EGU24-4310, updated on 21 Jul 2024
https://doi.org/10.5194/egusphere-egu24-4310
EGU General Assembly 2024

New Arctic quality metrics based on oceanic transports for CMIP6

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Oceanic transports of heat, volume and salinity are an integral part of the Earth's energy and mass budgets and play a key role in regulating the Earth's climate. Changes in the ocean's transport patterns may affect regional as well as global climates. Accurate monitoring is critical and there are several regional measuring lines like the RAPID 26N and OSNAP (Overturning in the Subpolar North Atlantic Program) array, as well as measuring lines across Arctic water straits, which are equipped with moorings and other advanced measuring systems. It is desirable to compare the transports calculated by these instruments with ocean reanalyses and climate models. However, this is challenging because the moorings are not aligned with the model grids, and the ocean model grids get complicated especially towards more northern latitudes.

To address this challenge, we introduce StraitFlux (https://pypi.org/project/straitflux/), a versatile tool enabling precise and mass-consistent calculation of volume, heat, and salinity transports across any oceanic section. We have used StraitFlux to calculate transports from reanalyses and climate models (CMIP6) in the Arctic region and to compare them to available observations. While we find some biases, especially in straits that are narrow and bathymetrically complicated, the results generally show that reanalyses capture the main current patterns quite well. Climate models on the other hand exhibit larger and often systematic deviations from the mooring and reanalysis output. The spread among climate models is 3-5 times larger than the spread between observation-based transports and reanalyses or among reanalyses, and it cannot be explained by natural variability. The large spread in flux quantities is related to mean-state biases in relevant state quantities. It helps to quantify and understand the strong connections between lateral OHT and the mean state as well as changes in the Arctic Ocean and sea ice.

Expanding on our methodology, we develop physically based metrics tailored to the Arctic, to detect outliers from the CMIP6 model ensemble and constrain model projections using a weighting approach incorporating the models' performance and independence. This effectively reduces the spread of future projections of Arctic change. Further, using StraitFlux, we investigate constrained changes in Arctic volume, heat, and salinity transports for the main SSP scenarios. We examine cross-sections of the main Arctic gateways to assess future changes in the structures and strengths of the main currents and their effects on the Arctic system.