The story of extreme Greenland melt: an ocean perspective

Storyline simulations on weather and ocean extremes linked to Greenland Ice Sheet–melting

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In Short

- Designing storyline simulations for extreme Greenland ice sheet melt events
- Impact of extreme meltwater runoff on circulation and surface conditions in the subpoalr North Atlantic
- Investigating linkages to weather extremes over Europe

Melting of the Greenland ice sheet and the associated runoff into the subpolar North Atlantic has the potential to significantly impact the strength of the Atlantic Meridional Overturning Circulation (AMOC) and thus the entire global thermohaline circulation (e.g., Hu et al., 2011; Swingedouw et al., 2013; Jackson and Wood, 2018). As the meltwater spreads in the subpolar North Atlantic, it gets entrained into the Subpolar Gyre (SPG, Figure 2) and enhances stratification in the Labrador Sea (LS) weakening the local deep convection and thus likely reducing the production of North Atlantic Deep Water (NADW). The latter is an integral part of the AMOC, which further links to the global ocean circulation. It is therefore crucial to better understand the role of Greenland meltwater runoff extremes on the surface conditions of the subpolar North Atlantic. Moreover, as the large-scale atmospheric circulation links European climate and weather events closely with conditions over the North Atlantic, we want to investigate a potential role of Greenland Ice Sheet melt for weather conditions over Europe. While there is evidence that major undulations in the strength of the AMOC impacts European temperatures and precipitation (Dima et al., 2021; Ionita et al., 2021), it is largely unknown whether annual melt extremes over Greenland have the potential to cause short-term AMOC variations with downstream impacts for Europe.

We propose to investigate the influence of Greenland Ice Sheet melt extremes on the surface conditions of the North Atlantic in an eddy-rich climate model simulation under present day and warmer climate conditions.

Our scientific objectives are:

- Creating novel storyline climate model simulations for extreme melt events on Greenland with an eddy-rich ocean

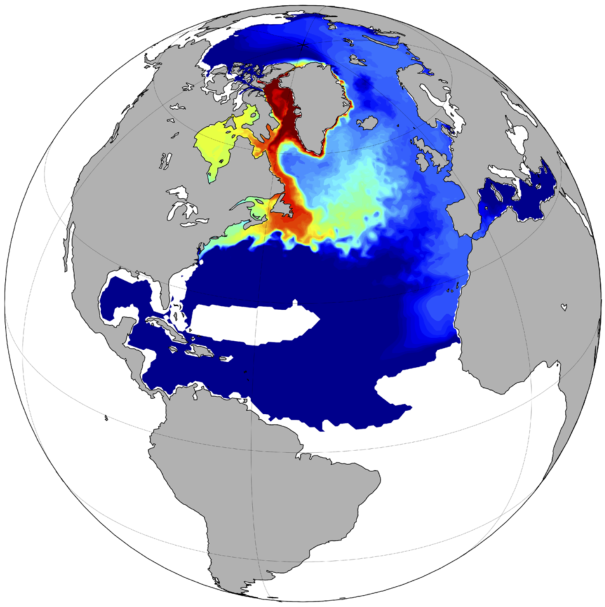

Figure 1: *Greenland melt-water redistribution in a FOCI-VIKING10 simulation after 50 years of freshwater-release at 0.05 Sv depicted by vertical maximum of tracer concentration.*

- Investigating the signature and consequences of extreme meltwater runoff on conditions of the subpolar North Atlantic in present and future warmer climates
- Detecting and attributing changes in weather patterns associated with such extreme melt events

For the proposed work the complex and coupled global climate model (GCM) of the Flexible Ocean and Climate Infrastructure (FOCI) of GEOMAR will be used (Matthes et al., 2020). Here, we specifically apply FOCI-OpenIFS, which consists of NEMO3.6 (Nucleus for European Modeling of the Ocean, Madec, 2012) and OpenIFS (Kjellsson et al., 2020). The ocean model is applied to a global 1/2°grid (ORCA05) with 46 vertical levels. The ocean model is combined with the sea ice model LIM2 (Fichefet and Morales Maqueda, 1997), which runs on the same horizontal grid.

Ocean and atmosphere are coupled via the OASIS3-MCT coupler (Valcke et al. 2013). It performs the exchange of momentum, heat and freshwater fluxes as well as sea-ice properties between the two components. The coupler also handles the necessary grid transformations between the atmospheric spectral and oceanic tripolar ORCA grid. The coupling with the atmosphere is carried out every hour and the ocean host model is updated with

FOCI

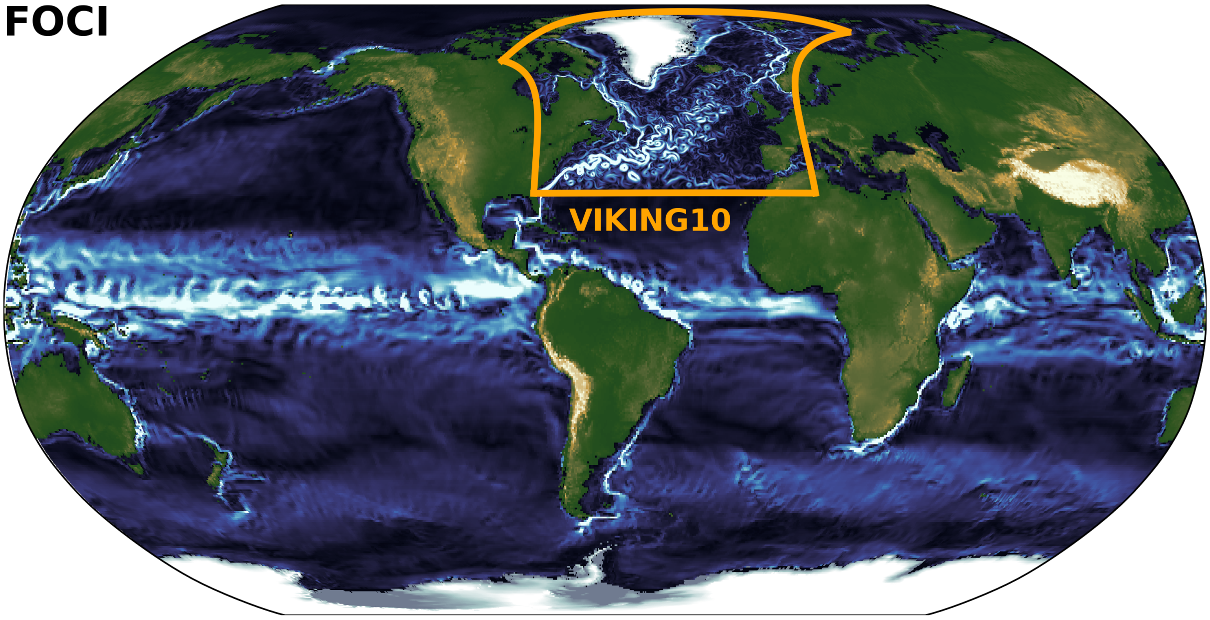

Figure 2: Snapshot of upper ocean current speed in a global coupled climate model simulation with FOCI-VIKING10. The default global ocean at 1/2° grid resolution clearly lacks mesoscale ocean features. By implementing the 1/10° North Atlantic nest VIKING10 an eddy-rich ocean is simulated in the refinement region (orange outline). Note, color scale highlights current speeds exceeding 0.5 m/s in white.

the 3D field of the nest model prior to every time step.

The redistribution of meltwater around Greenland and in the subpolar North Atlantic strongly depends on mesoscale ocean dynamics (Böning et al., 2016; Martin and Biastoch, in prep.). We thus apply an 1/10° ocean nest named VIKING10 into the ocean model of FOCI using AGRIF (Adaptive Grid Refinement In Fortran, Debreu et al., 2008). The nest facilitates a horizontal grid refinement of factor 5 from 1/2° to 1/10° in the subpolar North Atlantic and Atlantic Arctic (31° to 85°N, Fig. 1) following the example of Böning et al. (2016). AGRIF ensures 2-way exchange meaning the nest is forced at its boundaries by the global ocean model and feeds back its 3-D state to this base model. At the surface the nest is forced with the same atmospheric fluxes as the base model but does not directly provide its state to the atmosphere—instead, the coupler in FOCI receives the ocean surface conditions from the global base model.

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