Press Release
Jena, December 5th, 2013

Max-Planck-Institut
für Biogeochemie

No Undo for Climate Change: Potential Pitfalls of Geoengineering

Global warming alters the intensity of the water cycle, and the magnitude of these changes has now been explained by scientists of the Max-Planck-Institute for Biogeochemistry in Jena, Germany. Using a simple physical approach, the study explains how the water cycle reacts to surface warming and that it responds differently to heating by sunlight or by a stronger atmospheric greenhouse effect. This has important consequences for potential interventions that aim to undo global warming by reflecting sunlight by geoengineering: While such interventions may cool down temperatures, simultaneous changes in the water cycle and the atmosphere cannot be compensated at the same time.

Precipitation should generally increase in a warmer world. When the surface warms due to a stronger atmospheric greenhouse effect, for instance due to more carbon dioxide in the atmosphere, the air near the surface is warmer and can hold more moisture. This should result in greater evaporation, greater rainfall, and thus a stronger cycling of water. With every degree of warming, air can hold about 7% more moisture. Climate model predictions generally show such an increase in rainfall with global warming, but they predict an increase of only about 2% per degree warming, which seems puzzling.

This puzzle has now been addressed in a study just published in the journal Earth System Dynamics of the European Geosciences Union, by scientists of the Max-Planck-Institute for Biogeochemistry in Jena, Germany. Dr. Axel Kleidon and his colleague Dr. Maik Renner looked at the processes that heat and cool the surface and how these change when the surface warms. Evaporation plays a key role here because it requires a lot of heat to evaporate water. Yet, the evaporated water from the surface also needs to be transported into the atmosphere. Kleidon and Renner applied a physical limit to this vertical transport and derived the same 2% increase in the water cycle predicted by climate models. They related this low increase, not to the general capacity of air to hold water vapor, but rather to the differential change in this capacity between the air near the surface and the air when it condenses in the atmosphere.

However, Kleidon and Renner also found that this 2% increase only applies to the case in which the surface warming was caused by a stronger atmospheric greenhouse effect. When the surface is

Postfach 10 01 64
07701 Jena, Germany

Hans-Knöll-Straße 10
07745 Jena, Germany

Tel.: +49-(0)3641 57-60
Fax: +49-(0)3641 57-70
www.bgc-jena.mpg.de

Direktoren

Prof. Susan E. Trumbore, PhD
Phone: +49 (0)3641 57-6110
susan.trumbore@bgc-jena.mpg.de

Prof. Dr. Martin Heimann
Tel.: +49 (0)3641 57-6350
martin.heimann@bgc-jena.mpg.de

Dr. Markus Reichstein
Phone: +49 (0)3641 57-6273
mreichstein@bgc-jena.mpg.de

Forschungskoordination & Presse

Dr. Eberhard Fritz
Phone +49 (0)3641 57-6800
efritz@bgc-jena.mpg.de

Presse & Öffentlichkeitsarbeit

Susanne Hermsmeier
Phone: +49 (0)3641 57 6801
sherms@bgc-jena.mpg.de

heated more strongly by sunlight instead, they estimated that the water cycle would increase more strongly by about 3% per degree warming. This stronger increase is a consequence of the need to balance the greater energy input by sunlight with stronger cooling fluxes from the surface, which involves a stronger increase in evaporation.

“These different responses to surface heating are easy to explain”, says Kleidon, and uses a pot on the kitchen stove to illustrate. “The temperature in the pot is increased by putting on a lid, or by turning up the heat, but these two cases differ by how much energy flows through the pot”, he says. Similar effects take place when the surface warms: A stronger greenhouse effect puts on a thicker “lid” over the surface, whereas more heating by sunlight turns up the heat, enhancing the energy flow through the surface, and hence has a greater effect on the water cycle.

The consequences of these insights are profound. Studies of global warming generally lump sunlight and the atmospheric greenhouse effect into a single term, while Kleidon and Renner found that these two causes of surface heating have rather different impacts on the hydrologic cycle and on the vertical transport within the atmosphere. Their study provides important insights for understanding global climate change, specifically to the goals of geoengineering that attempts to compensate global warming by reducing the amount of sunlight reaching the surface by enhanced atmospheric reflection. When Kleidon and Renner applied their results to such a geoengineering scenario, they found that the compensation for a 2 degree warming weakens the water cycle by 2% and vertical transport by almost 8%. A similar response was also reported in a very recently published climate model intercomparison study on geoengineering. “It’s like putting a lid on the pot and turning down the heat at the same time”, explains Kleidon. “While in the kitchen you can reduce your energy bill by doing so, in the Earth system, this slows down the water cycle with wide-ranging potential consequences”, he concludes.

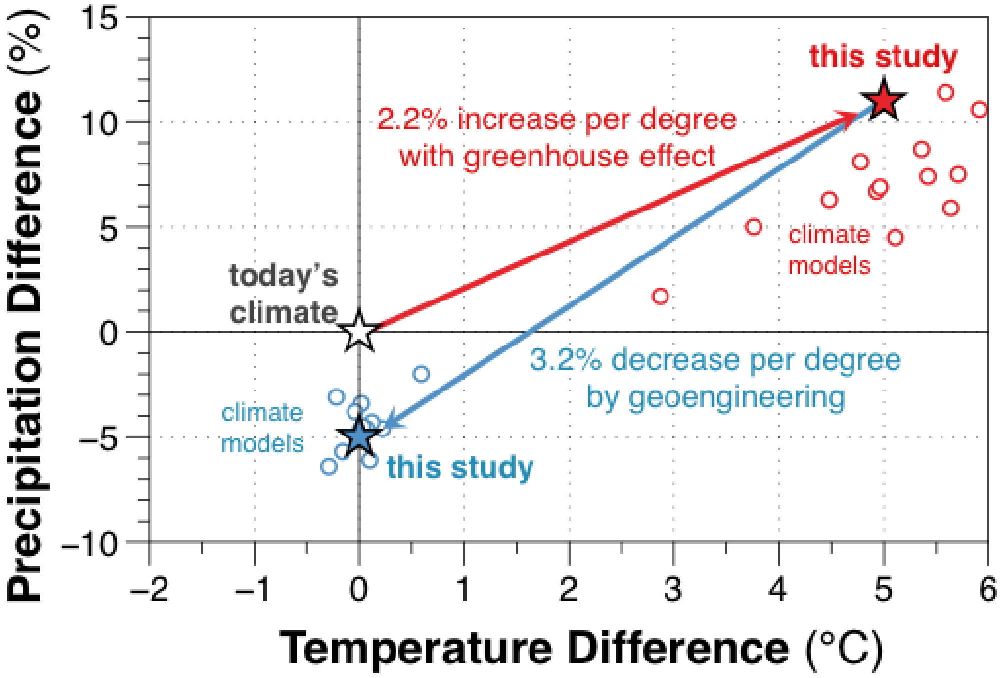
Publication:

Kleidon and M. Renner, 2013: A simple explanation for the sensitivity of the hydrologic cycle to surface temperature and solar radiation and its implications for global climate change; *Earth System Dynamics.*

http://www.earth-syst-dynam.net/recent_papers.html

Contact:

Dr. Axel Kleidon
Biospheric Theory & Modeling Group
Max Planck Institute for Biogeochemistry
Hans-Knoell-Str. 10, 07745 Jena, Germany
Phone: +49 3641 576217 , Fax: +49 3641 577217
Email: akleidon@bgc-jena.mpg.de
http://www.bgc-jena.mpg.de/index.php/BTM/Home



based on:
Kleidon and Renner (2013) *Earth System Dynamics*
climate model data from Tilmes et al. (2013) *Journal of Geophysical Research*

Figure above: The study by Kleidon and Renner calculated the changes of the water cycle by a warming caused by the greenhouse effect and by solar radiation to be 2.2% and 3.2% per degree of warming respectively. If global warming would result in a temperature increase of 5° C, this would enhance precipitation by 11% (red arrow). Would this warming be compensated by geoengineering, then precipitation would decline more strongly (blue arrow). Hence, geoengineering may compensate temperatures, but the water cycle would be weakened by 5% compared to the present-day. A recently published intercomparison study of much more complex climate models (circles) agrees with these estimates.

Picture: Annett Junginger; imaggeo.egu.eu