Investigating Antarctic krill connectivity

Assessing the effect of environmental and biological conditions on Antarctic krill large-scale connectivity facilitated by ocean currents.

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In Short

- Investigate the large-scale connectivity of Antarctic krill via ocean currents throughout the Southern Ocean, with special focus on the Lazarev Sea.
- Find regions from where existing populations can supply the Lazarev Sea krill population.
- Investigate how environment and biological parameters such as temperature and food availability influence the survival of krill during such a long-distance transport.

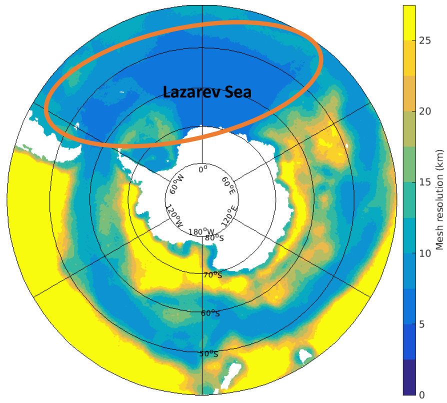

Figure 1: *Resolution of the LAZAREV mesh developed in this project. The mesh is based on the HR mesh [5] with increased resolution in the Lazarev Sea area marked with an orange oval.*

Motivation

Antarctic krill, *Euphausia superba*, is a key component of the Antarctic marine food web that plays a fundamental role in the transfer of energy between the lower and the upper trophic levels. It has been found capable of grazing as much as 55% of the net primary production and many of the top predator populations are dependent on krill as a food source, such as whales, seals, seabirds, penguins and fish. In addition, it is a growing, globally important fisheries resource.

Many marine populations, such as Antarctic krill or other zooplankton and fish stocks, are structured by their physical environment. As a result, the spatial relationships between physical and biological processes are potentially key to understanding their distribution and abundance. Dispersal occurs mostly during early life through advection by ocean currents, when young individuals are not yet capable of active movement. Older life stages exhibit behavior and active movement and can therefore often move on different spatial scales. Larval dispersal by ocean currents and connectivity between different oceanic regions have been identified as crucial factors for structuring marine populations as well as for designing networks of Marine Protected Areas (MPAs), or even understanding the spread of marine pests.

Krill distribution is concentrated in the southwest Atlantic sector, with the Lazarev Sea biomass between 0.6 to 16.8 ind m^{-2}). Studies in the Lazarev Sea point to large spatial and temporal variations in krill standing stock, which also surveys in several other regions such as the Scotia Sea have shown. These strong variations have been partially related to variations in sea-ice extent and fluctuations of recruitment due to changing enviromental conditions in source populations upstream and are known to have major impacts on krill predators.

Transport and connectivity of Antarctic krill between regions spatially far apart have been demonstrated for the western Antarctic Peninsula and South Georgia regions [1],[2]), with krill spawned at the Antarctic Peninsula and the Weddell Sea supplying the South Georgia krill population. Separate, observational studies in the Lazarev Sea (Fig. 1) concluded that this region does not support a single self-maintaining population, but represents a complex transition zone of stocks with different origins, which was hypothesized to maybe stem from the Scotia Sea and the Cosmonaut Sea. It is this hypothesis that this proposed project is going to investigate.

Aim

The aim of this study is to quantify the connectivity of Antarctic krill living in different regions in the Southern Ocean large distances apart and how both environmenetal (temperature, currents) and also biological factors (food concentration) can impact this connectivity. To achieve this, we want to 1) investi-

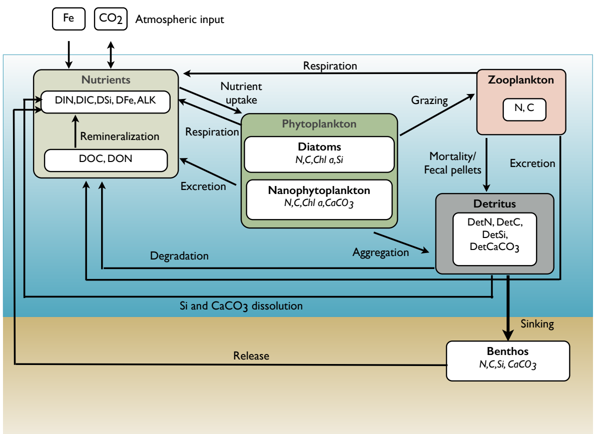

Figure 2: *Schematic of the basic pathways resolved in the biochemical model REcoM2. The model tracks 21 state variables that can be grouped (indicated by boxes) into dissolved nutrients (upper left) and carbonate system parameters, phytoplankton (center), zooplankton (upper right), detritus (middle right), and benthos (lower right). Arrows show source and sink terms.*

gate the impact of the horizontal model resolution on the representation of filaments, fronts and eddies, 2) find out from which regions krill populations can supply input to the Lazarev Sea krill population, and 3) investigate how environment and biological parameters influence the survival of krill during such a long-distance transport.

Methods

For the work proposed here we apply the high-resolution, circumpolar hydrodynamic Finite-Element Sea ice Ocean Model (FESOM) coupled to the Regulated Ecosystem Model 2 (REcoM2) (Fig. 2) [3],[4]. Previously this model system ran on the HR grid [5]. However, the relatively low horizontal resolution on the continental shelf and shelf break was identified as a potential weakness of the model configuration with respect to the representation of mesoscale eddies, as they are very important features for krill retention and accumulation of food such as phytoplankton and copepods.

To overcome this issue and improve the representation of mesoscale frontal processes the horizontal model resolution in the region between 20°W to 40°E, the larger Lazarev Sea region, was increased (Fig. 1). We will conduct a suit of tuning experiments to adjust sub-gridscale parameterizations to the new, finer resolution in both FESOM and REcoM2. These simulations are important as previous moves to higher resolution grids gave rise to problems in the ecosystem model. We will then evaluate the tuning experiments by comparing them with high-resolution synoptic observations and use the best-performing configuration to perform a 50-year model run. This reference run will provide the basis for Lagrangian particle simulations with an individual-based model of krill that utilize the FESOM-REcoM2 output in form of environmental conditions (temperature, salinity and currents) as well as biological conditions (nutrient, phytoplankton and zooplankton distribution and abundance) to investigate how these factors impact connectivity of Antarctic krill.

WWW

https://www.awi.de/en/science/biosciences/marine-biogeoscience/main-research-focus/mathematical-modelling.html

More Information

[1] B.A. Fach, J.M. Klinck: Transport of Antarctic krill (Euphausia superba) across the Scotia Sea. Part I: Circulation and particle tracking simulations, *Deep-Sea Research I.* **53(6)**, 987-1010 (2006). doi:10.1016/j.dsr.2006.03.006.

[2] B.A. Fach, E. E.Hofmann, E.J. Murphy: Transport of Antarctic krill (Euphausia superba) across the Scotia Sea. Part II: Krill growth and survival, *Deep-Sea Research I.* **53(6)**, 1011-1043 (2006). doi:10.1016/j.dsr.2006.03.007.

[3] V. Schourup-Kristensen, W. Wekerle, D. A. Wolf-Gladrow, and C. Völker: A skill assessment of the biogeochemical model REcoM2 coupled to the Finite Element Sea Ice Ocean Model (FESOM 1.3), *Geoscientific Model Development.* **7(6)**, 2769-2802 (2014). doi: 10.5194/gmd-7-2769-2014.

[4] V. Schourup-Kristensen, D. Sidorenko, D. A. Wolf-Gladrow, and C. Völker: Arctic Ocean biogeochemistry in the high resolution FESOM 1.4-REcoM2 model. *Progress in Oceanography.* **168**, 65-81 (2014). doi: 10.1016/j.pocean.2018.09.006.

[5] D.V. Sein, S. Danilov, A. Biastoch, J.V. Durgadoo, D. Sidorenko, S. Harig, Q. Wang: Designing variable ocean model resolution based on the observed ocean variability. *Journal of Advances in Modeling Earth Systems.* **7(6)**, 2769-2802 (2014). doi: 10.1002/2016MS000650.

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