geoengineering, climate engineering, and earth engineering) and associated images

We categorized responses to open-ended answers into climate engineering and other groupings. As with M11, we identify correct answers as those that satisfy at least two of the three conditions: (1) descriptions that suggest an environmental state or process is being changed intentionally; (2) those that are related to climate change (but not the source of climate change); and/or (3) those that are artificial or human-made. The first author coded each response with several iterations, using extensive computer-aided keyword sorting. The results are shown in Table S2.

Unlike a survey of the English-speaking countries (M11), very few respondents chose geography and genetic engineering. Also, few responses included an explicit mention of civil engineering (*doboku* or *doboku kogaku* in Japanese).

Note that Questions 5-10 were placed on the same page, which might have led some respondents to guess that the three words had the same meaning.

Table S2. Categorization of answers to open-ended questions about the three terms. Geotechnical science/engineering refers to science/engineering that is related with the solid earth.

Category	Q6. Geoengineering	Q8. Earth Engineering	Q10. Climate Engineering
Geoengineering (correct definition)	6.1%	5.4%	12.2%
Environmental science	1.7%	16.7%	25.3%
Environmental engineering	11.2%	12.5%	8.9%
Geotechnical science/engineering	1.5%	3.5%	0.1%
Other science/engineering	14.3%	6.3%	2.0%
Energy (including geothermal) & resources	1.9%	2.7%	1.3%
Environmental problem and protection	4.8%	4.6%	2.6%
Natural phenomena	2.8%	4.0%	6.8%
Other	4.1%	5.6%	2.1%
Don’t know	36.5%	23.7%	23.2%
No answer (blank)	15.0%	15.0%	15.5%

3. Impression of the articles

Most of respondents thought that the short articles they had read were clear or somewhat clear, and understood the content (Table S3).

Also they thought that the materials were either supportive of, or neutral about, climate engineering. Table S4 describes how subjects evaluated the four short articles. 6% or fewer subjects thought that the articles were opposed to climate engineering. When the article did not explicitly mention side effects, roughly half of respondents considered it biased toward supporting climate engineering. Impression of the M4 article type was similar between the online and 2012 classroom surveys. For the 2014 classroom survey, the short article contained additional explanations on social concerns, which led to an increase in the perceived neutrality.

Table S3. Responses to Q17 "Do you feel that the information you just read was clear?". The units are percent.

		Unclear	Somewhat unclear	Somewhat clear	Clear
2011 online	M1	4.46%	27.55%	57.0%	11.0%
	M2	3.30%	23.08%	60.1%	13.5%
	M3	2.40%	27.15%	59.9%	10.6%
	M4	3.50%	24.88%	57.7%	13.9%
2012 classroom		1.47%	12.50%	61.8%	24.3%
2014 classroom		2.38%	5.56%	52.4%	39.7%

Table S4. Responses to Q18 “Is the present information neutral?” Choices are: (supportive) “It was supportive of climate engineering”; (neutral) “It was neutral, and did not support or oppose climate engineering”; and (opposed) “It was opposed to climate engineering.” The units are percent.

		Supportive	Neutral	Opposed
2011 online	M1	47.9%	46.8%	5.35%
	M2	50.3%	46.0%	3.70%
	M3	31.3%	62.4%	6.29%
	M4	40.5%	56.0%	3.50%
2012 classroom (M4)		39.0%	59.6%	1.47%
2014 classroom		21.6%	69.6%	8.80%

4. Attitudes toward climate engineering

Our survey reveals a high level of support for climate engineering research, although the respondents were generally cautious about its actual implementation. For example, a number of respondents noted that the earth's temperature is very complicated and not amenable to a single-technology solution, and that emphasis should be first placed on emissions reductions.

Table S5. Attitudes toward climate engineering.

Question	2011 online survey	2012 classroom survey	2014 classroom survey
Q20S1: Do you think that climate engineering should be used as a solution to global warming?	2.66±0.85 51.4%	2.71±0.88 51.1%	2.48±0.89 42.5%
Q20S2: Do you think scientists should study climate engineering?	3.36±0.71 84.9%	3.56±0.63 92.6%	
Q14S2 (2014 online survey): Do you think scientists should study climate engineering with theoretical calculations, computer simulations, and indoor experiments?			3.27±0.85 82.7%
Q14S3 (2014 online survey): Do you think scientists should conduct climate engineering experiments in the natural environment to examine its efficacy and side effects?			2.86±0.96 61.4%
Q20S3: What do you think about using climate engineering to stop a climate emergency?	3.00±0.81 68.9%	3.29±0.71 82.2%	3.16±0.81 77.8%
Q20S4: If climate engineering was possible today, what would you think about using it immediately?	2.31±0.94 37.1%	1.92±0.97 21.3%	1.74±0.81 15.7%
Q20S5: Do you think that climate engineering should never be used, no matter the situation?	2.02±0.83 19.8%	1.67±0.77 12.5%	1.71±0.83 13.4%
Q21S1: Climate engineering will harm the planet rather than help it.	2.48±0.83 29.6%	2.29±0.74 30.4%	2.28±0.74 26.8%
Q21S2: With enough research, I believe climate engineering will turn out to be safe and effective.	2.91±0.77 61.9%	3.03±0.80 72.8%	3.00±0.75 67.7%
Q21S3: Climate engineering should be used so we can continue to use oil, coal, and natural gas, without worrying about reducing CO2 emissions.	2.00±0.85 22.7%	1.64±0.73 12.5%	1.66±0.74 11.8%
Q21S4: Climate engineering is the easy way out.	2.60±0.87 43.3%	2.54±0.92 50.7%	2.33±0.95 42.5%
Q21S5: Research into climate engineering will lead to a technology that will be used by the government no matter what the public thinks.	2.84±0.88 57.1%	2.74±0.80 57.4%	2.77±0.94 59.1%
Q21S6: The earth's temperature is too complicated to fix with one technology.	3.49±0.65 87.3%	3.67±0.56 90.4%	3.58±0.60 94.4%
Q21S7: Humans should not be manipulating nature in this way.	2.75±0.88 51.1%	2.64±0.99 49.3%	2.78±0.92 57.1%
Q21S8: If scientists find that climate engineering can reduce the impacts of global warming with minimal side-effects, then I would support its use.	2.86±0.84 62.1%	2.96±0.76 69.1%	2.93±0.92 69.3%

5. Predictors (independent variables) for regression analysis

The following tables describe how each index is constructed. All continuous variables are normalized so that they have a mean of zero and a unit standard deviation. Categorical variables are treated as dummy variables, which take either 0 or 1. For repeated questions, we have used those that appear before the article on climate engineering. We have limited ourselves only to the online survey because the sample sizes of the classroom ones were small.

Table S6. List of predictors for the regression analysis.

Predictor	Definition and scale range
Trust in each source	Q22S1-S8
Science attitude index	Sum of responses to Q31S1 and Q31S2 (see below)
Bad impression index	Q2 (1. Slightly negative to 5. Very negative)
Understanding index	Sum of responses to Q11S1 and Q11S2
Risk perception index	Sum of responses to Q12S1, Q13S1, Q13S2, Q14S1, Q14S2
Action preference index	Sum of responses to Q15S1-Q15S5
Policy preference index	Sum of responses to Q16S1 and Q16S2
Inglehart index	4-item post-materialism index, combining Q29S1 and Q29S2, based on Inglehart (1971) and the World Values Survey (http://www.worldvaluessurvey.org/, accessed 22 April 2013).
Sex	Pre-collected by the survey company
Age	
Dummy variable for religiousness	Q34, 1 if yes
Dummy variable for education (undergraduate or above)	Q32, 1 if college or graduate school
Dummy variables for article types	Denotes which message was randomly assigned to each of the respondents

Table S7. Correlation coefficients among variables. The result here implies that combining the responses to Q31S1 and Q31S2 would give a science attitude index.

	Q30	Q31S1	Q31S2	Q31S3	QQ31S4
Q30	1				
Q31S1	0.34	1			
Q31S2	0.37	0.59	1		
Q31S3	-0.07	0.07	0.11	1	
Q31S4	-0.19	-0.14	-0.16	0.24	1

Table S8. Science attitude index. Unlike other questions, the scales range from 1 (completely disagree) to 10 (completely agree). *n* = 3450.

	Mean	Std Dev	Cronbach's alpha
Science attitude index	14.31	3.06	0.74
Q31S1	7.05	1.73	
Q31S2	7.26	1.71	

Table S9. Understanding index. *N* = 3761. Scales range from 1 (disagree) to 4 (agree).

	Mean	Std Dev	Cronbach's alpha
Understanding index	6.87	1.35	0.75
Q11S1	3.60	0.66	
Q11S2	3.27	0.84	

Table S10. Risk perception index. N =3361. Scales range from 1 (not concerned at all, no impact, no possibility) to 4 (very concerned, very large impact, very likely).

	Mean	Std Dev	Alpha if deleted	Cronbach's alpha
Risk perception index	15.84	3.20		0.87
Q12S1	3.22	0.78	0.84	
Q13S1	3.52	0.67	0.86	
Q13S2	3.21	0.76	0.84	
Q14S1	3.01	0.84	0.84	
Q14S2	2.88	0.87	0.85	

Table S11. Action preference index. N = 4013. No = 0, Yes = 1.

	Mean	Std Dev	Alpha if deleted	Cronbach's alpha
Action preference index	2.85	1.49		0.65
Q15S1	0.84	0.37	0.59	
Q15S2	0.66	0.47	0.59	
Q15S3	0.55	0.50	0.63	
Q15S4	0.29	0.45	0.59	
Q15S5	0.51	0.50	0.57	

Table S12. Policy preference index. n = 3616. Scales range from 1 (oppose) to 4 (support).

	Mean	Std Dev	Cronbach's alpha
Policy preference index	4.3	1.61	0.65
Q16S1	2.24	0.99	
Q16S2	2.09	0.88	

6. Credibility of information sources

Table S13. Trusted sources of information. Shown is the fraction of respondents who trusted or somewhat trusted each information source. The rows are sorted according to the value in the online survey.

	Fraction of respondents who trusted or somewhat trusted each source		
	Online (2011)	Classroom (2012)	Classroom (2014)
Q22S4: University researchers	78.9%	86.0%	84.1%
Q22S6: The United Nations & international organizations	72.7%	80.0%	85.7%
Q22S8: Friends and family	48.7%	39.0%	29.9%
Q22S2: Private companies	46.6%	42.6%	45.2%
Q22S3: Environmental protection groups	44.9%	35.3%	40.5%
Q22S1: Government	32.6%	23.5%	42.5%
Q22S5: The media	29.8%	9.6%	13.4%
Q22S7: Religious leaders	3.9%	2.2%	2.4%

7. Comparison of the three survey instruments

The following table describes how the online survey instrument compares with the in-class ones. We only describe the online survey instrument in full, as the texts are virtually identical for each set of corresponding questions.

Table S14. Correspondence of questions among the three surveys.

Content of questions	Online survey	In-class surveys (2012 and 2014)
Image about climate change	Q1-Q4	Q1-Q4
Awareness of climate engineering, etc.	Q5-Q10	N/A
Concern about climate change	Q11-Q16	Q5-Q10
Article	Four kinds of articles	Only one type (M4, all) (For the 2014 classroom survey, the material was slightly modified)
Question on the presentation of article	Q17-Q19	Q11-Q13
Impression of climate engineering	Q20-Q21	Q14-Q15 (For the 2014 classroom survey, the question on research acceptance was divided into two)
Trust in information sources	Q22	Q16
Concern about climate change (repeated)	Q23-Q28 (repeat of Q11-Q16)	N/A
Post-materialist and attitude toward science	Q29-Q31	Q17-Q19 (For the 2014 classroom survey, the question on post-materialism was replaced with one on the New Ecological Paradigm)
Education	Q32	N/A
Demographic	N/A (survey company maintains a database of this type of information, hence not included in the survey)	Q20-Q23 (sex, age, department, year)
Question on whether respondent is willing to answer religious/political questions	Q33	N/A (caution is given as a text, not a question)
Religious and political attitudes	Q34-Q36	Q24-Q26 (The list of political parties was adjusted to reflect the situation at the time of each survey.)

8. Note on the survey instrument

The survey instrument was pre-tested and corrected for clarity. Many questions are based on a four-point Likert scale, consisting of “disagree,” “somewhat disagree,” “somewhat agree,” and “agree.” In Japanese surveys, it is common to use the four choices that correspond to these English phrases. See, for example, samples of official surveys conducted by the Cabinet Office of the Government of Japan (http://www8.cao.go.jp/survey/h24/h24-shougai/3.html and http://www8.cao.go.jp/survey/h24/h24-danjo/3.html, accessed 27 March, 2013). In contrast, the wordings used by M11 are “strongly disagree,” “disagree,” “agree,” and “strongly agree.” As with M11, we included an option of “unsure” in many questions, while removing the “neutral” response.

The length of the full article in the survey instrument was determined so that it roughly matches that of a typical Japanese newspaper article, which is significantly shorter than in English-language papers. Because of the space constraint, we admit that the articles presented here may have communicated some information inaccurately.

The article mistakenly missed the word “eruption” after “volcano,” although the preceding paragraph included “explosion” to indicate a major volcanic eruption. The responses to open-ended questions suggest that the survey participants correctly understood the message, and that the bias due to the exclusion is presumably negligible.

Mercer et al. (2011) included a question on chemtrails and associated conspiracy theories. In Japan, although there are some blogs dedicated to the topic, the “chemtrails” conspiracy theory (Watson, 2001) is not widely known. For example, a search into the three newspapers (*Asahi*, *Yomiuri*, *Mainichi*) with the query *kemutoreiru* or *kemu-toreiru* returned no results. We therefore excluded this question.

9. Survey instrument of the online survey in March 2011

Q1: 地球温暖化について何か悪い印象がありますか？

［はい / いいえ］

Q1: Do you have any negative feelings about global warming?

[Yes / No]

Q2: 前の質問で「はい」と答えた方にお聞きします。悪い印象を数字で表すとどうなりますか？５段階評価で答えてください。

［１．少しだけ悪い，５．すごく悪い］

Q2: If you have replied yes above, please answer this question.　How would you describe your negative feelings on a 5-point, numeric scale?

[1 (slightly negative) to 5 (very negative)]

Q3: 地球球温暖化について何か良い印象がありますか？

［はい／いいえ］

Q3: Do you have any positive feelings about global warming?

[Yes / No]

Q4: 前の質問で「はい」と答えた方にお聞きします。良い印象を数字で表すとどれほどですか？5段階評価で答えてください。

［１．少しだけ良い，５．すごく良い］

Q4: If you have replied yes above, please answer this question.　How would you describe your positive feelings on a 5-point, numeric scale?

[1 (slightly positive) to 5 (very positive)]

Q5: ジオエンジニアリングという言葉を聞いたことがありますか？

［はい／いいえ／分からない］

Q5: Have you ever heard of *jioenjiniaringu* [geoengineering]?

[Yes / No / Unsure]

Q6: ジオエンジニアリングという言葉を聞いて何を思い浮かべますか？

［自由回答，100 文字以内］

Q6: What comes to your mind when you hear *jioenjiniaringu* [geoengineering]?

[Open-ended, up to 100 Japanese characters]

Q7: 地球工学という言葉を聞いたことがありますか？

［はい／いい／分からない］

Q7: Have you ever heard of *chikyu kogaku* [earth engineering]?

[Yes / No / Unsure]

Q8: 地球工学という言葉を聞いて何を思い浮かべますか？

［自由回答，100 文字以内］

Q8: What comes to your mind when you hear *chikyu kogaku* [earth engineering]? *[Open-ended, up to 100 Japanese characters]*

Q9: 気候工学という言葉を聞いたことがありますか？

［はい／いい／分からない］

Q9: Have you ever heard of *kiko kogaku* [climate engineering]?

[Yes / No / Unsure]

Q10: 気候工学という言葉を聞いて何を思い浮かべますか？

［自由回答，100 文字以内］

Q10: What comes to your mind when you hear *kiko kogaku* [climate engineering]? *[Open-ended, up to 100 Japanese characters]*

Q11: 以下の各文章についてどう思いますか？当てはまるものをそれぞれお選びください。

［1. そう思わない、2. どちらかと言えばそう思わない、

3. どちらかと言えばそう思う、4. そう思う、5. 分からない］

Q11: For the following questions, please indicate which best describes your opinion.

[1. Disagree, 2. Somewhat disagree, 3. Somewhat agree, 4. Agree, 5. Unsure]

1. 地球温暖化は起きている

1. Global warming is taking place

2. 人間が出す CO_2 が主な原因で地球温暖化が起きている

2. CO_2 from human activities is primarily responsible for global warming

Q12: 以下の文章についてどう思いますか？４段階評価で当てはまるものをお選びください。

［1. 心配が全くない←→4.とても心配，5. 分からない］

Q12: For the following questions, please indicate which on a 4-point scale best describes your opinion.

[1 (Not concerned at all) to 4 (Very concerned), 5. Unsure]

1. 地球温暖化についてどれほど心配ですか?

1. How concerned are you about global warming?

Q13: 以下の各文章についてどう思いますか？４段階評価で当てはまるものをそれぞれお選びください。

［1. 影響が全くない←→4. 影響がとてもある, 5. 分からない］

Q13: For the following questions, please indicate which on a 4-point scale best describes your opinion.

[1 (no impact) to 4 (very large impact), 5. Unsure]

1. 地球温暖化は（人間を除く）自然に対してどれほど影響があると思いますか？

1. How serious of a threat do you believe global warming is to non-human nature?

2. 地球温暖化の現在の影響はどれほど深刻ですか？

2. How serious are the current impacts of global warming around the world?

Q14: 以下のものが今後 50 年間で地球温暖化が原因で起きる可能性はどれぐらいだと思いますか？4 段階で評価してあてはまるものを選んでください。

［1. 起きる可能性がない ←→ 4. 可能性がとても高い, 5. わからない］

Q14: How likely do you think it is that each of the following will occur during the next 50 years due to global warming? Please choose the choice from a 4-point scale that best describes your opinion.

[1 (No possibility) to 4 (very likely), 5. Unsure]

1. 世界全体で多くの人の生活水準が落ちる

1. Worldwide, many people's standard of living will decrease.

2. 自分自身(または家族)の生活水準が落ちる

2. My (or my family's) standard of living will decrease.

Q15: 以下の温暖化対策について、現在行っているものも含めて、あなたは今後取り組みたいと思いますか。それぞれお答えください。

[1. いいえ，2. はい]

Q15: Among the following action items for global warming mitigation, which one would you like to do from now (or are you doing already)? Please answer each question.

[1. No / 2. Yes]

[The order of statements randomized]

1. 電球や家電、自動車などを買う時に省エネ性能や燃費を参考にする

1. Use energy-efficiency as a selection criterion when buying a light bulb, a household appliance, or a motor vehicle

2. 環境に優しいエネルギー機器 (太陽電池、家庭用燃料電池、エネルギー効率の良い給湯器) を導入する

2. Install an environmentally friendly energy device (a solar panel, a fuel cell, or an energy-efficient

water heater)

3. 環境のために車ではなくバスや電車、地下鉄を利用する

3. Use a bus, a train, or a subway instead of driving for environmental protection

4. 地球温暖化防止に活動している団体や個人のために寄付したり、手伝う

4. Donate money to, or volunteer with, an organization working on issues related to global warming

5. 家族や友人に温暖化対策について話す

5. Talk to family or friends about how to solve the problem of global warming

Q16: 以下の地球温暖化対策の政策について、あなたのお考えをそれぞれお聞かせください。

［1. 反対、2. どちらかと言えば反対、3. どちらかと言えば賛成、4. 賛成、5. 分からない］

Q16: Please describe the choice that best matches your opinion for the following proposed policies for global warming mitigation.

[1. Oppose, 2. somewhat oppose, 3. somewhat support, 4. support, 5. Unsure]

[The order of statements randomized]

１. 人々があまり自動車を使わないように、 ガソリンにかかる税金を 15 円/リットル程度追加する。 このようにして温暖化の原因となる二酸化炭素の排出を減らす

1. To encourage people to drive less and thus reduce carbon dioxide emissions, increase the gasoline tax by about 15 yen per liter.

2. エネルギー効率を上げるために、産業にエネルギー税をかける。 この税金は、あなたが買う食べ物や衣類などすべてのものの価格を押し上げ、 合計で一人当たり年間約 3.8 万円になる

2. To encourage industry to be more fuel efficient, introduce a business energy tax. This tax would raise the average price of most things you buy, including food and clothing. The additional burden will be approximately 38,000 yen per year per person.

以下の説明文をご覧ください。

Please read the following article.

[The four types of articles described in the main text are composed with the message blocks shown below as follows.

M1 (basic): (a)

M2 (dangerous climate change): (a) + (c)

M3 (side effects): (a) + (b)

M4 (all): (a) + (b) + (c)]

(a)	最近,科学者が温暖化対策として人工的に地球を冷やす方法,気候工学を提案しています.二酸化炭素(CO_2) を減らさずに地球を冷ます技術です.地球温暖化が危険になるおそれが高まり,重要な対策として関心を呼んでいます.国際的な科学組織である気候変動に関する政府間パネル(IPCC)も,効果や副作用といった研究を評価することになりました. 一番有望と見られているのが太陽光を反射する技術です.火山の大爆発の後,微粒子が成層圏に達し太陽光を反射します. 1991 年のフィリピンの火山の後, 地球 の温度は 0.5°C 下がりました.火山を真似て，人工的に微粒子を上空大気に撒けば地球を冷ますことができます．一部の国では雨が減るという副作用も懸念されていますが,サイエンス・フィクションではなく科学的に地球温暖化が抑えられることが分かっています. また CO_2を 減らすのに比べてコストが安いことも分かってきています.	Recently some scientists are proposing climate engineering that aims at artificially cooling the earth to counteract global warming. This technique enables cooling of the earth without reducing carbon dioxide emissions. The recognition of an increased risk of dangerous climate change has led to interests in this set of options. The Intergovernmental Panel on Climate Change, a global scientific body, is now tasked with assessing research on the efficacy and side effects of such techniques. The most promising among various proposed techniques is intended to reflect sunshine back to the space. After a volcanic explosion, small particles reach the stratosphere, reflecting back sunlight. The 1991 volcano [volcanic eruption] in the Philippines caused the earth to cool by 0.5 degrees Celsius. Mimicking a volcano, one can cool the earth by artificially injecting small particles into the upper atmosphere. There are concerns that some countries might experience side effects such as reductions in precipitation. Nevertheless, this method is not a science fiction and validated by science. Moreover, this option is now considered to be cheaper than CO_2 emissions reductions.
(b)	最近の研究では気候工学の副作用の理解が進んできました．アジアやアフリカの夏の雨が減る恐れがあることが分かってきました．雨季の雨が減ると，インドなどの農作物に大きな影響が出て,国際的な食料問題になりかねません．対策であるはずの気候工学が更なる問題を生まないように，副作用を事前に調べ，抑えることも重要です.	Recent studies have elucidated possible side effects of climate engineering. In particular, there is a possibility that the summer rain in Asia and Africa could decrease in response to climate engineering. If the summer rainfall decreased, the crop in regions like India could be severely affected, potentially leading to an international food crisis. It is therefore crucial to examine possible side effects and

		explore methods to contain them beforehand.
(c)	気候工学に関心が集まっている理由は，CO_2がなかなか減らず，地球温暖化の進みが想像以上に早いからです．このままだと危険になるまで温暖化が進み，大きな被害がでるおそれがあります．例えばグリーンランドの氷が溶けて海面が約5m 上昇するかもしれません.日本では 非常に強大な台風が上陸する可能性が高まったり，豪雨が今まで以上に強まったり，猛暑が非常に頻繁になったりします.地球温暖化の最悪の事態を避けるためには人工的に地球を冷やす最終手段の研究も必要だと，科学者は語っています.	The reason for an increasing interest in climate engineering is that while the pace of CO_2 emissions reductions has been slow, the rate of global warming is faster than expected. If the current trend continued with further global warming, a significant damage could materialize. For instance, the melting of Greenland Ice Sheet may trigger a 5-meter sea-level rise. In Japan, the risk of landing of a very intense typhoon would become higher, the flood and precipitation extremes stronger, and very warm summers more frequent. Scientists are now suggesting that researching on artificially cooling the earth as the last resort is necessary.

Q17: いま読んだ情報は明快でしたか?あてはまるものをお選びください。

[不明快　どちらかと言えば不明快　どちらかと言えば明快　明快]

Q17: Do you feel that the information you just read was clear?

[Unclear, somewhat unclear, somewhat clear, clear]

Q18: いま読んだ情報は中立的だと思いますか? もしくは偏っていると思いましたか?あてはまるものをお選びください。

[気候工学を支持する方に偏っている / 中立である / 気候工学に反対する方に偏っている]

Q18: Do you feel that the information you just read had a bias?*[It was supportive of climate engineering / It was neutral, and did not support or oppose climate engineering / It was opposed to climate engineering]*

Q19: 今読んで何か疑問に思ったところはありますか？

［自由回答，500 文字以内］

Q19: Do you have any questions related with the article above?

[Open-ended, up to 500 Japanese characters]

[For the following questions, a link button to the article was shown so that each respondent could read the article again while answering questions.]

Q20: 今、説明を読んでいただいた気候工学についてお聞きします。 以下の各文章についてどう思いますか？当てはまるものをお選びください。

［４段階：そう思わない，どちらかと言えばそう思わない，どちらかと言えばそう思う，そう思う，分からない］

Q20: Next, we ask you about climate engineering.　What do you think of each of the following statements? Please choose the one that best describes your thinking.

[4-point scale: disagree, somewhat disagree, somewhat agree, agree, unsure]

[The order of statements randomized]

1. 気候工学を温暖化対策として使うべきだと思いますか?

1. Do you think that climate engineering should be used as a solution to global warming?

2. 科学者は気候工学を研究すべきだと思いますか?

2. Do you think scientists should study climate engineering?

3. 危険な地球温暖化が差し迫った時、気候工学を使うべきと思いますか?

3. What do you think about using climate engineering to stop a climate emergency?

4. もし気候工学が現在使えるのならば、今すぐに使うべきだと思いますか?

4. If climate engineering was possible today, what would you think about using it immediately?

5. 気候工学はいかなる状況でも使わないべきだと思いますか?　[For the sub-question 5, ないべき(never) was shown in red.]

5. Do you think that climate engineering should never be used, no matter the situation?

Q21: 以下の各文章についてどう思いますか?あてはまるものをお選びください。

[４段階評価：そう思わない，どちらかと言えばそう思わない，どちらかと言えばそう思う，そう思う，分からない]

Q21: What do you think of each of the following statements?　Please choose the one that best describes your thinking.

[4-point scale: disagree, somewhat disagree, somewhat agree, agree, unsure]

[The order of statements randomized]

1. 気候工学は地球を助けるどころかより悪い方向に導いてしまう

1. Climate engineering will harm the planet rather than help it.

2. 十分な研究がなされれば、気候工学は安全で効果的なものになる

2. With enough research, I believe climate engineering will turn out to be safe and effective.

3. 石油、石炭、天然ガスを使わなくして CO_2 を減らして温暖化対策をするのではなく、気候工学を使って温度を下げればよい

3. Climate engineering should be used so we can continue to use oil, coal, and natural gas, without worrying about reducing CO_2 emissions.

4. 気候工学は安易な打開策である

4. Climate engineering is the easy way out.

5. 気候工学の研究開発が進むと、一般市民の意見を聞くことなく、政府が実施してしまう

5. Research into climate engineering will lead to a technology that will be used by the government no matter what the public thinks.

6. 地球の温度は一つの技術で解決できないほど複雑である

6. The earth's temperature is too complicated to fix with one technology.

7. 人間は気候工学のような手法で自然を改変すべきではない

7. Humans should not be manipulating nature in this way.

8. もし科学者の研究によって、気候工学は小さい副作用で地球温暖化を解決できると分かったら、私は気候工学を使ってもいいと思う

8. If scientists find that climate engineering can reduce the impacts of global warming with minimal side-effects, then I would support its use.

Q22: 気候工学の情報源として、誰を信頼しますか?

[信頼しない，どちらかと言えば信頼しない，どちらかと言えば信頼する，信頼する]

Q22: Who do you trust as a source of information about climate engineering?

[Distrust, somewhat distrust, somewhat trust, trust]

[The order of statements randomized]

1. 政府 Government
2. 民間企業 Private companies
3. 環境保護団体 Environmental protection groups
4. 大学の研究者 University researchers
5. メディア The media
6. 国連・国際機関 The United Nations and international organizations
7. 宗教家 Religious leaders
8. 友達や家族 Friends and family

ここで再度地球温暖化についてあなたのお考えをお聞きします。気候工学の説明を受けて考えが部分的に変わったかもしれませんし、 変わっていないかもしれません。 今のあなたのお考えをお答えください。

Now we ask you about global warming once again.　You might have changed your opinion on global warming after learning about climate engineering, or not.　Please share with us your current thinking.

[Q23-Q28: repeat of Q11-Q16]

Q29:わが国の向う１０年間の国家目標をどう設定したらよいかについて、よく議論されます。 次に、いろいろな人が最も重視する目標がいくつかあげてあります。あなたはこれらの中で何が最も重要だと思いますか。また二番目に重要なものはどれですか?

［国家の秩序の維持／重要な政府決定に関してもっと国民に発言権を与える／

*物価の抑制／*言論の自由の擁護／わからない］

Q29: People often talk about what the aims of this country should be for the next ten years.　In the following are listed some of the goals which different people would give top priority.　Would you please tell which one of these you consider the most important?　And which would be the next most important?

[Maintaining order in the nation/Giving people more say in important government decisions/

Fighting rising prices / Protecting freedom of speech / Unsure]

Q30: 長期的に考えた場合、科学の進歩は人類の利益となるでしょうか、それとも人類の害となるでしょうか。 あなたの考えをお知らせ下さい。

［利益となる／害となる／利益にも害にもなる／わからない］

Q30: In the long run, do you think the scientific advances we are making will help or harm mankind?

[Will help / Will harm / Some of each / Unsure]

Q31: 次のような意見に対して、あなたは賛成ですか、反対ですか。 1 は「全く反対」を、10 は「全く賛成」を示すとします。

[1.全く反対←→10.全く賛成，わからない]

Q31: Now we ask how much you agree or disagree with each of the following statements. For these questions, a 1 means that you "completely disagree" and a 10 means that you "completely agree."

[1 (completely disagree) to 10 (completely agree), Unsure]

[The order of statements randomized]

1. 科学技術は私たちの生活をより健康に、楽に、快適にしている。

1. Science and technology are making our lives healthier, easier, and more comfortable.

2. 科学技術によって、より大きな機会が次世代にもたらされるだろう。

2. Because of science and technology, there will be more opportunities for the next generation.

3. 科学技術は私たちの生活をあまりにも速く変えている。

3. Science and technology make our way of life change too fast

4. 私たちは科学に頼りすぎて、信仰をおろそかにしている。

4. We depend too much on science and not enough on faith.

Q32: 最終学歴をお答えください。

［中学校／高等学校／短期大学（高等専門学校を含む）／

専門学校（専修学校専門課程）／大学／大学院／その他／答えたくない］

Q32: Please describe your educational background.

[Junior high / High school / Two-year college (including college of technology) /

Vocational school / University / Graduate school / Other / Would rather not answer]

Q33: 以降に、宗教や支持政党についてご回答いただく設問がございます。 宗教・支持政党のその設問でのご回答は任意ですが、ご協力できるかお答えいただけますか。

［宗教や支持政党に関する設問に協力できる／

宗教に関する設問だけなら協力できる／

支持政党に関する設問だけなら協力できる／

宗教や支持政党に関する設問には協力できない］

Q33: In the following, we will ask you about your religions and political parties you support. Responding to the following is voluntary. Could you take part in answering them?

[Can answer questions regarding religions and political parties /

Can answer only questions regarding religions /

Can answer only questions regarding political parties /

Would rather not answer]

Q34: あなたは、信仰や信心を持っていますか。

［持っている／持っていない／答えたくない］

Q34: Do you have a religious faith?

[Yes / No / Would rather not answer]

Q35: 前問で持っていると答えた方にお聞きします。 それはどのような信仰ですか、この中からいくつでもあげてください 。

［神道／仏教／キリスト教／その他の宗教／答えたくない］

Q35: If you have answered yes in the previous question, what religion do you believe in? Please list all that apply.

[Shinto-ism / Buddhism / Christianity / Other / Would rather not answer]

Q36: あなたは何党を支持していらっしゃいますか？（ひとつだけ)

［民主党／自由民主党／公明党／日本共産党／社会民主党／国民新党／みんなの党／新党日本／たちあがれ日本／新党改革／その他／支持なし／答えたくない］

Q36: Which political party do you support? (choose only one)

[Democratic Party of Japan / Liberal Democratic Party / New Komeito / Japanese Communist Party / Social Democratic Party / People's New Party / Your Party / New Party Nippon / Sunrise Party of Japan / New Renaissance Party / Other / Do not support any particular political party / Would rather not answer]

10. Changes in the 2014 in-class survey

Here we describe the changes made for the 2014 in-class survey. The question on attitudes toward climate engineering was replaced with the following:

Q14: 今、説明を読んでいただいた気候工学についてお聞きします。 以下の各文章についてどう思いますか？ *［４段階：そう思わない，どちらかと言えばそう思わない，どちらかと言えばそう思う，そう思う，分からない］*

Q14: Next, we ask you about climate engineering. What do you think of each of the following statements? *[4-point scale: disagree, somewhat disagree, somewhat agree, agree, unsure]*

1. 気候工学を温暖化対策として使うべきだと思いますか?

1. Do you think that climate engineering should be used as a solution to global warming?

2. 科学者は理論計算，コンピューター・シミュレーションや研究室内の実験で気候工学を研究すべきだと思いますか？

2. Do you think scientists should study climate engineering with theoretical calculations, computer simulations, and indoor experiments?

3. 科学者は実際の自然環境で効果や副作用を検証する気候工学の実験を行うべきだと思いますか？

3. Do you think scientists should conduct climate engineering experiments in the natural environment to examine its efficacy and side effects?

4. 危険な地球温暖化が差し迫った時、気候工学を使うべきと思いますか?

4. What do you think about using climate engineering to stop a climate emergency?

5. もし気候工学が現在使えるのならば、今すぐに使うべきだと思いますか?

5. If climate engineering was possible today, what would you think about using it immediately?

6. 気候工学はいかなる状況でも使わ**ないべき**だと思いますか?

6. Do you think that climate engineering should never be used, no matter the situation?

The short article was corrected for previous mistakes (though they were minor), and more importantly, a paragraph was added to explain the social concerns more fully.

最近、科学者が温暖化対策として人工的に地球を冷やす方法、気候工学を提案しています。二酸化炭素（CO_2）を減らさずに地球を冷ます技術です。地球温暖化が危険になるおそれが高まり、重要な対策として関心を呼んでいます。国際的な科学組織である気候変動に関する政府間パネル（IPCC）も、効果や副作用 **に関する** ~~といった~~研究を評価 **しました** ~~することになりました~~。	Recently some scientists are proposing climate engineering that aims at artificially cooling the earth to counteract global warming. This technique enables cooling of the earth without reducing carbon dioxide emissions. The recognition of an increased risk of dangerous climate change has led to interests in this set of options. The Intergovernmental Panel on Climate Change, a global scientific body, ~~is now tasked with assessing~~ assessed research on the efficacy and side effects of such techniques.
一番有望と見られているのが太陽光を反射する技術です。火山の **大噴火** ~~大爆発~~の後、微粒子が成層圏に達し太陽光を反射します。１９９１年のフィリピンの火山 **噴火** の後、地球の温度は０．５℃下がりました。火山を真似て、人工的に微粒子を上空大気に撒けば地球を冷ますことができます。一部の国では雨が減るという副作用も懸念されていますが、サイエンス・フィクションではなく科学的に地球温暖化が抑えられることが分かっています。また CO2 を減らすのに比べてコストが安いことも分かってきています。	The most promising among various proposed techniques is intended to reflect sunshine back to the space. After a **major** volcanic eruption ~~explosion~~, small particles reach the stratosphere, reflecting back sunlight. The 1991 ~~volcano~~ **volcanic eruption** in the Philippines caused the earth to cool by 0.5 degrees Celsius. Mimicking a volcano, one can cool the earth by artificially injecting small particles into the upper atmosphere. There are concerns that some countries might experience side effects such as reductions in precipitation. Nevertheless, this method is not a science fiction and validated by science. Moreover, this option is now considered to be cheaper than CO2 emissions reductions.
最近の研究では気候工学の副作用の理解が進んできました。アジアやアフリカの夏の雨が減る恐れがあることが分かってきました。雨季の雨が減ると ~~（インドのなどの）~~農作物 **の生産** に大きな影響が出て、国際的な食料問題になりかねません。**また成層圏のオゾン層を破壊する可能性も指摘されています。** 対策であるはずの気候工学が更なる問題を生まないように、副作用を事前に調べ、抑えることも重要です。	Recent studies have elucidated possible side effects of climate engineering. In particular, there is a possibility that the summer rain in Asia and Africa could decrease in response to climate engineering. If the summer rainfall decreased, the crop **production** ~~in regions like India~~ could be severely affected, potentially leading to an international food crisis. **In addition, some have pointed out that it could destruct the stratospheric ozone layer.** It is therefore crucial to examine possible side effects and explore methods to contain them beforehand.
気候工学に関心が集まっている理由は、CO2 がなかなか減らず、地球温暖化の進みが想像以上に早いからです。このままだと危険になるまで温暖化が進み、大きな被害がでるおそれがあります。例えばグリーンランドの氷が溶けて海面が約５ｍ上昇するかもしれません。日本では非常に強大な台風が上陸する可能性が高まったり、豪雨が今まで以上に強まったり、猛暑が非常に頻繁になったりします。地球温暖化の最悪の事態を避けるためには人工的に地球を冷やす最終手段の **検討** ~~研究~~も必要だと、科学者は語っています。	The reason for an increasing interest in climate engineering is that while the pace of CO2 emissions reductions has been slow, the rate of global warming is faster than expected. If the current trend continued with further global warming, a significant damage could materialize. For instance, the melting of Greenland Ice Sheet may trigger a 5-meter sea-level rise. In Japan, the risk of landing of a very intense typhoon would become higher, the flood and precipitation extremes stronger, and very warm summers more frequent. Scientists are now suggesting that ~~researching on~~ **investigation into** artificially cooling the earth

	as the last resort is necessary.
しかし、科学者も諸手を挙げて推薦しているわけではありません。コストの低い気候工学は一国でも行うことが可能なため、世界の気候を一部の国がコントロールしてしまう懸念があります。副作用は世界中に広がるため、国際紛争の火種になるかもしれません。さらには地球全体の気候を人類がコントロールしていいかという倫理的な問題もあるのです。	**The scientists are not wholeheartedly endorsing this technology, however. There is a concern that a single country could control the global climate with a low-cost option. Because of the global influence of side effects, it could lead to an international conflict. Moreover, it would present an ethical question about whether humans would be ever allowed to control the world climate.**

The question on the post-materialism index was replaced with the following one on the New Ecological Paradigm.

Q17:以下の文章についてどう思いますか？あてはまるものに〇をつけてください。*［4段階：そう思わない，どちらかと言えばそう思わない，どちらかと言えばそう思う，そう思う，分からない］*

Q17: For each of the following statements, please choose the one that best describes your opinion [on a 4-point scale]. *[4-point scale: disagree, somewhat disagree, somewhat agree, agree, unsure]*

1. 地球は場所と資源が限られた宇宙船のようなものである

1. The Earth is like a spaceship with very limited room and resources.

2. 人類は自然を支配するために存在する

2. Humans were meant to rule over the rest of nature

3. 自然のバランスは非常に繊細で、簡単に崩れてしまう

3. The balance of nature is very delicate and easily upset

4. 人類は、ゆくゆくは自然の仕組みを十分に理解し、コントロールできるようになるだろう

4. Humans will eventually learn enough about how nature works to be able to control it

5. 現状がこのまま続けば、危機的な環境問題が起こるだろう

5. If things continue on their present course, we will soon experience a major ecological catastrophe