# Geoengineering: A Solution to Sea Level Rise

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With climate change being one of the most pressing issues of our time (Ming et al, 2013), measures must be taken to mitigate, adapt, and ultimately solve this problem. A promising method is geoengineering, which aims to mitigate climate change through the deliberate manipulation of Earth's climate (Russell et al., 2012). There are two main geoengineering methods, both aiming to reduce the implications of greenhouse gases (GHG) in the atmosphere: carbon dioxide removal (CDR) and solar radiation management (SRM) (Russell et al., 2012). CDR aims to remove carbon dioxide from the atmosphere, limiting the amount of solar radiation trapped, while SRM aims to increase reflectivity, increasing albedo by reflecting more solar radiation, resulting in less heat being trapped (Russell et al., 2012). This essay will explain how geoengineering is a potential solution to a sea-level rise, a serious issue associated with climate change, through analyzing studies and predictions about the effect of geoengineering on large impact ice sheets.

Sea level rise is a prominent issue resulting from climate change for which geoengineering may hold the solution. As excess GHG, many being anthropogenic, accumulate in and overwhelm Earth's atmosphere, solar radiation becomes trapped creating the warming effect we know as climate change. As temperatures increasingly rise, land ice melts, contributing to an increase in sea-levels. The main cause of sea-level rise is ice sheet melt (Bamber et al., 2019), as a result, the focus in combating sea-level rise can be turned to large impact ice sheets two of which are the

Thwaites Glacier, Antarctica (Wolovick & Moore, 2018) and the Greenland Ice Sheet (GIS), Greenland (Ryan et al., 2018). Mitigating and ultimately solving sea level rise is important as in the process of sea-level rise coastline is lost. With 10% of the world population living in coastal areas, sea-level rise is a pressing issue that impacts hundreds of millions of people and hundreds of billions of dollars in infrastructure (United Nations, 2017).

Thwaites Glacier is projected to be the largest individual contributor to sea-level rise (Wolovick & Moore, 2018) with the potential to raise sea levels by 13 feet in some areas (Angle, 2018) making limiting the melt of this glacier critical. Thwaites is threatened by warming waters that have or will result in Marine Ice Sheet Instability (MISI) where the ice sheet collapses from the point where ice lifts off the bedrock, causing the ice to go afloat in the ocean, contributing to sea-level rise (Wolovick & Moore, 2018). Once this process begins it is unlikely that it will stop as it is dynamic feedback, so a method to prevent and reverse MISI is relevant (Wolovick & Moore, 2018). A 2018 study by Wolovick and Moore investigated whether geoengineering in the form of locally targeted intervention could combat the collapse of the glaciers. This would entail building walls where the glacier meets the ocean, the area of the glacier most vulnerable to melt, to prevent the warm waters from causing MISI (Angle, 2018). This study applied computer models to determine the effectiveness of locally targeted intervention which have yielded positive results thus far predicating stabilization of the glacier and the potential of regaining mass (Wolovick & Moore, 2018). These results show that this is a potential tool in the prevention of sea-level rise. As it is a relatively new method, the researchers emphasized that more research is needed, especially as it pertains to design, for this to be successful (Wolovick & Moore, 2018).

Locally targeted intervention has some benefits as it takes place on a local scale as opposed to a global scale, removing the barrier of international cooperation. Additionally, it can be employed in areas that are at risk of MISI and threaten sea-level rise (Wolovick & Moore, 2018). However, it requires a lot of materials and is very expensive (Angle, 2018). So, even if it is effective, it may not be realistic. It could also have negative impacts on the sensitive Antarctic ecosystem (Angle, 2018). Overall, results show that locally targeted intervention at Thwaites shows potential in combating sea-level rise, however, more research is required to establish its design, effectiveness, and impact.

Where Thwaites was projected to be, the GIS is currently the largest individual contributor to sea-level rise (Ryan et al., 2018), if the entire glacier were to melt, the sea-level could rise 7.3 meters (Applegate & Keller, 2015), making this another glacier where slowing the melt is critical. Due to its sensitivity to surface temperatures (Applegate & Keller, 2015), a proposed solution is stratospheric aerosol geoengineering, a form of SRM which releases sulfate aerosols into the atmosphere to reflect solar radiation. A 2019 study by Moore et al investigated the response of the GIS to stratospheric sulfate aerosol injection. In this study, computer models along with four GHG scenarios correlating with a variety of policies were used to predict the impact of temperature increase on sea-level rise as the result of GIS melt. They then proceeded to model fifty years (2020-2069) of sulfate aerosol injection into the stratosphere and the following twenty years (2070-2089). The model injected 5Tg/year of $SO_2$ into the stratosphere which is equivalent to one quarter of the 1991 Mount Pinatubo volcanic eruption which had a global cooling effect. Results showed that using this method, the surface melt of the GIS could be reduced by 15-20 percent, dependent on the climate scenario used. These results show that this is a potential tool in the prevention of sea-level rise. However, there are reservations when using this method as it could impact climate systems as precipitation may be reduced (Moore et al., 2019).

Finally, albedo modification (AM) is proposed to reduce the melting of the GIS. AM entails lowering surface air temperatures by intentionally increasing Earth's surface reflectivity (albedo) (Applegate & Keller, 2015). A 2015 Applegate and Keller study simulated multiple climate scenarios using computer modeling and compared the mass loss from the GIS with and without AM. Fifty scenarios were considered varying in timeline and method of AM. The result of this study is that AM would ultimately lower Greenland's surface air temperatures, and while mass loss from the GIS would continue, this method could prevent mass loss in the GIS ultimately reduce its contribution to sea-level rise (Applegate & Keller, 2015). This supports the findings of the 2019 Moore et al. study. Additionally, while this is a potential solution to the GIS melt, this is not necessarily transferable to other large glaciers such as West Antarctic Ice Sheet as the melt is impacted by an increase in ocean temperatures as opposed to surface temperatures (Applegate & Keller, 2015. This emphasizes the need not only for case-specific solutions to the impacts of climate change but also for reversing climate change at its source.

While it is evident that geoengineering shows promise in preventing contributions to sea level rise, it is important to understand the limitations of this research as well as the consequences of geoengineering. As mentioned above, the implementation of geoengineering can have unintended consequences on the ecosystem (Angle, 2018) and many aspects of the climate

(Royal Society, 2009), as a result, it is important to understand the known risks associated with this method as well as the fact that there may be some unknown risks. Some of these consequences of geoengineering can have global implications in unpredictable ways, which can make it making governance and international cooperation a barrier in implementing these solutions. Additionally, implementing these come at a cost and require adequate design. While this is a concern for stratospheric aerosols (Royal Society, 2009) it is a significant issue for locally targeted geoengineering. It is expensive (Angle, 2018) and requires a precise design which is yet to be comprehensively researched, the 2019 Wolovick & Moore study focused on the effectiveness of a variety of designs where the feasibility of this feat of engineering must also be accounted for. The combination of risks and feasibility limitations of geoengineering make computer models the main way to test the effectiveness. This means that the studies are limited by the capability and accuracy of the computer model and the climate scenarios they rely on. While climate scenarios are scientifically projected, they are very difficult to accurately predict, considering projections do not just involve temperature changes, but also changes in precipitation which will vary with AM implementation (Applegate & Keller, 2015).

Through examining the above case studies involving two high-impact glaciers it became evident that geoengineering is a promising method to slowing sea-level rise resulting from sheet ice melt. However, it also became evident that more research into the consequences, design, and effectiveness needs to be done in this field before these methods can be implemented to predict and manage potential risks. While it is clear that this has the capability of mitigating the effects of climate change by providing a solution to sea-level rise, it was made clear in all studies that this is no replacement for reducing carbon emissions, the true solution to climate change. "[Geoengineering] is not intended to solve the climate change problem. [Geoengineering] is intended to buy time to let our descendants or heirs find the solution for us" (Ming et al., 2014). The false belief that it is a solution must be dispelled as it could threaten the efforts to reduce emissions. To conclude, while more research is still required in this field, geoengineering holds the promising potential for reducing the sea-level rise that threatens millions.

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