Exploring the Scientific Discourse on Solar Radiation Management and the Global South

Representation and Recognition of the Global South in Knowledge Production on Solar Radiation Management

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Faculty of Geosciences, Utrecht University

Master's Thesis (45 ECTS)

Supervisor: Prof. Frank Biermann

Second Reader: Dr. Carole-Anne Sénit

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Abstract

In the Anthropocene, climate change and its associated impacts are an emerging threat. In the light of global shortcomings in meeting mitigation and adaptation targets, the discourse on geoengineering technologies, including solar radiation management (SRM), emerged. While the technical feasibility of these technologies is still in the experimentation phase, their social, ecological, and economic implications require scientific scrutiny. Scholars attribute the leading role in governing geoengineering to scientists as they steer collective decisions about geoengineering while state action is often absent. This stresses the importance of investigating the scientific discourse, where scholars from the Global South and their interests are systemically underrepresented.

In this research project, I will investigate the representation and recognition of the Global South in the knowledge production on solar radiation management (SRM). A mixed quantitative-qualitative research strategy focussing on the global scientific discourse will be supported by empirical work applying a bibliometric analysis and a sociology-of-knowledge discourse analysis. The data pool for the empirical analysis consists of journal articles on solar radiation management from 2009 to 2020 and a number of semi-structured interviews with researchers from the Global South or stakeholders from the science-policy interface.

The quantitative analysis of the representation of the Global South in knowledge production on SRM shows low but increasing representation of non-Western authors and institutions. However, only a few of these can be attributed to the Global South, but rather to wealthier countries such as Japan. In particular, the funding of research on SRM is in the hands of Global North institutions. With regard to the recognition of the Global South as legitimate participants in the scientific discourse, the structural analysis of discourse shows that calls for this are widespread, but there are only few indications for their interests being recognised in the discourse. So far, underpinned by normative or strategic rationales, the Global South is often spoken for by scholars from the Global North.

Key Words: Solar Radiation Management; Scientific Discourse; Global South; Sociology-of-Knowledge Discourse Analysis (SKAD); Bibliometric Analysis

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Table of Contents

1. Introduction 9
   1.1. Background 9
   1.2. Scientific and Societal Relevance 11
   1.3. Research Objective and Research Questions 12
   1.4. Research Framework 13
2. Theoretical Framework 14
   2.1. From Discourse Theory to Discourse Analysis 14
   2.2. The Research Divide between Global South and North 15
   2.3. Representation and Recognition Justice 17
   2.4. Conceptual framework 18
3. Methodological Framework 20
   3.1. Research Strategy 20
   3.2. Method 1: Bibliometric Analysis 20
   3.3. Method 2: Sociology-of-Knowledge Discourse Analysis (SKAD) 21
   3.4. Data Collection 23
   3.5. Data Analysis 28
4. Results from Bibliometric Analysis 32
   4.1. Publication Trend 32
   4.2. Representation in Scientific Output 33
   4.3. Scientific Output per Discipline 34
   4.4. Scientific Output per World Region 36
   4.5. Affiliations 37
   4.6. Funding Sponsors 39
5. Results from Discourse Analysis 41
   5.1. WHY: Which demand rationales structure calls for SRM research? 41
   5.2. WHAT: Which interests of the Global South are constructed? 44
   5.3. WHO: Which speaker positions are available in the discourse? 46
   5.4. WHY: Which demand rationales structure calls for GS engagement in research? 49
   5.5. HOW: How is and should the Global South be engaged in knowledge production? 54
6. Discussion 57
   6.1. Key Findings 57
   6.2. Reflecting on Results 58
   6.3. Reflecting on Dominant Structures 59
   6.4. Sensitivity Analysis of Bibliometric Analysis 61
   6.5. Limitations and Future Research 64
7. Conclusion 65

References 66
Appendix A. Journal Articles for Discourse Analysis 73
Appendix B. Interview Guideline 78

Appendix C. Informed Consent Form 80
Appendix D. Data Tables for Bibliometric Analysis 81
Appendix E. Data Tables for Discourse Analysis 83
Appendix F. Data Tables for Sensitivity Analysis 89

List of Figures

Figure 1. Research framework 13
Figure 2. The world by region 17
Figure 3. Conceptual framework 19
Figure 4. Triangulation of methods and data types 20
Figure 5. Process of data collection of peer-reviewed journal articles 25
Figure 6. Distribution of articles that (not) mention global south actors and interests 32
Figure 7. Percentage of peer-reviewed articles that (not) mention terms related to Global South. 33
Figure 8. Subject areas of peer-reviewed articles on solar radiation management 34
Figure 9. Subject areas of peer-reviewed articles on SRM 35
Figure 10. Number of authors of journal articles on SRM and Global South 36
Figure 11. Top ten affiliations 37
Figure 12. Top ten affiliations to which authors publishing on SRM and GS most frequently belong to 38
Figure 13. Most frequent sponsors of SRM research 39
Figure 14. Most frequent sponsors of SRM research mentioning the Global South 40
Figure 15. Distribution of authors per article for all articles on SRM not considering the Global South (Query 1-Query 2) 61
Figure 16. Distribution of authors per article for all articles on SRM considering the Global South (Query 2) 62
Figure 17. Distribution of number of affiliations per author (in %) for Query 1-Query 2 (N=280) .. 63
Figure 18. Distribution of number of affiliations per author (in %) for Query 2 (N=44) 63

List of Tables

Table 1. Primary and secondary search words 24
Table 2. Anonymised Information on Affiliation and Word Region of Interviewees 27
Table 3. Analytical Framework for Bibliometric Analysis 28
Table 4. Guiding Questions for Identifying Discursive Structures 30
Table 5. Example for Coding Approach 31
Table 6. Interview guideline 79
Table 7. Peer-reviewed articles that (not) mention Global South Actors and interests 81
Table 8. Subject areas of peer-reviewed articles 81
Table 9. Overview of demand rationales for research on SRM 83
Table 10. Overview of speaker positions for research on SRM 85
Table 11. Overview of categorisation of interests from the Global South regarding SRM 86
Table 12. Overview of demand rationales for engaging the Global South 87
Table 14. Distribution of number of authors per article for Query 1-Query 2 (N=280) 89
Table 15. Distribution of number of authors per article for Query 2 (N=44) 89
Table 16. Distribution of number of authors per affiliation for Query 1-Query 2 (N=280) 90
Table 17. Distribution of number of authors per affiliation for Query 2 (N=44) 90

1. Introduction

1.1. Background

Despite international efforts, greenhouse gas emissions continue with potentially devastating global consequences (Boettcher et al., 2017). Calls for research into geoengineering techniques have become more popular as a potential drastic response to climate change (Reynolds & Horton, 2020). In early 2021, members of the indigenous Sámi people, who live across northern Scandinavia, Finland and eastern Russia, sent letters to Harvard researchers, their advisory committee and the Swedish Space Corporation (Saami Council, 2021). Their concern was a planned series of tests of solar radiation management technologies as part of SCoPEx, the Stratospheric Controlled Perturbation Experiment, over Sápmi, their homeland. Even though the first test was only supposed to ensure that a high-altitude balloon would work and not release any chemical particles, the Saami Council and Swedish environmental organisations spoke out categorically against this series of tests. They complained about a lack of consultation and rejected the idea of solar radiation management per se. As Åsa Larsson Blind, the vice president of the Saami Council, points out, "this goes against our worldview that we as humans should live and adapt to nature" (Dunleavy, 2021, para. 3). This conflict is part of the broader debate on solar radiation management as it raises questions regarding the governance of research and its underlying rationales (Gupta et al., 2020). Further, it highlights the responsibilities of researchers to ensure that research is subject to legitimate societal review, especially through climate vulnerable communities, and the need for openness to possible outcomes, even to alteration or rejection (Frumhoff & Stephens, 2018).

As illustrated above, research on and potential deployment of geoengineering and its associated technologies are heavily debated among stakeholders such as researchers, policymakers, and NGO representatives. While opponents argue with the uncertainty of and the high-risk profile of these technologies and resulting challenges for global democracy (Anshelm & Hansson, 2014a), proponents make use of arguments such as that "the severity of climate change now justifies the assessment and investigation of all means that might be able to counteract it" (Anshelm & Hansson, 2014b, p. 107).

Geoengineering comprises a set of technologies used to achieve zero net emissions through removing CO_2 from the atmosphere or altering the global energy balance by blocking or reflecting sunlight (Royal Society, 2009). This research will focus on the latter set of technologies, known as

solar radiation management (SRM)[1], that block or reflect incoming sunlight to affect the global mean temperature (Matzner & Barben, 2020). SRM technologies include stratospheric aerosol injection, marine cloud brightening, and ocean fertilisation (Royal Society, 2009). The most prominent one among these, stratospheric aerosol injection (SAI), would involve spraying aerosol particles into the upper atmosphere that would block or reflect incoming sunlight. These technologies have not been tested at scale and understanding their potential risks and benefits has instead largely been based on, for instance, computer modelling and laboratory experimentation (Boettcher et al., 2017). Apart from questions of technological feasibility and affordability, social, political and moral questions concerning responsibility, global democracy, power and justice have increasingly gained attention (Royal Society, 2009). Research on SRM plays an essential role as SRM techniques are still in the development phase. Scholars state that the absence of governance structures for geoengineering increases the influence of epistemic communities around geoengineering through issue-framing and agenda-setting (Reynolds & Hortons, 2020). This is supported by findings of Talberg and colleagues (2018) who attribute academics the leading role in governing geoengineering as they steer collective decisions about geoengineering while state action is mostly absent. They describe states as paralysed due to competing contradictions between precaution concerning risks of geoengineering and promoting research to decrease harmful effects of climate change (Talberg et al., 2018).

There are many challenges for governance and responsible science since research has been conducted mostly in countries of the Global North. Knowledge production on solar radiation management is characterised by geographical imbalance because researchers from the Global North, mainly Europe and North America, and their affiliated organisations dominate the scientific discourse (Biermann & Möller, 2019). The Global South has a special role in the discourse, as many regions and people are and will be particularly affected by climate change, and at the same time have hardly contributed to ongoing climate change. Researchers from the Global South and populations vulnerable to climate change are barely engaged in the discourse and not included as equal partners in solar geoengineering research (Hourdequin, 2019; Winickoff et al., 2015). This lack of involvement translates into low influence on knowledge production and low acknowledgement of their concerns (Biermann & Möller, 2019).

[1] Synonyms for solar radiation management include 'solar geoengineering', 'solar radiation modification' and 'solar climate engineering' (Reynolds, 2019). For a discussion of geoengineering terminology, I refer to Schäfer and Low (2018).

1.2. Scientific and Societal Relevance

Conducting empirical social science research on SRM is important according to Burns et al. (2016) who stress that this will be crucial in the coming decade. The *scientific relevance* of this research project is based on the observation that many who are involved in the scientific discourse on SRM make statements about the Global South, but researchers from the Global South are not very involved. In the debate on SRM actors often draw upon vulnerable populations as a discursive resource which should enhance the legitimacy of their own arguments (Schäfer & Low, 2018). Claims on behalf of vulnerable populations are made by different actors, ranging from those who oppose research on SRM (e.g. ETC Group et al., 2017) to those advocating for it (Horton & Keith, 2016). For instance, some claim that dependencies of the Global South on industrial countries, which have the means for such technological interventions, would increase (Biermann & Möller, 2019) and create a form of neo-colonialism that would perpetuate global injustice of social, economic, and environmental relationships (Anshelm & Hansson, 2014a). On the other hand, this perspective can also be interpreted as a form of paternalism (Rahman et al., 2018). If global warming keeps on rising and increasingly threatens vulnerable groups in the Global South, the potential benefits of applying certain geoengineering technologies might outweigh the associated risks and developing countries would decide that geoengineering is in their interest (Rahman et al., 2018). It is therefore relevant to examine the scientific discourse on SRM with a focus on the Global South. It is important to not only consider how others speak about SRM in regard to the Global South, but also capture their own perspectives. To this point, not much research has been done to explore how the Global South is represented and recognised in the scientific debate on SRM specifically (e.g. Winickoff et al., 2015; Carr & Yung, 2018).

In addition, the *societal relevance* of conducting research is high due to its global dimension and potential effects. The discourse on geoengineering and SRM in specific raises and reflects upon many ethical, economic, and political challenges (Anshelm & Hansson, 2014a). One of these challenges includes that global technologies such as SRM require a new form of global democracy and deliberation, especially in the context of the Global South. Currently, research on SRM focusses mostly on countries with large populations and both great geopolitical as well as economic importance (Sugiyama et al., 2020). From a social justice perspective, this is problematic as it leads to vulnerable actors and voices not being heard (Sugiyama et al., 2020). Thus, the research topic at hand is highly relevant for Global South societies where existing inequalities could be exacerbated through the high risks and dependencies possibly created through geoengineering governance (Biermann & Möller, 2019).

Recent studies confirm the importance of engaging diverse global publics and groups within the Global North and Global South around geoengineering governance (Burns et al., 2016). For instance, in 2018, a group of twelve scholars from the Global South called for developing countries to lead on the research on SRM (Rahman et al., 2018). Also, it is essential that scientists from the Global South can conduct research based on their national context considering regional concerns and conditions and play a central role in research and the discourse around SRM (Rahman et al., 2018). Also, public perception studies show that social science research on SRM is often skewed towards Western countries (Preston & Carr, 2018). Thus, it is important to understand how people from Global South societies perceive SRM and how their interests are addressed in the scientific discourse SRM (Preston & Carr, 2018).

1.3. Research Objective and Research Questions

The research objective is to provide insights on how and why Global South actors are (in)visible and (un)recognised in the knowledge production on solar radiation management.

This will be achieved by studying the representation of stakeholders from the Global South in the scientific discourse on SRM from 2009 to 2020 and examining the discursive structures shaping the extent to which vulnerable people from the Global South and their interests are recognised. This research aims to answer this main research question:

> *To what extent and why are Global South actors and their interests represented and recognised in the knowledge production on solar radiation management?*

The following sub-questions steer the research and help to answer the main research question:

> SQ1 *To what extent are academic stakeholders from the Global South represented in the scientific community of solar radiation management?*

In order to answer research sub-question 1, I will quantify the involvement of Global South scholars in the knowledge production on SRM.

> SQ2 *Which discursive structures shape the recognition of the Global South in the scientific discourse on solar radiation management?*

In order to answer research sub-question 2, I will identify the discursive structures underpinning the scientific debate on SRM related to Global South and explore storylines and frames emerging from the discourse.

1.4. Research Framework

The following research framework (Figure 1) explains the steps that will be taken in order to answer the research question and sub-research questions. Literature review will help to get more familiar with the theoretical concepts 'discourse', 'Global South', 'representation', and 'recognition' relevant for this research. After deriving the conceptual and analytical framework for the analysis, the data needed for the empirical analysis will be collected. I will first conduct a bibliometric analysis using meta-data of journal articles published on the topic of SRM and the Global South from 2009 to 2020. This will help me to explore the representation of the Global South in a quantitative manner. Secondly, I will conduct a discourse analysis based on peer-reviewed journal articles and interviews with researchers from the Global South working on SRM. The aim of the following empirical sociology-of-knowledge-based discourse analysis (SKAD) is to better understand how the representation and recognition of Global South actors are being shaped by discursive structures of the scientific discourse on SRM. Using SKAD will help me to illustrate why SRM research is considered necessary, what interests are constructed, who holds authoritative speaker positions, why engagement of the Global South is considered necessary, and how engagement takes place. To validate the results achieved by analysing journal articles and obtain direct insights, semi-structured interviews will be conducted with researchers from the Global South. Overall, these steps will guide me to formulate results to the initial research questions and discuss these.

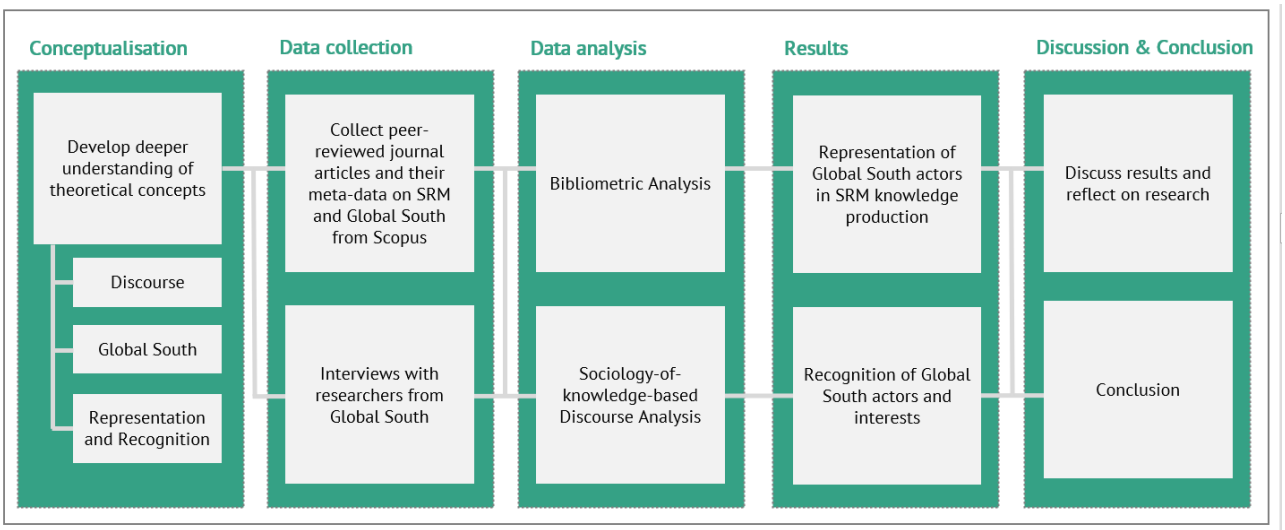

Figure 1. Research framework

2. Theoretical Framework

2.1. From Discourse Theory to Discourse Analysis

The discourse concept is based on the basic ontological assumption of social constructivism (Uther, 2014). Social constructivist research places the impact of ideas, e.g. in the form of discourses, as central determinants at the centre of scientific knowledge interest. A social constructivist research perspective therefore views reality not as objectively given, but as socially constructed through intersubjective constructions of meaning and interpretation that are shared by several actors (cf. Adler 1997). This leads to the central assumption of discourse theory: that reality is socially constructed and not given objectively.

In the following, I will clarify the discourse concept applied to this research. In political science, two discourse-theoretical strands have gained importance. Concepts of discourse can be divided in agency-driven and structurally-derived concepts of discourse. The agency-driven discourse concept is mostly based on the work of Habermas (1995) who understands discourse as a public debate carried out by strategic actors. Discourse ethics focus on the "normative quality of discussions" (Hajer & Versteeg, 2005, p. 176) and aim at formulating ideal conditions for argumentation processes (Keller, 2011a). The presence of these ideal conditions would imply that actors argue in an "egalitarian discursive space" (Boettcher, 2020a, p. 2). However, there are asymmetries of power that underpin deliberative processes and shape what can be said and by whom (Bäckstrand et al., 2010). Thus, a structural rather than an agency-driven understanding of discourse can help to identify these asymmetries in order to analyse how they shape the engagement of the Global South. In contrast to Habermas, Foucault (1973) understands discourse as a "system of ideas and practices that construct 'truths' about objects, subjects and social realities and, therefore, are a medium of power relations" (Leipold et al., 2019, p. 447). Related to this definition of discourse by Foucault, my aim is not to provide universal truths but rather understand how multiple and often competing truths on SRM, a widely debated and controversial topic, in the context of the Global South are produced through scientific discourses. Thus, I understand the discourse concept in the Foucauldian sense rather than the Habermasian sense and therefore apply discourse analysis which helps to empirically investigate a given discourse (Keller, 2011a). The discourse concept will help to structure and examine selected documents and interviews regarding the construction of Global South actors and their interests made by the researchers and authors (Anshelm & Hansson, 2014a). Based on a system of ideas and beliefs, SRM can be understood through storylines and frames that are reproduced in the discourse. Exploring discourses and their language is essential to identify

power structures that shape what is recognised as knowledge on SRM and who is a legitimate actor to generate this knowledge (Milliken, 1999). These narratives are relevant when understanding the recognition of Global South actors and their interests in the discourse on SRM.

Discursive approaches form an established field of analysis for social science scholars in general (Anshelm & Hansson, 2014a) and particularly for topics related to environmental policy (Leipold et al., 2019; Uther, 2014). Applying the discourse concept and conducting a discourse analysis is a suitable approach to study the scientific field of SRM. Since SRM is an emerging field, discourse analysis allows for an explorative manner that is helpful when encountering new matters (Matzner, 2013). Based on the previously defined Foucauldian discourse concept, I will apply discourse analysis to analyse the scientific discourse on SRM. Discourse analysis, however, is not a particular method, but rather a research perspective that includes a broad range of related approaches that focus on either studying language-in-use or structures of socio-cultural meanings (Keller, 2013; Leipold et al., 2019). Its concrete methodological implementation needs to be specified through its disciplinary and theoretical embedding (Keller, 2011a). The Foucauldian discourse concept which can be understood as a theoretical "tool box" (Foucault, 2002, p. 651) as Foucault does not give concrete instructions nor methodology for the research-pragmatic implementation of discourse analysis (Uther, 2014). Discourse analysis is the study of language-in-use (Wetherell et al., 2001) and focusses on detecting "a particular linguistic regularity" (Hajer & Versteeg, 2005, p. 175) inherent in discussions. Language is not considered a neutral medium but rather a powerful tool that shapes one's view of the world (Hajer & Versteeg, 2005). Instead of a single reality, governed by immutable natural laws, discourse analysis follows an interpretative and social constructionist tradition that assumes the existence of multiple realities (Hajer & Versteeg, 2005).

2.2. The Research Divide between Global South and North

There is a global North–South divide in research across several scientific disciplines, also environmental science (Blicharska et al., 2017). Continued Northern domination of climate change science, as well as limited research led by Southern researcher, is a barrier for the development and implementation of climate agreements and actions on both global and national scale. If knowledge were to be generated in a more equal manner, thus, not biased by Northern domination of knowledge production and sensitive to local context, then knowledge would be perceived as more relevant and impartial. Blicharska et al. (2017) stress the need for scientific investigation of the North-South divide in research in order to create awareness for and to overcome this divide, and to develop concrete measures to increase Southern-led research in Southern countries.

This divide motivated me to focus on the Global South and to contribute to a better understanding of SRM research in the context of the Global South. Considering Global South actors in this research is relevant as they currently do not play a significant role in science and decision-making on SRM. This conceptualisation is important as Global South actors have particular interests and concerns that can differ from those of the Global North. Their interests and concerns are currently underrepresented in the discourse, for instance, they stress the need for appropriate climate models accounting for potential regional impacts of geoengineering on areas (e.g. rain-fed agriculture) relevant for the livelihood of many (Winickoff et al., 2015). Another concern is the general need for strengthening SRM research and governance in the Global South (Winickoff et al., 2015).

In this research, I will utilise the concept of "Global South". This concept should not be taken literally as the equator dividing the world in two, instead, it only refers loosely to the regions of Africa, Asia, Oceania, and Latin America (Dados & Connell, 2012; Wolvers et al., 2015). Rather than referring to an exact geographical location, the concept of the Global South and Global North emphasises geopolitical relations of power (Dados & Connell, 2012). Despite the heterogeneity of the Global South, share the perception of being "disempowered, marginalized and disenfranchised by the international system" (Najam, 2003, p. 305). It also aims to take into account the "history of colonialism, neo-imperialism, and differential economic and social change through which large inequalities in living standards, life expectancy, and access to resources are maintained" (Dados & Connell, 2012, p. 13). Inequality can also be linked to the lower capacity to pursue research and, thus, both lower influence and access to resources and information (Biermann, 2006) which results in the described North-South divide in knowledge production (Blicharska et al., 2017). Terms such as "Third World" or "Developing World" focus on development as main difference between countries have a hierarchising and Eurocentric tendency according to more critical authors (Glokal e.V., 2013). Despite the concept of Global South and Global North not being flawless either (Wolvers et al., 2015) and simplifying reality (Bouteligier, 2011), I will use these terms in this research.

Figure 2 shows all countries grouped into seven regions based on administrative purposes by the World Bank (The World Bank, 2021). Conceptualising the Global South and Global North, the regions Europe & Central Asia and North America are assigned to the Global North while the remaining regions East Asia & Pacific, Latin America & Caribbean, Middle East & North Africa, South Asia and Sub-Saharan Africa fall under the category Global South. However, a few countries such as Australia or Japan are located in regions mostly belonging to the Global South but are actually part of the Global North.

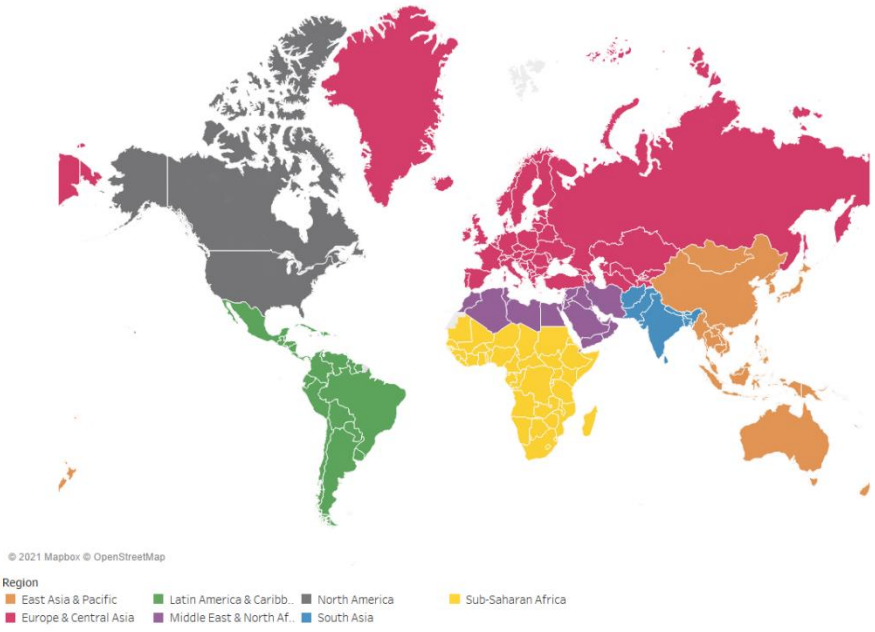

Figure 2. The world by region (The World Bank, 2021)

Climate vulnerability is a frequently used term when it comes to the Global South in the context of climate change and SRM. Whenever terms related to vulnerability are used in the examined discursive data, I will refer to vulnerability instead of the Global South to be transparent about the used terms in literature. As Jasanoff (2003) highlights, focussing on vulnerability is legitimate and also desired when addressing topics related to sociotechnical change such as SRM. Involving stakeholders from the Global South equally is important as most regions in the Global South are extremely vulnerable to climate change (Reynolds & Horton, 2020; Sen Roy, 2018).

2.3. Representation and Recognition Justice

According to Leach et al. (2018), it should be acknowledged that extreme forms of inequity should not be tolerated as they are not compatible with a fair and sustainable image of the Anthropocene. As discussed previously, knowledge production between the Global North and the Global South is often characterised by inequity regarding access and contribution to different sources and knowledge (Visvanathan, 2005). Based on this understanding of inequity, I will apply a justice lens and derive two concepts, namely representation and recognition. In regards to SRM, justice is often conceptualised based on utilitarian and distributional grounds with a focus on distributional outcomes and comparative risk assessments (McLaren, 2018; Flegal & Gupta, 2018; Hourdequin, 2018; Preston & Carr, 2018). These authors point out that this narrow paradigm of distributional justice and assessing it through "quantitative cost-benefit analyses of potential physical harms" (Preston & Carr, 2018, p. 310) leads to missing out on other injustices. By mainly focussing on

physical and economic harms, distributional justice does not help to identify how and why certain groups and their interests have been neglected historically. Therefore, Hourdequin (2018) developed a multidimensional conceptualisation of justice. This approach goes going beyond distributive justice by incorporating procedural, participatory, and recognition justice. Of these dimensions, according to Preston and Carr (2018), recognitional justice in specific is often disregarded by advocates of SRM and therefore, recognition or potential misrecognition is important to be considered. In the following, I will operationalise procedural and participatory justice with the help of the concept of representation (Hourdequin, 2018). *Recognition* is defined as "an individual or a group being adequately acknowledged" (Preston & Carr, 2018, p. 310) by appreciating "who people are, where they are coming from, and what they are saying about their situation" (p. 312). Therefore, the consideration of diverse values and perspectives is at the core of recognition (Hourdequin, 2018, 2019). Recognition complements representation in the sense of not only having the formal opportunity of having a voice in the discourse, but also one's perspectives being taken seriously (Hourdequin, 2018). Thus, the concept of recognition is applied as it helps to assess to what extent Global South actors are taken seriously as subjects and their interests. *Representation* is a common concept applied in a quantitative way in order to determine participation in research activities (Biermann & Möller, 2019; Ho-Lem et al., 2011). Representation is understood as geographical representation of authors and their affiliations in knowledge production. For instance, Ho-Lem et al. (2011) conclude that scientists of developing countries are underrepresented in the IPCC after counting authorship by country in IPCC assessment reports. Another example is provided by Biermann & Möller (2019) who studied the representation of experts in the epistemic community around geoengineering by analysing participation in research events. The findings of both studies support the overrepresentation of Global North actors in climate science and the low representation of Global South Actors. This lack of involvement translates into low influence on knowledge production and low acknowledgement of their concerns (Biermann & Möller, 2019). To conclude, representation and recognition are both relevant concepts derived from a multidimensional approach to climate justice.

2.4. Conceptual framework

Based on the concepts 'discourse', 'Global South', 'representation, and 'recognition' the following conceptual framework is derived (Figure 3). The analysis does not hypothesis or prove direct-causal correlations, but rather aims at tracing the emergence of socially constituted discursive structures. These shape how the Global South and related interests are represented and recognised in the scientific discourse.

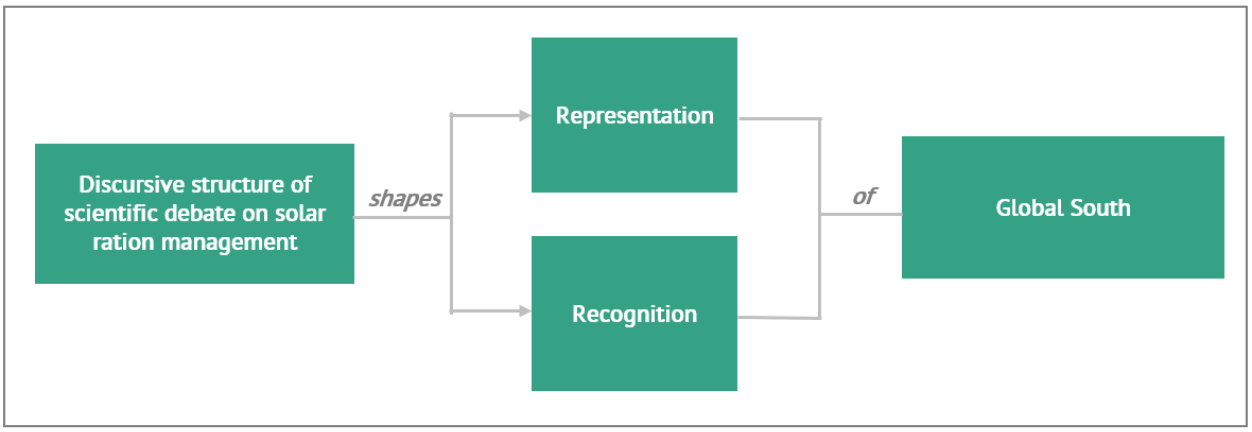

Figure 3. Conceptual Framework

In the process of designing this research project and specifying its conceptual design and research strategy, I validated and discussed the relevance of the research topic and potential research designs with three experts from the field via interviews. This also helped me to familiarise myself with the complex research field beyond the literature review, which in turn increased my theoretical knowledge as a starting point for developing the research design and strategy.

3. Methodological Framework

In the following, I will introduce the selected methods including bibliometric analysis and a sociology-of-knowledge-based discourse analysis. Secondly, I will explain which data types are used, from which sources data is obtained and how it is collected. Thirdly, the data analysis will be outlined.

3.1. Research Strategy

The research strategy combines both quantitative and qualitative approaches (Figure 4). The first part consists of a quantitative assessment of the representation of the Global South in the knowledge production on SRM. The second part includes a qualitative exploration of the scientific discourse based on secondary literature and semi-guided interviews. The analysis of journal articles provides relevant insights on representation and recognition in the discourse; however, a comprehensive discursive analysis should include other sources of qualitative data to increase the validity of the results. Following the aim of triangulating data from different data sources and applying different methods (Flick, 2011), discursive elements identified in the journal articles will be verified and expanded with the help of semi-structured expert interviews (Uther, 2014).

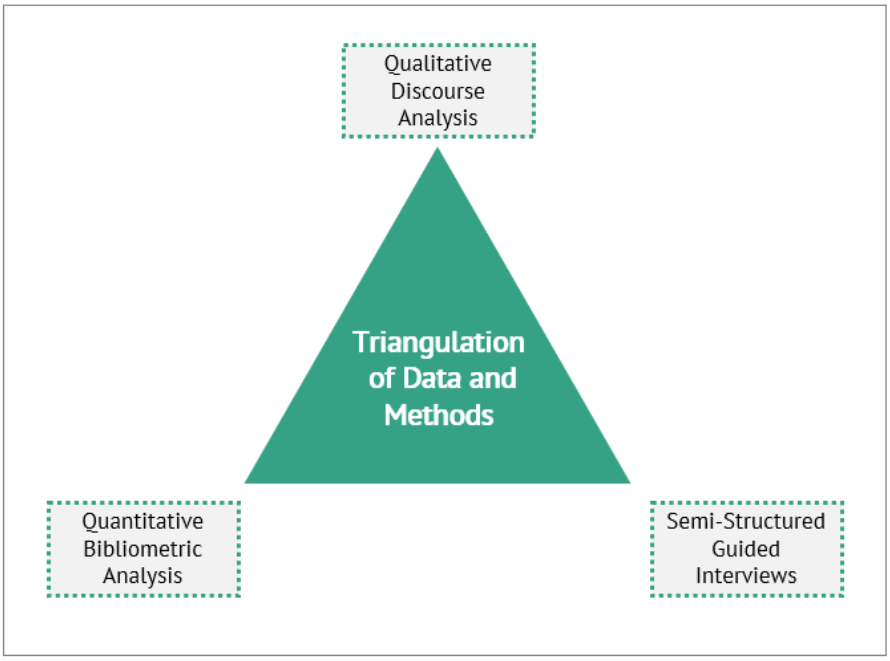

Figure 4. Triangulation of methods and data types

3.2. Method 1: Bibliometric Analysis

Due to the lack of formal governance for geoengineering technologies (Jinnah, 2018), scientific research de facto shapes the future development of the geoengineering landscape (Oldham et al., 2014). In order to inform policy debates and steer future research, it is important to achieve a better

understanding of the nature and state of scientific research (Belter & Seidel, 2013). This can be done by bibliometric analysis which is "the quantitative analysis of publications" (Belter & Seidel, 2013, p. 417). Bibliometric analysis helps to investigate scientific output and the resonance of scientific output (Ball, 2014). In this study, I focus on the former as it provides a useful starting point for future research. Therefore, I will examine the scientific output of the epistemic community working on topics related to SRM. An analysis of the resonance of the scientific output could be a topic for future research. Until now, there has been little bibliometric analysis done specifically on SRM research. Other prominent bibliometric analyses on geoengineering research include the following: First, Belter and Seidel (2013) conducted a bibliometric analysis of climate engineering research and analysed 750 articles published between 1988 and 2011. Regarding the geospatial distribution of climate engineering research, they highlight that the production of articles is dominated by Western countries and by English-speaking authors. A comparison of country percentages with related disciplines from environmental science shows that the overrepresentation of English-speaking research goes beyond the so-called usual English-speaking bias. They conclude that geoengineering research is not distributed evenly globally, which could lead to undermining both the quality and inclusiveness of geoengineering research. Finally, the authors stress the need for global dialogue, research, and consent due to the potential global impacts of geoengineering technologies (Belter & Seidel, 2013). Secondly, Oldham et al. (2014) analysed a dataset of 825 scientific publications on climate engineering published between 1971 and 2013, of which 193 were on SRM, in terms of trends, institutions, authorship and funding. They highlight emerging structures of the interplay between scientific research and patent activities.

3.3. Method 2: Sociology-of-Knowledge Discourse Analysis (SKAD)

Discourse analysis is a relevant research strategy often applied in research on geoengineering governance (Anshelm & Hansson, 2014a; Jacobson, 2018). According to Keller (2011a), knowledge cannot be traced back to an innate, cognitive system of categories, but to symbolic systems that are produced in and through discourses. The debates on geoengineering and SRM seem to not primarily concern facts, instead, contrasting worldviews and differing understandings of the relationship between humans and nature constitute the split between advocates and critics (McLaren & Corry, 2021b). Thus, instead of quantifying the debate to create "facts", using a qualitative and interpretative approach is suitable to explore the multiple realities when exploring the discourse at hand.

In the Foucauldian sense, discourse analysis helps to illuminate "a particular discursive structure that might not be immediately obvious to the people that contribute to the debate" (Hajer & Versteeg, 2005, pp. 175–176). Since Foucault does not suggest any binding methodology on how to implement discourse analysis in research, I will specify the type of discourse analysis applied in this research in the following. With the help of the Foucaldian-inspired structurally-derived sociology-of-knowledge discourse analysis (SKAD), discourse will be conceptualised as "system of ideas, concepts and categories that shapes what it is possible to [...] know and say within a given debate" (Boettcher, 2020a, p. 3). My understanding of SKAD is based on the theoretical work of Keller (2011a, 2011b, 2013) and the application of SKAD to topics related to geoengineering by Boettcher (2020a, 2020b). Discursive structures are defined as "systemic, historically contingent, relatively robust manifestation of power/knowledge relations within a given discursive sphere" (Boettcher, 2020b, p. 893). Consequently, discursive structures can both enable and restrict as they constitute subjects, objects and rationales of research and governance that can solidify into formal institutional arrangements and at the same time limit what can be said and known about a particular topic. While structurally-derived discourse approaches tend to negate agency of those who participate in debates, Hajer and Versteeg (2005) stress the need for analysing how certain actors impose powerful frames onto debates as they actively position themselves. However, actors are not entirely free as they draw upon rules and resources available to them within certain discursive structures and reproduce these (Keller et al., 2018). From a pool of individual utterances by different actors engaged in the debate, SKAD analysis aims to reverse-engineer the underlying structures and highlight the role they play in shaping social reality. This understanding of the shaping function of discursive structures has implications for how to conceptualise and analyse the role of discourse. Inviting more Global South scholars into the debate might not open up the debate it is continues to operate within the boundaries of the same discursive structures (Boettcher, 2020b). Thus, existing power and knowledge structures would shape their contributions and not enable a shift in debate. Therefore, it is relevant to identify existing discursive structures of the scientific discourse regarding GS actors. This could help to reflect upon enabling and restricting structures in order to potentially open them up for engagement of the Global South. To conclude, it is important to elaborate on discursive structures of the debate on as they have a constitutive effect on how current and future engagement of actors from the Global South can be imagined, designed and institutionalised (Boettcher, 2020b). Thus, the following analysis aims to identify the structures underpinning the scientific sphere of the SRM debate, and critically discuss the shaping effects they may have on the current and future representation and recognition of Global South actors. The emerging structures are summarised with the help of the four main categories *why*, *what*, *who*, and

how (2020a). The first category, *why*, helps to understand which rationales underpin the calls for research on SRM. This category, *why*, is applied a second time to identify rationales that underpin the calls for stronger involvement of the Global South in the research on SRM. The second category, *what*, contributes to a better understanding of the objects of the discourse defined as the topics mentioned in regard to the Global South. The third category, *who*, refers to available speaker positions within the discourse. This category is relevant as dominant networks of researchers and experts play an important role in establishing scientific norms and presumptions about topics and practices of research (McLaren & Corry, 2021a). Since the research community on geoengineering is predominantly from the Global North (Biermann & Möller, 2019), it is important to investigate which speaker positions are available specifically in the research community on solar radiation management for the Global South. The last category, *how*, relates to the modes of current involvement of the Global South in knowledge production on SRM, also considering future aspects emerging from the discourse.

3.4. Data Collection

In this section, I will explain the type of data used, data sources and the process of data collection. For the bibliometric analysis, metadata of journal articles on SRM is compiled. For the discourse analysis, selected journal articles on SRM that mention the Global South to some extent and interview transcripts are analysed.

3.4.1. Peer-reviewed Journal Articles

First, I intend to analyse the representation of scientists and both academic and funding institutions from the Global South in the scientific discourse on SRM. Therefore, I intend to examine peer-reviewed articles on solar radiation management and associated technologies. Peer-reviewed articles published in journals form the corpus of this analyses as they are considered to be "the most tangible products of climate engineering research" (Belter & Seidel, 2013, p. 417). Despite changing science communication, for instance through Twitter or blogs, journal articles are still a representative proxy for research on SRM. Analysis journal articles can lead to useful insights into the nature of SRM research (Belter & Seidel, 2013) since journal articles play an important role in setting the tone of the discourse on geoengineering (Jacobson, 2018). Across different disciplines, journal articles on SRM communicate scientific knowledge in a certain way as they contain certain conceptualisations of SRM, its research and the Global South. As data source, the Scopus data base, one of three standard databases among Web of Science and Google Scholar, is used for retrieving data for the bibliometric analysis and the discourse analysis. Scopus is chosen due to its availability

to my research institution; and a brief search for the used key words in the other data bases revealed similar results. Regarding data collection, first, articles on SRM are identified, and in the second phase, articles on SRM that mention topics related to the Global South are identified within the previous results. To search for the articles, I first set some search terms for both search steps. The search terms applied in the first search include "solar radiation management", "solar geoengineering", and "solar radiation modification" (see Table 1). These terms were selected as the are commonly used to describe proposed technologies that aim to block or reflect sunlight (Reynolds, 2019). The search terms applied in the second search are terms commonly used to refer to topics to the Global South, i.e. the "Global South", "poor" referring to the global poor or poor countries, "vulnerable" referring countries or people vulnerable to climate change, often referred to as the most vulnerable, and lastly, "developing countries" and "least developed countries" (Table 1).

Table 1. Primary and secondary search words

Primary search words	Secondary search words
1. Solar radiation management	1. Poor
2. Solar geoengineering	2. Vulnerable
3. Solar radiation modification	3. Developing countries
	4. Least developed countries
	5. Global South

In order to retrieve all journal articles published on SRM, the first step is to query Scopus using the following search string:

> TITLE-ABS-KEY ("solar radiation management" OR "solar geoengineering" OR "solar radiation modification") AND (EXCLUDE (PUBYEAR , 2021)) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (LANGUAGE , "English"))

The results (N=324) include all articles on SRM as mentioned in their title, abstract or key words. Articles from 2021, the year this research is being conducted, are not taken into consideration to focus on full calendar years only. Also, only finally published articles and articles written in English were selected. Excluding non-English articles does not present much of a bias, as query 1 yielded only two non-English articles other than the 324 English-language articles. The analysis includes

articles published between 2009 and 2020. While the limit of 2020 was deliberately chosen by me, the start in 2009 results from when articles for the chosen search terms first appeared.

In order to retrieve all journal articles on SRM that relate to the Global south, the following search string is applied:

> ((TITLE-ABS-KEY ("Solar radiation management") OR TITLE-ABS-KEY ("solar geoengineering") OR TITLE-ABS-KEY ("solar radiation modification"))) AND ((("developing countries") OR ("least developed countries") OR ("poor") OR ("global south") OR ("vulnerable"))) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (EXCLUDE (PUBYEAR , 2021))

Querying Scopus again with the more specific second search string leads to 51 articles, of which N=44 remained after the articles were scanned for accuracy and articles topically not relevant were removed. The results include a fraction of the previous search, namely all articles on SRM that mention any term related to the Global South in any part of the article. The process of data collection is illustrated in Figure 5 below.

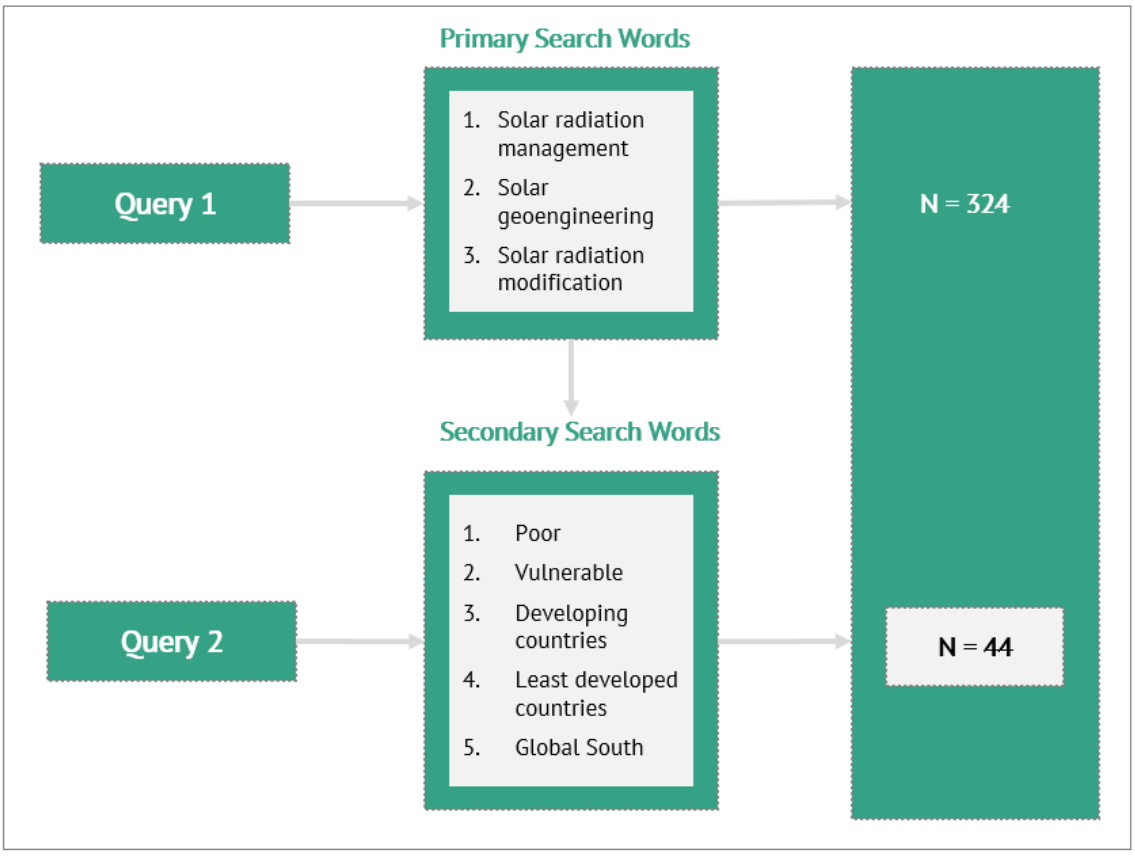

Figure 5. Process of Data Collection of Peer-Reviewed Journal Articles

Besides retrieving the selected journal articles from Scopus, I compiled metadata of the selected articles for the bibliometric analysis. Metadata for the categories “documents by year”, “documents by subject area” and “documents by funding sponsor”. The sponsors of research were not available for all articles. For other categories that were relevant for the analysis but not available on Scopus, such as “documents by affiliation” and related geographical attributes, I compiled the required metadata manually.

3.4.2. Semi-Structured Interviews

Semi-structured interviews with members of the scientific community from the Global South will complement results from the previous discourse analysis of journal articles. I follow the research tradition of sociology of knowledge since the interviews focus on the interviewees themselves and aim to reconstruct knowledge including their personal attitudes from narratives emerging from the interview (Hildebrandt, 2015). The reason for conducting interviews is to gain a better and more detailed understanding of this controversial topic. Furthermore, there is only limited scientific output in the form of journal articles by authors from the Global South, so this missing perspective will be supplemented by the interviews. The chosen type of interviews is semi-structured in order to guide the questions towards relevant units of analysis and leave enough room for the interviewee to come up with additional insights. The semi-structured nature of the interviews is considered suitable to allow for spontaneous follow up on relevant issues and include further questions, for example encourage further questions to arise as the interviews progress, allow response to be fully probed and explored, allow the interviewer to follow up on relevant issues raised spontaneously by interviewees (Yeo et al., 2013).

For the semi-structured interviews, relevant interview partners are identified in two stages. First, key scientific actors from the Global South are selected by analysing background literature and the selected journal articles for the discourse analysis. Secondly, further interview partners were approached through snowballing starting with the network of previous interview partners. Criteria for potential interview partners to be selected include that they are currently 1) active in the research community on SRM and 2) either associated with any Global South region or at the interface of inviting them to the SRM conversation. As for most regions besides North America and Europe there are only a few experts or people involved in research SRM, the interviewees are considered to be experts for their specific location (Uther, 2014). The ideal aim would be to have a representative sample of interviewees based on their affiliation, their geographic location, and their opinion regarding SRM. However, the low representation of Global South scientists makes it

difficult to reach representative sample size. I have contacted over 35 individuals and managed to conduct nine interviews in the end. Therefore, the selected group of interviewees is not entirely representative in terms of geography. The scientific interests of the interviewees, however, is diverse and covers a range of topics regarding SRM: potential risks and benefits (Interview 1) such as regional impacts of SRM on temperature, precipitation (Interview 5, 7, 8), agriculture and food production (Interview 7, 8), health (Interview 2); governance (Interview 1, 3); humanitarian concerns (Interview 5); and implications on ordinary people (Interview 7). The final data pool for the analysis consists of nine interview transcripts from interviews with Global South scientists/actors at the interface (see Table 2)

Table 2. Anonymised Information on Affiliation and Word Region of Interviewees

Interviewee	Affiliation	World Region
Interviewee 1	Science-policy interface	Europe & Central Asia
Interviewee 2	Academia	South Asia
Interviewee 3	Academia	Latin America & Caribbean
Interviewee 4	Science-policy interface	Europe & Central Asia
Interviewee 5	Academia	Latin America & Caribbean
Interviewee 6	Academia	East Asia & Pacific
Interviewee 7	Academia	Sub-Saharan Africa
Interviewee 8	Academia	Sub-Saharan Africa
Interviewee 9	Academia	Sub-Saharan Africa

The stated primary purpose of the interviews was to empirically understand the interests of Global South researchers regarding SRM. Each interview was semi-structured around a series of around ten main questions and few situational follow-up questions in order to understand the interviewees' opinions on (1) their interests in SRM and their motivation to research SRM, (2) their own research experience with SRM, and (3) their thoughts on SRM research in the context of the Global South. The first part aimed at understanding why they consider SRM research (reason for dealing with SRM); the second part aimed at understanding on which topics they have worked, and which results for Global South regions they achieved (assessment of risks and side effects); the third part aims at understanding the discursive structures of how Global South actors are currently engaged and why this is considered necessary (attitudes towards GS engagement and opinions on the international discourse). The interview guideline (see Appendix B) helps to ensure the comparability of the interviews.

With the interviewee's consent, each interview was recorded and transcribed. The consent form (see Appendix C) was signed by each interviewee and ensures that they were informed about my research project and agree with the interview data being used in this research report. With the informed consent form, I guarantee to handle the collected data carefully and store it separately from the rest of the research project's data. Due to the sensitivity of the matter and since I asked interviewees for their personal opinion which does not necessarily correspond to their affiliation's opinion, I decided to anonymise the name of the interviewees.

3.5. Data Analysis

First, I will specify the analytical framework and procedure for the bibliometric analysis. Secondly, I will outline the sociology-of-knowledge discourse analysis (SKAD) that aims to identify discursive structures by first empirically deconstructing the discourse and then reconstructing its discursive structures (Boettcher, 2020b). With the help of qualitative content analysis, the analysis of empirical material is complemented by a priori elements from theory (Bücke, 2020).

3.5.1. Quantitative Analysis of Bibliometric Data

The categories that are examined with the help of bibliometric analysis are based on categories offered by Scopus and inspired by analyses in the field of bibliometrics (Belter & Seidel, 2013; Oldham et al., 2014). Particular attention is paid to geographic representation. For the bibliometric analysis, the categories and indicators as described in Table 3 will be used. I will create suitable graphs with the help of Excel (Appendix D).

Table 3. Analytical Framework for Bibliometric Analysis

	Categories	Indicator	Description
1	Publication trend	Absolute number of journal articles per year	Journal articles are grouped by year and presented over time from 2009 to 2020.
2	Representation of Global South	Relative number of journal articles	Journal articles are grouped by whether they make a reference to the Global South or not over the total time span.
3	Scientific output per discipline	Absolute number of journal articles per discipline	Discipline or subject area refers to the thematic focus of the journal in which the article was published in. Multiple

			counting is possible as some journals can be assigned to >1 disciplines.
4	Scientific output per region	Absolute number of journal articles per world region	The world regions (cf. chapter 2.2.) are assigned based on the country of author's affiliation.
5	Affiliation	Absolute number of authors' contributions to articles per affiliation	The ten most frequent affiliations of authors are visualised. Counting is based on the number of contributions made by authors from each affiliation.
6	Sponsor	Absolute number of journal articles per funding sponsor	The ten most frequent sponsors of journal articles are visualised. One article can be sponsored by >1 sponsor.

For all categories, I conduct a comparative analysis between articles with reference to Global South (Query 2) and articles without reference to Global South (Query 1 – Query 2). Thus, I compare journal articles retrieved by Query 1 – Query 2, i.e. articles on SRM that do not mention the Global South (N=280), with articles retrieved by Query 2, i.e. articles on SRM that do mention the Global South (N=44).

Since publications are often written by several authors or assigned to several disciplines, an assignment rule is necessary. Usually, a distinction is made between whole and fractional counts, which both have advantages and disadvantages (Deutsches Zentrum für Hochschul- und Wissenschaftsforschung GmbH [DZHW], 2018). With whole count, a publication is fully attributed to each research unit, i.e. if there are several authors, the publication is assigned to each author, thus, counted as 1 for each author. This counting method is quite intuitive, but counts an article several times if, for example, several authors are involved. Another option is fractional count, with the help of which publications are assigned proportionally to each research unit. This would mean that, for example, if there are four authors, each publication is counted as 1/4. This counting method means that in the end the sum of units corresponds to the total number of publications; however, authors who cooperate frequently are disadvantaged, and individual authors are emphasised more. As authors do cooperate frequently (see chapter 6.4. for sensitivity analysis) when writing literature about SRM, I decide to apply the whole counting. This is not only applied to cases where there is >1 author per journal article, but also to >1 affiliation per author, thus, each affiliation of an author is counted.

3.5.2. Qualitative Content Analysis of Discourse

Following the examples of Boettcher (2020a, 2020b), I will outline the steps taken in order to identify discursive structures with the sociology-of-knowledge discourse analysis (SKAD). First, a data pool of discursive products, namely the journal articles retrieved with the second search query (N=44) (see Appendix A for compilation of all articles) and the interview transcripts (N=9) is compiled. With the help of *qualitative content analysis*, the data pool can be analysed based on a set of categories that enable me to systematise and interpret the complex empirical material (Bücker, 2020). A common approach regarding qualitative content analysis is the combination of categories that were defined a priori in a deductive manner and text-based codes which are the result of open coding (Schreier, 2012). A set of main categories, here the guiding questions for analysis (Table 4), is developed based on prior knowledge. The selection of questions is inspired by literature on discourse analysis by Keller (2011a), Uther (2014) and Boettcher (2020a). The following questions structure the search for discursive elements:

Table 4. Guiding Questions for Identifying Discursive Structures

	Main categories		Guiding questions
1	WHY	Rationales	What demand rationales are structuring calls for SRM research?
2	WHO	Speaker positions	What authoritative speaker positions are available within the structure of the SRK research discourse? // Who appears as a speaker in the scientific discourse on SRM?
3	WHAT	Objects	What is defined and constructed as interests of the Global South?
4	WHY	Rationales	What demand rationales are structuring calls for GS engagement?
5	HOW	Modes	How are GS actors/institutions invited into the conversation on SRM?

These main categories and related guiding questions help to structure the coding process and for each category, subcategories are built when applied to empirical material (Mayring, 2010; Schreier, 2012). Subcategories for each main category *why*, *who*, *what*, and *how* are derived in an inductive manner. For the main category *why*, in order to distinguish between the different demand rationales

that emerge from the discourse, I will apply Jinnah's (Jinnah, 2018) categorisation into functional, strategic and normative rationales. First, I refer to functional demands which are driven a rational attitude aimed at problem solving. Second, strategic demands are those that reflect by national interests for instance regarding national economic and security. Third, normative demands are driven by a desire to strengthen or create norms in order to ensure global justice. This differentiation will be applied to both sections following guiding questions on *why*, namely why SRM research is (not) considered in general and why the Global South should (not) be engaged in the debate.

Next, the selected peer-reviewed articles are read carefully. Relevant data elements are identified by applying the guiding questions to the text. These data elements are inductively coded with the help of the qualitative data analysis software NVivo. In the next step, recurring frames are identified and related to each other so that storylines in the form of subcategories emerge in an inductive manner. All frames belonging to the same storyline are then clustered among the same subcategory. When relating discursive elements to each other, discourse-analytical techniques such as considering equivalence and contrariety between these elements are taken into account (Keller, 2011a; Boettcher, 2020b). An example of the coding approach is illustrated in Table 5.

Table 5. Example for Coding Approach

Main category	Subcategory (=Storyline)	In-vivo code (=Frame)
WHY: Normative demand rationales for research on SRM	Research on SRM as moral obligation to the global poor and most vulnerable	"Notions of equity are being evoked by some experts in advocating for further research on solar geoengineering (Flegal & Gupta, 2018, p. 46)

This analytical approach is understood as iterative since findings are checked against further data (Heindl, 2015). To sum up, this approach to analysis allows for deconstructing the discourse into its smallest elements, followed by reconstructing these discursive elements into subcategories and identifying the relationships between these categories (Heindl, 2015; Boettcher, 2020a). Thereby, the discursive structure shaping the (*why*) rationales behind research on SRM and engagement of the Global South, (*what*) interests of Global South, (*who*) speaker positions, and (*how*) modes of engagement can be identified. For better readability, the sources from which the respective storylines are drawn are not in the body text, but in the Appendix E.

4. Results from Bibliometric Analysis

The aim of this chapter is to answer research sub-question 1, thus, illustrate to what extent academic stakeholders from the Global South are represented in the epistemic community of solar radiation management. In this chapter, all aspects, i.e. publication trend, representation of Global South in total scientific output, scientific output per discipline, scientific output per region, , affiliation, and sponsorship will be analysed and compared for both the total number of journal articles on SRM mentioning (N=44) and not mentioning (N=280) topics related to the Global South.

4.1. Publication Trend

Historically speaking, discussions on geoengineering date back several decades (Caldeira & Bala, 2017). Many argue that Nobel Prize winner Paul Crutzen's call for research on stratospheric aerosol injection in 2006 (Crutzen, 2006) lead to this increase in interest in and research on geoengineering (Boettcher et al., 2017) and introduced the topic to a broader audience (Caldeira & Bala, 2017). Furthermore, research on geoengineering became more scientifically and socially acceptable (Gupta & Möller, 2019).

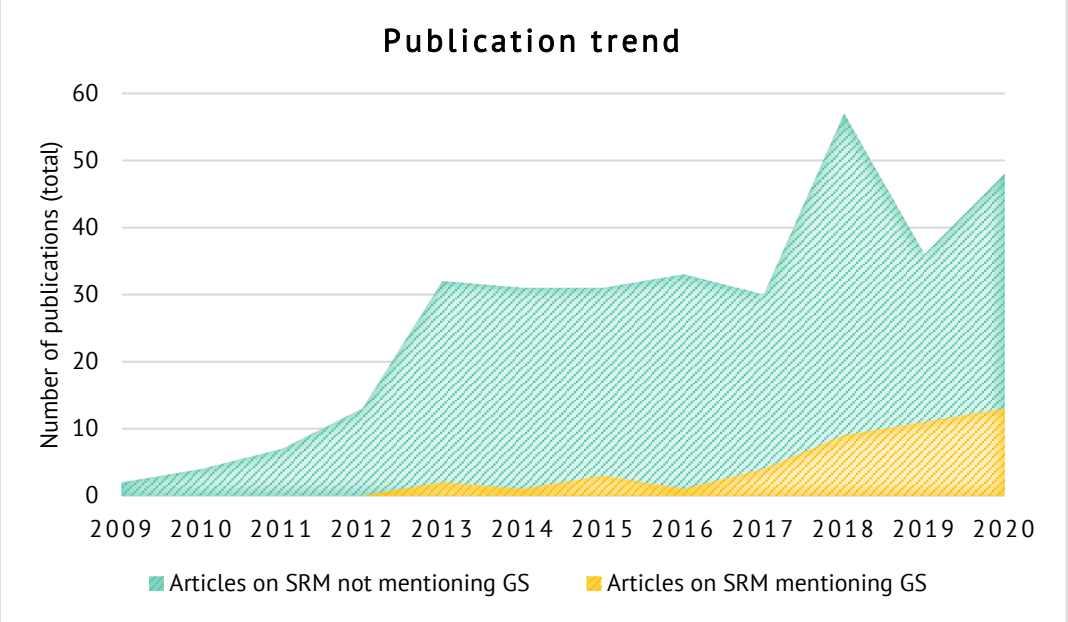

Figure 6. Distribution of articles that (not) mention global south actors and interests

As shown in Figure 6, journal articles on the topic of solar radiation management surged after 2009. At this point, it is important to emphasise a small number of journal articles has been already published before 2009. As Oldham et al. (2014) point out, the number of journal articles was limited to 16 between 1990 and 2007, and then increased to 15 in 2008 alone. The fact that the terms I use indicate the first publications on solar radiation management for 2009 is almost certainly due to the

use of different terminology. It appears that before 2009 more specific but also more diverse terms were used instead of the umbrella term 'solar radiation management'. Followed by a steep increase between 2011 and 2013, the publication rate stagnates until 2017. With a peak in 2018 and after a slight decrease between 2018 and 2019, the future trend seems to be characterised by continued interest in and research on SRM.

The number of articles mentioning terms related to Global South actors and interests appears to be relatively low until 2016. It becomes evident that before 2012, there seemed to be no references made to the Global South at all. In the period between 2012 and 2016, only a few peer-reviewed articles regarding the Global South were published. Since 2017, a slight increase in publications on SRM regarding GS can be observed. Research and the publication of journal articles, also policy assessments, on SRM is often attributed a de-facto governance power in the literature (Gupta & Möller, 2019). Due to the low number of articles on SRM that take the Global South into account, and because this number has only recently increased, research on SRM, mostly by the Global North, also de-facto governs the aspects of SRM related to the Global South. After 2020, an increase in publications with regard to the Global South can be expected as the first phase of research on SRM by Global South researchers supported by the Solar Radiation Management Governance Initiative (SRMGI) and the DECIMALS funds will end, thus, their research output will be published.

4.2. Representation in Scientific Output

In total, 324 peer-reviewed articles on the topic of solar radiation management (as mentioned in title, abstract, keywords) were identified based on the database Scopus. Of these, 44 mention terms related to the Global South (as mentioned anywhere in the article). Consequently, the remaining 280 articles do not mention any terms related to the Global South. The relative percentage of articles mentioning terms related to the Global South amount up to 14%, while 86% of the retrieved articles do not mention any terms related to the Global South (see Figure 7). This translates into one out of six articles published on SRM considering the Global South in some way.

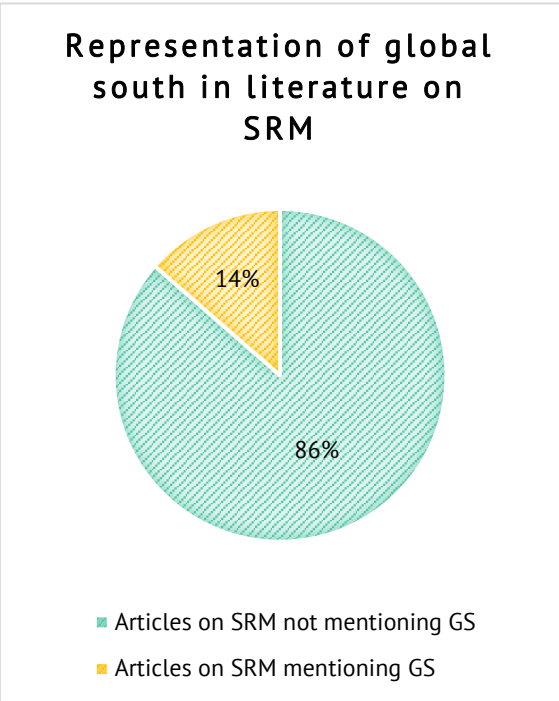

Figure 7. Percentage of peer-reviewed articles that (not) mention terms related to Global South (total from 2009 to 2020)

4.3. Scientific Output per Discipline

Over time, geoengineering research become more multi- or interdisciplinary as not only physical scientists continued to invest geoengineering but also a large number of social and political scientists, philosophers and economists showed interest in the ethical, political and economic dimensions of solar radiation management (Caldeira & Bala, 2017). Most articles on solar radiation management address topics related to environmental science, earth and planetary sciences, and social sciences (see Figure 8). Articles from other disciplines such as Energy, Arts and Humanities, or Engineering play a rather subordinate role.

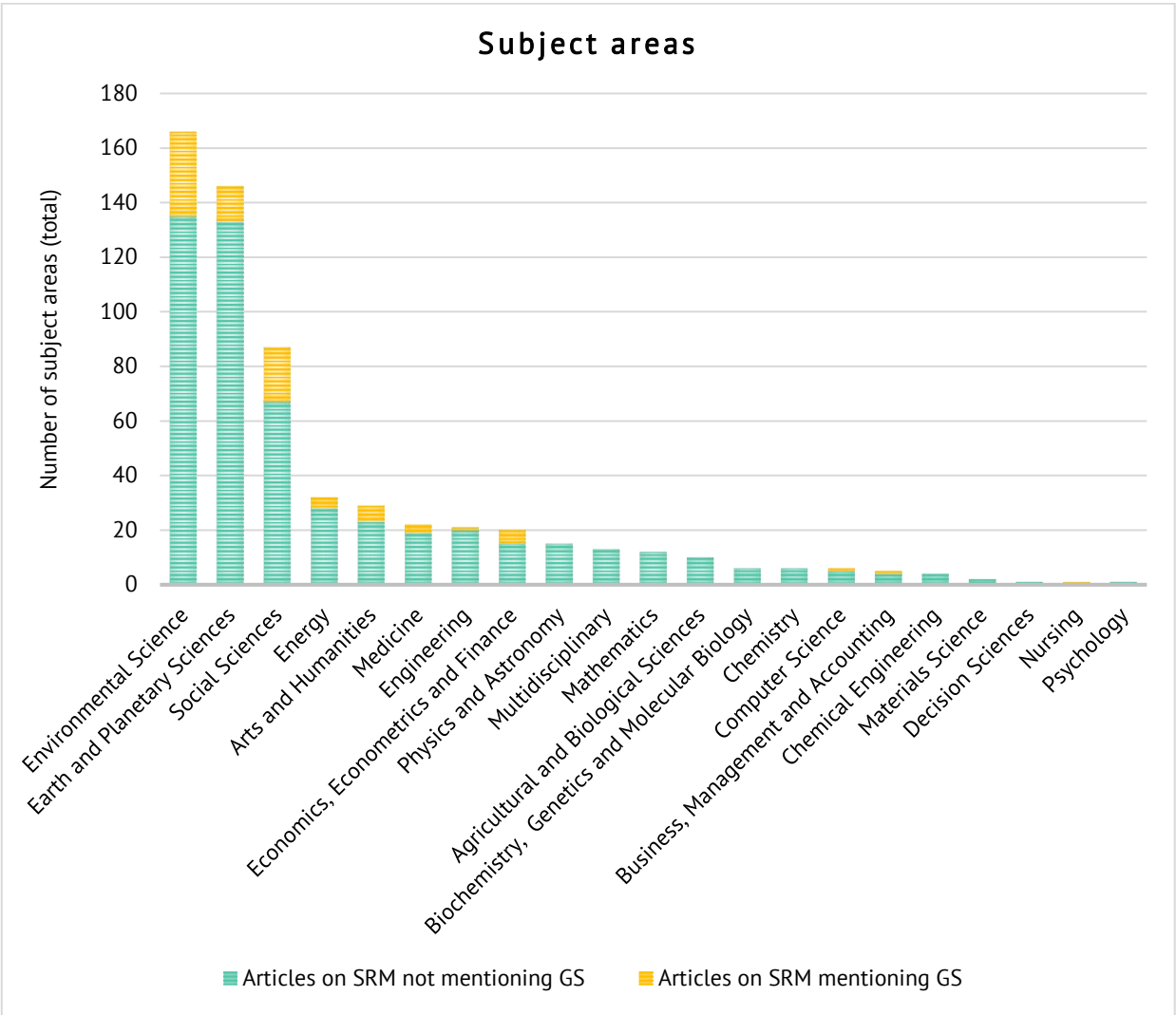

Figure 8. Subject areas of peer-reviewed articles on solar radiation management from 2009 to 2020) (see Appendix D for data)

When comparing the disciplines of articles mentioning global south stakeholders and interests with those that do not (Figure 9), it becomes clear that environmental science, social sciences, and arts and humanities are the most prominent subject areas mentioning GS. In relative comparison, especially earth and planetary sciences fall short in this regard.

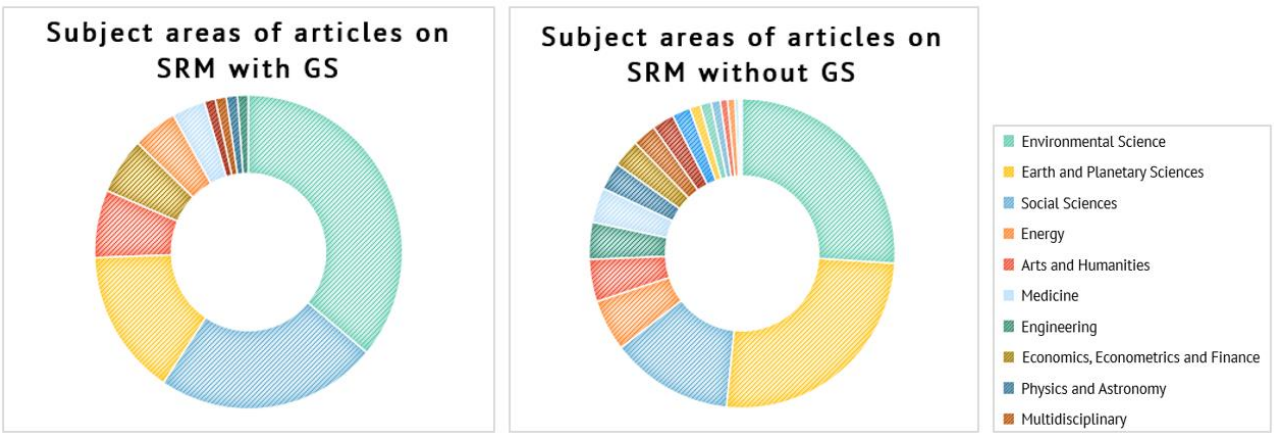

Figure 9. Subject areas of peer-reviewed articles on SRM that do not mention (left) and that mention (right) GS actors and their interests (from 2009 to 2020)

4.4. Scientific Output per World Region

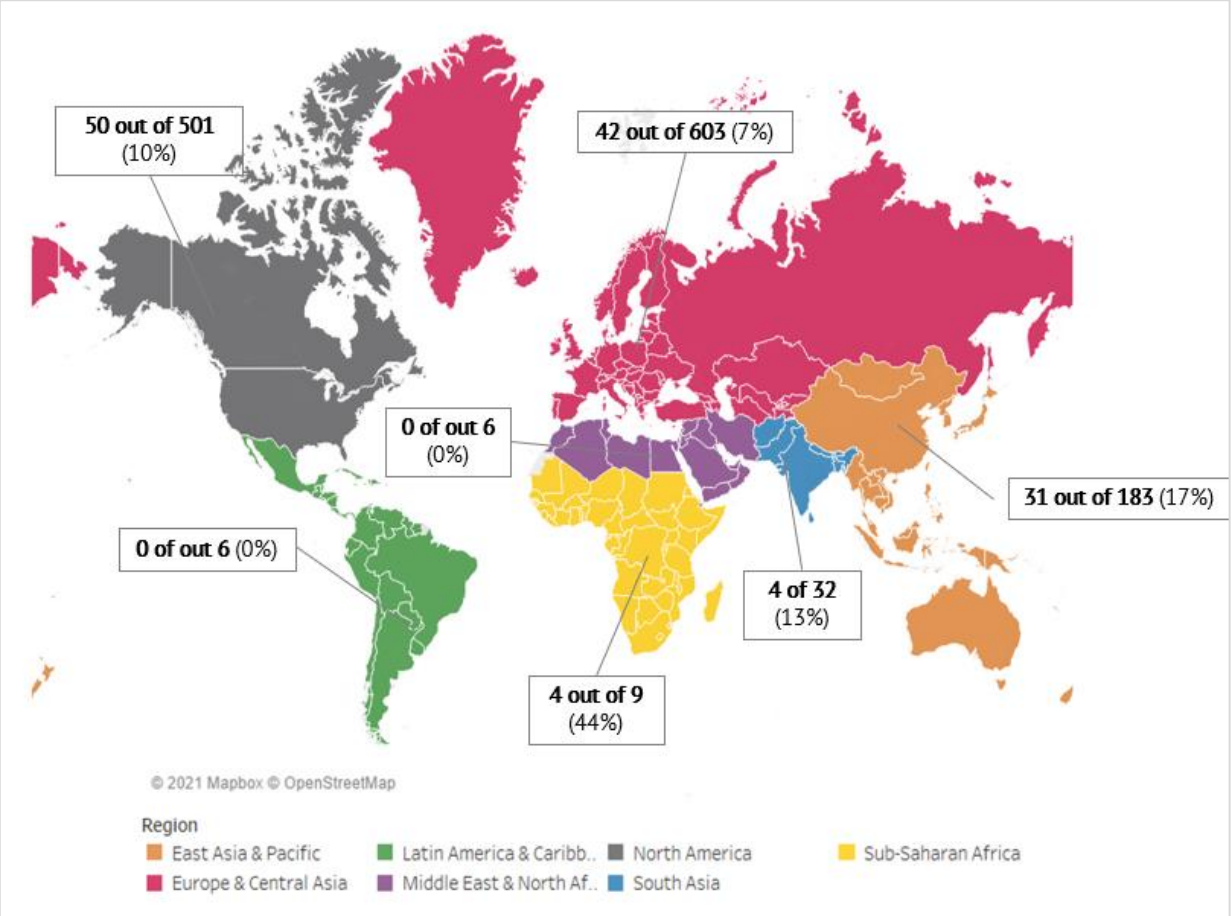

Figure 10. Number of authors of journal articles on SRM and Global South based on their affiliation's world region as share of total amount of journal articles on SRM (from 2009 to 2020) (The World Bank, 2021)

In the following, I address the distribution of authors, who have contributed to journal articles on SRM, among world regions. This is based on the country their respective affiliation is located in. Figure 10 shows the share of contributions made by authors on SRM and the Global South as a proportion of the total number of contributions to articles on SRM in general. The total number of contributions is highest for Europe with 603 contributions and North America with 501 contributions. Thus, authors from the Global North play a prominent role as their institutions publish most of the research on SRM. Of the remaining world regions, only authors from affiliations located in East Asia & Pacific contribute a significant amount with 183 contributions. The other world regions, which are home to most of the countries that are part of the Global South, do barely contribute to journal articles on SRM. Most research that addresses SRM in relation to the Global South takes place in the Global North, i.e. North America with 50 contributions and Europe with 42 contributions. Furthermore, researchers at institutions in East Asia & Pacific also publish on SRM in the context of the Global South with 31 contributions so far. However, I would like to note that authors of these articles are mainly from institutions in relatively wealthy East-Asian countries such

as Japan, China, New Zealand, and Australia which are not considered to be part of the Global South. Authors from world regions home to countries mostly being part of the Global South, namely Latin America & Caribbean, South Asia, Sub-Saharan Africa, and Middle East & North Africa, barely contribute to current literature on SRM in general or in relation to the Global South.

4.5. Affiliations

Figure 11 ranks those affiliations that publish most frequently on SRM by the number of contributions of authors belonging to the respective affiliation. Each bar is complemented by the number of contributions affiliated authors made regarding SRM in regard to the Global South.

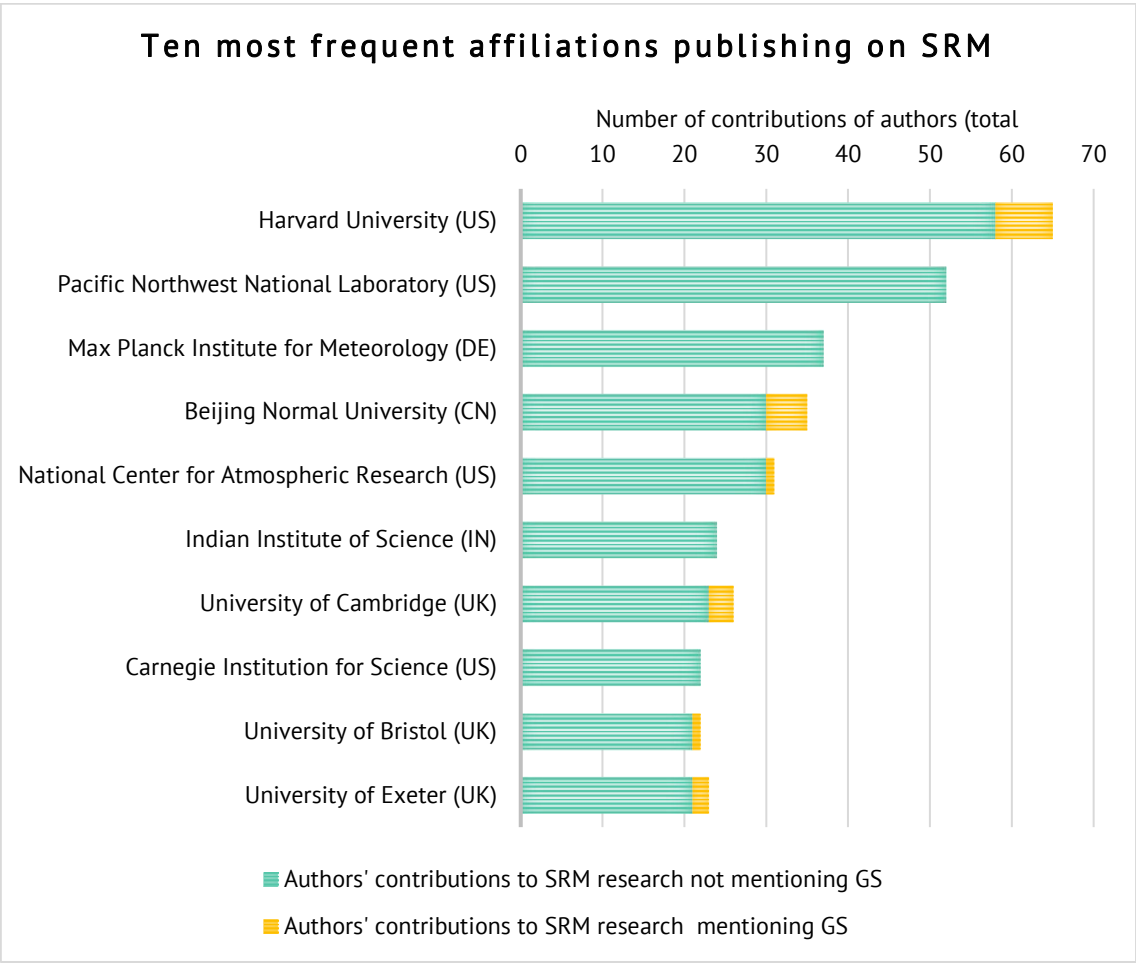

Figure 11. Top ten affiliations to which authors publishing on SRM but not on GS most frequently belong to

This shows that, in absolute numbers, the largest number of scientists conducting research on SRM belongs to Harvard University (US) followed by the Pacific Northwest National Laboratory (US). They are followed by several institutions from Germany, China, India, and the United Kingdom. Therefore, research on SRM is still the main domain of the Global North, however, affiliations from China as non-Western country and India as country being part of the Global South contribute significantly to research on SRM as well.

Figure 12 ranks those affiliations that publish most frequently on SRM and the Global South by the number of contributions of authors belonging to the respective affiliation. Each bar is complemented by the number of contributions affiliated authors made regarding SRM without mentioning the Global South. When investigating the affiliations of authors that publish on SRM most frequently with reference to the Global South, it becomes clear that institutions from the United States are leading, see positions 1, 3 and 4 (Figure 12). Other institutions, i.e. position 4 to 10, that publish relatively less on SRM have a higher proportion of literature on SRM in regard to the Global South. Interestingly, the Indian Institute of Science holds position six on overall contributions to the literature on SRM but does not publish SRM literature with regard to the Global South at all. The only remaining affiliation that is located in a country of the Global South is the University of Cape Town (South Africa), which publishes relatively little, but half of their output on topics related to SRM and the Global South.

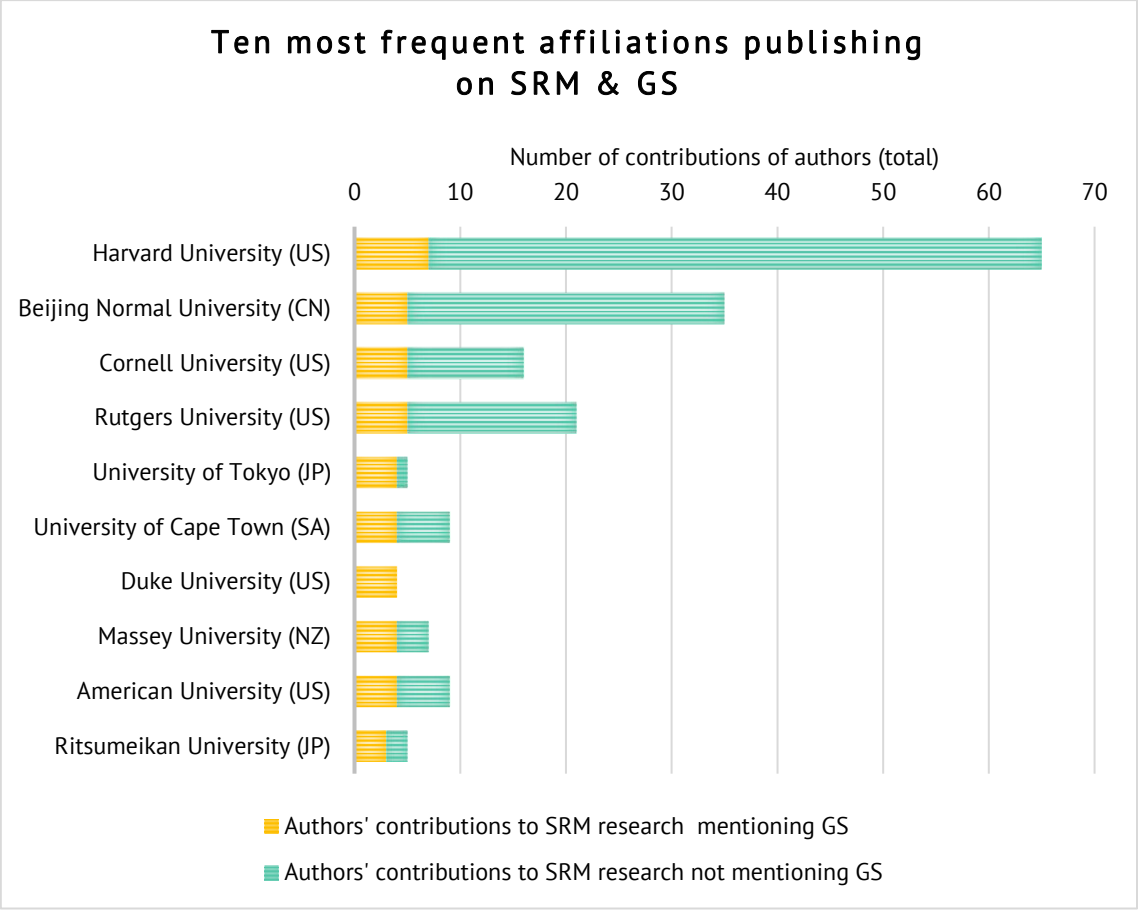

Figure 12. Top ten affiliations to which authors publishing on SRM and GS most frequently belong to

4.6. Funding Sponsors

In the following, I will elaborate on the sponsors funding research on SRM with and without regard to the Global South. Figure 13 which shows the most common sponsors of SRM research. Sponsors are ranked depending on the number of journal articles they have funded on SRM. Each bar is complemented by the number of articles each respective affiliation has published that address topic related to SRM and the Global South. Each bar is complemented by the number of contributions affiliated authors made regarding SRM without mentioning the Global South. Here, the European Commission takes the lead in funding SRM research, closely followed by the US National Science Foundation. Other institutions funding SRM research include mainly foundations and institutes from the United States, the United Kingdom, Germany, and China. Thus, the institutions funding research on SRM most frequently are located exclusively in the Global North.

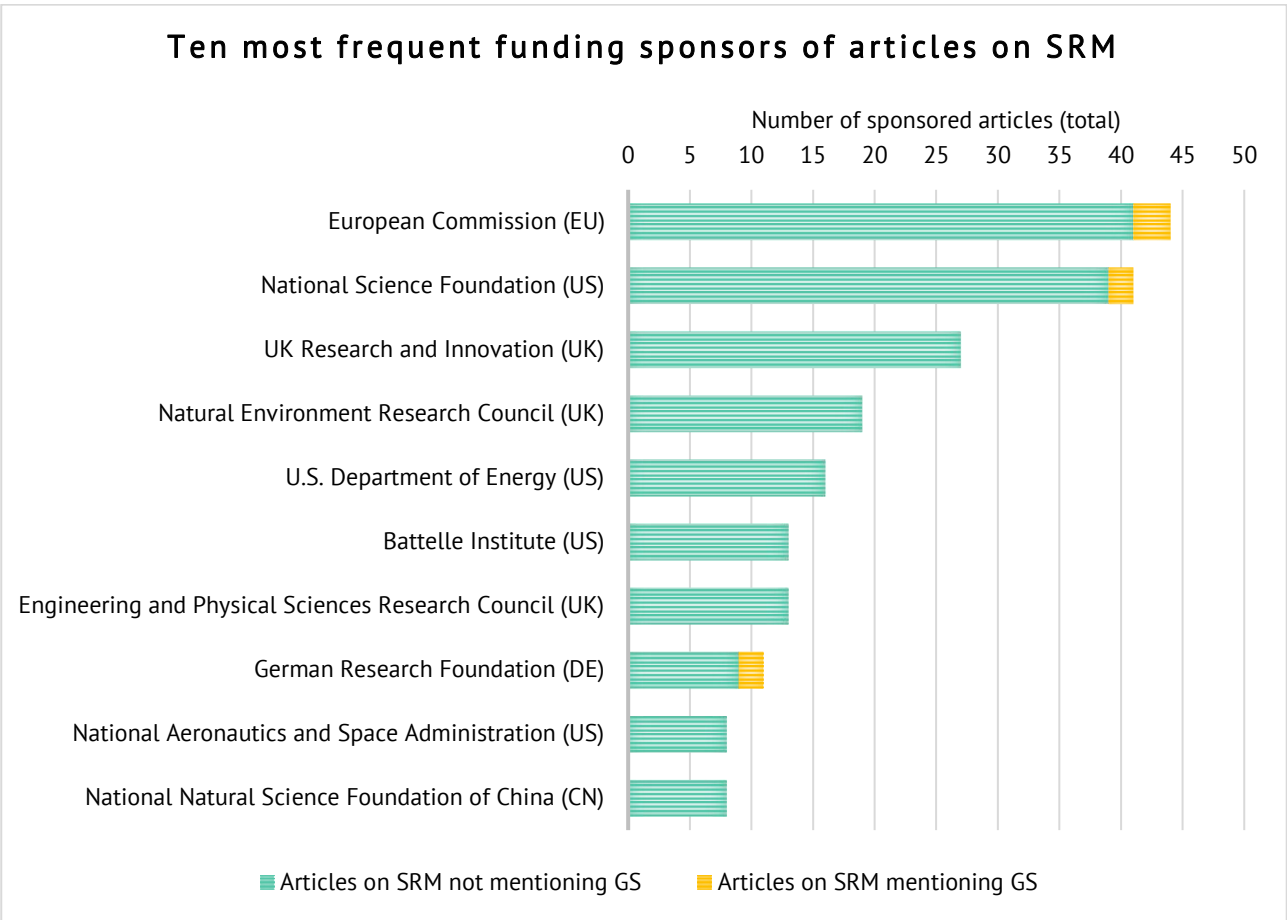

Figure 13. Most frequent sponsors of SRM research

Instead of looking at which institutions fund the most research on SRM in general, I will look into which institutions fund specific research on SRM in the context of the Global South. Figure 14 ranks those sponsors that fund articles on SRM and the Global South most frequently by the number of

articles. Each bar is complemented by the number of articles that sponsors funded regarding SRM without mentioning the Global South.

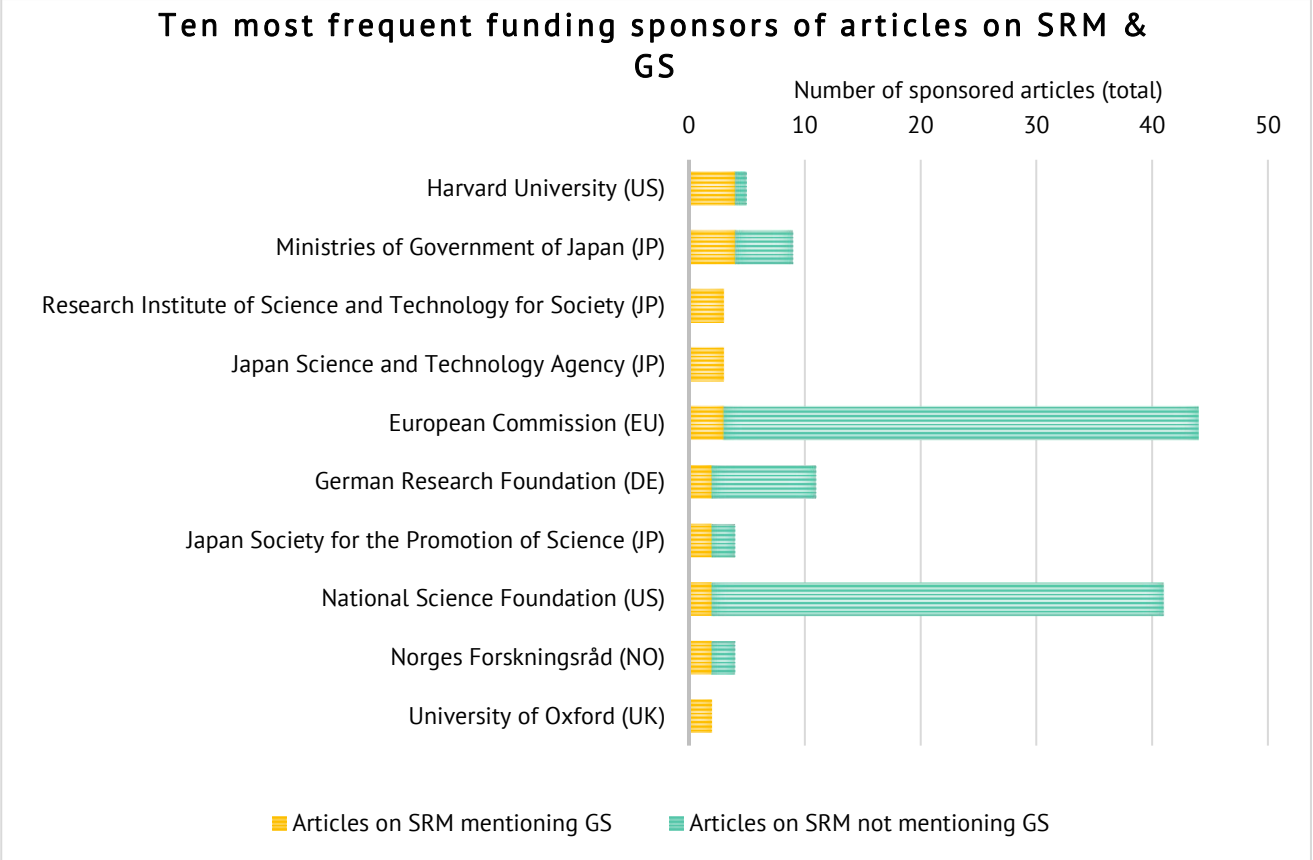

Figure 14. Most frequent sponsors of SRM research mentioning the Global South

Compared to Figure 13, only two of the major funding institutions are involved, namely the European Commission (EU) and the National Science Foundation (US). The remaining institutions fund relatively little research on SRM and in some cases only research on SRM in which the Global South is also mentioned. In terms of geographical representation, the sponsors are located in the Global North, but with three institutions from Japan, non-Western countries are also included. These findings support the work by Stephens and Surprise (2020) who point out that research on SRM is mainly funded by sponsors located in the Global North. They argue that this phenomenon leads to a further concentration of political and economic power in the Global North.

5. Results from Discourse Analysis

In order to answer the second research sub-question, I will describe the results of the sociology-of-knowledge discourse analysis (SKAD) to discourse analysis. As outlined in both the theory and methods section, the results section is categorised into five dimensions that structure the various frames and storylines emerging from the discourse.

5.1. WHY: Which demand rationales structure calls for SRM research?

This first category, while not directly related to the Global South, presents the context for the categories of discursive structures that follow. In the following section, I will outline the demand rationales underpinning the calls for research on SRM.

5.1.1. Functional demand rationales

SRM research needed due to failure of mitigation strategies

There is a demand for research on SRM due to the global shortcomings in mitigating climate change. In literature, this is commonly referred to as poor performance or even failure *o*f mitigation efforts. Others say that current efforts are insufficient or only little progress has been made. Many share a sense of pessimism regarding future more aggressive mitigation and refer to the unlikelihood of aggressive mitigation in the near-term future. This argument is often based on the aspect of time as many state that emissions are not reduced fast enough to avoid dangerous climate impacts. As others put it, if global emissions are not cut soon and if current mitigation strategies do not succeed, SRM could serve as potential solution for limiting global warming. This is exemplified by Asayama et al. (2019) who carefully state that „if the pace of global CO2 emissions cuts is not accelerated soon, there might be an increasing demand to look into [..] solar geoengineering as potential 'extreme solutions'" (p. 21). Thus, research on SRM is considered important depending on current mitigation efforts as SRM is described as potentially reducing global temperatures and cooling the planet with quicker.

SRM research needed to reach 1.5°C climate target under Paris Agreement

Another functional demand rationale refers to the 1.5°C target as mentioned under the Paris Agreement. Thus, the need for the climate research community to consider SRM technologies is grounded on the perception that this target cannot or is unlikely to be attained anymore through emission cuts only. More careful framings entail that SRM would enhance chances to meet Paris goal or that SRM should be considered, even when possibly rejected, for its potential contribution to the 1.5°C target. Interestingly, some put the need for SRM forward as implicit demand from the

Global South as they were the ones who pushed for this ambitious target during the climate negotiations. However, others point out that they not necessarily endorsed SRM to reach this target, but rather aimed for strong mitigation pathways. Interviewees mention these first two rationales, namely international failure in advancing mitigation of greenhouse gases and doubts whether the 1.5°C climate target set out in the Paris Agreement will be reached.

SRM research needed as SRM is potentially more cost-effective than mitigation and adaptation

Another reason mentioned in order to justify research into SRM is its potential cost-effectiveness. SRM is described as relatively inexpensive compared to both mitigation and adaptation, often together with the rapidness of SRM in achieving results as Rickels et al. (2020) describe, "SRM technologies like stratospheric aerosol injection have prospects of altering the global mean temperature at rather low operational cost and almost instantaneously" (p. 1).

SRM research motivated by intellectual curiosity and career opportunities

On a more personal level, interviewees appear to be motivated by a strong interest in SRM research. This can be explained by for instance a fascination for SRM despite its controversy or its focus on providing technological solutions to global challenges. Especially early-career researchers seem to be motivated by career opportunities in this emerging field of research and the possibility of international exposure. As one early-career interviewee describes it, "I'm in this phase of life, while still many things come as an opportunity rather than a strong choice" (Interview 2). The more pragmatic aspect of funding being available in this field also motivated some to engage in research on SRM. Also, most interviewees have worked on related issues such as climate modelling before starting to become interested in SRM.

SRM research in order to create knowledge and clarify uncertainties

Another functional demand rationale evoked frequently during the interviews is the necessity of conducting research on SRM in order to create more knowledge on SRM. Through research, a better understanding of its risks and benefits should be achieved, knowledge gaps should be closed, and uncertainties should be resolved. As one interviewee states, "knowing is better than not knowing" (Interview 2). However, some acknowledge that it is impossible to achieve a full understanding of the potential impacts of SRM as there are also many unknow uncertainties. As one interviewee says, "we need to research to understand if it's an option or not [...] by doing research, it doesn't necessarily mean that it's going to be an option" (Interview 8). Also, it links to research to policy-making, so the role research is to inform policy-making based on facts.

5.1.2. Strategic demand rationales

SRM research to determine whether and how to reduce risks and impacts from climate change

This framing portrays SRM as an opportunity in order to potentially counter dangerous climate change and its associated risks and impacts. As Low (2019) describes, "the controversial idea of solar radiation management (SRM) has in recent years been the subject of growing debate as a form of geoengineering [...] aimed at counteracting the impacts of climate change" (p. 90). SRM is described as having the potential to reduce risks, especially when referring to worst-case climate scenarios, and counteract impacts of climate on humans and eco-systems. Some describe the legitimacy of SRM as a future strategy depending on how harmful climate change will be. Regarding the specific people and places for which SRM would potentially reduce risks, it is often referred to the global poor and vulnerable people and regions in the Global South. Researchers from the Global South justify the need for research on SRM by describing climate change as both alarming and serious. Of particular concern is the benefits SRM could have for their regions, the potential impact of climate change on the livelihoods on (vulnerable) people and the role SRM could play in protecting their livelihoods. Other strategic demands are driven by the motivation to minimise future adaptation needs and preventing climate migration from the perspective of both developed and developing countries.

5.1.3. Normative demand rationales

Research as moral obligation to the global poor

One of the main reasons for SRM research put forward in the scientific discourse is based on equity concerns for the global poor. This "social justice lens" is based on a distributive and consequentialist understanding of justice which is constructed in order to legitimise research. Some experts argue that there is a moral obligation to research SRM research in the interest of developing countries due to the harmful impacts of climate change on vulnerable people. Thus, not considering research on SRM would equal to the global rich not taking responsibility to deal with the historical inequities of climate change. Especially in the short-term, they argue, emissions reduction only will not mitigate all harms to the global poor. Therefore, knowledge creation on SRM has the potential to benefit everyone and particularly the global poor. The rationale behind this call for research in the interest of vulnerable people entails a demand for assessing the distributive outcomes and risks associated with climate change versus SRM, and whether SRM could reduce surface temperature faster than mitigation and cheaper than adaptation. The line between demanding research and deployment is often not as clear-cut as Hourdequin (2019) critically argues, "they [i.e. Horton and Keith] offer no reasons to think that SRM research alone will benefit the poor; without the link to

deployment" (p. 80). This demand for research on equity grounds can also be related to underlying strategic rationales, such as stating that research and even deployment of SRM out of national interests is legitimate if it benefits the global poor as side effect. Other authors are critical of these arguments and point to historical injustices not justifying SRM in order to protect the vulnerable but rather demanding aggressive mitigation, adaptation and funding hereof. Furthermore, they stress the potential of SRM to increase current and future inequalities. From the perspective of multidimensional justice, so arguing on the grounds of procedural and participatory justice, legitimising SRM research as moral obligation to the poor follows a paternalistic reasoning. Benefits for vulnerable people are only assumed as no data or consultation process becomes evident.

5.2. WHAT: Which interests of the Global South are constructed?

In the following, I will provide an overview of the interests of the Global South regarding SRM which are constructed in the scientific discourse.

Interests regarding climate change and SRM

First, I address topics related to *climate change* recurring in the scientific discourse. Yet, this can only cover some of the many aspects related to climate change. Many agree that increased risks and impacts of climate change cause damages which affect both humans and ecosystems and especially the most vulnerable, while inaction on both mitigation and adaptation continues. Some allocate responsibility for mitigation efforts in the Global North due to historical injustices, and few in both Global North and Global South except for least developed countries. It is considered important to understand the interests of the Global South regarding climate change better as some point out that peoples' attitude towards climate change potentially influence someone's attitude towards SRM. Researchers mention the correlation of serious concerns regarding climate change with openness to the possibility of considering solar geoengineering, referring to China and India. Sugiyama et al. (2019) conclude that "concern about climate change [is] one of the most important indicators of SRM perceptions, particularly among populations who are highly vulnerable to the impacts of climate change" (p. 643). Thus, especially climate vulnerable groups, who would suffer most from the effects of continuing climate change, are portrayed as being so desperate for solutions to reduce climate change that they could be more willing, yet reluctantly, to explore SRM. In addition, interviewees among six Asian countries would support SRM technologies stronger if costly mitigation efforts would be decreased. However, these results relate to relatively wealthy countries from the Global South. While mitigation is often mentioned in regard to SRM, adaptation is only briefly mentioned in the context of Global South countries receiving funds for adaptation and poor

countries having less resources for adaptation available. As one interviewee claims, adaptation is mainly absent from the discourse and researchers from the Global North lack understanding of adaptation in the context of the Global South.

Interests of Global South put forward by others

Secondly, I will outline which *interests of the Global South* regarding SRM emerge from the discourse. It is important to note that these interests are mostly put forward by researchers from the Global North, which can be proponents of research on SRM who use the Global South to justify research and critics who raise ethical concerns on behalf of the Global South. Some researchers emphasise the importance of research on SRM in the interest of the most vulnerable people and world's poorest people. As described in the demand rationale on SRM research as moral obligation to the poor, SRM is considered to potentially "alleviate some of the anticipated harms of climate change for some of the world's most vulnerable in the near term" (Hourdequin, 2018, p. 271). The potential benefits of SRM for regions such as Sub-Saharan Africa and South-East Asia, which suffer most from ongoing climate change, are described as high because SRM could limit the impacts of climate change. Based on the climate vulnerability of groups and regions from the Global South, proponents of research on SRM highlight a number of aspects why SRM could be in the interest of the Global South. SRM is portrayed as being faster and cheaper than mitigation and adaptation and thus as effective and practicable option to alleviate damages from climate change. SRM could buy time for economic development in developing countries associated with increasing emissions. Strategies such as buying time for aggressive mitigation, limiting adaptation needs, or peakshaving are deemed legitimate if they intent to protect people from the Global South. Opponents of SRM from the Global South, however, mention a number of ethical concerns related to responsibility, fairness and justice. As Suarez & van Aalst (2017) point out, "our main concern is that their voices will not be heard and considered with sufficient weight in decision making about SRM. This applies from decisions about investments in research to actual application at scale [...]" (p. 913).

Interests of Global South put forward by themselves

Thirdly, I want to highlight interests by the Global South raised by themselves or in their geographical context. As Bluemling et al. (2019) remark, "the role and position of major developing countries has hardly been studied, leading to only a very limited picture of the entire global problematique" (p. 365). Yet, Delina (2020) highlights literature on geoengineering that is relevant for the Global South regarding modelling at regional level, critique on current SRM research, and governance aspects. In the analysis, however, country- or region-specific viewpoints regarding the Global South barely emerge from the discourse, however, those few available show that most

opinions on SRM from the global South are ambivalent. On the one hand, there is a desire to benefit from technological development and to see whether SRM offers a solution to ongoing climate change. On the other hand, there are many concerns regarding SRM, especially regarding the potential impacts on the regional scale and its implications for climate vulnerability of people and regions. Most interviewees from the Global South describe a lack of public understanding of SRM regarding their respective countries. This can be mostly attributed to the prevalent low awareness of SRM and the related lack of knowledge of SRM, the science behind it, and potential risks and benefits. Priorities of stakeholders are often on other issues such as combatting poverty or environmental issues which are perceived to be more urgent. As one interviewee points out, "doing something we are experts in" (Interview 2), which is not SRM but for instance adaptation, is considered to be important. Resulting from this is a lack of funding and competition among research areas. This leads one interviewee to propose that due the scarcity of resources, the Global South should only follow the debate on SRM instead of conducting original research themselves. Resulting from the challenge of funding and potential competition with other fields such as national mitigation and adaptation, most interviewees stress the need for international funding which emerges as main interest. Other concerns by the Global South emerging from the discourse include the there is a lack of knowledge about the impacts of SRM interventions at the regional scale. Current research efforts only cover a small fraction of regions of the Global South. That leads to another concern being that SRM could have negative side-effects on vulnerable regions, and also transfer risks to the most vulnerable. Other aspects that are highlighted by people from the Global South include: concerns regarding equitable participation in debates, the credibility of models and their equity implications, reframing moral hazard as moral responsibility, and in general reconsidering framings present in the discourse, a lack of agency and self-determination, and compensation mechanisms in case SRM were to be deployed.

5.3. WHO: Which speaker positions are available in the discourse?

Current positions available in the scientific discourse linked to the authority to conduct research and produce knowledge on SRM are described in the following section. Also describe how speaker position means for Global South / Speaker positions do not give a complete picture but are rather competing framings of who has authority to speak.

Exclusive speaker position held by Western elite

The first storyline constructs SRM research as a rather exclusive endeavour which is reserved for mostly white men at elite institutions. As Delina (2020) writes, a "circle of experts in relatively

richer countries in the Global North currently lead most efforts to advance research on science and technologies, modelling, and the governance of geoengineering" (p. 975). Present framings in the discourse include concepts such as "(geo)clique", "elite", and "circle of experts" which characterise the SRM research sphere as hardly accessible. Also, these critical frames are mentioned along with ethical concerns such as elites aiming at perpetuating the carbon or economy geopolitical concerns such as adopting militarised approaches, the capture of research and policy agendas regarding SRM through elites and a continuation of exploitation of developing countries.

Predominantly Western speaker position

There is great consensus regarding SRM research and debates being centred in primarily Western countries and institutions, particularly the United States and Western Europe. Some state that, opposed to the first storyline under 3.1, SRM research is not exclusively happening in the Global North, but most of it. Interviewees from the Global South also point out that expertise on SRM is allocated in Western research communities. Some interviewees explicitly refer to their own role and stress that they do not see themselves as experts on the matter but rather as learners or followers. This shows that they do not perceive themselves in an authoritarian speaking position. Related to this framing of speaker positions being occupied by mostly Global North researchers is criticism targeting these discursive structures for exacerbating knowledge and power imbalances between wealthy and not wealthy countries and generally speaking, their unjust domination. Current modes of research on SRM and its funding are criticised for amassing epistemic and geopolitical power in the Global South. Therefore, the Western bias of research on SRM raises questions of epistemic power as it reinforces and exacerbates existing asymmetries in knowledge and expertise, which is even called expert imperialism by some. As Stephens and Surprise (2020) critically summarise, "solar geoengineering research – independent of the desires of individual researchers – maintains contemporary systems of power, which we define as systems of colonial capitalism that thrive on fossil fuels and the perpetuation of inequality, exploitation and domination buttressed by patriarchal white supremacy" (p. 3). Following this narrative, new research programmes aiming at involving more researchers from the Global South would still contribute to maintaining the Western-dominated systems of power.

According to this storyline, the involvement of Global South in research remains low, despite efforts create research capacity in the Global South through international collaborations or national research programmes. Most interviewees refer to themselves as one of the few academics in their country that are interested in SRM, follow the issue and work, mostly unpaid and only using a fraction of their time, on the matter. In contrast, research on SRM in the Global North is much more

institutionalised due to the resources available, as one interviewee describes "leading experts from Global North had to build up expertise by having the time, space, and, most importantly, the money". Especially when asked about further interview partners, most said that there are only few individuals and academics familiar with the topic or instead referred me to scientists from Global North countries. Some describe themselves to have a "following" role than being involved in original research. Despite their little actual involvement, vulnerable people are mentioned frequently in the debate, so this leads to the assumption that while they often do not have a voice in the debate, others speak on behalf of them for various reasons. Vulnerable populations are often cited by researchers from the Global North as a key reason to proceed with research as they argue that the deployment of SRM could potentially benefit them. Different frames emerge around research being legitimised by concerns for vulnerable populations, such as Western researchers as "risk managers" for vulnerable people on behalf of the Global South.

Growing speaker position of Global South due to increased efforts

While most research being allocated in the Global North, there are increasing efforts to build research capacity in the Global South, either through non-profit-initiatives such as the SRMGI or national research efforts such as in India and China. When it comes to research occurring elsewhere than the USA and Europe, the Solar Radiation Management Governance Initiative is frequently mentioned. The SRMGI which has been running public engagement workshops in the Global South for almost a decade and launched a grant programme, the DECIMALS Fund, to encourage epistemic work on SRM at Global South institutions. Selected research team receive funding in order to explore potential impacts of SRM on their regions. Part of the programme is to link the DECIMALS researcher with the GeoMIP community in order to obtain data. In addition, there have been attempts to include the Global South in public perception studies which are usually skewed towards Western countries. Critical voices point out that the few non-Western countries included in perception studies are usually either wealthy countries or only country being investigated, and the national results being taken as pars pro tot representing the whole region. Furthermore, research on SRM that is happening in the Global South often focusses on countries that are more populous than other and possess geopolitical relevance such as India. This means that less powerful and more vulnerable voices from other countries in the Global South could also be subjugated to more powerful opinions also from the Global South. Also, an interviewee points out that researchers from the Global South that are involved in the research on SRM are usually part of the national elite. This shows how difficult it might be to include the opinions of researchers from the Global South and particularly vulnerable people.

Exclusion of Global South and particularly vulnerable people

Despite efforts to increase the representation of researchers from the Global South mentioned previously, many argue that their engagement and involvement is still rather low or even that their voices are not present at all. This means that according to this storyline the diverse perspectives and concerns of the Global South are barely part of the research and debate or not even all. As one interviewee describes it, "when it comes to the discourse on SRM in in Africa, who people discussing SRM are very, very limited. And decimal seems to be the only the only ones that sporadically discusses and maybe very few privates that are doing it as private research and the likes." (Interview 7).

Regarding the role of the vulnerable, Hourdequin (2019) mentions that "vulnerable populations have not yet been included as equal partners in deliberations, planning, and research concerning SRM" (p. 449). If benefits to the vulnerable are prioritised based on equity grounds, then they should be recognised as active subjects instead of passive agents and undifferentiated objects in an expert discourse (Jasanoff, 2003). Even if the more geographically diverse speaker positions are available in the debate, how to guarantee the inclusion of vulnerable people? "You cannot get an illiterate farmer or fisherman to become a computer modeller of SRM." (Interview 5). It cannot be assumed that scientists from countries with some regions or groups particularly at risk from potential negative impacts of SRM would automatically speak in interest of especially vulnerable.

5.4. WHY: Which demand rationales structure calls for GS engagement in research?

Calls for global conversations, engagement of more voices from the Global South, and ultimately knowledge production by the Global South are widespread in the scientific debate. As one interviewee explains, the "research community should be more representative of the whole humanity" (Interview 3). On the other hand, this widespread recognition is contradicted by actual participation in knowledge production and the resulting status of literature. As Nicholson et al. point out, "there is much work to be done to broaden the foundation to [..] underrepresented groups who may be impacted by SRM governance decisions and to ensure full engagement by relevant expert communities (Nicholson et al., 2018, p. 324). This observation correlates well with the need for engaging the Global South particularly. In the following, I want to illustrate which rationales emerge from the discourse calling for the involvement of the Global South.

5.4.1. Functional demand rationales

Better research through considering cultural, ethical and geographical aspects through GS researchers

The following functional demands for GS engagement emerging from the discourse are all based on the understanding that involving researchers from the Global South would lead to better research. For instance, including contributions from the Global South could further the understanding of SRM in their context and also relate it to other topics such as democracy and accountability. Calls for research are motivated by the need to create local knowledge on GS regions and by GS researchers. This should allow for debates among stakeholders in order to assess whether SRM is a potential option or not which is described in more detail under strategic demand rationales. While SRM is often considered as addressing climate change at the global scale, some authors note that it is important to study SRM at more localised scales and in relation to different cultural, historical and geographical perspectives (Buck, 2018). This is because local discrepancies in radiative forcing as a result of deployment could lead to regional climate changes, and because the impact of solar geoengineering on precipitation and the hydrologic cycle is not well understood (NAS 2015). Importantly, this research should be conducted by researchers from the Global South themselves as one interviewee explains, "Not, for example, a person from region B does the study and say region A is going [..] to be impacted in in this way, without the local knowledge." (Interview 8). The engagement of researchers from the Global South is deemed necessary because of to the *different values and local knowledge* prevalent in certain countries or cultures. As one interviewee describes, "So I will understand more the needs of the people from the Global South than somebody from the Global North." (Interview 7). This rationale intends to enrich existing studies which are led by Global North scientists. As the deployment of SRM would have global effects, the associated technologies should be assessed from all kinds of cultural backgrounds and cultural knowledge in order to enrich existing research. For instance, risks associated with SRM are interpreted differently across cultural and geographical backgrounds. Interviewees point out to the importance on being involved in research on regional and local level in order to understand the potential impacts of SRM on their own region. Thus, research taking regional and culture-specific aspects as well as prevalent local knowledge into account and being conducting by researchers from these regions is argued to be desirable from a functional perspective. Some argue that this geography-specific research could help to counter geographic imbalances in knowledge production on SRM, and, thus, decrease the risks of what is described as "elite capture of research and policy agendas" (Delina, 2020, p. 975).

Solving little GS engagement

Many open questions regarding the type and the stage of engagement in order to *solve the "problem" of little GS engagement* emerge from the discourse. Following the logical of the functional rationale would mean to try and solve the problem of too little GS engagement. However, there are many open questions linked to this rationale. For example, it remains open at what point in the process people from the Global South should be involved, and, above all, in what way depending on the degree of participation that is desired, and which groups from the Global South. Normative claims that broad public engagement is needed "from the earliest states of the SRM conversation" (Nicholson et al., 2018, p. 324) are contradictory to the actual low involvement of the Global South as the conversation on SRM has already moved past this early state (see development of publication trend in chapter 4.1). Others support this claim by stating that a just governance mechanism would imply representation of vulnerable populations at the deliberative phase itself. The examined literature shows that various form of public engagement with different participatory standards are currently promoted such as information-sharing activities for instance through focus groups, and dialogic forms of engagement for instance in the form of deliberative workshops.

5.4.2. Strategic demand rationales

Involvement of the Global South not needed for strategic reasons

The interviewed researchers from the Global South all agree that GS engagement is important and that they should definitely be involved, but to different degrees. However, as GS involvement is still considered to be low, there could be *hidden strategic rationales* present in the discourse that do not support GS engagement. Barely any author openly states that developing countries should *not be engaged* or why they should not be engaged. As one interviewee notes, more questioned this a decade ago. One example shows that geoengineering is described as no issue for developing countries that are not emerging powers and instead, developing countries should focus on economic growth and adaptation.

Geopolitical and environmental concerns

Another strategic rationale put forward by some authors is that international research beyond the prevailing Western research bias is needed due to *social and environmental concerns* and, thus, to assess the potential ecological, environmental and (geo)political ramifications of SRM on regions.

Achieving social acceptability and legitimise decision-making

Some authors argue that including the international research community and their perspectives on and perceptions of SRM is needed in order to *create social acceptance* and to *increase the levels of*

perceived fairness. Collecting perspectives beyond the Wester bias is considered important in order to create social acceptability for SRM governance. Also, public involvement will lead to higher levels of perceived fairness regarding decision-making processes. Eventually, the research of global public perceptions is deemed necessary in order to *legitimise research and decision-making* on SRM. Knowledge creation by the Global South is seen as important in order to achieve a better understanding of risks and benefits of SRM and clarify scientific uncertainties. Countering Western-based knowledge production by assessing SRM for themselves would allow for national and local debates among stakeholders in the Global South. By starting a broader conversation about SRM like the Global North and engaging different stakeholders, the Global South should be enabled to make their own informed decisions regarding SRM. Broad debates led by the Global South could empower them not just to be followers in SRM but to form their own opinions. Others frame not involving the Global South as an *obstacle to global conversations*. Related to this, interviewees consider the involvement of GS researchers important in order for "the topic [SRM] to move faster" (Interview 2) and consider the *Global South as driver of innovation in climate policy.*

Critique on current engagement Global South

However, some *critical voices* emerge from the discourse stating that expanding the global distribution of researchers on SRM does not address the structural power imbalances inherent to the research and governance of SRM. In addition, mechanisms that aim at a more inclusive participation of people from the Global South are described as potential "vehicle to generate consent" (Stephens & Surprise, 2020, p. 3) for policies prescribed by Northern actors. Another critical frame related to a strategic but also normative rationale addresses the concern that the debate will shift from promoting ambitious mitigation to enhancing capacities of the Global South, and, thus, becomes less about historical responsibilities.

5.4.3. Normative demand rationales

Emancipatory approach

One interviewee aptly illustrates the core of the emancipatory approach: "How would you feel if someone changed your rainfall on your behalf? Would you mind if I changed your rainfall and temperature on your behalf? Because I do." (Interview 5). An *emancipatory claim* to participation emerges from both some interviews and some papers, calling for the interests of the Global South, especially the vulnerable and marginalised, to be represented by themselves and not others. As one interviewee points out, "We cannot be just an object that would suddenly be impacted by SRM deployment" (Interview 6). Authors that follow an emancipatory approach argue that the voices of Global South actors need to be included to take the needs of the people most vulnerable to climate

change impacts into account. Thus, the current debates should become more inclusive to decrease the marginalisation of the most vulnerable. This is particularly important to address the current imbalances in knowledge production in the SRM. To counteract this imbalance and the accompanying marginalisation of the Global South, the public and researchers from the Global South should be given a voice in the discourse.

Global impacts of SRM

Some point out the global character of SRM meaning that the deployment of SRM would have *global consequences*, and, thus, everyone affected has a right to be involved. As one interviewee points out, "everybody must be involved in making decisions about whether or not and if yes, how, and if not, how to live with the consequences" (Interview 1). Due to the global impacts and related concerns SRM would have if ever deployed, those affected should have a say about whether or how research should proceed. Since research is considered "the gateway for potential wide-scale deployment" (Sugiyama et al., 2017) scientists from the Global South should have a right to influence whether and how research should proceed. This makes some kind of global conversation necessary for the future governance of SRM. This would also involve international research with affected stakeholders being listened to and actively participating.

High vulnerability to uncertain and potentially adverse side-effects

Another normative rationale evoked in the discourse justifying the need for more engagement of the Global South is based on the *potential side-effects* SRM could have on them and their related *particular vulnerability*. Vulnerability is framed as being likely to suffer the worst outcomes from SRM deployment. The deep uncertainties of the potential impacts and their probability to impact vulnerable people disproportionally require public deliberation, and, thus, a broad societal debate including scientists and ordinary citizens from the Global South. This proposal goes beyond the limited public engagement exercises done so far as there is an explicit call for "including indigenous and socially disadvantaged people that might be disproportionately impacted by deployment" (Sugiyama, 2017, p. 6). Another aspect mentioned is that global power dynamics are currently not set up to ensure the assessment of the risks that the most vulnerable face. As one interviewee points out, the impacts of SRM are unlikely to be equal across the world and the Global South will be worse off - "that's the way it always works" (Interview 1). Even if the potentially negative impacts of SRM would be the same around the world, due to their vulnerability and missing capacities, Global South would struggle with dealing with them.

Consequence of "moral obligation to the poor"

Another frame emerges when thinking further about the normative rationale behind SRM research as *'moral obligation to the poor'*. Although not commonly mentioned, some authors argue that the logical consequence of referring to vulnerable people in arguments for geoengineering, then the engagement of these groups and their priorities must be more explicit.

5.5. HOW: How is and should the Global South be engaged in knowledge production?

Current modes of knowledge production in the Global South

Besides an internationally funded research programme on SRM in India, the Solar Radiation Management Governance Initiative (SRMGI) is the main mechanism inviting researchers from the Global South into the knowledge production on SRM. The interviewees describe the SRMGI as an important step in the right direction towards knowledge production in the Global South as most say that this is the only opportunity for them to get involved in this field of research. However, they are aware that it only covers a few countries and regions and is thus limited. Besides the research itself, community building among the scientists from the Global South but also between them and scientists from the Global North is a crucial aspect of the SRMGI and the DECIMALS fund. International collaboration with so-called volunteers plays an important role in formulating the results of the research. The extent to which international scientists are involved in the Global South research projects varies depending on the local teams.

Need for opening up debate and building interdisciplinary knowledge communities

Many argue that there is a gap regarding the involvement of *multi-, inter-, and transdisciplinary research* of geoengineering techniques and promote the need for interdisciplinary knowledge communities. Current attempts aiming at capacity development in the Global South focus on aspects of natural science; but it is noted that it is particularly challenging to create an inter- and transdisciplinary cohort in the Global South and acquire funding for it. Interviewees from the Global South support this call for more interdisciplinary research. Some authors also stress the need for distributing capacity more equally, establishing an international governance body with those not represented from the Global South and involving those groups on whose behalf claims for SRM are currently raised. Producing knowledge on SRM would thus require not only inputs from modelers and natural scientists but from a range of researchers and stakeholders with various backgrounds. Opening up the debate to collaboration among academic disciplines and different actors could pave the way to towards more responsible research. Yet, "transdisciplinarity might very well also bring into a situation where the debate on solar geoengineering is trapped by entrenched divisions

between the pros and cons of further research" (Asayama et al., 2019, p. 30). Asayama also mentions the danger of reducing diverging opinions prematurely to one consensual position.

Need for innovative ways of public engagement

In the research community on SRM, many *call for public engagement* which resulted in numerous studies being published based on workshops and surveys. However, most public engagement studies are based on Global North publics and experts. The few attempts (Winickoff et al., 2015) at engaging the Global South on the discourse on SRM are called extraordinary. Thus, a need for involving currently underrepresented groups and expert communities of both the public and experts emerges. Increased global engagement could possibly result in framings in current discourse being revised from the perspective of non-Western paradigms. Several studies on public perceptions of SRM have been conducted in the past, but few directly involved the public or other stakeholders in scenario development. Related to the normative rationale that engagement should not only be about voicing interests but also active participation, more innovate research designs are put forward by some including participatory scenario research. While most acknowledge that research on public perceptions is important in order to inform a democratic discourse on SRM, some point out to the risk that this type of research could be used instrumentally by powerful actors to legitimise their own positions.

Need for region-specific empirical data

Another mode of knowledge production in regard to the Global South is to conduct *empirical studies* specific to regions in the Global South. Although region-specific data is only available for a few countries in the Global North, many authors have stressed the need for region-specific data for global assessments and policymaking. However, this is not necessarily connected to a call for region-specific research with the consultation of researchers from the Global South or even research by Global South researchers themselves. Some call for a "truly Global South scholarship", thus, research by Global South researchers, in order to assess potential harms and benefits and whether SRM should be considered by policymakers. In addition, some refer to Rahman et al. (2018)'s proposal to prioritise research on local effects and impacts of SRM and give developing countries a leading role in research on SRM.

Need for global dialogue

Occasional calls for other forms of engagement include the idea of a *global forum* to initiate a dialogue between various actors and develop shared norms regarding SRM research and governance. Others stress the need for a *dialogical approach* that should be inclusive and recognise diverse perspectives and local conditions such as cultural traditions and past experiences with technology;

especially of those that are most affected by climate change and have been historically marginalised.

6. Discussion

6.1. Key Findings

With the help of bibliometric analysis, I assessed representation quantitatively in order to answer the first research sub-question. Therefore, I illustrate to what extent academic stakeholders from the Global South are represented in the scientific community of solar radiation management. Since the last decade, the number of publications on SRM has risen sharply, and also the number of articles on SRM in relation to the Global South has increased recently. However, with 14%, the share of journal articles dealing with SRM and the Global South in the total number of journal articles is low. Conversely, this means that 86% of all journal articles on SRM do not explicitly refer to the Global South. Research on SRM is a multi- and interdisciplinary research field with environmental sciences, earth and planetary sciences and social sciences being the most common disciplines. Relatively speaking, journal articles on SRM related to the Global South are more likely to be published in journals from environmental sciences, social sciences, and arts and humanities. Most of the scientific output on SRM is produced by authors from the Global North; and in those cases where non-Western authors are involved in knowledge production, they are from wealthy countries such as Japan. Thus, the Global South remains relatively underrepresented in knowledge production on SRM. While sponsorship of SRM research seems to remain in the hands of funding institutions from the Global North, the affiliations of authors involved in research on SRM see to be more diverse in terms of geographical representation. What becomes evident when comparing bibliometric data for the selected categories between the scientific output with and without regard to the Global South is that it is not necessarily the few authors or institutions from the Global South that discuss SRM in a Southern context.

In order to answer the second research sub-question, I conducted a sociology-of-knowledge discourse analysis (SKAD). This allows for answering the second research sub-questions, thus, identifying the discursive structures that shape the recognition of the Global South in the scientific discourse on solar radiation management. First, I identified demand rationales underpinning calls for research on SRM. Rationales are of strategic, functional, and normative kind and all emphasis the need for research. Secondly, I analysed which speaker positions are available in the discourse. Speaker positions possessing the authority to conduct research include conceptualisations of exclusively Western research by elites and predominantly Western research. Some attribute a growing speaker position to the Global South due to efforts over the last decade, however, others say they, and especially those most vulnerable to climate change and the potential side-effects of

SRM, are entirely excluded. Thirdly, I investigated the interests of the Global South that are constructed in the discourse. These interests are divided into two groups, depending on the speaker. While others construct SRM as potential chance but also risk for the Global South, researchers from the Global South stress that awareness on SRM is very low which makes it difficult to assess. Fourthly, I considered another set of demand rationales, specifically those that underpin calls for the engagement of the Global South. Again, these are divided into functional, strategic, and normative claims. Lastly, I investigated modes of knowledge production involving the Global South. Most storylines emerging from the discourse are of normative character and stating how research should be, for instance, inter- and transdisciplinary and more equally distributed.

6.2. Reflecting on Results

The results of the bibliometric analysis fall in line with previous research and confirms the low representation of the Global South in knowledge production on SRM. Yet, the research community seems to be growing and becoming more diverse in terms geographical representation. However, this mostly concerns influential countries of the Global South such as India or South Africa. Other regions, such as Latin America, seem to be entirely excluded from the scientific debate. The sociology-of-knowledge discourse analysis (SKAD) allows for identifying how discourse shapes the way how we talk about certain things. In this case, how we talk about why research on SRM is (not) needed, who is conducting research on it, what are aspects relevant to the Global South, why the Global should (not) be involved, and how the Global South is and could be involved in knowledge production. Identifying what is not said in the discourse is an important element of discourse analysis (Keller, 2011a). This would be particularly relevant for this research as there seems to be a large contrast between widespread calls for involving more actors from the Global South and their actual quantitative involvement. Therefore, I suggest that there are *hidden rationales* that could not be identified in this research which do not support the claims for increasing involvement of the Global South. Analysing these would have required an informal entry into the research field, for example, through participation in conferences. The same applies to rationales calling for research on SRM. While the interviewed researchers from the Global South perceive research on SRM as very important, there are certainly many actors from the Global South, also in the academic world, who oppose research. Again, these rationales against research on SRM were not identified in this paper as they were not common in the selected data. What makes it more convenient to agree with the need for research is the widespread *logic of differentiation between supporting research or deployment*. This development is part of the whole discourse on SRM shifting towards mainstream consideration (Jacobson, 2018). According to Jacobson (2018), this discursive distinction was put

forward by scientific assessments report on SRM as has led to the decoupling of concepts. However, these concepts are intertwined, since in the discourse potential risks and benefits of deployment are discussed frequently, not those of research.

6.3. Reflecting on Dominant Structures

So far, I have collected and presented the storylines and frames underpinning the total of five different types of discursive structures. This leads to two important related questions: First, which of these structures seem to dominate the scientific discourse? And secondly, which storylines are predominant within each structure? While further empirical analysis would be required to fully answer these questions, I will prefer a first and brief indication in the following. In order to be able to determine how common and frequent different statements appear in the discourse, I use NVivo to document their occurrence. For the prevalence of statements, I measure the representativeness of their category, i.e. in how many of the 44 journal articles they appear. For the frequency of statements, I examine their weighting, i.e. record how often they occur in the respective journal articles. Tables including the categories used and their representation and weighting in the discourse can be found in Appendix E. I will not compare the representation and frequency of storylines and frames based on data type, so between those emerging from the journal articles and those emerging from interviews. These two types of data are hardly comparable due to their different number and type.

Comparing the five types of structures (1-5), I conclude that demand rationales underpinning the need for research on SRM are most frequently evoked. (1) Among these rationales, strategic considerations aiming at the assessment of the extent to which SRM could possibly reduce climate change risks and impacts are most prominent. Another rationale which is also frequently evoked is the necessity of research on SRM in order to reach international climate targets. (2) Regarding the second discursive structure, the available speaker positions, the storyline of speaker positions being occupied by predominantly Western speakers is mentioned in the highest number of articles. (3) Considering the interests of the Global South no strict distinction between the different storylines can be made as they all appear in the same amount of journal articles. Only the frequency varies slightly as interests of the Global South put forward by themselves are mentioned most frequently withing these articles. (4) I have identified multiple demand rationales underpinning calls for engaging the Global South in research which makes it more difficult to identify the predominant ones. Taking all storylines into account, normative demand rationales seem to outweigh other rationales as many call for more engagement of the Global South on normative grounds. (5)

Regarding the modes of knowledge production and engagement of the Global South, calls for future research demand inter- and transdisciplinary research including public engagement and a stronger focus on regional assessments in the Global South.

From a methodological point of view, identifying dominant structures is challenging. The research design of this research involved the analysis of journal articles which belong to the secondary literature. In order to be transparent, it is important to mention that for each journal article the coded statements reflect the scientific discourse and not automatically the opinion of the authors. Therefore, the identification of the representativeness and weighting of statements does not automatically translate into the number of researchers making one specific statement. The reason is that an author of secondary literature could refer to another secondary paper written by an unknown number of authors, or primary literature, again written by an unknown number of authors, or even own observations. To fully measure representation and frequency of statements and taking this methodological concern into account would go beyond the limits of research project.

6.4. Sensitivity Analysis of Bibliometric Analysis

In order to assess the validity of the results, I will highlight sensitivity regarding the bibliometric analysis and data applied in this research.

The selected counting method has a decisive effect on the results of the bibliometric analysis. As I explained and justified in chapter 5.3.1. under data analysis, I chose the whole counting method. Apart from the advantages, this method also has a specific disadvantage which is important to take into account. Through the whole counting method, journal articles with more than one author are weighted stronger, since their respective affiliations are measured in the same way as if they were a single author of an article. In addition, authors with more than one affiliation are weighted stronger since additional affiliations are counted in the same way. In the following, I explain whether this influences the results significantly. The underlying data can be found in the Appendix F.

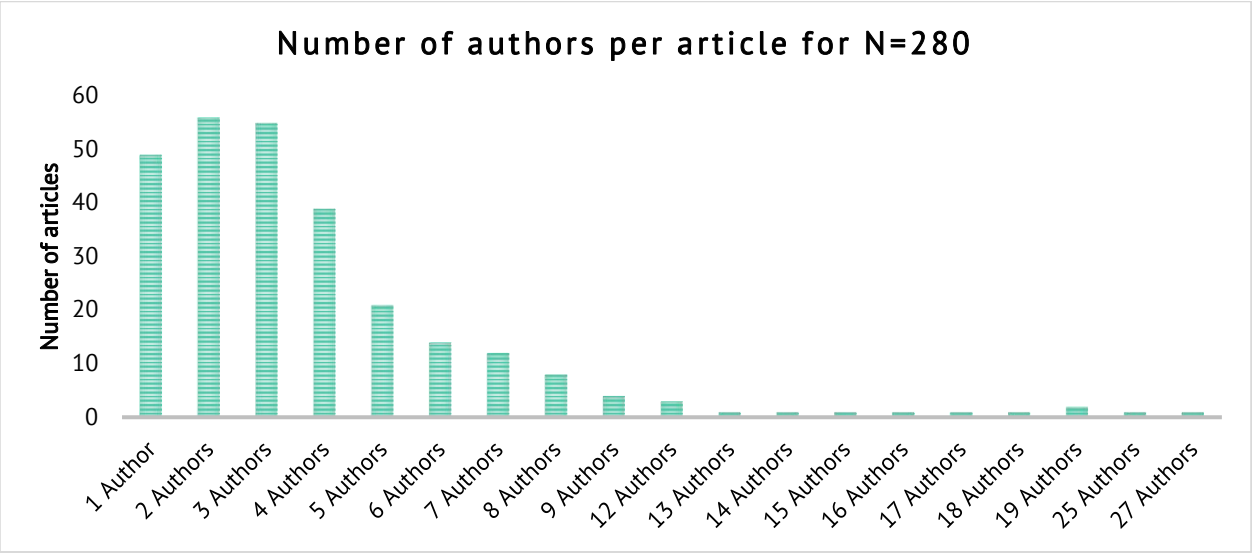

Figure 15. Distribution of authors per article for all articles on SRM not considering the Global South (Query 1-Query 2)

Regarding the *distribution of authors* per article, most articles are authored by between one and four authors. With over 70% of all articles being written by not more than four authors, this applies to the articles on SRM not mentioning the Global South (Figure 15). This is also true for the articles on SRM mentioning the Global South, as over 60% of them are written by not more than four authors (Figure 16). There are only a few outliers with an extremely high number of authors. Therefore, I regard the risk of potentially overrepresenting authors' affiliations and, consequently, their country, as low.

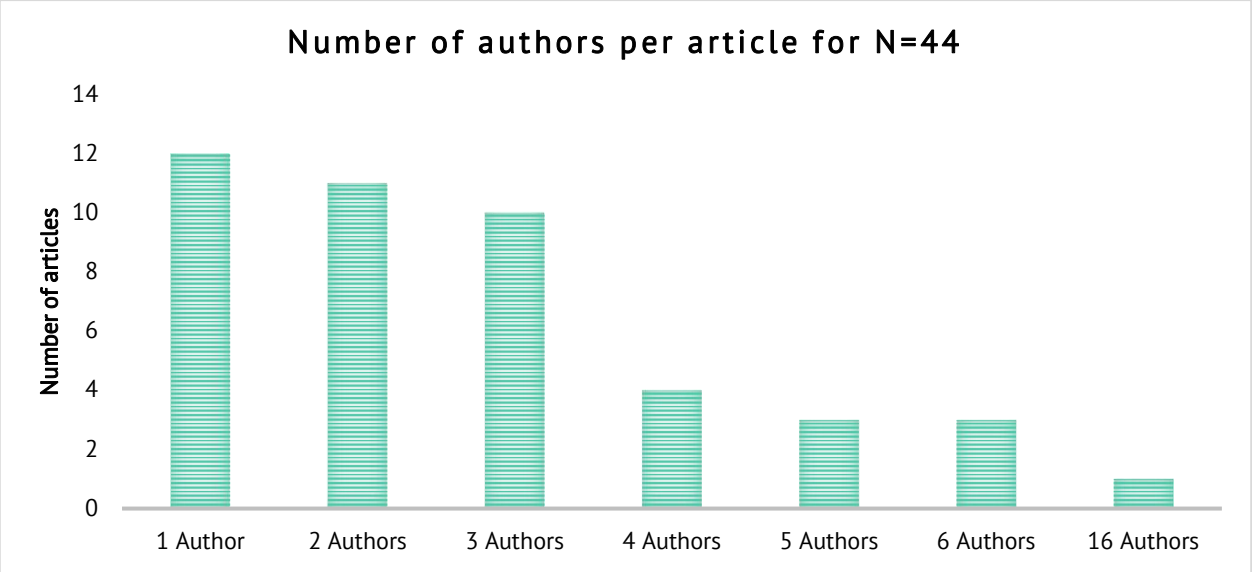

Figure 16. Distribution of authors per article for all articles on SRM considering the Global South (Query 2)

Regarding the *distribution of number of affiliations* for all authors, I want to investigate how frequent authors belong to more than affiliation. First, I will look into the distribution of affiliations for authors of the 280 articles on SRM without reference to the Global South (Figure 17). Of 1080 authors[2], 89% are affiliated with one affiliation only. The remaining 11% are either affiliated with two or three affiliations

[2] The number of authors is based on the number of contribution one author has made. If author A has coauthored five journal articles on SRM, he/she is also counted five times. This means that N=1080 is not the absolute amount of different authors who have published on SRM between the years 2009 and 2020.

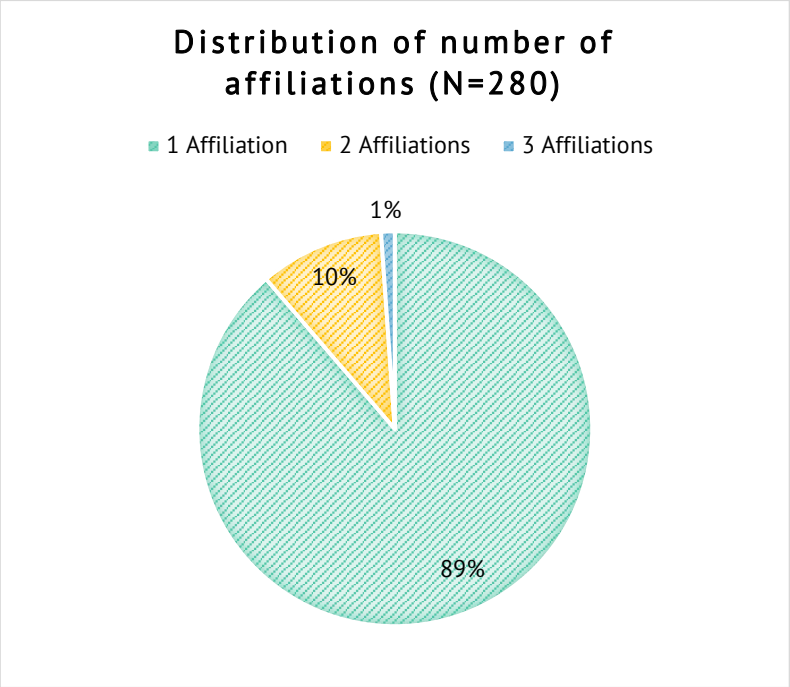

Figure 17. Distribution of number of affiliations per author (in %) for Query 1-Query 2 (N=280)

For the remaining 44 articles on SRM with reference to the Global South (Figure 18), 92% of the 131 authors are working for only one affiliation. Again, the remaining 8% are either affiliated with two, three or four affiliations.

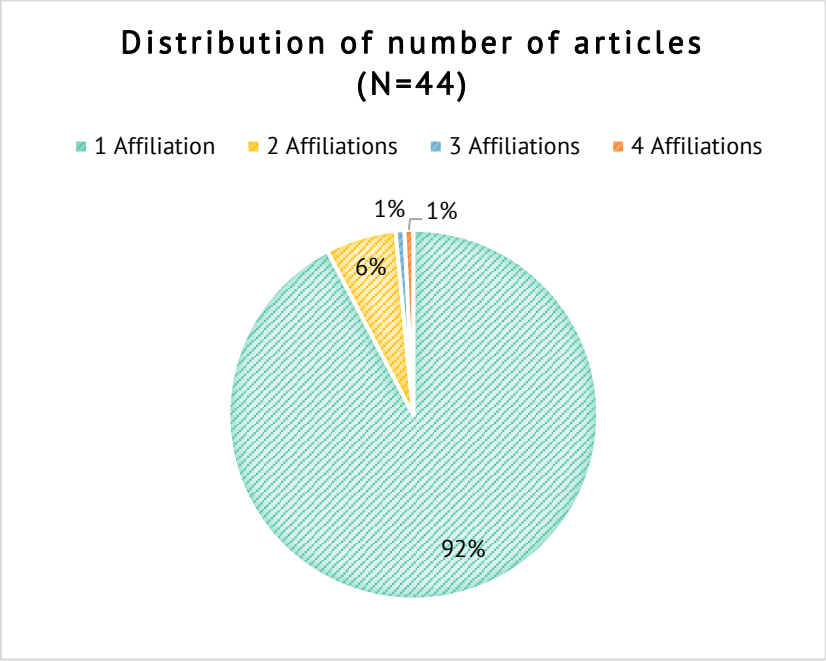

Figure 18. Distribution of number of affiliations per author (in %) for Query 2 (N=44)

The outcome of assessing the sensitivity of results from the bibliometric analysis show relatively low influence. I conclude that the validity of the results was only affected to a small extent by the whole counting method.

6.5. Limitations and Future Research

There are several limitations based on the research design and selected data types and methods, also due to the complexity and the novelty of the research topic at hand. In the following I will present the most prominent one, also pointing out to gaps that might be worthwhile for future research to address.

I consider my findings to be of rather explorative nature. Especially the discursive structures are not comprehensive but rather a starting point for future research. They can serve as indications and are thought-provoking for future enquiry. For instance, the chosen data types, i.e. journal articles and interviews with researchers, lead to ignoring an essential question: Should research on SRM be done at all? This is an inherent challenge of the chosen data type as it would be unusual to find articles by researchers that work on topics related to SRM but are against research per se. Instead, one could examine informal output such as blog posts, discussion papers and talk to selected opponents. Also, interviewing researchers from related research areas might be worthwhile talking to. They might be aware of geoengineering or SRM but not be in favour of research.

There are also a few limitations regarding the data types and data collection process. Even though peer-reviewed journal articles are important scientific output, they also present a high barrier for the Global South to engage in. More informal output such as blog posts or grey literature might have yielded more literature on the Global South. Also, the selection of interviewees is slightly biased as junior researchers were more willing to participate in my research. Professors and experienced researchers from the Global South might have influenced my results in a different direction. Widening the number of interviewees is a recommendation for future research on this topic as saturation regarding this data type has not been reached in the sampling process.

Future research from social science could analyse SRM with a postcolonial lens or with a stronger focus on multidimensional justice. These two approaches seem to be promising in order to contribute to the growing body of literature on SRM. Especially the postcolonial lens could help to analyse relationships between SRM and postcolonialism as the effects of colonialism still affect countries of both Global South and Global North in many areas such as politics and science (Franzki & Kwesi Aikins, 2010). One research interest of postcolonial theory is to criticise the neo-colonial power relations that exist and e.g. shape scientific discourses on geoengineering today (Castro Varela & Dhawan, 2020). A postcolonial lens could serve as a criticism of eurocentrism with Europe (and North America) being the privileged space of modernity (Matin, 2013) where knowledge and decision-making on geoengineering takes place.

7. Conclusion

This research aims to shed light on the extent to which Global South actors and their interests are (not) represented and (not) recognised in the knowledge production on solar radiation management. In order to answer this main research question, I first conducted a bibliometric analysis of the scientific output on solar radiation management in order to examine representation in a quantitative manner. The number of publications on SRM has risen sharply, and also the number of articles on SRM in relation to the Global South has increased recently. However, 86% of all journal articles on SRM do not explicitly refer to the Global South or related terms. I conclude that academic stakeholders from the Global South are barely represented in the scientific community on solar radiation management. However, the participation of researchers from non-Western institutions is slowly increasing. Secondly, I conducted a sociology-of-knowledge discourse analysis (SKAD) and identified the discursive structures that shape the recognition of the Global South in the scientific discourse on solar radiation management. The structural analysis of discourse shows that calls for engaging the Global South in the debate are widespread, but there are only few indications for their interests being recognised in the discourse. So far, underpinned by normative or strategic rationales, the Global South is often spoken for by scholars from the Global North. Since there is only low representation of the Global South in the discourse, only a few of their interests emerge in discourse. Thus, the recognition of these is strongly limited by the low representation of the Global South and the prevalent dominant speaker positions of the Global North. I argue that this exclusion of the Global South who are most vulnerable to climate change is an enormous obstacle to participatory justice and recognition justice. Discursive structures shaping the modes of knowledge production and the engagement of the Global South do highlight aspects relevant for the future. However, it remains open whether these will lead to the Global South becoming represented and recognised as legitimate participants in the scientific discourse on SRM.

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Appendix B. Interview Guideline

First, thank you for taking the time. I really appreciate it.

If you don't mind, I would first briefly introduce myself and my research project: I am Alina and currently working on my master's thesis research project. I am following the research master's programme Sustainable Development with a focus on Earth System Governance at Utrecht University.

In my thesis, I try to understand better how researchers and people from the Global South and their interests are (1) represented and (2) recognised in debates. So far, I have analysed peer-reviewed articles published on the topic of SRM over the last decade (retrieved from Scopus). To add to my findings, I am conducting semi-guided interviews with members of the scientific community regarding SRM.

Before we can start, I would like to go through some formalities. In my thesis report, you will be completely anonymised. Also, I would like to record the interview in order to be able to transcribe it and make use of it in a scientifically correct way. Is that fine with you?

I have prepared a consent form summarising all aspects. I would need your signature on it in order to be allowed to use this interview for my thesis. If that is fine with you, I would ask to send me the signed form after our talk.

Alright! Any questions so far?

Table 6. Interview guideline

	MAIN QUESTIONS	FOLLOW-UP QUESTIONS	CHECK – HAS THIS BEEN MENTIONED?
PART 1: INTRODUCTION	▪ I would like to ask you to briefly introduce yourself?	[What would you say is your geographical affiliation?]	- Background - Role/position
PART 2: MOTIVATION/INTEREST	▪ What was your motivation to start working on the topic of solar geoengineering/SRM?		- Motivation - Rationale behind own engagement
	▪ Which aspects of SRM interest you most?		- Research priorities
	▪ Could you share your own experience with SRM research?	Can you summarise the results of your research? (Main findings) Did you reach out policy makers?	- Personal involvement - Main findings
PART 3: RESEARCH ON SRM	▪ What is your opinion on the necessity of research (and maybe deployment) of SRM in the context of Global South countries?	How would you describe the associated risks especially compared to risks posed by climate change?	- Arguments for/against research of SRM in context of GS - Arguments for/against deployment of SRM in context of GS - Weighing risks
	▪ How would you describe the role of researchers from the Global South in the current scientific debate on SRM?	What role, voice, or agency do the vulnerable currently have in geoengineering decisions?	- Scope of GS engagement - Character of GS engagement - Authority
	▪ Why do you think it is important to involve stakeholders from the Global South into the debate?		- Quantitatively: More? - Qualitatively: better?
PART 4: DISCURSIVE STRUCTURES	▪ Which mechanisms/structures are in place to ensure vulnerable peoples' concerns are taken into account?	How should that happen? What needs to be put in place?	- Available funds etc. - Future prospects - Challenges
	▪ What are challenges when it comes to creating research capacity in the Global South?		- Understand local context

Appendix C. Informed Consent Form

For participation in MSc thesis project: Representation and Recognition of Global South Actors and their Interests in Knowledge Production on Solar Geoengineering

conducted by: Alina Weiss, MSc Student at Utrecht University

To be completed by the participant

I confirm that:

- I am satisfied with the received information about the research;
- I have been given opportunity to ask questions about the research and that any questions that have been risen have been answered satisfactorily;
- I had the opportunity to think carefully about participating in the study;
- I will give an honest answer to the questions asked.

I agree that:

- the interview data will be anonymised;
- the interviews will be recorded for scientific purposes.
- the data to be collected will be obtained and stored for scientific purposes;
- the collected research data can be shared with other scientists (e.g. supervisor).

I understand that:

- I have the right to withdraw my consent to use the data;
- I have the right to see the research report afterwards.

Name of participant: _____

Date: ___ / ___ / ____

Signature: _____

To be completed by the investigator

- I declare that I have explained the above mentioned participant what participation means and the reasons for data collection.
- I guarantee the privacy of the data.

Name of investigator: Alina Weiss

Date: _____

Signature: _____

Appendix D. Data Tables for Bibliometric Analysis

Table 7. Peer-reviewed articles that (not) mention Global South Actors and interests

Year	Articles on SRM not mentioning GS	Articles on SRM mentioning GS	Articles on SRM mentioning GS (in%)
2009	2	0	0,0%
2010	4	0	0,0%
2011	7	0	0,0%
2012	13	0	0,0%
2013	30	2	6,3%
2014	30	1	3,2%
2015	28	3	9,7%
2016	32	1	3,0%
2017	26	4	13,3%
2018	48	9	15,8%
2019	25	11	30,6%
2020	35	13	27,1%
total	280	44	13,6%

Table 8. Subject areas of peer-reviewed articles

Subject area	Articles on SRM total	Articles on SRM not mentioning GS	Articles on SRM mentioning GS
Environmental Science	166	135	31
Earth and Planetary Sciences	146	133	13
Social Sciences	87	67	20
Energy	32	28	4
Arts and Humanities	29	23	6
Medicine	22	19	3
Engineering	21	20	1
Economics, Econometrics and Finance	20	15	5
Physics and Astronomy	15	15	0

Multidisciplinary	13	13	0
Mathematics	12	12	0
Agricultural and Biological Sciences	10	10	0
Biochemistry, Genetics and Molecular Biology	6	6	0
Chemistry	6	6	0
Computer Science	6	5	1
Business, Management and Accounting	5	4	1
Chemical Engineering	4	4	0
Materials Science	2	2	0
Decision Sciences	1	1	0
Nursing	1	0	1
Psychology	1	1	0

Due to the large amount of data underlying the remaining graphs, data tables can be sent on request.

Appendix E. Data Tables for Discourse Analysis

Table 9. Overview of demand rationales for research on SRM

Underlying demand rationale	SRM research is needed for the purpose of …	Number of articles this frame is part of	Number of references made to this frame	References	Interviews this frame is part of
Functional	Insufficient mitigation efforts	13	15	Aldy & Zeckhauser, 2020; Asayama et al., 2019; Grasso, 2019; Grieger et al., 2019; Mahajan et al., 2019; McKinnon, 2018; Pamplany et al., 2020; Reynolds, 2015; Rickels et al., 2020; Svoboda & Irvine, 2014; Visschers et al., 2017; Wieding et al., 2020 Interview XX	Interview 3; Interview 6
	Reaching climate goals	11	20	Aldy & Zeckhauser, 2020; Asayama et al., 2019; Flegal & Gupta, 2018; Grasso, 2019 McKinnon, 2018; Nicholson et al., 2018; Suarez & van Aalst, 2017; Sugiyama et al., 2017; Sugiyama et al., 2018; Sugiyama et al., 2020; Wieding et al., 2020	Interview 6
	Cost-effectiveness compared to mitigation and adaptation	8	9	Grieger et al., 2019; Hourdequin, 2018; Mahajan et al., 2019; McKinnon, 2018; Pamplany et al., 2020; Rickels et al., 2020; Stephens & Surprise, 2019; Svoboda, 2015	-
	Intellectual curiosity and career opportunities	-	-	-	Interview 2; Interview 4; Interview 5; Interview 6; Interview 7

	Achieving better understanding of SRM	-	-	-	Interview 2; Interview 4; Interview 5; Interview 8
Strategic	Reducing climate change risks and impacts	15 (34%)	23	Asayama et al., 2019; Emmerling & Tavoni, 2018; Flegal & Gupta, 2018; Grieger et al., 2019; Horton & Keith, 2019; Low, 2017; Mahajan et al., 2019; McKinnon, 2018; Pamplany et al., 2020; Payne et al., 2015; Stephens & Surprise, 2019; Svoboda, 2015; Svoboda & Irvine, 2014; Visioni et al., 2020; Visschers et al., 2017	Interview 1; Interview 2; Interview 7
Normative	Moral obligation to the global poor and most vulnerable	8 (18%)	20	Flegal & Gupta, 2018; Gunderson et al., 2019; Hourdequin, 2018; Ott, 2018; Pamplany et al., 2020; Stelzer & Schuppert, 2016; Stephens & Surprise, 2019; Svoboda et al, 2019	Interview 4

Table 10. Overview of speaker positions for research on SRM

Speaker position	Number of articles this frame is part of	Number of references made to this frame	References	Interviews this frame is part of
Exclusive speaker position held by Western elite	3	6	Delina, 2020; Low, 2017; Stephens & Surprise, 2019	-
Predominantly Western speaker position	11	21	Bala & Gupta, 2019; Bluemling et al., 2019; Delina, 2020; Flegal & Gupta, 2017; Hourdequin, 2018; Hourdequin, 2019; Low, 2017; Morrow, 2020; Ott, 2018; Stephens & Surprise, 2019; Sugiyama et al., 2020	Interview 2; Interview 4
Growing speaker position of Global South due to modest efforts and progress in conducting research in the Global South	7	10	Bala & Gupta, 2019; Bluemling et al., 2019; Delina, 2020; Morrow, 2020; Stephens & Surprise, 2019; Wei et al., 2018; Sugiyama et al., 2020	Interview 1; Interviews 4; Interview5; Interview 8
Global South holding very limited speaker position or no speaker position	4	4	Delina, 2020; Flegal & Gupta, 2017; Pamplany et al., 2020; Hourdequin, 2019	Interviews 3, 4, 5, 6, 7, 8

Table 11. Overview of categorisation of interests from the Global South regarding SRM

Discursive categorisation	Number of articles this frame is part of	Number of references made to this frame	References	Interviews this frame is part of
Interests and aspects related to climate change	9	12	Aldy & Zeckhauser, 2020; Hourdequin, 2018; Mahajan et al., 2019; McKinnon, 2020; Ott, 2018; Stelzer & Schuppert, 2016; Sugiyama et al., 2020; Svoboda et al., 2019; Visioni et al., 2020	Interview 2
Interests of Global South put forward by others	9	12	Carr et al., 2013; Flegal & Gupta, 2018; Grasso, 2019; Haywood et al., 2013; Hourdequin, 2018; Ott, 2018; Pamplany et al., 2020; Suarez & van Aalst, 2017; Visschers et al., 2017	
Interests of Global put forward by Global South themselves	10	19	Bluemling et al., 2019; Delina, 2020; Mahajan et al., 2019; Flegal & Gupta, 2018; Pamplany et al., 2020; Pinto et al., 2020; Reynolds, 2015; Suarez & van Aalst, 2017; Svoboda et al., 2019; Svoboda & Irvine, 2014	Interview 1-9

Table 12. Overview of demand rationales for engaging the Global South

Underlying demand rationale	Engaging the Global South is needed for the purpose of…	Number of articles this frame is part of	Number of references made to this frame	References	Interviews this frame is part of
Introduction	Calls for engaging GS in debate by many	4	6	Delina, 2020; Nicholson et al., 2018; Payne et al., 2015; Sugiyama et al., 2020	Interview 1-9
Functional	Better research through considering cultural, ethical and geographical aspects through GS researchers	4	7	Delina, 2020; Flegal & Gupta, 2020; Pamplany et al., 2020; Visschers et al., 2017	Interview 1; Interview 2; Interview 6; Interview 7
	Solving little GS engagement	3	4	Nicholson et al., 2017; Pamplany et al., 2020; Suarez & van Aalst, 2017	-
Strategic	NOT needed for..	1	1	Suarez & van Aalst, 2017	-
	Geopolitical and environmental concerns	2	3	Sugiyama et al., 2020; Visschers et al., 2017	-
	Obstacle to global conversations	1	1	Sugiyama et al., 2020	Interview 2
	Achieving social acceptability // allow for decision-making	3	3	Nicholson et al., 2018; Sugiyama et al., 2020; Visschers et al., 2017	Interview 1; Interview 4; Interview 8

	Global South as innovative and pushing for more climate action	1	1	Delina, 2020	Interview 4
	Critique on current engagement Global South	2	3	Flegal & Gupta, 2020; Stephens & Surprise, 2020	-
Normative	Emancipatory approach	3	3	Asayama et al., 2019; Suarez & van Aalst, 2017; Sugiyama et al., 2020	Interview 5; Interview 6
	Global impacts of SRM	5	6	Delina, 2020; Nicholson et al., 2017; Sugiyama et al., 2017; Sugiyama et al., 2020; Visschers et al., 2017	Interview 1; Interview 6
	High vulnerability to uncertain and potentially adverse side-effects	4	8	Suarez & van Aalst, 2017; Sugiyama et al., 2017; Sugiyama et al., 2020; Visschers et al., 2017	Interview 1; Interview 4
	Consequence of “moral obligation to the poor”	1	1	Suarez & van Aalst, 2017	-

Appendix F. Data Tables for Sensitivity Analysis

Table 13. Distribution of number of authors per article for Query 1-Query 2 (N=280)

Number of authors per article	Number of articles
1 Author	49
2 Authors	56
3 Authors	55
4 Authors	39
5 Authors	21
6 Authors	14
7 Authors	12
8 Authors	8
9 Authors	4
12 Authors	3
13 Authors	1
14 Authors	1
15 Authors	1
16 Authors	1
17 Authors	1
18 Authors	1
19 Authors	2
25 Authors	1
27 Authors	1

Table 14. Distribution of number of authors per article for Query 2 (N=44)

Number of authors per article	Number of articles
1 Author	12
2 Authors	11
3 Authors	10

4 Authors	4
5 Authors	3
6 Authors	3
16 Authors	1

Table 15. Distribution of number of authors per affiliation for Query 1-Query 2 (N=280)

	Authors (in %)	Authors (absolute)
1 Affiliation	88,7%	958
2 Affiliations	10,2%	110
3 Affiliations	1,1%	12
	100%	1080

Table 16. Distribution of number of authors per affiliation for Query 2 (N=44)

	Authors (in %)	Authors (absolute)
1 Affiliation	91,6%	120
2 Affiliations	6,1%	8
3 Affiliations	0,8%	1
4 Affiliations	0,8%	1
Total	100%	131