

## A rudimentary consideration on anthropogenic climate change and countermeasures to it, "geoengineering" in particular

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The issue called "anthropogenic climate change" (ACC) or "global warming" is such a chain of causes and effects that human industrial activities result in increase of concentration of greenhouse gases such as carbon dioxide in the atmosphere, enhancement of the greenhouse effects, and cause changes of climate which can be characterized by increase of global mean surface temperature. It also have such aspects as sea level rise and changes of dryness, which have impacts on human society. The impacts are given unevenly between regions and between generations.

Since 1998 when the IPCC was established, the countermeasures to ACC has been discussed in terms of "mitigation" and "adaptation". In its 5th Assessment Reports (AR5) to be published in 2013-14, another category called "geoengineering" is added. Here I tentatively follow the categorization of AR5.

The human society has developed within the constraint of the environment, by adapting to it. Climate, including its changes, is part of the environment, and adaptation to it is one of basic functions of the human society. There are a few notable issues, however. Since the start of agriculture, the human society has experienced the climate of Holocene which has extraordinarily small variability in the context of the whole Quaternary era. Also, in the modern world, adaptation by migration has become difficult, since clear national boundaries and land ownership have been developed, and population has increased so much thanks to technologies which also involve utilization of fossil fuel. In addition, with recent development of global ideas of equality between nations and humanitarianism,

people tend to value avoiding such fates where many people die untimely.

In the middle 20th century, it was hoped to technologically control climate within a state favorable to human society. Development of science resulted in two pieces of understanding. One is that the climate is a complex system with large uncertainty due to nonlinearity and difficulty of observation. Another is that emission of carbon dioxide by burning of fossil fuels is an important forcing that shifts the energy balance of the climate system. Then, people tended to think a kind of "passive intervention" by reducing the forcing that human activities already have made as the major countermeasure to the climate change. It has become customarily called "mitigation".

The essence of mitigation is reducing use of fossil fuels. International decision making on it has not been very successful even though 20 years have passed after the establishment of UNFCCC in 1992. It is because energy resources is fundamental to economical development.

In this context, hopes to technologically control climate, e.g. "geoengineering" have risen again. It is still difficult, however. The technology is not finished, and the knowledge about effects, side-effects and costs is uncertain.

Two major sub-categories of "geoengineering" are called "carbon dioxide removal" (CDR) and "solar radiation management" (SRM).

CDR is equivalent to mitigation as far as it reduces the forcing to the atmosphere, but it modifies the environment of geological formations, soil, or ocean, where the carbon dioxide is put. In addition, failure of sequestration is possible. "How much environmental modification and possibility of accidents people can tolerate" will be a subject of social decision making. The decision making can be done within a country if the sequestration is made within its territory.

SRM can cancel the greenhouse forcing in global mean sense, but it will enhance it in some of latitude bands and seasons. Assessments of its impacts is as difficult as regional projection of ACC. The fact that this is intentional makes the issue of liability more serious. Thus, such an international governance regime that is much stronger than the current UNFCCC regime is necessary, in addition to technological feasibility, to include SRM in policy options.

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