Ice loss? Safe, man!

No tipping point for the sea ice loss in present climate

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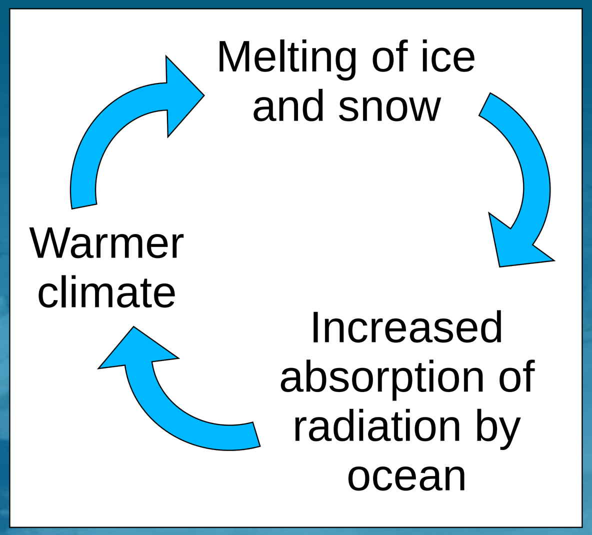
INTRODUCTION

Sea ice is a key component for the arctic climate and biological systems. The recent massive decrease of the arctic summer sea ice extent in 2007 poses the question, of whether this is an indicator of a "tipping point". Tipping points are understood as critical melting points, beyond which the sea ice cannot recover. If this were to happen, it would cause severe impacts on the arctic and global ecosystems, as well as on sea-ice and ocean dynamics. The ice-albedo feedback is thought to be the main factor causing this possible instability. An energy balance model (EBM) is used to study the effects of this feedback mechanism. Further analysis is carried out to explain the observation of the 2007 minimum.

ICE-ALBEDO EFFECT

The albedo is the fraction of the incident energy that is reflected by a surface. Melting sea ice in a warming climate decreases the Earth's albedo. This leads to higher absorption of radiation by the ocean and thus further warming and melting occur. This is called the ice-albedo feedback.



ENERGY BALANCE MODEL

A simple 1-D EBM including a global earth albedo (α) is used to analyze the possible instability introduced by the ice-albedo feedback. The imbalance between the incoming shortwave solar radiation (F_{SW}) and the outgoing longwave radiation ($\varepsilon\sigma T^4$) causes changes in surface temperature (T).

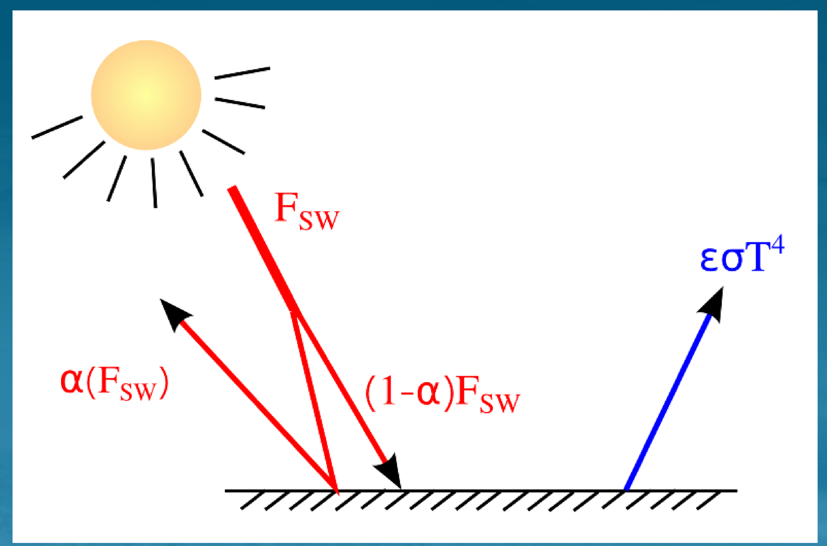


Figure 1: EBM scheme with F_{SW} the solar incoming radiation, α the albedo and $\varepsilon\sigma T^4$ the emitted radiation from the Earth. Balance is made at the Earth's surface.

$$c\frac{dT}{dt} = F_{SW}\left(1-\alpha(T)\right) - \varepsilon\sigma T^4$$

ε: Emissivity
σ: Stefan-Boltzmann constant

EBM STABILITY ANALYSIS

A stability analysis, using a linear dependency of the albedo on the temperature ($\alpha = \alpha_0 - \beta T$) and current climate parameters, gives the following criterion for stability:

$$\beta \leq 0.0154 K^{-1}$$

The current estimate $\beta = 0.009\ K^{-1}$ shows that the present climate is stable. This is possible due to the neutralizing influence of stabilizing feedbacks (infrared cooling feedback in this model). However in a warming climate, these factors could become less effective which may lead to instability. Although the present climate does not indicate the existence of a tipping point, a minimum of the Arctic summer sea ice extent was observed in 2007. The following sections aim at explaining this observation.

THE 2007 MINIMUM – THE THINNING EFFECT

The evolution of the minimum sea ice extent in the last 60 years shows a major decrease in 2007. However having a look at the change of the ice extent from year to year, one can notice that the decrease in 2007 was of similar size to previous year to year changes. The major loss of sea ice in 2007 can be explained by a recent shift in the sea ice thickness distribution. The average thickness of sea ice is in fact now lower than in the previous decades, leading to a higher ratio of ice loss to remaining ice for the same volume of melted ice. This ratio experiences more variability from summer to summer for thinner ice than for thicker ice. Therefore today's ice extent has a stronger dependency on the weather and the predictability of the future summer sea ice extent becomes more difficult.

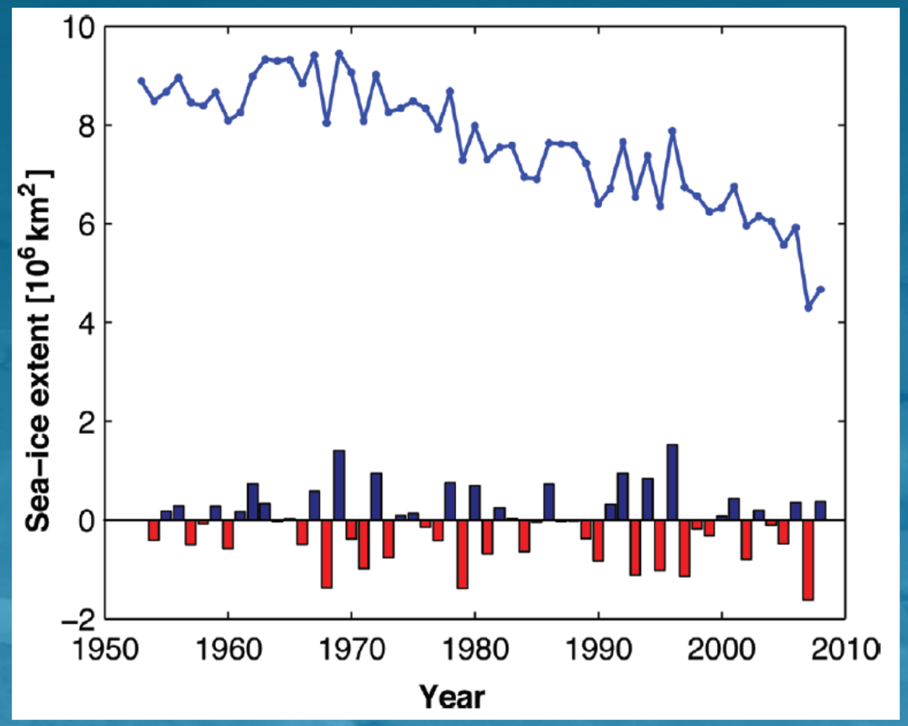


Figure 2[1]: Minimum Arctic sea-ice extent between 1953 and 2008 as blue line and year-to-year changes as blue (positive) and red (negative) histogram.

THE 2007 MINIMUM – ICE GROWTH RATE

Recent simulations have shown that thin ice grows faster than thicker ice. Looking at the ice growth over a one year period, the simulation predicts that the growth of first-year ice has approximately double the size compared to the growth of the pre-existing ice which remained throughout the summer. The difference in growth rates is mainly due to the fact that pre-existing ice has higher snow coverage. The snow insulates the ice not allowing heat exchanges at the ice–atmosphere boundary in order to produce more ice. This faster growth of thin ice can be regarded as a stabilizing feedback, which allowed the recovery over the winter in 2007/2008 thus showing higher summer sea ice extent in 2008 and the following years.

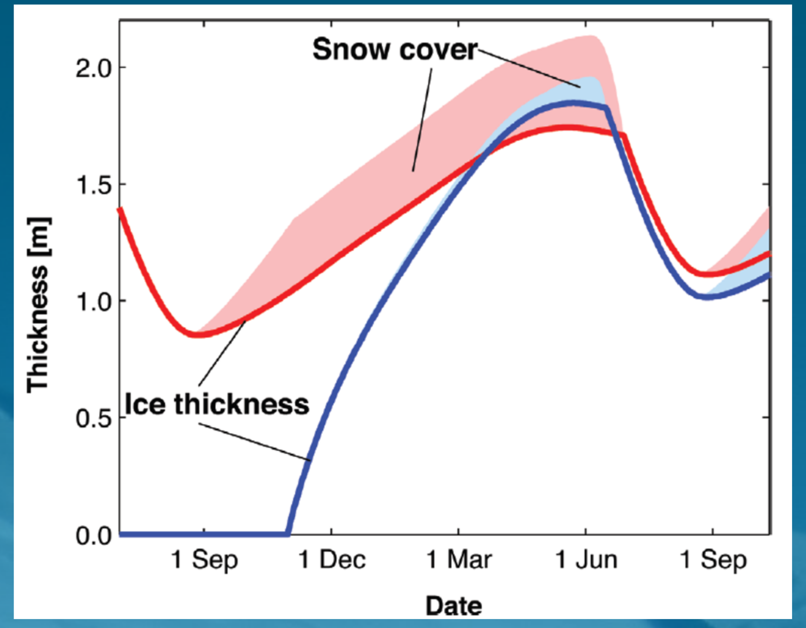


Figure 3[1]: Ice thickness of first-year ice (blue) and pre-existing ice (red) over a one year period. The thinner ice (blue) has higher growth rate than thicker ice (red), that survived throughout the summer.

CONCLUSIONS

- There is currently no tipping point for the Arctic summer sea ice loss.
- Even without tipping points, strong variability in the sea ice extent exists, causing consequences for the earth system.
- Further global warming could lead to tipping points for both summer and winter sea ice loss.

Reference:

1. Notz, D., 2009: The future of ice sheets and sea ice: between reversible retreat and unstoppable loss, *Proc. Nat. Ac. Sci.*, **106**(49), 20590-20595.

Additional Reading:

Winton, M. (2006), Does the Arctic sea ice have a tipping point?, *Geophys. Res. Lett.*, **33**, L23504

I. Eisenman and J.S. Wettlaufer (2009). Nonlinear threshold behavior during the loss of Arctic sea ice. *Proc Natl Acad Sci USA* **106**, 28-32

Bitz, C. M., G. H. Roe, 2004: A Mechanism for the High Rate of Sea Ice Thinning in the Arctic Ocean. *J. Climate*, **17**, 3623–3632