KEY RESULTS

- Prominent decadal fluctuations in simulated Atlantic Water heat content in Fram Strait
- Warming trend in Atlantic Water since 1970, but also relatively warm 1930s
- Simulated Northern Hemisphere sea ice extent decline since 1950 is stronger than observed
- High correlation between Atlantic Water temperature anomalies and sea ice bottom melting North of Svalbard
- Sea Ice thinning occurs relatively homogeneously over the deep Arctic Basin and is similar to observations (Yu et al., 2004)

BACKGROUND

Warm and salty Atlantic Water (AW) enters the Arctic Ocean through the Fram Strait and the Western Barents Sea (Fig. 1). This Atlantic Water is present below the Arctic sea ice cover, but the depth varies by region and over time. In regions north of Svalbard the Atlantic Water has a direct impact on the sea ice cover.

Both historical observations and outcome from a fully coupled earth system model show a warming trend in core temperature of the Atlantic Water inflow over the last few decades (1977-2015) (Fig. 2, Muilwijk, 2016).

Figure 1: Regional circulation schematic of Atlantic Water inflow and circulation in the Arctic Ocean. (Polyakov et al., 2012).

Over the twentieth century, the Atlantic Water temperature records from observations show two warm periods, in the 1930s-40s and in recent decades, and two colder periods, early in the 1900s and in the 1960s-70s (Muilwijk, 2016). We believe that the recent Atlantic Water warming trend in the Arctic Ocean may be part of long-term multimodel variability, which is influenced and reinforced by strong anthropogenic forcing. We will investigate this variability and the physical mechanism behind using NorESM-O forced by a twentieth century reanalysis data set for the period 1871-2009 (He et al., 2016).

Figure 2: Timeseries of AW-core temperature (black) measured in the Fram Strait. Data from the Norwegian Institute of Marine Research. Figure from Muilwijk (2016).

VARIABILITY OF ATLANTIC WATER HEAT

Figure 3: Annual mean barotropic flow in the AW-inflow region from NorESM-O for the period 2000-2009.

Figure 4: Simulated yearly mean Atlantic Water heat content from NorESM-O forced by twentieth century reanalysis in the Fram Strait (A), West Spitsbergen Current (B) and the Barents Sea Opening (C). Red and blue bars show decadal anomalies.

Figure 5: (Left) Sea ice extent and thickness with spatial trends for the period 1979-2009 from NorESM compared with observations.

Figure 6: Near the Atlantic water inflow region, the warm water has a direct impact on the sea ice cover. The figure shows spatial correlation between bottom melting and Atlantic Water temperature variations in NorESM.

PASSIVE TRACERS IN THE ARCTIC OCEAN

Figure 7: Atlantic Water and freshwater pathways in the Arctic Ocean will be investigated in NorESM-O using passive tracers released on locations a)-g) for the period 1980-2009.

Figure 8: Example of surface layer concentration in 2009 for different tracers released in 1980.

ONGOING WORK: CLIMATE RESPONSE FUNCTIONS IN THE ARCTIC OCEAN

Another set of simulations with the ocean-sea ice component of the Norwegian Earth System Model (NorESM-O) has been run. This simulation is part of a coordinated set of Arctic modeling experiments where our goal is to compute and compare “Climate Response Functions” (CRFs) - the transient response of key observable indicators such as sea-ice extent, ice export through the Fram Strait, freshwater content of the Beaufort Gyre, Atlantic Water flow, etc - to abrupt “step” changes in forcing fields across a number of Arctic models (Marshall et al., 2017). The idea is that the convolution of time series from this forcing with the respective CRF then yields a (linear) response of observable indicators.

Figure 9: A schematic of circulation pathways in the Arctic Ocean and key “switches” that can perturb it. Thick blue pathways show general branches of sea ice drift and surface water circulation. Red arrows represent inflows of warm Atlantic waters entering the Arctic Ocean. Key “switches” for the Arctic, that will be perturbed in the model, are also indicated: winds interior (WI in the Beaufort Gyre) and exterior (WO), river runoff (R, orange arrows). Figure from Marshall et al., (2017)

ONGOING ANALYSIS: SEA ICE VARIABILITY AND BOTTOM MELTING

Figure 10: (Left) Sea ice extent and thickness with spatial trends for the period 1979-2009 from NorESM compared with observations.

Figure 11: Near the Atlantic water inflow region, the warm water has a direct impact on the sea ice cover. The figure shows spatial correlation between bottom melting and Atlantic Water temperature variations in NorESM.