Group 4
Project Title: Polar oceans in a changing climate
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Background/motivation:
Climate change is particularly prominent in the polar oceans, with important modifications of the coupled physical, chemical and biological processes. The arctic ocean is freshening due to a variety of factors, such as increased freshwater inputs from river runoff and higher imports of relatively fresh Pacific waters through the Bering Strait. This is reflected in changes in the thermohaline structure of the ocean, with potentially important consequences on ocean circulation and stratification. These physical transformations of the polar environment lead to modifications of the biogeochemical cycles and the ocean's biology. In turn, the polar oceans can impact the climate by providing gaseous precursors for aerosol formation in the atmosphere, such as dimethylsulfide (DMS). In remote regions, bioaerosols may constitute most of the available ice nucleating particles and in a changing climate, these could play a bigger role in the Arctic. Ecological impacts can also be important and certain species are experiencing changes to their core habitat, which can be defined in terms of the environmental characteristics that are considered the most important. For instance, the habitat of ringed seals in the eastern canadian arctic can be characterized by snow and sea ice seasonality, and then the impact of climate change can be assessed by studying changes in these variables.

Research questions: How well do models represent the following aspects of the polar oceans in comparison to observations? What have been the consequences of the changing climate in the last decades and are these trends reproduced by models? How are these different aspects interconnected?

- Salinity, fresh water content and its impact on stratification
- DMS concentrations in the ocean and flux to the atmosphere
- Environmental characteristics of ringed seals habitat

Data:

- Salinity : CMIP6 model data ; satellite data (Martínez 2022), WOA, PHC
- DMS : CMIP6 model data (NOAA, GFDL-CM4 and NCAR, CESM2-WACCM) ; Observation and satellite climatologies (Galí 2019, Wang 2020, Hulswar 2022)
- Seal habitat : CMIP6 model data (UKESM, HadGEM3), Satellite data (G. Spreen, AMSR2 ASI sea ice concentration data and AMSR-2 winter snow depth on Arctic sea ice) ; Sea-ice observations from the Canadian Ice Service ; Aerial surveys of ringed seals hauled out on sea ice (S. Ferguson)

Suggested reading : [introductions]

Cottier, F., Steele, M., & Nilsen, F. (2017). Sea ice and Arctic Ocean oceanography. In D. Thomas , Sea Ice (3 ed., pp. 195-217). [chapter 7] WILEY Publications. https://doi.org/10.1002/9781118778371.ch7

Levasseur, M. Impact of Arctic meltdown on the microbial cycling of sulphur. *Nature Geosci* **6**, 691–700 (2013). https://doi.org/10.1038/ngeo1910

References: [model evaluations and data references]

- Salinity

Khosravi, N., Wang, Q., Koldunov, N., Hinrichs, C., Semmler, T., Danilov, S., & Jung, T. (2022). The Arctic Ocean in CMIP6 models: Biases and projected changes in temperature and salinity. Earth's Future, 10(2). https://doi.org/10.1029/2021EF002282

Martínez, J., Gabarró, C., Turiel, A., González-Gambau, V., Umbert, M., Hoareau, N., González-Haro, C., Olmedo, E., Arias, M., Catany, R., Bertino, L., Raj, R. P., Xie, J., Sabia, R., and Fernández, D. (2022). Improved BEC SMOS Arctic Sea Surface Salinity product v3.1, Earth Syst. Sci. Data, 14, 307–323, https://doi.org/10.5194/essd-14-307-2022

- DMS

Hulswar, S., Simó, R., Galí, M., Bell, T. G., Lana, A., Inamdar, S., Halloran, P. R., Manville, G., and Mahajan, A. S. (2022) Third revision of the global surface seawater dimethyl sulfide climatology (DMS-Rev3), Earth Syst. Sci. Data, 14, 2963–2987. https://doi.org/10.5194/essd-14-2963-2022

Galí, M., Devred, E., Babin, M., & Levasseur, M. (2019). Decadal increase in Arctic dimethylsulfide emission. *Proceedings of the National Academy of Sciences*, *116*(39), 19311-19317. https://doi.org/10.1073/PNAS.1904378116

Wang, W. L., Song, G., Primeau, F., Saltzman, E. S., Bell, T. G., & Moore, J. K. (2020). Global ocean dimethyl sulfide climatology estimated from observations and an artificial neural network. *Biogeosciences*, *17*(21), 5335-5354. https://doi.org/10.5194/bg-17-5335-2020

- Seal habitat

Ferguson SH, Young BG, Yurkowski DJ, Anderson R, Willing C, Nielsen O. 2017. Demographic, ecological, and physiological responses of ringed seals to an abrupt decline in sea ice availability. PeerJ 5:e2957. https://doi.org/10.7717/peerj.2957

Ferguson, S.H., Yurkowski, D.J., Young, B.G., Fisk, A.T., Muir, D.C., Zhu, X. and Thiemann, G.W., 2020. Comparing temporal patterns in body condition of ringed seals living within their core geographic range with those living at the edge. Ecography, 43(10), pp.1521-1535. https://doi.org/10.1111/ecog.04988

McCrystall, M.R., Stroeve, J., Serreze, M. et al. New climate models reveal faster and larger increases in Arctic precipitation than previously projected. Nat Commun 12, 6765 (2021).
https://doi.org/10.1038/s41467-021-27031-y

Crawford, A., Stroeve, J., Smith, A. et al. Arctic open-water periods are projected to lengthen
dramatically by 2100. Commun Earth Environ 2, 109 (2021).
https://doi.org/10.1038/s43247-021-00183-x