EGU General Assembly 2024

EGU24-17517, updated on 20 May 2024
https://doi.org/10.5194/egusphere-egu24-17517
EGU General Assembly 2024

Impact of the Greenland Ice Sheet on the Atmosphere and Ocean

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The accelerating mass loss of the Greenland Ice Sheet (GrIS) and its potential disappearance under high-emission scenarios, make the understanding of associated implications of a melted GrIS for the global climate paramount. Here, we present a comprehensive analysis of the effects of a disintegrated GrIS on the atmosphere and ocean. For this, a set of steady-state simulations with altered topography resembling an ice-free state was performed with the Max Planck Institute for Meteorology Earth System Model (MPI-ESM). The model consists of components for the atmosphere, ocean and land, and includes dynamic vegetation. Additional sensitivity experiments, allow for the first time to disentangle the individual contributions of changes in the GrIS surface elevation and properties (e.g., albedo, vegetation cover) to the simulated climate response.

In a scenario with disintegrated GrIS, the atmospheric circulation is different. Reduced blocking and warmer air temperatures over Greenland induce differences in near-surface winds in the Arctic. In the ocean, the transport of sea ice and water masses changes in absence of the GrIS. Sea-ice export increases through the Norway-Svalbard section, the Nares Strait and the Canadian Archipelago, while it decreases through the Fram Strait. Further, water-mass export through the Fram Strait and import through the Norway-Svalbard section weakens, whereas export through the Nares Strait and the Canadian Archipelago increases. Due to the changed ocean-mass transports, the Arctic Ocean and Greenland-Iceland-Norwegian Seas freshen. The freshening in the Greenland-Iceland-Norwegian Seas increases the buoyancy, attenuating deep-water formation. In the Labrador Sea, a higher salt import via Davis Strait decreases vertical stability, allowing for enhanced deep-water formation.

The sensitivity experiments show that the oceanic response can be predominantly attributed to the change in wind stress due to the lower surface elevation over Greenland, amplified by the change in Greenland's surface-properties. Only in the Labrador Sea, changes in GrIS surface properties dominate the differences in the signal. Heat from a stronger summer warming over Greenland due to the reduced albedo and changes in vegetation is stored in the Labrador Sea and keeps ocean temperature warmer throughout the entire year, as compared to an experiment considering only a lower surface elevation. These findings suggest that both reduced mechanical blocking and changes in Greenland's surface properties, due to a disintegration of the GrIS, are key for the atmospheric and oceanic response. Further, the simulations indicate that a disintegrated GrIS influences not only the local climate around Greenland but also the remote climate. This is a step forward in understanding the distinct effects of a changing GrIS on the full climate system.