Climate Engineering and the Role of Feedbacks in the Climate Structure

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A key to addressing Climate Engineering is to formulate as complete a delineation as possible of the feedbacks within the climate system that set the foundation for determining irreversible behavior of the coupled system. These feedbacks and the irreversibility associated therewith define both the imperative to consider climate engineering and the potential risks associated therewith.

To pick a few (of many) examples:

1. The rapid increase in GHG forcing sets in place a feedback structure coupling increases in convective injection of water vapor into the stratosphere at mid-latitudes that will both decrease the lower stratospheric temperature (via radiative cooling) and accelerate the conversion of inorganic chlorine to free radical form that in turn accelerates the rate of catalytic ozone loss via the coupled catalytic step involving bromine and chlorine radicals. This was highlighted in the NRC NASA Earth Sciences Decadal Survey (2007) in the human health chapter (chapter 6) because of its link through ozone to melanoma and basal cell carcinoma. Ozone loss (and thus UV dosage), are far more sensitive to water vapor increases and associated temperature decreases than they are to chlorine loading given the current structure of the system. Were this increase in stratospheric water vapor to begin, it could well be irreversible.
2. Perhaps the most notorious is the release of methane and carbon dioxide from melting clathrates and permafrost at high latitudes of the Northern Hemisphere: there are 800 to 1000GtC tied up in those systems such that a 1%/yr melt rate would add 8-10 GtC/yr to the atmosphere. When this carbon release begins to couple into the climate structure, not only will it be irreversible, but every climate forecast currently in existence will have to be fundamentally reappraised.
3. The loss of half the permanent Arctic Ice Cap since 1980 initiates four feedbacks: influx of warmer ocean water, decreased albedo, increased IR emission upward from the warm ocean replacing the ice cap, and increasing thermal energy transport to the region via atmospheric transport over warmer terrestrial systems and ocean surfaces replacing ice and snow. Arctic ice cover is indeed the heat shield for Greenland with its ice volume equal to 7 meters of sea level rise – yet we do not have an accurate time series of the Greenland glacial volume nor do we have the observations to establish the structural feedbacks within the Greenland glacial system to distinguish between a simple "melt" model and a "collapse" model initiated by water lubrication of the bedrock. As you know, both the time scale and the irreversible nature of sea level rise depend sensitively on which perspective – melt or collapse – dominates.

4. Increased climate forcing by carbon release from fossil fuel combustion leads to an associated feedback increasing temperature, water vapor, clouds, etc. in the troposphere, but how potent is this feedback? The answer depends critically on how the feedback controls water vapor increases as a function of altitude, latitude, longitude and season. We lack the high accuracy observations to establish these key feedbacks in the climate system as a whole that are needed to test and systematically improve decadal climate forecasts. In fact there is a profound lack of high accuracy time series regarding the climate system. The Keeling record is perhaps the only one universally respected.
5. Increased climate forcing by carbon release drives changes in the lower troposphere that execute phase transitions at altitudes between 0.5 and 1.5 km altitude that in turn initiate a precipitous decrease in snow pack longevity in the mountain regions that feed summer water to the agricultural areas of the western and mid-western US. This loss of melt water and the associated snow fields and glacial structures couples into feedbacks that control both summer temperatures and soil moisture in the key water sheds required to sustain this (and other) nation's crop yields. Evidence is clear in both the Columbia River and Colorado River water sheds, but the quantification of these feedbacks remains ill defined.

To date:

- In virtually all cases, these potent feedbacks have not been dissected nor quantified.
- Our federal research structure is sufficiently lacking in strategic design that there are not even programs into which innovative research approaches explicitly addressing these feedbacks can be fielded.
- While there is a great deal of "activity" in the national climate programs, there is a remarkable absence of coherence and insight required to distinguish success from failure as we move forward.