

# Solar Radiation Modification - A "Silver Bullet" Climate Policy for Populist and Authoritarian Regimes?

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## Abstract

Populist and authoritarian leaders are increasingly coming to power in large countries. They often have a climate sceptic approach and do away with mitigation policies when coming to power. Increasing impacts of extreme meteorological events linked to climate change could lead to a situation where the supporters of the populist leader or elites crucial for the survival of an authoritarian regime are pushing to do something to address climate change. In order not to lose power, the leader may look for quick and cheap solutions. In such a context, solar radiation modification (SRM), for example, by stratospheric aerosol injection (SAI), will become very attractive as it is likely to have low costs and rapid effects. Populist or authoritarian governments are unlikely to care for negative impacts of SRM abroad as they often act nationalistically with an explicit disdain for multilateral solutions. We discuss the incentive structure and political economy that populist and authoritarian leaders may face regarding unilateral use of SRM and elaborate how the international community could try to prevent or at least 'contain' such unilateral uses of SRM. Unfortunately, such 'containment' is contingent on the most powerful states not being populist or authoritarian regimes.

## Policy Implications

- The international community needs to proactively address the threat of unilateral implementation of solar radiation modification by introducing robust global monitoring systems for such actions as well as a system of credible sanctions against regimes found to implement solar radiation modification.
- A consensus-oriented approach as required under the UN Framework Convention on Climate Change (UNFCCC) would not allow a timely reaction against unilateral solar radiation modification. Moreover, it can be blocked by a small number of authoritarian and populist regimes. A broad coalition of democratic countries should be formed which could mount credible sanctions.
- Given that unilateral implementation of solar radiation modification by authoritarian regimes could start relatively quickly, triggered by impacts of meteorological extreme events, the international response to discovery of preparations needs to be coordinated in an effective and rapid manner.
- The democratic coalition needs to have clear procedures in place that can serve as a credible deterrent. The design of such procedures should take lessons from international arms control into account.

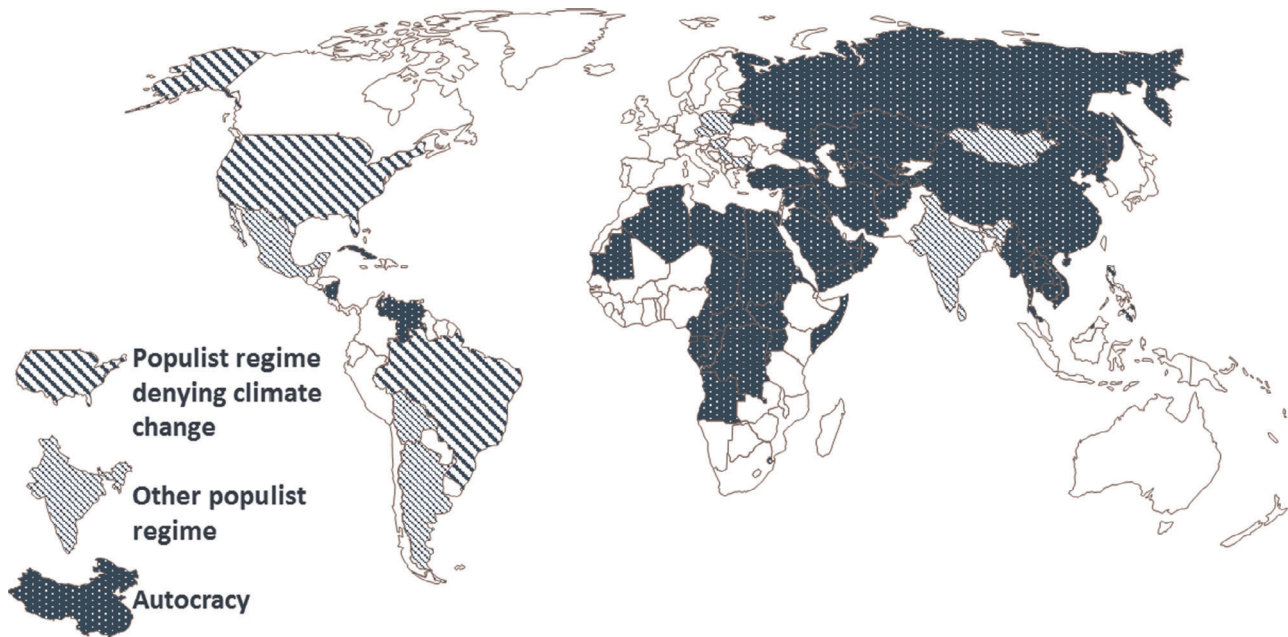
## Introduction

The issue of anthropogenic climate change is leading to an increasing polarization of political responses. On the one hand, since 2018 in the wealthy democracies of Western Europe climate policy has gained unprecedented voter support in the wake of the 'Fridays for Future' youth movement to stop climate change. On the other hand, in the last years in many countries around the world populist and authoritarian<sup>1</sup> regimes have come to power (see Figure 1) some of which openly support climate denialism (see Coglianese, 2019; Kyle and Gultchin, 2018). Muradian and Pascual (2020) discuss the potential implications of this tendency on environmental policies.

At the same time, impacts of meteorological extreme events are increasing around the world and this increase is likely to accelerate further unless greenhouse gas mitigation is stepped up significantly (Masson-Delmotte et al., 2018). A wide body of research sees a strong influence of extreme events on public opinion regarding climate change (see e.g., Howe et al., 2014 and Hamilton et al., 2015, for a different view see Carmichael and Brulle, 2017).

In contrast to popular belief, authoritarian leaders are sensitive to the opinion of key elites (Bueno de Mesquita and Smith, 2011; Olson, 1993; Weeks, 2008). Populists that have come to power democratically and do not turn towards authoritarianism will try to remain in power through taking up the concerns of their electorate. Thus, important

Figure 1. Populist and autocratic regimes worldwide.



Source: Kyle and Gultchin (2018) for populist regimes, Freedom House (2019 for autocratic regimes (non-free states)).

segments of populations under authoritarian and populist regimes could demand their leaders fight climate change when exposed to extreme events.

Applying a public choice perspective, this article discusses whether solar radiation modification (SRM) could become a technology of choice for authoritarian and populist regimes<sup>2</sup> shifting from climate change denialism to a proactive climate policy under the pressure of accelerating climate change. It sees itself in the strand of qualitative deductive social science (Low and Schäfer, 2019) as so far we have no case of a regime trying to apply SRM. While the democratic governability of SRM has frequently been discussed (Horton et al., 2018; Szeszyski et al., 2013) the only research that has specifically considered the role of authoritarian regimes so far is Markusson et al. (2018) stating that ‘an autocratic leader of a rich nation could unilaterally deploy SRM technology’.

Compared to greenhouse gas mitigation achieving the same temperature outcome, the direct deployment costs of SRM are consistently reported to be several orders of magnitude lower (Lin, 2009; Harding and Moreno-Cruz, 2016). This could lead to ‘free driving’ that is, a race for unilateral implementation, and eventual over-provision of temperature reduction (Weitzman, 2015). Emmerling and Tavoni (2018) estimate the over-provision of SRM to be of a similar order of magnitude as the under-provision of classical greenhouse gas mitigation due to free riding. Given the potential for unilateral, ‘rogue’ implementation of SRM that disregards potential negative impacts on other countries (first raised by Ricke et al., 2008, discussed in detail by Bodansky, 2013; Rabitz, 2016; Moreno-Cruz and Smulders 2017; Svoboda, 2017), our analysis tries to elaborate possible decision-

making criteria and scenarios for SRM implementation, based on generic, qualitative understanding of the incentive structures that drive populist and authoritarian leaders. Building on these scenarios, the article looks at ways with which the international community could prevent implementation of SRM by populist and authoritarian regimes shunning international collaboration.

### Populism, authoritarianism and climate policy

While populism has existed in democracies since the 19th century (Beeson, 2019), its revival in the 2010s has come as a surprise. In large countries on all continents, populist leaders have won democratic elections. Some of these leaders like Russia’s Putin and Turkey’s Erdogan have progressively dismantled democratic institutions and set up increasingly authoritarian regimes (see Figure 1).

#### Populists as climate sceptics

While in the early 1990s climate change mitigation was not ideologically contested, from the late 1990s climate scepticism was embraced by right wing parties in the Anglo-Saxon world and since the late 2010s by populists of various colours around the world. The first strong climate sceptic populist campaign in an industrialized democratic country was undertaken in Australia by the Liberal Party who under Tony Abbott in 2011 dismantled the elaborate carbon pricing scheme set up by the preceding government (see Beeson, 2019). A key event in the upswing of climate sceptic populism was the election of US President Trump in 2016. Trump openly campaigned on a populist platform,

denigrated climate policy (see O’Gorman, 2018) and was strongly supported by the ‘Tea Party’ movement, which was openly climate-sceptic (Lockwood, 2018). Trump proactively repealed climate change mitigation policy instruments and withdrew from the Paris Agreement. Since Trump’s election, populist parties in Europe have stepped up their climate scepticism that previously was not strongly visible (Lockwood, 2018). Moreover, developing countries that had been staunchly supporting international climate policy like Brazil and the Philippines have since then elected openly climate sceptic populist leaders. Lockwood (2018) and Forchtner (2019) explain this surge of climate scepticism among populists by their ‘antielitism’ which sees climate policy as a ploy of a ‘corrupt and illegitimate liberal, cosmopolitan elite’ to suppress the ‘normal’ people anchored locally. This is reinforced by the core electorate of populist parties being low-skilled, blue collar workers often linked to fossil fuel extraction and processing (Lockwood, 2018), industries which suffer if greenhouse gas mitigation is implemented.

A specific form of populism could be environmental policy-oriented and left-wing (see Beeson, 2019). This article does not look into such forms of populism as they have not (yet?) been able to win democratic elections. A specific case of a democratically elected, right wing populist leader supporting climate change mitigation is Indian Prime Minister Modi, but he is certainly not an environmental populist, as he clearly states that economic development has precedence compared to environmental protection (Hope, 2014).

In contrast to populist movements emerging in democratic countries, authoritarian leaders have not generally taken a climate sceptic stance. Especially the Chinese leadership has consistently stated that it sees climate change as a major challenge (Kopra, 2018). Several African autocracies take a proactive approach, especially noteworthy have been Ethiopian leader Zenawi’s (Paul and Weinthal, 2019) and Rwanda’s Kagame’s (Jones et al., 2015) embracing of the issue. Arab region autocrats have long tried to slow down international climate policy, but refrained from generally climate sceptic statements.

#### Authoritarian/populist approach to climate policy if population sees climate change as important

The drivers for authoritarian and populist leaders to engage in climate policy are discussed below in turn.

Authoritarian leaders cannot ignore the population they govern. Even the most ruthless dictator has an ‘encompassing interest in his domain that leads him to provide a peaceful order and other public goods that increase productivity’ (Olson, 1993, p. 567). A dictator who has not cared about climate policy will do so if key parts of the population supporting him see the climate change issue as important (see e.g., Weeks, 2008 for foreign policy of authoritarian regimes).

Once decisions have been taken, authoritarian regimes can act swiftly and on a large scale (McCarthy, 2019; Wilson, 2019). This observation has led to sweeping statements like ‘the authoritarian Chinese system has some advantages

when it comes to addressing climate change’ (Runciman, 2019). Also, Beeson (2010) sees authoritarian regimes in Asia as more capable of responding to complex environmental pressures than democratic ones. However, Gilley (2012) doubts whether such regimes actually achieve a high performance, as local actors may try to give pure ‘lip service’ to central directives.

Historically, authoritarian regimes have liked large-scale interventions into nature, like Stalin’s Plan for the Transformation of Nature’ that was to divert large Siberian rivers into the Aral Sea basin (Micklin, 2014; Wilson, 2019). China has never shied away from large-scale manipulation of nature, for example in the context of hydrological engineering (Crow-Miller et al., 2017). For propaganda of the Chinese regime making nature yield to man’s needs see Figure 2.

Currently, the Chinese regime is proactively pursuing modification of rainfall on large scales (Bluemling et al., 2019; Guo et al., 2015; Knowles and Skidmore, 2019) after successes with that technology to achieve rainfall-free weather during the Olympic Games of 2008 (Knowles and Skidmore, 2019, p. 5). Thus, ‘authoritarian regimes could readily exploit geoengineering technologies’ (Schneider, 2018).

The common characteristic of ‘new’ climate sceptic populism in industrialized countries is the ability to ‘shield’ the electorate supporting the populist leader from any influence that could lead to the ‘discovery’ that climate change is real and leads to negative impacts on the economy and society. Such shielding can be orchestrated by political actors through modern social media that target ‘information’ to suit the ideological preferences of specific groups within the population (see e.g., O’Gorman, 2018 how Trump used

**Figure 2.** Propaganda of Chinese autocratic regime ‘Make the high mountains submit and the rivers give way’ (1958).



Source: Crow-Miller et al. (2017).

Twitter in his 2016 campaign, or Zuk and Sulecki, 2020 on directed media strategies of the Polish populist government). These approaches are more effective than in the past, where 'push' media were not available and individuals had to proactively look for information. Many now expect that massive meteorological extreme events are likely to overcome such shielding when individuals are directly exposed to the impacts of the event. For example, farmers in Switzerland who are usually staunch supporters of the climate sceptic Swiss People's Party started to oppose the climate sceptic course of the party after the severe drought of 2018 and the heatwaves of 2018 and 2019 that heavily impacted farm revenues (Kucera, 2019).

However, it remains unclear how severely extreme events need to impact people to reach significant pressure on the populist leader to throw climate scepticism overboard and fight climate change. For example, neither Hurricane Katrina that devastated New Orleans in 2005 and caused over 1,000 deaths nor Hurricane Sandy that did heavy damage to New York in 2012 were sufficient to shift US populist voters away from climate scepticism (Carmichael and Brulle 2017; Hamilton et al., 2015). Much sceptic communication especially via social media stressed that there had always been hurricanes and that there was no link between these and climate change. While according to Markusson et al. (2018) some observers thought in 2017 that Trump may embrace SRM, this did not happen. Apparently, the populist electorate still was convinced that climate change is a 'hoax' and therefore not worthy of any policy action.

Once the tipping point for the populist leaders to embrace climate change mitigation has been reached, given their disdain for policy solutions developed carefully in interaction with experts and potentially affected parts of the population, they are likely to take quick and bold decisions that show their ability to act (Vroom and Yetton, 1973). As the populist needs to be seen in direct control of his country's problems, simplistic approaches that can easily be understood by his electorate are attractive, especially if implemented more quickly than slow democratic processes would allow (Gurri, 2018). Such decisions can generate significant negative impacts without the leader losing support, as was the case in India with the demonetization (see below). Under such circumstances, the leader can push through much more risky decisions than would be possible under a democracy with checks and balances, protection of vulnerable groups and a willingness to take into account the results of a thorough scientific assessment.

### Dealing with interest groups

Only if the general population demands action on climate change, populist and authoritarian leaders will start to consider mitigation measures and assess the views of important interest groups regarding this topic (see Michaelowa, 1998 for a discussion of interest group positions on climate change mitigation). Populists have to ensure that they sustain their power base and the related economic interests (see Driesen, 2019). Normally, populist regimes are closely

linked to fossil fuel extraction and processing industries which see 'classical' greenhouse gas mitigation as a threat to their business. In democracies, such links are weaker, as shown by the lower prevalence of fossil fuel subsidies (Overland, 2010). Therefore, opposition against mitigation, maybe except for the forestry sector, is likely to be strong both in an authoritarian and a populist context.

While the interest groups are unlikely to prevent the leader from engaging, they are likely to put sufficient pressure to restrict the leader to low cost measures. Populists usually have portrayed climate change mitigation policies as costly and detrimental for their power base, for example, coal miners (see O'Gorman, 2018, on Trump's election campaign and coal mining). Thus for them, a low cost climate policy instrument is important to justify a turnaround in favour of climate policy.

### Key decision-making criteria for authoritarian and populist leaders regarding climate change mitigation

Given the preceding discussion, both authoritarian and populist leaders are likely to scrutinize the available actions for climate change mitigation once the tipping point has been crossed according to four criteria:

1. speed of achieving the desired outcome;
2. visibility of the leader when implementing the action;
3. low cost; and
4. ability to implement the action without external interference.

We will now discuss to what extent solar radiation modification actions fulfil these criteria.

### Characteristics of solar radiation modification attractive for populist and authoritarian leaders

Solar radiation modification includes an array of theoretically possible approaches (see de Coninck et al., 2018; Reynolds, 2019a). Among these, stratospheric aerosol injection (SAI) by planes or tethered balloons is seen as most relevant also given that the cooling mechanism is well known through large scale volcanic eruptions. As the second relevant technology marine cloud brightening (MCB) through sea salt spray emissions by ships is frequently mentioned. Cloud seeding or thinning above land areas is another, less prominent idea. Its physical cooling effectiveness is, however, not as well understood as that of SAI. It will therefore not be considered here.

Below, we discuss characteristics of SAI that make it attractive for populist and authoritarian regimes, and unattractive for stable democracies. The appropriateness of SAI for authoritarian contexts was already noted by Macnaghten and Szerszynski (2013).

### Relatively simple, rapid and visible

In contrast to greenhouse gas mitigation or carbon dioxide removal which requires long lead times and affects the climate system only incrementally, an SAI programme can



potentially be set up in a few years and could affect the climate almost instantaneously (Reynolds, 2019a). Technically, challenges to SAI deployment are limited as no technology breakthroughs are needed (de Coninck et al., 2018). MCB that requires setting up a much larger infrastructure than SAI will be slower in its implementation than SAI and thus less attractive to populists and authoritarian leaders.

All technologies used are highly visible – imagine the media attractiveness of a launch event for a large fleet of dedicated SAI aircraft, the hoisting of a huge balloon cum hose or the launch of an MCB vessel fleet with the leader cutting the ribbon. Given that a populist regime would be eager to show the action in an easy to understand way, the ability to communicate through simple slogans like ‘Hundred aircraft shielding us from global warming’ would make SAI more attractive compared to interventions that have complex results chains and cannot be summed up in simple images or texts. The leader could nicely build on an image of a ‘strongman’ directly controlling climate to the benefit of ‘his’ people. For an example how such images showing how the populist/ autocrat operates ‘climate control’ could look like see Figure 3.

Under a democratic regime with strong accountability procedures and ability of potentially negatively impacted groups to use the judiciary to prevent negative outcomes,

SAI would face similar challenges as carbon capture and storage (CCS) has faced in the past decade (Whitmarsh et al., 2019). This seemingly ‘silver bullet’ technology became heavily contested, leading to strong local opposition, inability to reach large scale and a much lower level of implementation than expected in the mid-2000s. It should be noted that any negative impacts of SAI would occur at much larger scales than those of CCS and thus public opposition might be less focused as it would have less of ‘not in my backyard’ characteristics, but be broader, comparable to the movement against forest dieback in the 1980s due to long distance SO<sub>2</sub> pollution and acid rain.

### Low costs

According to de Coninck et al. (2018), implementation of SAI to offset warming of 1–2°C could cost between US\$1 and 10 billion per year. For a populist regime of a large country, allocating such a budget would be relatively easy, especially if the regime frames it as an expense needed to ensure the welfare of its citizens as well as its national security. Reynolds (2019a) thus frames SAI as a ‘single effort’ public good whose level of provision depends on the single largest contribution. Costs of MCB are much less researched than those of SAI, but are seen in the same order of magnitude as those of SAI (Reynolds, 2019a).

### Unilateral implementation

Any country that is able to operate airports, and has access to sulphur (including from coal) could implement SAI, provided that it can procure planes able to spray aerosol (Smith and Wagner, 2018). Other countries can of course close their airspace to planes that inject aerosols, and theoretically, the airspace over the high seas could also be closed. The technology of tethered balloons with pipes may be more difficult to master but can principally be implemented on a country’s territory without being interfered by other countries. Operation of MCB requires access to the sea and ship-building capabilities. Both criteria are fulfilled by a large number of countries.

In contrast to this situation, advanced technology solutions for greenhouse gas mitigation are usually produced only in a few leading countries and need imports or dedicated industrial policies to set up production sites.

### Case study China and India: high climate change impacts in large Asian emerging economies as drivers of SRM?

To illustrate the discussion in the preceding section, we look at China and India as case studies, given that both emerging economies are likely to face substantial climate change impacts, and currently have authoritarian/ populist governments. Emmerling and Tavoni (2018) model SRM implementation and find that countries in Asia, and to a lesser extent Africa, could be the first movers as they could benefit substantially due to reduction of climate change impacts, while

**Figure 3.** The populist/autocrat controlling the climate.



Source: Drawing by Fritz Siebel, *Colliers*, May 28, 1954: front cover, see <https://picturingmeteorology.com/home/2017/1/6/weather-made-to-order-1954>.

generating significant costs due to side effects in other countries. We thus discuss whether authoritarian China and populist India could become such early movers.

Given China's authoritarian leadership tendency to go for large-scale solutions, its propensity for SRM may be high if climate change impacts are seen as unbearable. The still crucial role of coal mining and coal power generation and the relevance of large emissions-intensive heavy industry, would underpin the view of Bluemling et al. (2019) who see a clear risk that China could go for SRM given that its experiences with weather modification would lend SRM deployment greater legitimacy in the country. However, there is a broad set of literature seeing a very limited risk of China being a first mover. Moore et al. (2016) argue that the historical experience with large engineering through millennia and the criticism of mega-projects like the 'Three Gorges Dam' would make the government cautious. Also, Markusson et al. (2018) and Weng and Chen (2014) conclude that China would be unlikely to act unilaterally. But even Moore et al., (2016, p. 593) state: 'If some climate emergency were to befall parts of China – such as potentially disastrous flooding, that could be convincingly shown to be ameliorated by geoengineering, then of course China as any other nations, would be strongly tempted by it'.

Indian populist leaders may see the risk of SRM having negative impacts on the monsoon higher than the benefit of reduced climate impacts. Nevertheless, the populist government of Modi has been characterized by high-level campaigns with simple messages which did not build on a differentiated assessment of the situation. For example, the sudden demonetization of the two key denominations of banknotes in late 2016 severely disrupted economic life in India but still was seen favourably by large segments of the population. This was due to the perception that the leader did a bold step and some 'collateral damage' needed to be accepted.

If China was the first mover on SRM implementation and India was cautious regarding the technology due to the risks on the monsoon seen as higher than the potential benefits of a temperature decrease, a conflict with India could ensue if India sees a negative impact of the Chinese intervention on the monsoon. This would be geopolitically highly challenging. If India was a first mover, the risk of Chinese retaliation may be lower.

### Options for the international community to 'contain' unilateral SRM use by populist and authoritarian regimes

The use of SRM by populist and authoritarian regimes would not happen in a vacuum. It is likely that there will be some formal international governance for SRM. Possible approaches to such governance have been discussed in detail by researchers in the past years but mostly focused on governance of research on SRM, not its implementation (see e.g., Reynolds, 2019a, 2019b).

Populist and authoritarian regimes are unlikely to respect international governance systems. Especially in the context

of systems that require a consensual decision such as the UN Framework Convention on Climate Change (UNFCCC), such regimes can block the consensus. In this context, it should be noted that the US and Saudi Arabia – the former then governed by a populist and the latter by an absolute king – in early 2019 opposed a Swiss-backed resolution in the UN Environment Assembly calling for an assessment of SRM (and carbon dioxide removal) (Jinnah and Nicholson, 2019b). We discuss below whether there are possibilities to 'contain' SRM use by regimes that are openly hostile to international collaboration and governance.

### International SRM governance

Formally, there are no firm legal principles prohibiting unilateral SRM (see Fitzgerald, 2016 for a discussion on the background of US law). However, the emerging international governance framework for SRM is based on a range of multilateral treaties. Importantly, the resolutions of the conferences of parties to the Convention on Biodiversity which are often understood as a moratorium on SRM actually are non-binding (Reynolds, 2019a). Whether SRM would be regulated by a new institution or be allocated to an existing treaty regime such as the UNFCCC remains open. Weitzman (2015) makes a far-reaching proposal to have an international SRM governance body with a very simple voting rule where additional SRM could only be undertaken if states representing 3/4 of the world population support it, while existing SRM would have to be reduced if states representing 1/4 of the world population request this reduction. He calls for an executive arm to enforce penalties for noncompliance. Bodansky (2013, p. 549) sees such an approach as unrealistic 'finding no reason to think that an International Geoengineering Authority would be any more successful [than the UN Security Council] in curbing unilateral action when countries feel that their vital national interests are at stake'. Given that in the context of international climate policy non-consensus-based approaches so far have not emerged, Bodansky so far seems vindicated. While the UNFCCC regime over time has interpreted 'consensus' creatively, meaning that opposition from several small countries was just overridden, this is not possible for large, powerful countries.

### Monitoring of SAI and MCB implementation

An important precondition to prevent unilateral implementation of SRM is the ability to unequivocally recognize when SRM is undertaken (see Nicholson et al., 2018 regarding the need for transparent information on SRM deployment).

It should be relatively simple to identify dedicated structures such that reach the stratosphere and purpose-built planes capable of reaching the lower stratosphere at ~ 20 km altitude and flying there for extended period of time (Smith and Wagner, 2018). The use of only slightly modified planes hiding aircraft-operated SAI in conventional operation of civil aviation is not possible, as such planes could not fly above 16 km and thus be useless for SAI (Smith and Wagner, 2018).

Monitoring MCB will be much more difficult as it requires following ship routes and tracking ship exhausts. Under the rules of the International Maritime Organization, officially registered ships have to operate an automatic identification system which tracks their movements (Saputra et al., 2013). However, as fighting against piracy shows, non-registered vessels can only be detected using high resolution satellite imagery. If ships are designed purposefully for maximizing aerosol distribution, for example, through specific types of chimneys, identification of MCB should become easier. If a regime with a historically big shipping fleet uses standard commercial ships and retrofits them for MCB in not easily visible ways, detection may become virtually impossible. A sudden increase in a commercial shipping fleet not underpinned by increases in trade volumes would probably trigger second thoughts and be easier to detect.

Monitoring will be costly, especially if it has to be global and continuous. If SRM governance is allocated to a specific existing or newly set up institution like the solar geoengineering organization proposed by Reynolds (2019a), this institution should be made responsible for a coordinated monitoring approach (Reynolds, 2019a).

### Sanctioning unilateral SRM implementation

Once unilateral SAI or MCB has been detected through monitoring, the international community needs to decide how to address this. Horton (2011), Millard-Ball (2012) and Heyen et al. (2019) discuss the potential of direct countermeasures, such as the release of strong greenhouse gases or black carbon. However, given that such countermeasures would also have negative side effects, it would be relatively unlikely that they are implemented.

Classically, the international community addresses 'rogue' behaviour by putting in place sanctions. Surprisingly, the most recent research on SRM governance does not address this issue – neither a, 2019b) nor Fitzgerald (2016) mention the term 'sanctions', probably following Bodansky (2013) who just says that reining in unilateral SRM is impossible. In fact, under the UNFCCC there is no sanction regime and while the Kyoto Protocol had (weak) non-compliance rules, under the Paris Agreement compliance rules are essentially absent.

However, older literature has looked at sanction as a tool against rogue behaviour. Horton (2011, p. 59) raises 'trade sanctions, diplomatic isolation, linked reprisals in other issue areas, and even the use of force' to counter the threat of unilateral SRM.

The effectiveness of trade sanctions is contested (Peksen, 2019; Smeets, 2018). Successful approaches used a combination of sanctions addressing various fields, including trade, financial transactions and travel.

Experiences from other policy fields such as trade policy show that medium-sized rogue actors are often exposed to sanctions whereas very large and economically strong ones often have a sufficient retaliatory power to prevent them. In the case of several large countries being ruled by populists or autocrats and implementing SRM unilaterally, the

instrument of sanctions would probably not work. Markusson et al. (2018) stresses that willingness of unilateral SRM implementation would be linked to military power as only countries with a strong military would dare to act unilaterally. Only if these countries were confronted by a large coalition of governments having sufficient power to mount credible sanctions, might they refrain from unilateral SRM implementation. In order to make such a coalition credible, the coalition needs to have a good coherence. This requires also that coalition partners are clear on their own national interests and preference regarding various SRM deployment scenarios as the risk of defecting is greater the more a coalition member might suspect that ongoing SRM deployment is in its own interest. The history of sanctions in the context of nuclear non-proliferation has shown that they have been able to prevent open use of nuclear weapons but not the build up of nuclear weapon capacity (Ogbonna, 2017).

Horton et al. (2015) raise the possibility to invoke liability; this however again builds on the assumption that a state will accept international legal procedures which is unlikely for either a populist or an authoritarian state (Horton et al., 2015 on p. 267 explicitly state that enforcement would involve the 'exercise of power, the pursuit of interest, or the influence of institutions').

The assessment by Horton (2011), Parson and Ernst (2013) and Rickels et al. (2018) that the risk of countermeasures by other countries and side effects of SRM deployment by other countries would lead governments to refrain from unilateral SRM use seems overly optimistic given that populist and authoritarian leaders often dismiss such risks (Mattes and Rodriguez, 2014; Weeks, 2012). As unilateral SRM would be seen as 'projecting an image of strong leadership befitting a populist leader, feeding populist opinion, fear and support on which such a regime would depend' (Markusson et al., 2018, p. 9), countries subject to sanctions for unilateral SRM use might thus be more willing to engage in a military conflict in order to retaliate.

### Conclusions

Solar radiation modification through stratospheric aerosol injection or – to a lesser extent – marine cloud brightening – is a 'pandora's box technology'. It seemingly addresses the symptoms of the climate change problem rapidly and cost-effectively. It could be the ideal tool for an unscrupulous authoritarian or populist leader who wants to be seen as acting quickly and decisively against climate change. We conclude that it is becoming more likely that unilateral implementation of solar radiation modification is started as a reaction to extreme meteorological events, due to various trends described in the sub-sections below.

#### When can we expect populists to shift from climate change denialist to SRM user?

Since the mid-2010s, populism has been on the rise in industrialized and emerging economies. Populist leaders have a tendency to embrace climate denialism given their



Figure 4. Possible campaign poster for a populist SRM campaign.

## Which future do you want?



## Vote Trump. Vote climate control

Source: Text: author. Graph of farmers: <https://kenshohomestead.org/2019/09/26/weather-modification-matters-ii/>.

link to 'sunset' industries like fossil fuel extraction, opposition against globalization and multilaterally agreed solutions for global problems. They proactively feed their electorate with highly targeted (mis-)information through social media.

The acceleration of climate change in the second half of the 2010s has led to a proliferation of meteorological extreme events and related impacts. In some countries, this has led to a weakening of the populist climate denialism as the population clearly feels the impacts. The hurricane series in the Caribbean in 2017–19 and the droughts and heatwaves in 2018–19 in Europe herald the type of situation that could lead to a drastic shift of populist voter attitudes to climate change. If climate change progresses similarly rapidly in the first half of the 2020s, extreme events are likely to intensify further. Then, populists may suddenly shift from being climate denialists to 'protectors' of their population from climate change. Such a shift requires one or a suite of extreme events that is touching the entire population of a country that are so far out of the range of expected meteorological conditions that climate denialism is no longer credible for even the most credulous climate denialist. Once such a shift has happened, the populist could see SRM as a simple yet effective 'cure' of the climate change problem. Figure 4 provides an example what a populist campaign poster promoting SRM could look like.

Fossil fuel industries are likely to advocate for SRM if they cannot prevent action addressing climate change. Moreover, the military usually will support an SRM approach that strengthens the role of the military, for example, by being actively involved in deployment or by protecting deployment infrastructures (Markusson et al., 2018; Nightingale and Cairns, 2014).

## The unsatisfactory state of deterrents for rogue SRM implementation by authoritarian and populist leaders

Populists and autocrats are usually proud of ignoring international governance systems and often proactively try to undermine them. Only if international governance can credibly jeopardize the populist's or autocrat's power base, will the autocrat not violate the rules defined by the international community. This means that the autocrat needs to be confronted with sanctions that exceed the unilateral benefit of SRM action. As the chequered history of sanctions shows, support by the most powerful countries is a necessary but not sufficient condition for their success. While currently populist as well as authoritarian leadership exists in many powerful countries, a decline could be triggered by the inept handling of the COVID-19 crisis by many of these leaders. Thus, the size and power of a coalition sanctioning rogue SRM could increase. Eventually, the effectiveness of sanctions as a deterrent hinges on the credibility of the threat. This depends on the willingness of the coalition to persevere with the sanctions.

## Outlook

In a world of accelerating climate change with more and more powerful states dominated by populist and authoritarian leaders, the likelihood of unilateral SRM rises strongly as it has several characteristics that could make it seem like a 'silver bullet' solution to the 'wicked' climate change problem. There is no easy way to prevent such rogue interference with the earth's climate. Necessary, but not sufficient conditions for reining in SRM users are robust monitoring systems for SRM use under credible international institutions, clear understanding of potential SRM deployment implications and the public constitution of a coalition of democratic governments that commits itself to sanction any unilateral use of SRM in a way that goes beyond the sanctioning of development and testing of nuclear weapons undertaken in the past.

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