Time to Wait ?

Efforts to reduce greenhouse gas emissions decrease the risk of irreversible changes in the climate system

There is growing evidence that human greenhouse gas emissions affect the climate on Earth and contribute to global warming. Recent climate model simulations indicate that not only the absolute concentration of greenhouse gases, but also the rate of concentration increase determines how strongly the climate is perturbed. These models further suggest the existence of thresholds, beyond which irreversible changes may occur.

These new findings clearly indicate that a further delay of reduction measures tends to increase the risk of reorganisations in the climate system. 'Business-as-usual' and 'wait-and-see' policies reduce the option of choices in the future and lower critical thresholds of maximum greenhouse gas concentrations in the atmosphere.

The Ocean is a Dynamic Climate Factor

Due to the ocean's large heat storage, global warming is now expected to develop slowlier than first estimates in the 1970's. Ocean currents, however, have a profound influence on regional climate on Earth: the Gulf Stream is responsible for a relatively mild climate in the North Atlantic region; the El Niño-Southern Oscillation periodically leads to strong climatic variability in equatorial and tropical latitudes around the globe.

Is the North Atlantic Deep Circulation a Climate Switch ?

The heat transport associated with the meridional, thermohaline circulation in the North Atlantic leads to temperatures that are significantly higher than at similar latitudes elsewhere. In the last years scientists found, that increasing air temperatures warm the sea surface and a stronger hydrological

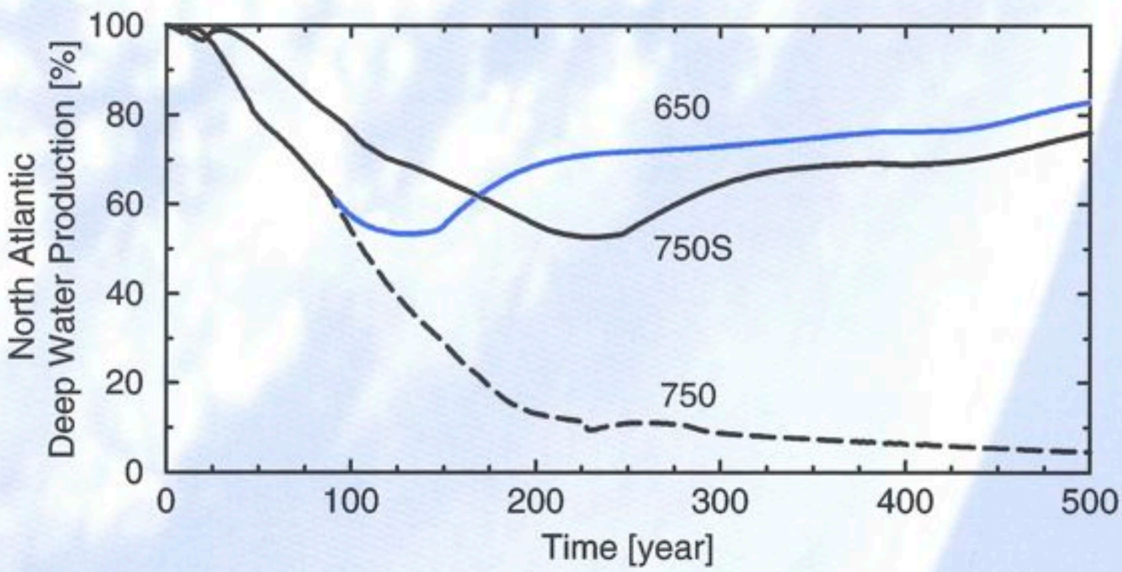

Figure 1: Evolution of the deep water production in the North Atlantic (in % of present) for different scenarios of anthropogenic greenhouse gas increase. The present coupled atmosphere-ocean climate model (ref. 2) exhibits a glo-bal mean temperature increase of $\Delta T = 3.7^{\circ}C$ for a doubling of CO_2 in agreement with ref. 1. Curve '650' is the ocean's response to an increase of CO_2 at a rate of 1%/year from 280 ppmv to the stabilization concentration of 650 ppmv. Deep water formation weakens initially but then recovers to a slightly reduced value. If instead the stabilization concentration is higher, 750 ppmv, and beyond the threshold, the circulation stops permanently (curve '750'). However, if the same maximum concentration is reached at only half the rate of CO_2-increase (0.5%/year), the circulation weakens initially, but recovers later (curve '750S'). The threshold CO_2-concentration is higher in this case. If the climate system is allowed more time to adjust to global warming, the occurrence of irreversible changes is less likely [Figure after ref. 2].

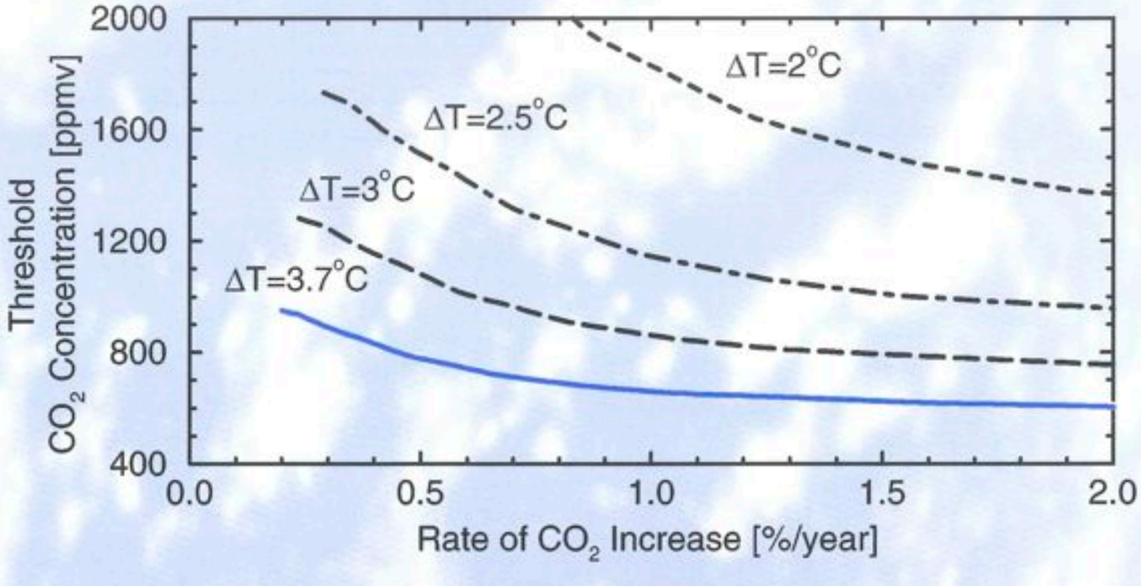

Figure 2: Threshold values of equivalent CO_2 concentrations as functions of the rate of CO_2-increase. For comparison, the mean rate in the decade 1980-1990 was about 1%/year. If the maximum CO_2 concentration exceeds the thres-hold values, the North Atlantic deep water production stops. Threshold values depend on the globally averaged temperature rise for a doubling of the atmospheric CO_2 concentration, ΔT, which is the model-dependent climate sensitivity. Current estimates range between 1.5 and 4.5°C. Threshold values for the experiments in Figure 1 are determined based on ΔT = 3.7°C; they lie at about 670 ppmv and 790 ppmv for 1%/year and 0.5%/year, respectively. The threshold values here are determined using a simplified climate model and specific emission paths described in ref. 2. The values cannot be used for a climate prediction as they depend on the particular climate model used as well as on the parameterizations included in that model.

cycle leads to fresher surface waters. Both these effects tend to reduce deep water formation. Such changes would result in reduced warming in the North Atlantic region. Model simulations show that the deep circulation could stop completely, if certain thresholds are passed. One such threshold is the maximum greenhouse gas concentration in the atmosphere (ref. 1).

Using a simplified, coupled atmosphere-ocean climate model, Swiss scientists recently demonstrated that not only the maximum CO_2 concentration but also the rate of CO_2-increase influences the deep circulation in the North Atlantic (ref. 2).

Speed of CO_2-Increase is Critical

At the present rate of atmospheric CO_2-increase climate models indicate that the thermohaline circulation may shut down permanently even if concentrations are stabilized at 750 ppmv. An atmospheric concentration of 750 ppmv will be reached in approximately 100 years, if emissions continue at today's rate. However, if emissions are reduced, the North Atlantic deep circulation continues to ope-rate at a slightly reduced speed, even if concentrations stabilize at levels above 750 ppmv. The reason for this rate-sensitive response lies in the ocean's limited speed of downward mixing of heat and excess freshwater from the upper-most layers into the deep ocean.

A reduction of emissions thus tends to increase threshold values, because the climate system has more time to adjust to the changes. Cost-benefit considerations of different climate policy options must take into account such thresholds in the climate system. Therefore, efforts to stabilize and then reduce greenhouse gas emissions early, increase threshold concentrations beyond which irreversible changes may occur.

References:

1. Manabe S. & Stouffer R., *Nature* **364**, 215-218 (1993).
2. Stocker T.F. & Schmittner A., *Nature* **388**, 862-865 (1997).

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