Virtual Workshop Multi-annual to Decadal Climate Predictability in the North Atlantic-Arctic, Sept 2021

Claudia Hinrichs, Q. Wang, N. Koldunov, L. Mu, T. Semmler, D. Sidorenko, T. Jung

ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Atmospheric wind biases: A challenge for simulating the Arctic Ocean in coupled models?

A preprint of this paper is available at https://www.essoar.org/doi/10.1002/essoar.10506855.1.

A

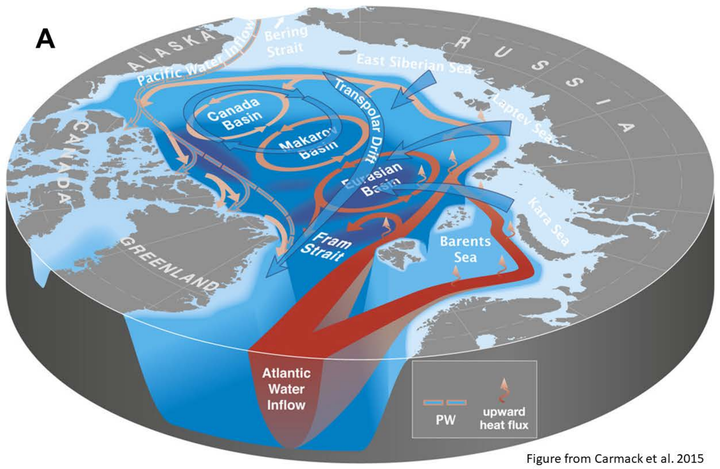
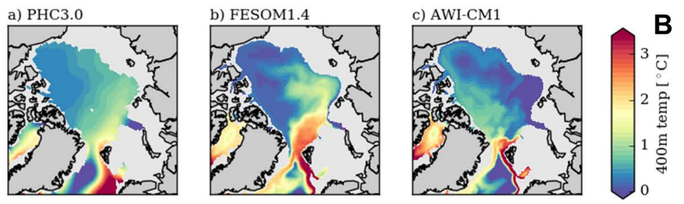


Figure from Carmack et al. 2015

1 Background

A: The circulation in the Arctic Ocean can be described as a two- layer system with warm Atlantic Water (AW) circulating the deep Arctic basins anticlockwise at approx. 400 m depth. Ongoing and future *Atlantification* - the observed warming in the AW layer together with weaker stratification - causes concern about the impact of increasing heat import on Arctic sea ice **[1].**

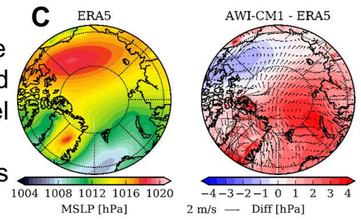
B: But many state-of-the-art climate models do not simulate the Atlantic Water (AW) layer in the deep Arctic Ocean well **[2,3]**, including the Alfred-Wegener-Institute's Climate Model AWI-CM1 **[4]**:

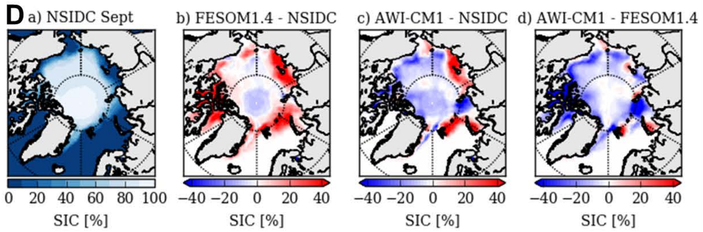


While AWI-CM's ocean model, FESOM **[5]** reproduces the cyclonic AW circulation well compared to the PHC3.0 climatology **[6,7]**, the temperature distribution in the coupled model AWI-CM1 indicates the wrong circulation direction.

2 AWI-CM1 Biases & Sensitivity experiments

C,D: If the standalone version of an ocean-sea ice model can successfully replicate the two-layer circulation, but coupling leads to a perturbed AW circulation, then the reason must lie in the changes in ocean surface forcing after coupling with the atmosphere model. We found a large-scale bias in sea level pressure and the associated wind field and a negative bias in the sea ice cover in the coupled model.





We conducted sensitivity experiments with our standalone ocean-sea ice model, to analyze the influence of biased wind and biased sea ice cover over the Arctic.

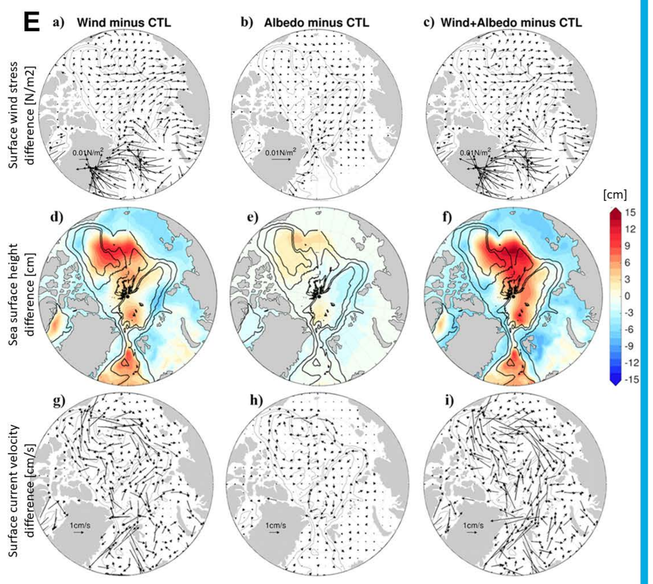
Table 1. Overview sensitivity experiments with FESOM1.4

	CTL	WIND	ALBEDO	WIND+ALB
Wind Forcing	CORE2 forcing	CORE2 forcing, except wind forcing north of 67°N replaced with wind from coupled simulation	CORE2 forcing	CORE2 forcing, except wind forcing north of 67°N replaced with wind from coupled simulation
Albedo Parameters	default	default	reduced	reduced

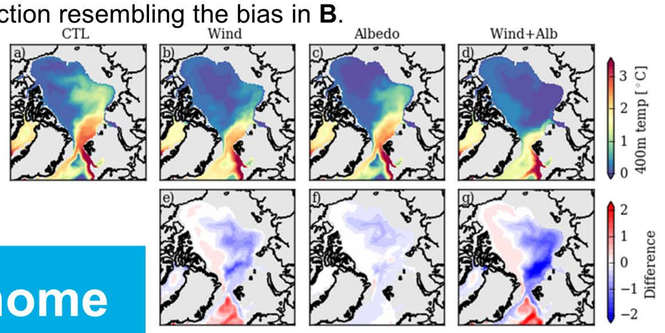
3 Results

Contact: Claudia.hinrichs@awi.de

E: In the Arctic, the bias in SLP, surface wind stress and ice cover lead to differences in ocean surface stress (a-c) and Ekman transport and to a redistribution of surface freshwater. The resulting changes in sea surface height (d-e) strengthen the anticyclonic surface current (g-i). This leads to a reversal of the deep counterflow carrying the warm AW at depth.



F: The result is a biased temperature distribution at 400 m F: a cold pool in the Eurasian Basin and warmer temperatures in the Canadian Basin indicating the wrong circulation direction resembling the bias in **B**.



4 Take home

- Biased Arctic sea level pressure and wind in atmosphere models can reverse Atlantic Water circulation in coupled climate models.
- The underestimation of sea ice cover can amplify this problem further.
- More model development is necessary to be able to study future Atlantification of the Arctic Ocean in CMIP models.

[1] Carmack, E., Polyakov, I., Padman, L., Fer, I., Hunke, E., Hutchings, J., . . . Layton, C. (2015). Toward quantifying the increasing role of oceanic heat in sea ice loss in the new Arctic. Bulletin of the American Meteorological Society, 96(12), 2079-2105. **[2]** Shu, Q., Wang, Q., Su, J., Li, X., & Qiao, F. (2019). Assessment of the Atlantic water layer in the Arctic Ocean in CMIP5 climate models. Climate Dynamics, 53(9), 5279-5291. doi:10.1007/s00382-019-04870-6. **[3]** Khosravi, N., Wang, Q., Koldunov, N., Hinrichs, C., Semmler, T., Danilov, S., & Jung, T. (2021). Arctic Ocean in CMIP6 Models: Historical and projected temperature and salinity in the deep basins. Earth's Future. doi:https://doi.org/10.1002/essoar.10507417.1. **[4]** Semmler, T., Danilov, S., Gierz, P., Goessling, H. F., Hegewald, J., Hinrichs, C., . . . Jung, T. (2020). Simulations for CMIP6 With the AWI Climate Model AWI-CM-1-1. Journal of Advances in Modeling Earth Systems, 12(9), e2019MS002009. doi:https://doi.org/10.1029/2019MS002009. **[5]** Wang, Q., Danilov, S., Sidorenko, D., Timmermann, R., Wekerle, C., Wang, X., . . . Schröter, J. (2014). The Finite Element Sea Ice-Ocean Model (FESOM) v. 1.4: formulation of an ocean general circulation model. Geoscientific Model Development, 7(2), 663-693. **[6]** Steele, M., Morley, R., & Ermold, W. (2001). PHC: A global ocean hydrography with a high-quality Arctic Ocean. Journal of Climate, 14(9), 2079-2087. **[7]** Wang, Q., Wekerle, C., Danilov, S., Wang, X., & Jung, T. (2018). A 4.5 km resolution Arctic Ocean simulation with the global multi-resolution model FESOM 1.4. Geoscientific Model Development, 11(4), 1229.

This project has received funding from the European Union's Horizon 2020 Research and Innovation program through grant agreement No. 727862.APPLICATE and from funding from the Helmholtz Association through the project 'Regional Climate Change (REKLIM)' and "Advanced Earth System Model Capacity". The simulations were performed at the German Climate Computing Center (DKRZ) using ESM-Tools (https://www.esm-tools.net/). The work reflects only the author's/authors' view; the European Commission and their executive agency are not responsible for any use that may be made of the information the work contains.

APPLICATE.eu
Advanced prediction in polar regions and beyond