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Views & Comments

Climate Intervention: Possible Impacts on Global Security and Resilience

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1. The climate change challenge

Climate change is no longer a future possibility: There is already ample evidence that conditions are changing. Sea level is rising at increasing rates [1], storms are becoming more intense [2], and communities that have depended on meltwater runoff from snowpack are running short of water during the dry season[†]. As difficult as it might be for a human population of more than seven billion to adapt to these changing conditions, potentially more worrisome is the destabilizing effects of refugees from drought, floods, and rising seas. For example, a multiyear drought in the Middle East has been implicated as a contributing factor in the current civil war in Syria [3]. On account of the potential for major disruption of global security, climate change is one of the most significant grand challenges of our time. It is co-dependent with energy, sustainability, and health grand challenges. If we solve the climate change grand challenge, it is likely we will have made significant inroads on those other issues.

2. Climate intervention

To date, most research on countering the impacts of climate change has focused on mitigating climate change by reducing greenhouse gas emissions or on adapting human and natural systems to make them more resilient to the effects of a changing climate. Recently a committee was convened by the US National Academy of Sciences (NAS) to consider a third option, climate intervention, also known as geoengineering [4,5].

The main finding of the report is that climate intervention is not a substitute for mitigation or adaptation. Efforts to address climate change should continue to focus most heavily on mitigating greenhouse gas emissions in combination with adapting to the impacts of climate change because these approaches do not present poorly defined and poorly quantified risks and are at a greater state of technological readiness. Climate intervention strategies are at a very early stage of development.

Many questions remain to be answered about effectiveness, economic costs, and potential for unintended consequences. That said, there could be potential for climate intervention to become part of the climate response portfolio in the future.

2.1. Carbon dioxide removal

Much could be gained at very low risk in pursuing carbon dioxide removal as part of a portfolio of climate strategies. Examples of carbon dioxide removal are natural methods that enhance biological or geological carbon sinks, such as beneficial changes in land use management and accelerated weathering of rocks, and industrial methods such as direct air capture and sequestration (DACS) or bioenergy with carbon capture and storage (BECCS). Additional research is needed to create viable, scalable, and affordable techniques, in particular to minimize energy and materials consumption.

A major advantage of this class of climate intervention is that it directly addresses the root cause of climate change: excess greenhouse gas in the atmosphere. The drawback, however, is that these approaches act slowly and are difficult to scale to the problem at hand. Ocean iron fertilization (OIF) is one approach to carbon dioxide removal that might bear adverse environmental consequences. The NAS Committee recommended more research before OIF could be considered as an effective or safe strategy.

The industrial approaches in particular must be coupled with reliable storage of the carbon dioxide for many thousands of years. Most likely sites for storage with sufficient high capacity are depleted hydrocarbon reservoirs and saline aquifers.

Additional study is required on best methods for carbon dioxide injection, particularly for depleted reservoirs with collapsed pore spaces, monitoring, and leakage detection. The economics of carbon dioxide capture would be greatly facilitated if industrial reuses of the captured gas could be found.

2.2. Albedo modification

A second class of climate intervention is albedo modification: reducing the amount of sunlight absorbed by Earth in order to cool the planet's surface. The NAS Committee considered in depth two strategies: deploying stratospheric aerosols (more specifically, injecting aerosol precursors such as sulfur dioxide into the stratosphere which transform into aerosols via subsequent processes) and marine cloud brightening (introducing aerosols near

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[†] An example is shown in http://www.water.ca.gov/climatechange/.

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the base of clouds to make them more reflective, most often done over oceans). Other methods such as deploying space mirrors or surface albedo changes (painting roofs white) were not examined in much detail because previous work has shown they are too costly or not scalable. Cirrus cloud modification was examined briefly, but there is limited research at this point.

As a class, albedo modification acts rapidly to cool the planet and is relatively inexpensive compared to carbon dioxide removal. One of the main drawbacks, however, is that it operates on a part of the climate system that is highly sensitive and currently least understood: Earth's radiative balance. The concern about albedo modification is that society would be trying to "dial down" Earth's temperature using a control knob which is highly sensitive, but the control of which is unknown.

Albedo modification currently poses significant risks. Environmental risks are both known and poorly known, such as decreases in stratospheric ozone, changes in the amount and patterns of precipitation, and poorly understood regional variability. Albedo modification does not impact atmospheric carbon dioxide levels, and thus would need to be continued until some other natural or human intervention returned carbon dioxide to acceptable concentrations. Difficult to quantify, but possibly more significant, is the potential for unanticipated, unmanageable, and regrettable consequences from albedo modification in political, social, legal, economic, and ethical dimensions. For these reasons, the NAS Committee recommended that albedo modification at scales that could alter climate should not be deployed at this time.

Nevertheless, there could be situations in the near future when society would need to understand better the signature and potential consequences of albedo modification. One example would be if there were to be a climate emergency, and decision makers would need to know if the risk of albedo modification is worse than the risk of doing nothing. Another situation could be if a unilateral/uncoordinated actor conducted an albedo modification action, and global decision makers needed to understand the consequences. A third situation would be to consider whether albedo modification could be used as part of a portfolio of strategies, for example to temporarily cool the planet while carbon dioxide removal is given sufficient time to reduce greenhouse gases to safe levels.

For these reasons, more research is needed on albedo modification. The first part of a research strategy to better constrain the potential impacts and risks of albedo modification would be to improve global capacity to detect and measure changes in radiative forcing and associated changes in climate. Current observational capabilities lack sufficient capacity to detect and monitor environmental effects of albedo modification deployment.

Research on albedo modification to date has involved a substantive amount of modeling. Eventually, some limited field deployments will also be helpful. Prior to initiating field work, the Committee recommends the initiation of a serious deliberative process to examine what types of research governance, beyond those that already exist, may be needed for albedo modification research, and the types of research that would require such governance, potentially based on the magnitude of their expected impact on radiative forcing, their potential for detrimental direct and indirect effects, and other considerations.

Table 1 gives the summary of contrasts between two different approaches to climate intervention.

Table 1

Summary of contrasts between two different approaches to climate intervention.

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Carbon dioxide removal proposals	Albedo modification proposals
address the cause of human-induced climate change (high atmospheric greenhouse gas (GHG) concentrations)	do not address the cause of human- induced climate change (high atmospheric GHG concentrations)
do not introduce novel global risks	introduce novel global risks
are currently expensive (or comparable to the cost of emission reduction)	are inexpensive to deploy (relative to cost of emissions reduction)
may produce only modest climate effects within decades	can produce substantial climate effects within years
raise fewer and less difficult issues with respect to global governance	raise difficult issues with respect to global governance
will be judged largely on questions related to cost	will be judged largely on questions related to risk
may be implemented incrementally with limited effects as society becomes more serious about reducing GHG concentrations or slowing their growth	could be implemented suddenly, with large-scale impacts before enough research is available to understand their risks relative to inaction
require cooperation by major carbon emitters to have a significant effect	could be done unilaterally
for likely future emissions scenarios, abrupt termination would have limited consequences	for likely future emissions scenarios, abrupt termination would produce significant consequences

3. Conclusions

Climate change is one of the grand challenges of our time, with the potential to impact global security. Climate intervention is one tool, along with mitigation and adaptation, for addressing this challenge. Carbon dioxide removal approaches are relatively safe, but research is needed to improve the technical maturity and economic competitiveness. On the other hand, albedo modification acts quickly and is relatively inexpensive. However, this class of solution is difficult to control in terms of the global and regional consequences, and thus should not be considered at this time.

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