Impact of Greenland icesheet's melting on sea level trends in the Arctic Ocean over 1998-2011

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INTRODUCTION

The IPCC indicates that Global Mean Sea Level (GMSL) very likely increased from 72 mm to 117 mm over the period 1971–2018 with the largest contributions from ocean thermal expansion (50%) and melting of ice sheets and glaciers (42%). The Greenland Ice Sheet (GIS) lost 4890 [4140–5640] Gt of ice between 1992 and 2020, causing sea level to rise by 13.5 [11.4 to 15. 6] mm (The IMBIE Team, 2021, AR6). The GIS mass losses are increasingly dominated by surface mass balance (SMB, increased surface melting and runoff). **Mass loss varies strongly, due to large interannual variability in SMB.**

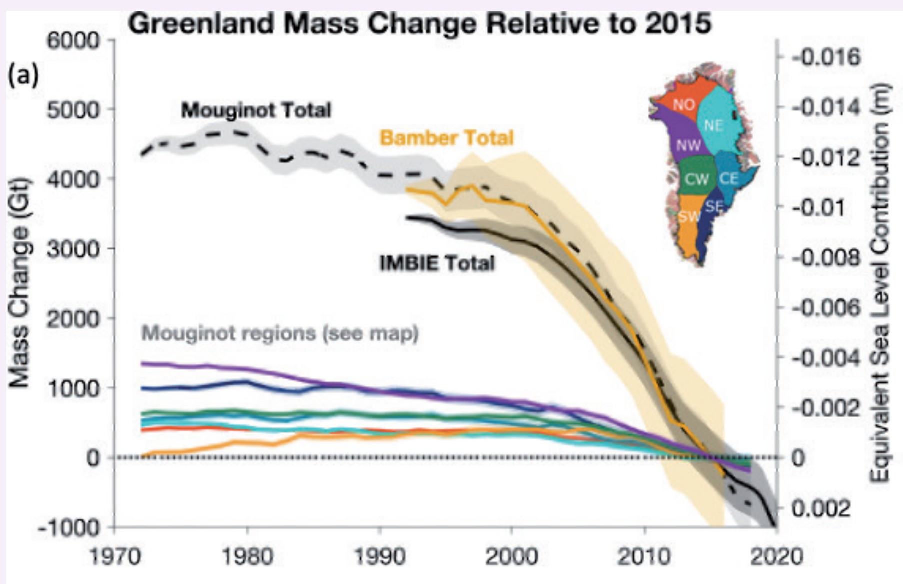

Figure 1: Time series of mass changes in GIS for each of the major drainage basins shown in the inset figure (Bamber et al., 2018b; Mouginot et al., 2019; The IMBIE Team, 2021) for the periods 1972–2016, 1992–2018, and 1992–2020 (IPCC, AR6, fig.9.16a).

METHOD

The main added values of this **sensitivity approach** are that it enables us to isolate GIS impact, to take into account the complex interactions between the GIS and ocean and sea ice, and to quantify them.

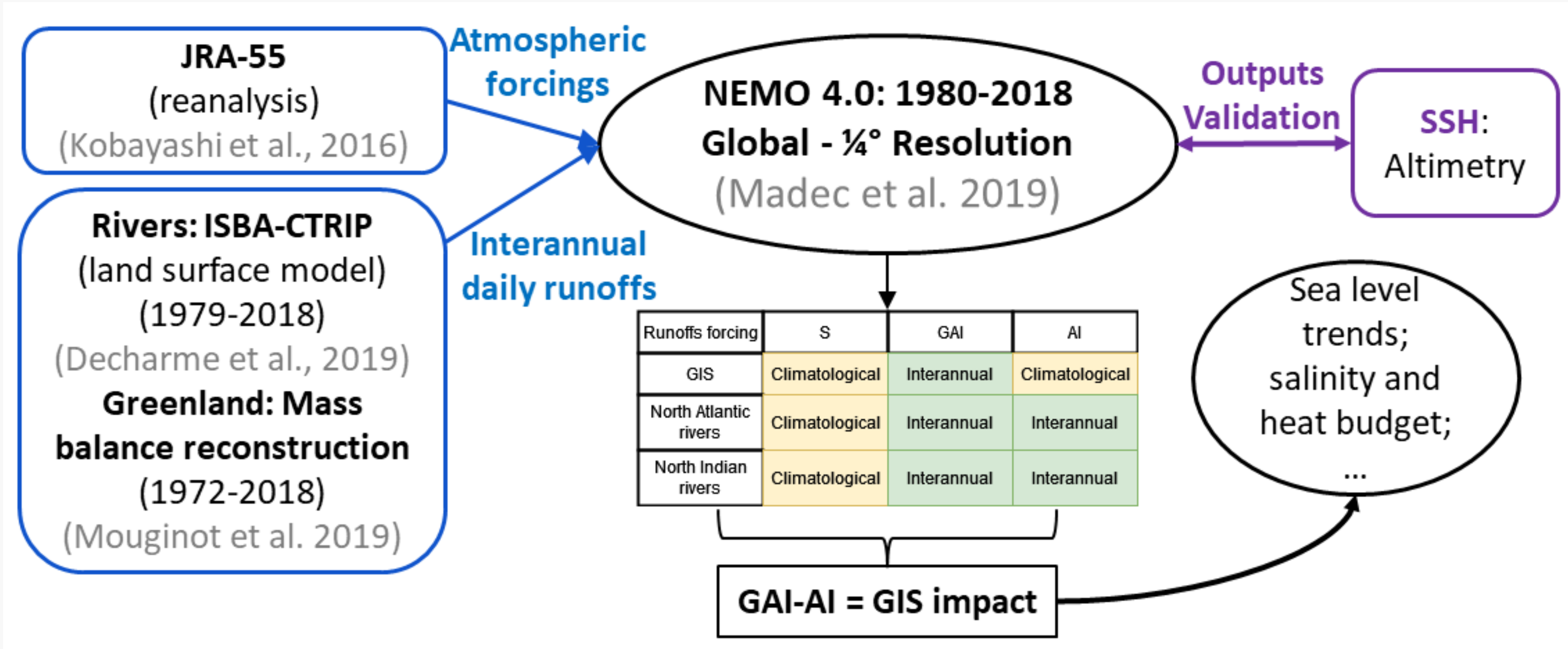

Figure 2: Numerical approach of the sensitivity experiments.

VALIDATION

SLA trends maps from 1998 to 2011 in the Arctic

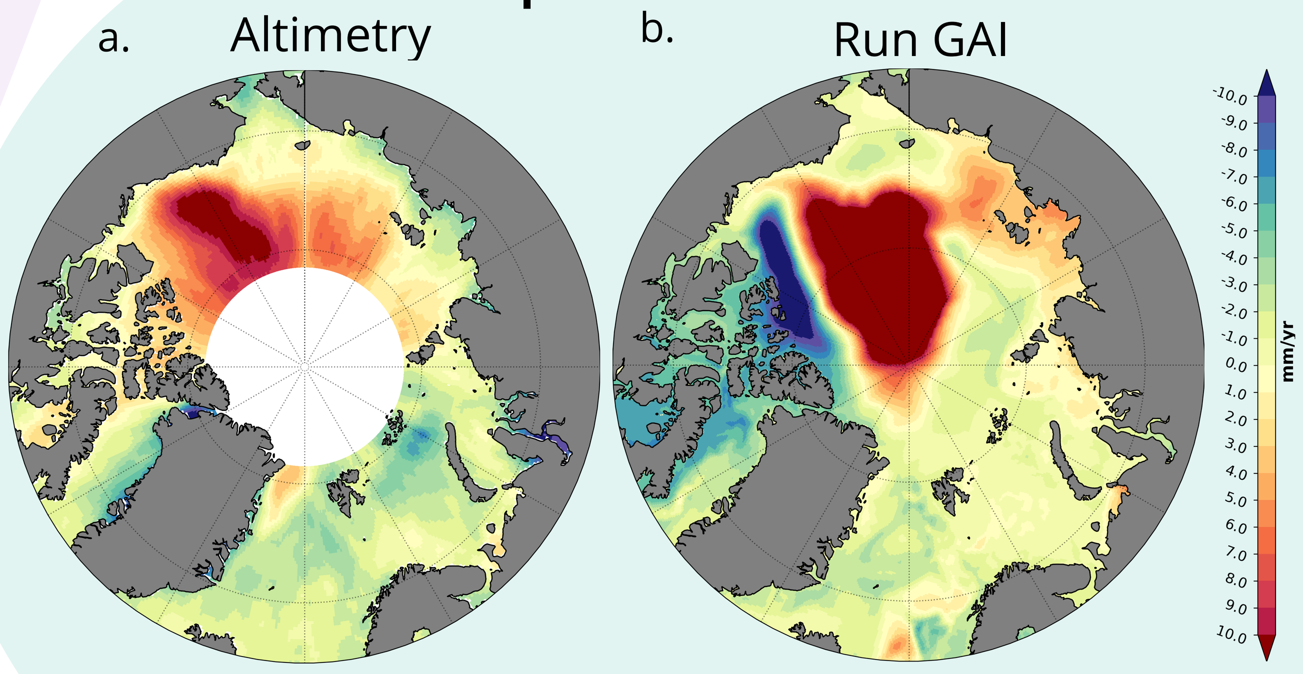

Figure 3: The CCI DTU/TUM SLA trends map (a) and the SLA trends maps of the run GAI (b) from January 1998 to December 2011 (mm/yr). The global mean sea level time series has been removed as well as the annual and semiannual signals.

Global SLA trends maps from 1993 to 2018

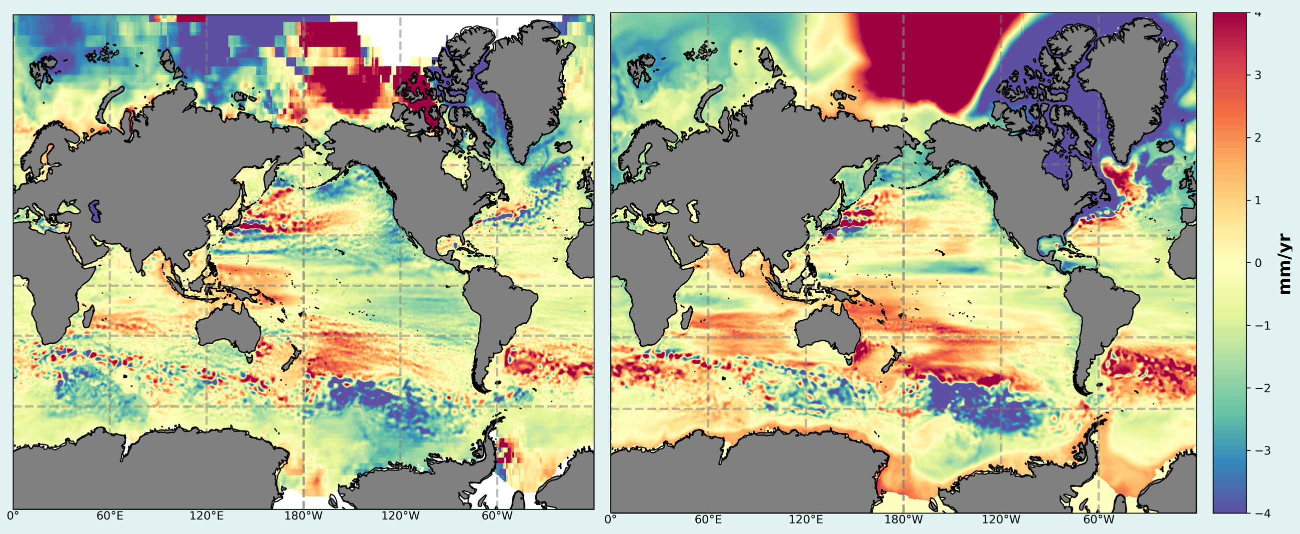

Figure 4: Observed SLA trend maps (Copernicus SSALTO/DUACS DT L4 product) (a) and the simulated SLA trends maps from the run GAI (b) from January 1993 to December 2018 (mm/yr). The global mean sea level time series has been removed as well as the annual and semiannual signals.

OBJECTIVES

Evaluate the impact of the **increased rate** of Greenland Ice Sheet (GIS) melting between 1998 and 2011 on **sea level and ocean circulation**.

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Trends maps from 1998 to 2011 of GIS impact on SSH, steric, and manometric sea level

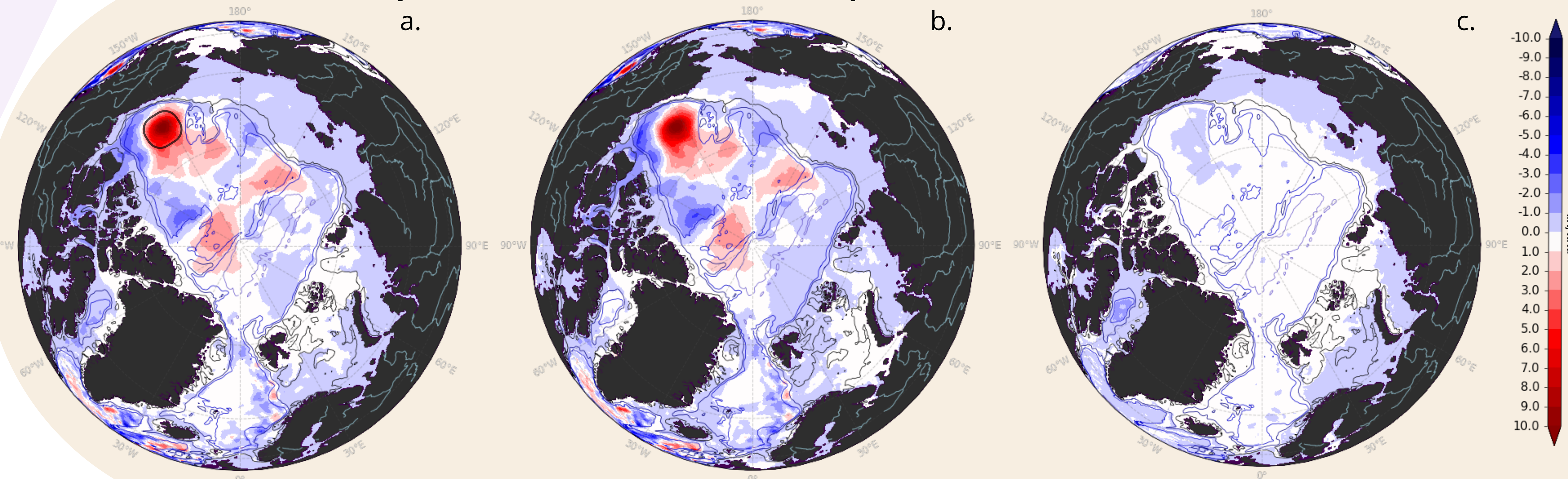

Figure 5: Maps of GIS impact (GAI-AI) on SSH trends (a) and on its decomposition in steric (b) and manometric trends (c).

RESULTS

We find that GIS melting have a **positive impact on regional sea level trends in the BG** (Fig.5a). The decomposition of the SSH trends into their steric (Fig.5b) and manometric (Fig.5c) components show that **GIS impact is maily steric,** that is via density changes.

GIS impact on the halosteric and thermosteric sea level trends from 1998 to 2011

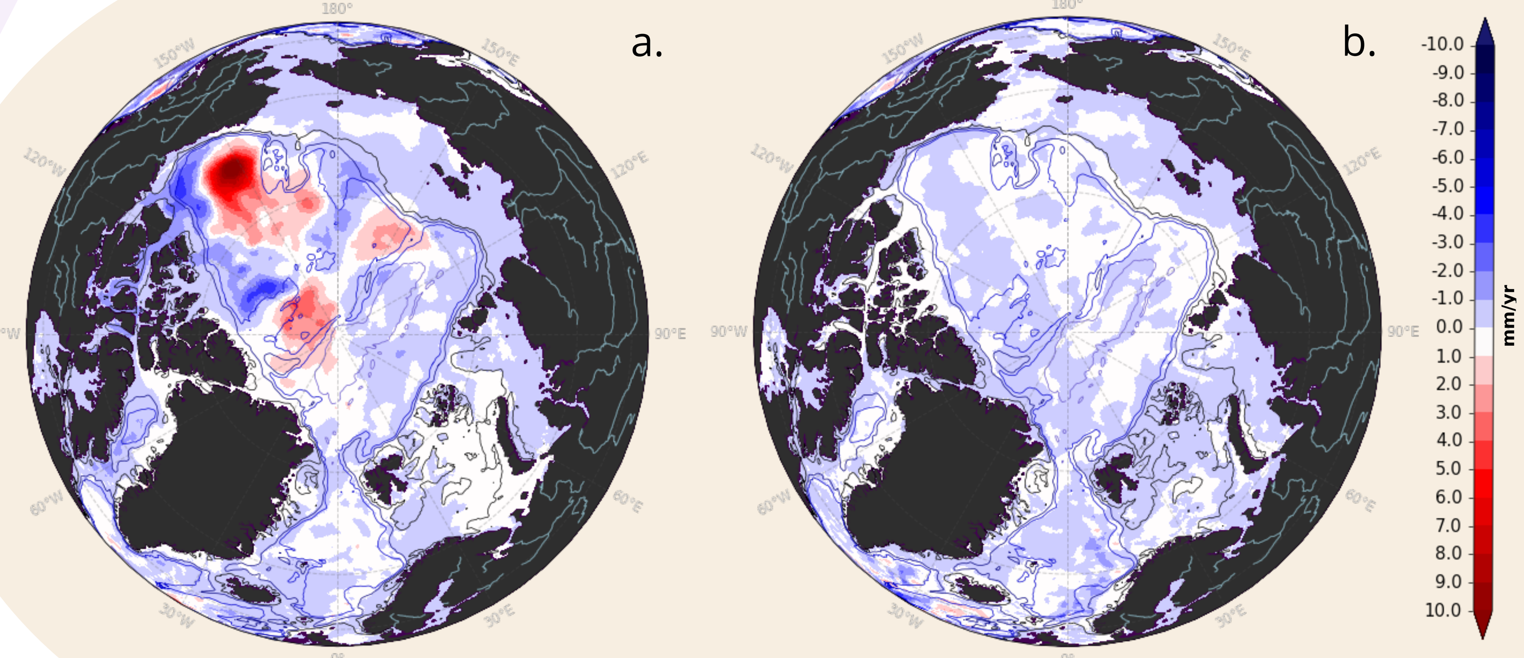

Figure 6: Maps of GIS impact on the upper 300m halosteric (a) and thermosteric (b) sea level trends over 1998-2011 in mm/yr.

The decomposition of the steric sea level trends into their halosteric and thermosteric components shows that **the impact of GIS melting is fully driven by salinity changes (i.e halosteric sea level)** (Figure 6).

Moreover, this halosteric impact is **mainly restricted to the upper 300m** of the ocean as it can be seen by the strong similarities between the SSH, steric and halosteric maps and the adjacent figure.

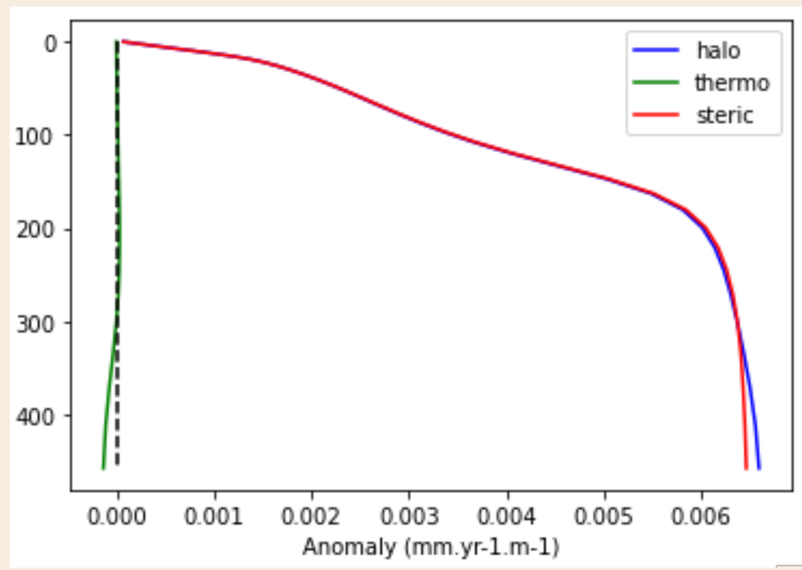

Figure 7: Vertical distribution of steric, halosteric, and thermosteric trend contributions averaged over the box defined in the Canada Basin.

CONCLUSION

There are strong SSH linear trends over 1998-2011 in the BG. It suggests that GIS melting can impact regions far away from its coast. In addition, this is a purely halosteric response reflecting the **accumulation of freshwater** in the BG. The BG dynamical balance is primarily driven by atmospheric forcing (Serreze et al., 2006). We hypothesize that seawater advected into the gyre's interior has been transformed due to GIS melting. Another plausible mechanism is the modulation of wind stress at the ocean surface by the presence/absence of sea ice induced by GIS melting (Dewey et al., 2018).

PERSPECTIVES

We plan to calculate **T and S budgets** in the BG to assess the relative importance of the different fuxes and the origin of the freshwater accumulating in the BG. We will evaluate the impact of GIS melting on **sea ice**. We also would like to understand the **circulation changes of the gyre and the influence of the shelf seas on it.** Finally, we want to assess GIS impact on the **stratification** of the Arctic ocean.

BIBLIOGRAPHY

Trisos, C.H., I.O. Adelekan, E. Totin, A. Ayanlade, J. Efitre, A. Gemeda, K. Kalaba, C. Lennard, C. Masao, Y. Mgaya, G. Ngaruiya, D. Olago, N.P. Simpson, and S. Zakieldeen, 2022: Africa. In: Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press. In Press.

Aagaard, K. and Carmack, E. C.: The role of sea ice and other fresh water in the Arctic circulation, Journal of Geophysical Research, 485–14,498, 1989.

Armitage, T. W. K., Bacon, S., Ridout, A. L., Thomas, S. F., Aksenov, Y., and Wingham, D. J.: Arctic sea surface height variability and change from satellite radar altimetry and GRACE, 2003-2014: ARCTIC SSH VARIABILITY, J. Geophys. Res. Oceans, 121, 4303–4322, https://doi.org/10.1002/2015JC011579, 2016.

Carmack, E. C., Yamamoto‐Kawai, M., Haine, T. W. N., Bacon, S., Bluhm, B. A., Lique, C., Melling, H., Polyakov, I. V., Straneo, F., Timmermans, M. ‐L., and Williams, W. J.: Freshwater and its role in the Arctic Marine System: Sources, disposition, storage, export, and physical and biogeochemical consequences in the Arctic and global oceans, J. Geophys. Res. Biogeosci., 121, 675–717, https://doi.org/10.1002/2015JG003140, 2016.

Carret, A., Johannessen, J. A., Andersen, O. B., Ablain, M., Prandi, P., Blazquez, A., and Cazenave, A.: Arctic Sea Level During the Satellite Altimetry Era, Surv Geophys, 38, 251–275, https://doi.org/10.1007/s10712-016-9390-2, 2017.

Dewey, S., Morison, J., Kwok, R., Dickinson, S., Morison, D., and Andersen, R.: Arctic Ice‐Ocean Coupling and Gyre Equilibration Observed With Remote Sensing, Geophys. Res. Lett., 45, 1499–1508, https://doi.org/10.1002/2017GL076229, 2018.

Haine, T. W. N., Curry, B., Gerdes, R., Hansen, E., Karcher, M., Lee, C., Rudels, B., Spreen, G., de Steur, L., Stewart, K. D., and Woodgate, R.: Arctic freshwater export: Status, mechanisms, and prospects, Global and Planetary Change, 125, 13–35, https://doi.org/10.1016/j.gloplacha.2014.11.013, 2015.

Rabe, B., Karcher, M., Kauker, F., Schauer, U., Toole, J. M., Krishfield, R. A., Pisarev, S., Kikuchi, T., and Su, J.: Arctic Ocean basin liquid freshwater storage trend 1992-2012, Geophys. Res. Lett., 41, 961–968, https://doi.org/10.1002/2013GL058121, 2014.

Regan, H. C., Lique, C., and Armitage, T. W. K.: The Beaufort Gyre Extent, Shape, and Location Between 2003 and 2014 From Satellite Observations, J. Geophys. Res. Oceans, 124, 844–862, https://doi.org/10.1029/2018JC014379, 2019.

Serreze, M. C., Barrett, A. P., Slater, A. G., Woodgate, R. A., Aagaard, K., Lammers, R. B., Steele, M., Moritz, R., Meredith, M., and Lee, C. M.: The large-scale freshwater cycle of the Arctic, J. Geophys. Res., 111, C11010, https://doi.org/10.1029/2005JC003424, 2006.