Investigating Arctic Ocean Freshwater Content Variability in a Changing Climate

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Introduction

- The Arctic Ocean is characterized by its strong stratification structure, primarily determined by salinity variations.
- Freshwater has changed more frequently in the Arctic Ocean in recent years due to differing rate of sources/transport pathways and exports especially within the Beaufort Gyre (BG).
- The BG serves as a large freshwater reservoir within the Arctic Ocean, where its accumulation and retention are influenced by wind forcing, surface currents among ice-ocean stress, and eddy-induced circulation and diffusivity.
- The BG, an ocean current that circulates in a clockwise motion, encompasses a large amount of the total freshwater in the Arctic Ocean. Depending on changes in the gyre's characteristics such as its strength and vertical movement, the amount of freshwater added can increase or decrease. In the last few decades (years), the BG has experienced anomalous freshening followed by its stabilization between 2007-2008.
- There is limited understanding of the role that the Russian Arctic Shelf and Eurasian basin plays in the Arctic Ocean's FWC. This region has often been overlooked in terms of FWC. The Russian Arctic Shelf exhibits a wide range of salinity variability due to seasonal sea ice advance and retreat as well as discharge from major rivers.

Comparison of Model Simulations

- We used all available in *situ* measurements, remote sensing observations, model simulations and reanalysis products to examine FWC over the Arctic Ocean.
- This study highlights the drawbacks and advantages of utilizing ocean model simulations (ECCO, MIZMAS, HYCOM, NEMO) and Reanalysis products (ORAS5, GLORYS12 and SODA3) for a comprehensive understanding of the Arctic Ocean's physical dynamics in changing climate.

Salinity Variations in the Arctic

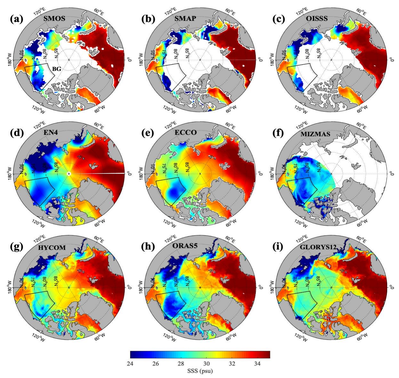

Figure 1. Arctic Ocean sea surface salinity (SSS) averaged over the month of September 2015 from satellites: (**a**) SMOS, (**b**) SMAP, (**c**) OISSS, objective analysis product: (**d**) EN4, and ocean model simulations: (**e**) ECCO, (**f**) MIZMAS, (**g**) HYCOM, (**h**) ORAS5, and (**i**) GLORYS12. (Hall et al. 2022).

Salinity Variations in the BG

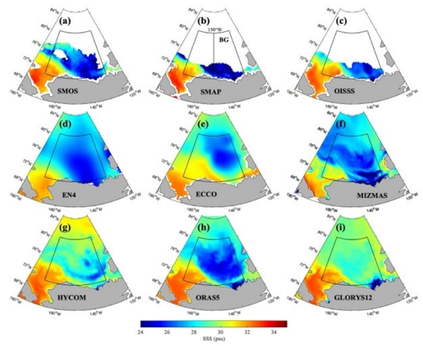

Figure 2. Arctic Ocean Sea surface salinity (SSS) averaged over the month of September 2015 in the Beaufort Gyre (BG) region derived from satellites: (**a**) SMOS, (**b**) SMAP, (**c**) OISSS, objective analysis product: (**d**) EN4, and ocean model simulations: (**e**) ECCO, (**f**) MIZMAS, (**g**) HYCOM, (**h**) ORAS5 and (**i**) GLORYS12. 150°W transect is outlined for comparisons in this study (Hall et al. 2021).

Role of the Russian Arctic Shelf

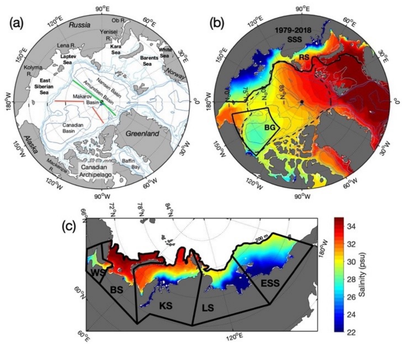

Figure 7. (a) Arctic Ocean and subarctic seas schematic with geographical labels and bathymetric line (b) Sea surface salinity (SSS; psu) from ORAS5 reanalysis averaged between 1979–2018 over the (Arctic Ocean region (>66°N) and the (c) Russian shelf region. The Russian Shelf (RS) and Beaufort Gyre (BG) regions are outlined in black, solid lines while the Arctic Basin region is denoted by black, dashed lines in (b). (Hall et al. 2023).

Region	FWC variance (m^2)		SSS variance (psu^2)	
	Mean	Maximum	Mean	Maximum
Arctic Ocean	0.58	**6.83**	0.43	**32.97**
Beaufort Gyre	1.63	4.73	0.57	6.01
Russian Shelf	0.27	**5.24**	0.79	**32.97**
ESS	0.68	**5.24**	1.00	7.61
LS	0.24	4.59	0.78	12.54
KS	0.21	3.62	1.11	**32.97**
BS +WS	0.04	2.26	0.14	6.24

Table 1. Average and max variance of deseasonalized freshwater content (FWC; m^2) and sea surface salinity (SSS; psu^2) of Arctic Ocean regions between 1979–2018. Bolded values indicate maximum variance from the Arctic subregions. (Hall et al. 2023).

- Overall, satellite observations are restricted to ice-free regions, and models tend to overestimate esea surface salinity.
- ORAS5 provides the strongest positive SSS correlation coefficient (0.612) and lowest bias to in situ observations compared to the other products.
- Discrepancies between models and SIZRS data are highest in GLORYS12 and ECCO.

Comparison of Model Simulations with SIZERS

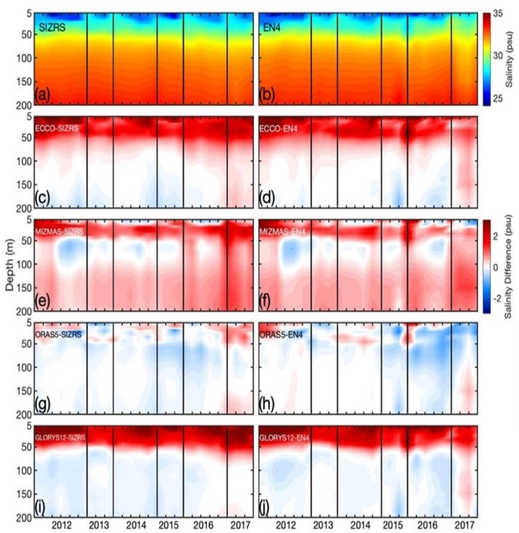

Figure 3. Salinity (psu) versus depth profiles averaged monthly over all SIZRS latitudes for (**a**) SIZRS and (**b**) EN4 from 2012–2017, and the departure of salinity from SIZRS (left column) and EN4 (right column) for the ocean models (**c,d**) ECCO, (**e,f**) MIZMAS, (**g,h**) ORAS5, and (**i,j**) GLORYS12. Grey, vertical lines separate years where months are not consecutive (Hall et al. 2021).

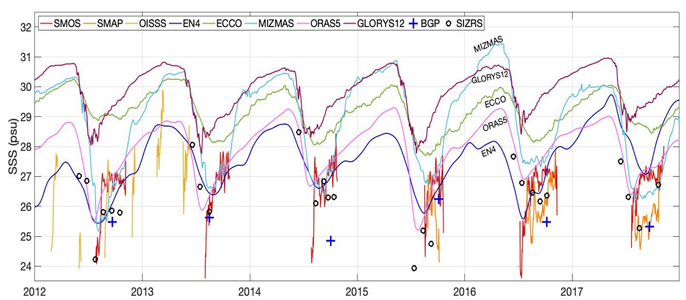

Figure 4. Averaged sea surface salinity (SSS) along a 150°W transect between 70.5°N–80.5°N among ocean products between Jan. 2012 – Dec. 2017 (Hall et al. 2021).

We used ONR sponsored Seasonal Ice Zone Reconnaissance Surveys (SIZRS) have been conducted since 2012 by the APL/UW (provided by Dr. Jamie Morrison) onboard US Coast Guard C–130 aircraft to make ocean and atmosphere sections across the Beaufort Sea seasonal ice zone (SIZ), the Beaufort Gyre Exploration Project (BGP) data, and *In situ* ship CTD data from the Russian Shelf from the Nansen and Amundsen Basins Observational System (NABOS) program.

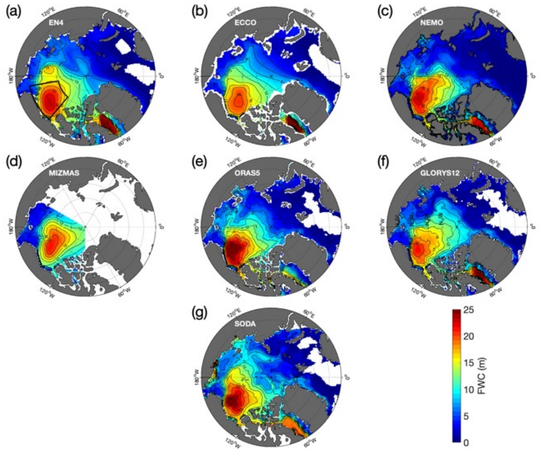

Figure 5. Averaged FWC (m) of the Arctic Ocean in 2017 for (a) EN4, (b) ECCO, (c) NEMO, (d) MIZMAS, (e) ORAS5, (f) GLORYS12, and (g) SODA. The Beaufort Gyre region is denoted with a black box in (a). Contours are every 2 m (Hoffman et al. 2023).

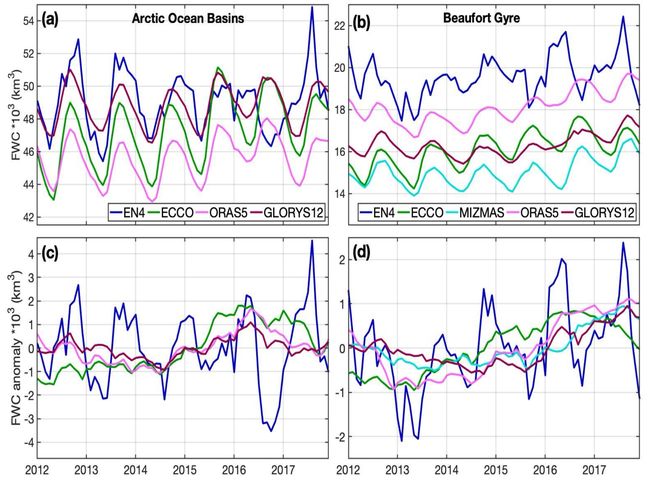

Figure 6. Timeseries of depth–integrated (5 m – 500 m) and box–accumulated freshwater content (FWC; km^3) in the (a,c) Arctic Ocean Basins (180°W–180°E, 67°N–90°N) and the (b,d) Beaufort Gyre (170°W–130°W, 70.5°N–80.5°N) from (top panel) raw data and the (bottom panel) departure from the monthly climatology between 2012 and 2017 (Hall et al. 2021).

Key Points

- Important regions like the BG that provide insight to the state of the changing Arctic Ocean in a warming climate show concerning dissimilarities in ocean models.
- Future sea ice melt will be even more of a contributing factor to the accumulation of FW to the BG in a changing climate.
- The RS contributes around 16% of freshwater content to the Arctic Ocean's storage with a decreasing trend that is mainly influenced by the Kara and Laptev Seas ((Hall et al. 2023).
- Neglecting the RS creates an error of up to 25% in assessing Arctic Ocean freshwater volume change across the 2007 regime transition ((Hall et al. 2023).

References & Acknowledgements

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