Description of the experiment

Ice and snow cover in the climate system

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Motivation

Due to climate change, the Earth's ice cover attracts particular attention in research as well as in general public. Hardly any other component of the Earth system shows the impact of climate change as distinctly as the melting glaciers of high mountain ranges or the rapid decline in Arctic sea ice extent. Additionally, the decline in ice and snow covered areas accelerates the warming of high latitudes significantly. Recent research also connects the unusual weather conditions of the mid-latitudes in recent years, like cold winters in Europe and the USA or heat waves in Western and Eastern Europe, with the melting of the Arctic sea ice.

Ice and snow have an important role in the climate system and its changes in turn impact the climate system. The following experiments with the Monash Simple Climate Model can help to understand the effects of ice and snow and their interaction with the climate system.

Model setup for the experiments

Depending on the user, the MSCM can be used in different levels of difficulty:

The standard version has 11 processes that can be switched on and off manually (see next page). However, some processes like diffusion or advection of water vapour and heat are not comprehensible for every user. Likewise, the term model correction is hard to grasp for non-professionals. Thus this version is rather suitable for advanced users (e.g. students or people with a strong background in climate physics).

The basic version combines several processes from the standard version under one generic term so that the number of the processes that can be switched on and off reduces to 6 (see next page). The model correction, although not visible, is switched on, if the water cycle is switched on. This basic version is suitable for users without previous knowledge in climate physics.

The experiments discussed here result in the same model performance for the standard as well as the basic version, because the processes not shown in the basic version are still incorporated in the model. Therefore, the experiments are outlined and explained only once in the section 'Model results and observations'.

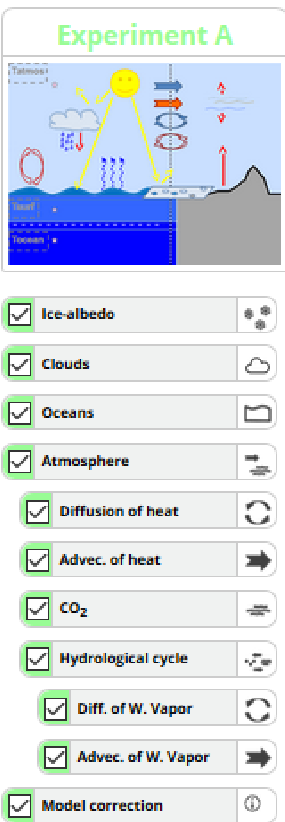
Processes switched ON in experiment A: **All processes**

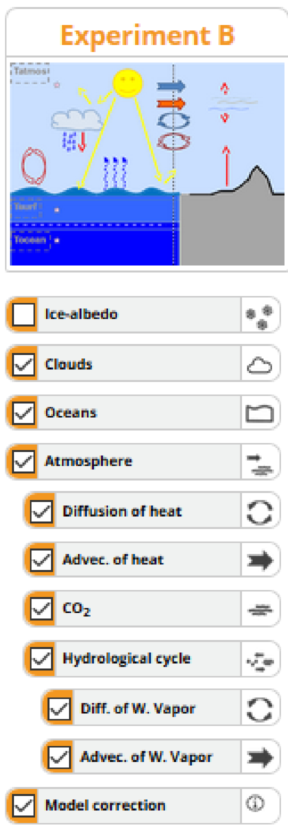
Processes switched ON in experiment B: **All processes except 'Ice-albedo'**

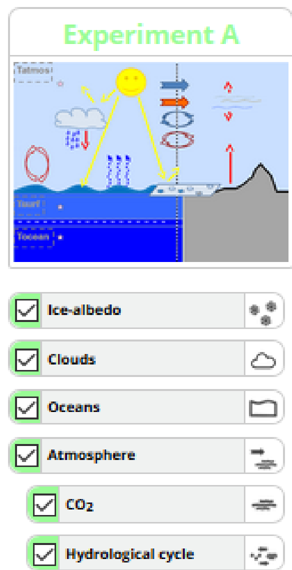
Following months will be compared: **January** (Northern winter/ southern summer) and **July** (Northern summer/ southern winter)

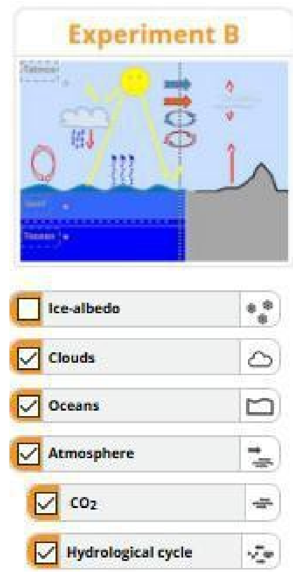
Standardversion

Basic version



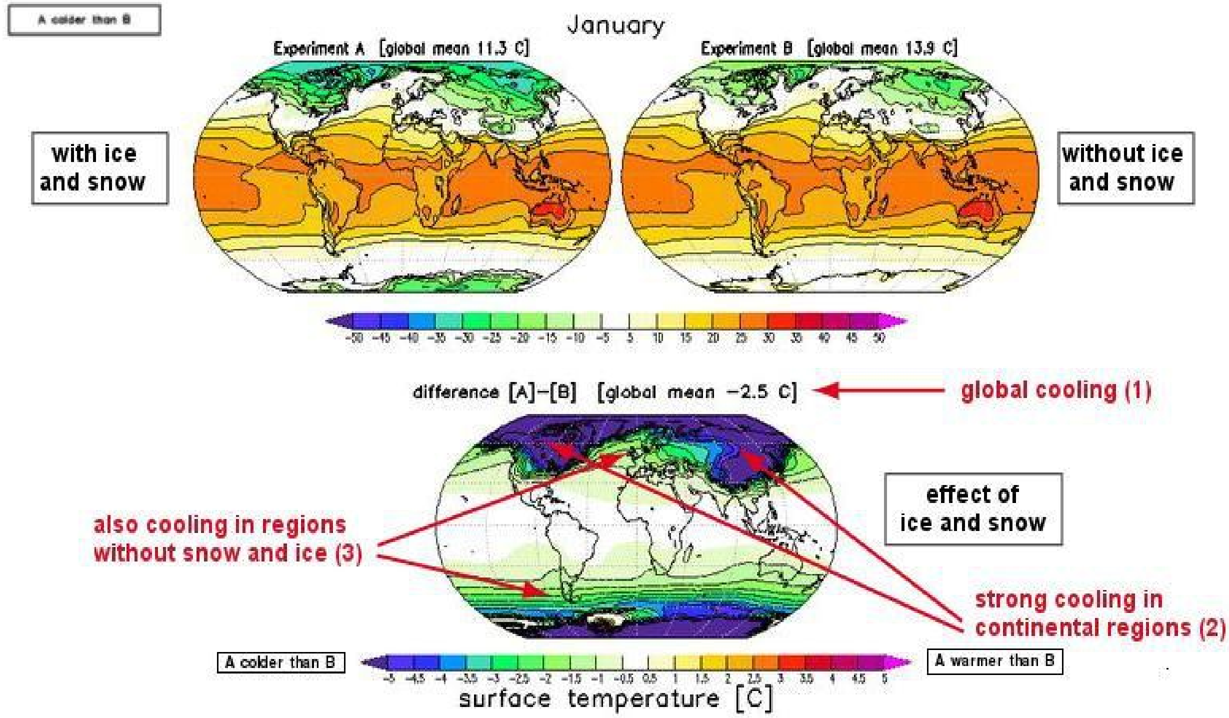




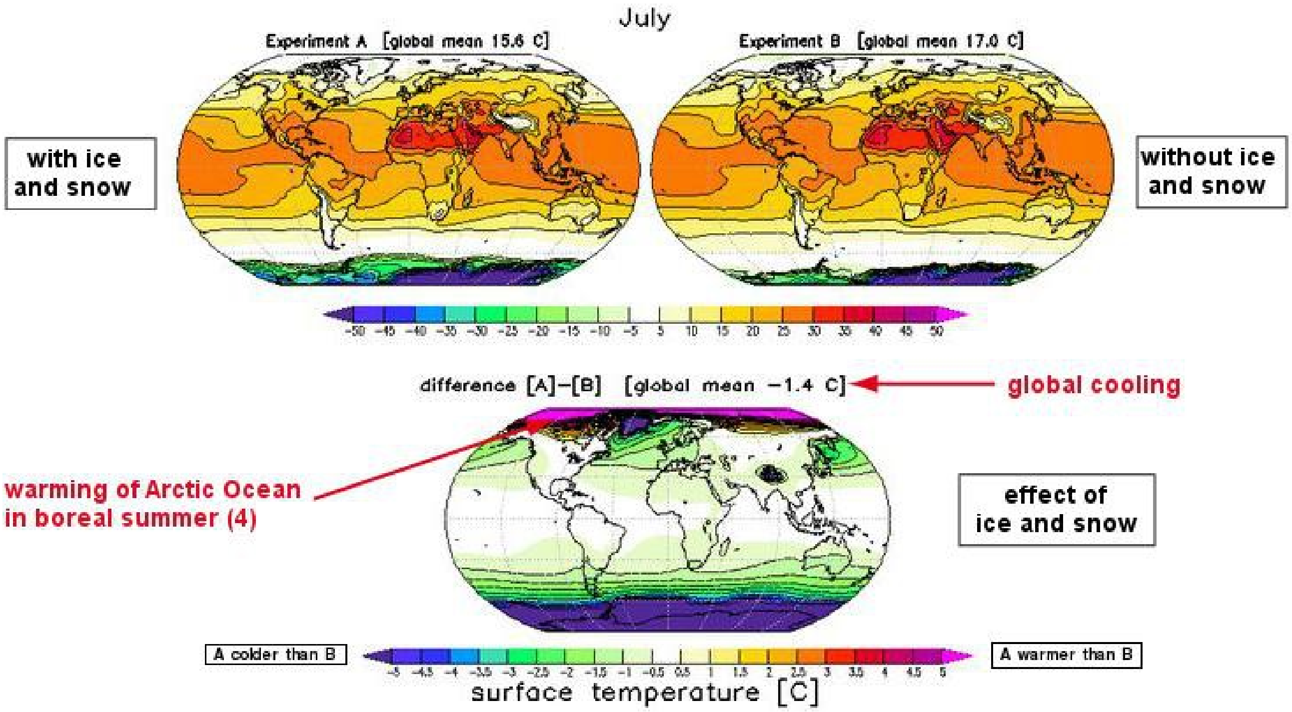


Model results and observations

JANUARY



JULY



Physical background and explanation of the model results

Ice and snow cover basically influence the climate in two ways:

1. through the energy balance of the Earth's surface: Ice and snow lead to an increase of the albedo, i.e. more incoming solar radiation is reflected
2. through the heat balance of the Earth's surface: Ice and snow isolate the underlying layers. Especially on oceans, this has a distinct effect and can, depending on the season, lead to either a warming or cooling.

Both processes are captured in the MSCM and can explain the model results.

Global observations

	Observation	Explanation
(1)	Globally, the ice and snow cover has a cooling effect (sign is negative).	Due to the high albedo of ice and snow, more incoming solar radiation is reflected back to space (see fig. 2), resulting in a cooling of the atmosphere.
(1)	The global cooling is more pronounced during Northern winter (January) compared to Northern summer (July).	There are larger land masses in the Northern Hemisphere, especially in the mid- and high latitudes (e.g. Siberia), that are impacted by the snow cover (see below and Fig. 1)

Regional observations

	Observation	Explanation
(2)	Pronounced cooling on the large land surfaces in Asia and North America.	Presence of large land surfaces, on which snow cover leads to a strong cooling due to the albedo effect.
(3)	With ice and snow cover switched on, even regions without ice and snow show a cooling, e.g. in the North Atlantic and the South Pacific.	The transport of cold air in the atmosphere (see Fig. 3) brings the cooling also to regions that are not covered by ice and snow.
(4)	Ice and snow lead to a warming of the Arctic Sea in Northern summer and a warming of small parts of the coastal waters in the Antarctica in Southern summer.	The ice cover isolates the relatively warm ocean from the atmosphere in Northern winter so that the ocean only releases little heat (see Fig. 4). As a consequence, the ocean is warmer in Northern summer with ice cover than without ice cover in winter. This results in a more continental climate with stronger seasonal variability.

Additional figures

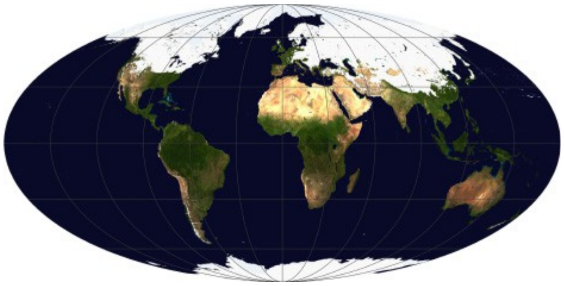


Figure 1: Ice and snow cover in Northern winter. Source: NASA

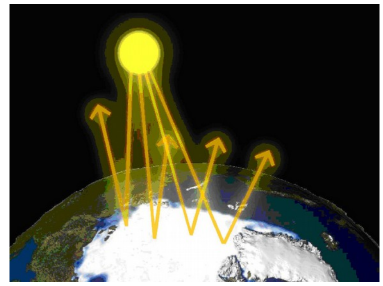


Figure 2: Ice-albedo feedback. Source: Dirk Notz, MPI-M

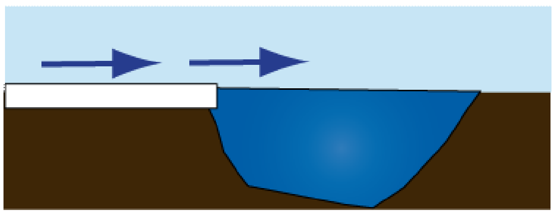


Figure 3: Cooling by transport of air masses. Source: Dieter Kasang

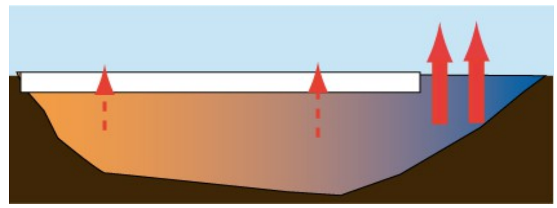


Figure 4: Heat storage of the ocean by isolation in winter. Source: Dieter Kasang

Helpful articles to work on the exercises:

Article	Topic
Cryosphere in the climate system	Overview of the global extent of ice and snow and their impacts on climate
Ice-albedo feedback	Positive feedback (amplified warming and decrease of sea ice extent) due to the ice-albedo effect
Sea ice	Processes of sea ice formation and melting, effects of sea ice on interactions between ocean and atmosphere, isolation effect of sea ice
Arctic sea ice	Observed decrease of Arctic sea ice extent, causes for sea ice melting, climatic consequences of sea ice melting (e.g. cold winters in Europe), projections of the Arctic sea ice in the future