The Antarctic Marginal Sea Ice Zone: A physical characterization and the link to biology

G. Castellani, B. Lange, F. Schaafsma, S. Arndt,
S. Schwegmann, M. Nicolaus, A.P. Van de Putte,
J.A. Van Franeker, M. Vortkamp, D. Kohlbach,
C. David, H. Flores

The marginal sea ice zone is a highly dynamic area due to the interaction of winds, waves and currents. In addition, the marginal sea ice zone is biologically important because of its brief, but intense spring primary production, which is an important carbon source for the marine food web from zooplankton, to fishes, to larger marine mammals. The strong variability in time and space, together with its exposure and vulnerability to weather changes, makes it hard to sample and characterize. In this work we present data collected in December 2014 and January 2015 (late spring and early summer) in the Antarctic marginal sea ice zone during a ship based expedition to the Eastern Weddell Sea. Sea ice surveys were conducted with a Surface and Under Ice Trawl (SUIT). The SUIT is equipped with a sensor array to characterize the environmental properties of the ice and under ice habitats such as: surface salinity, temperature, chl-*a*, spectral radiation, ice thickness, ice floe distribution, ice roughness and sea-ice algae content. The SUIT is also equipped with a net that enables the sampling and characterization of the under ice fauna. These observations in combination with biomass estimates from an echo-sounder allow us to investigate the link of sea-ice physical properties with the pelagic and under-ice community. The integration of satellite data and airborne sea-ice thickness and sea-ice surface properties allows a link and comparison between the SUIT spatial scale (~2 km) and a larger spatial scale (>10 km). Results highlight common features of the marginal ice zone but also strong differences due to temporal and dynamic changes. In particular, during late spring the marginal ice zone still extended to lower latitudes and it consisted of larger floes (>100m) and less ridges. During early summer, the marginal ice zone was a relatively small belt surrounding the ice edge and consisted of mainly small floes with higher ridge density. These differences cannot be assessed based on remote sensing data. Moreover, such differences result in a diverse pattern of the under ice light regime with a subsequent impact on sea-ice algae content and the under ice population.

The two-faced Marginal Sea Ice Zone: A physical characterization and the link to biology

Giulia Castellani[1], K.J. Müller[2], F.L. Schaafsma[3], S. Arndt[1], B.A. Lange[1,4], J. Ehrlich[1,4], M. van Dorssen[3], M. Nicolaus[1],A. Meijboom[3], A.P. Van de Putte[5], M. Vortkamp[1], B. Feij[6], J.A. van Franeker[3], H. Flores[1,4]

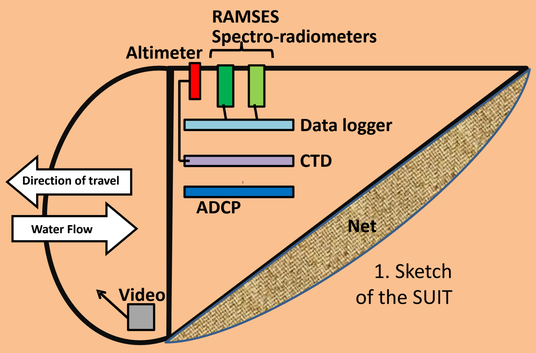
[1]Alfred Wegener Institute (AWI) Helmoholtz-Zentrum für Polar- und Meeresforschung (Germany); [2]University of Oldenburg (Germany); [3]IMARES (The Netherlands); [4]University of Hamburg (Germany); [5]Royal Belgian Institute of Natural Sciences (Belgium); [6]NIOZ (The Netherlands);

INTRODUCTION

The marginal sea ice zone (MIZ) is a very dynamic and active area. In addition, the MIZ is biologically important due to an intense spring primary production bloom, which is an important carbon source for the marine food web. Here we present data collected in the Antarctic MIZ during a ship-based expedition to the Eastern Weddell Sea. The work aims to characterize the physical environment of the MIZ and identify the possible environmental drivers of ecological processes.

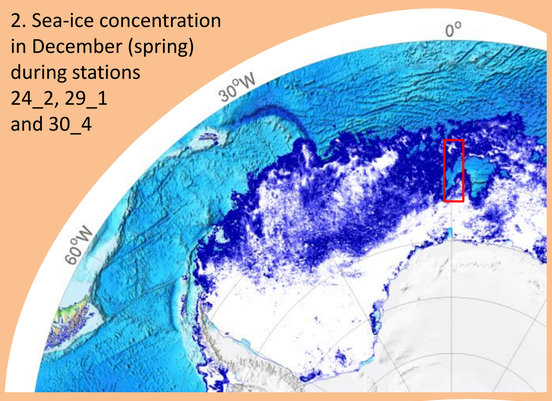
1. SAMPLING

Sea ice surveys were conducted with a Surface and Under Ice Trawl (SUIT). The SUIT is designed to sample under-ice fauna and it is equipped with a sensor array (Fig. 1) to measure the environmental properties: sea surface salinity, temperature, chl-*a*, under-ice spectral radiation, ice thickness, ice roughness and sea-ice algae content. In total, 6 profiles of ca. 2 km were collected in the MIZ in December 2014 (eastern transect, shown in Fig. 2) and January 2015 (western transect, shown in Fig. 3).

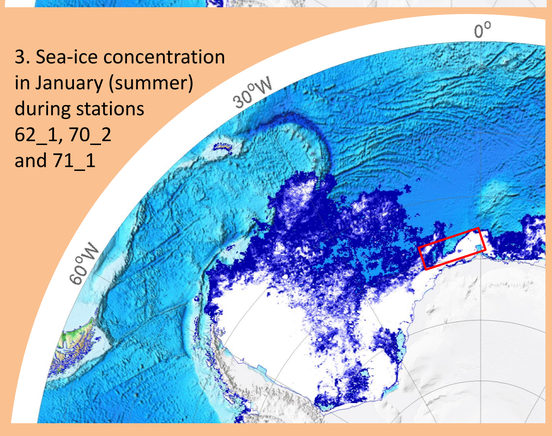


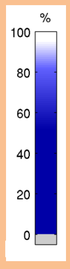
1. Sketch of the SUIT

2. Sea-ice concentration in December (spring) during stations 24_2, 29_1 and 30_4



3. Sea-ice concentration in January (summer) during stations 62_1, 70_2 and 71_1



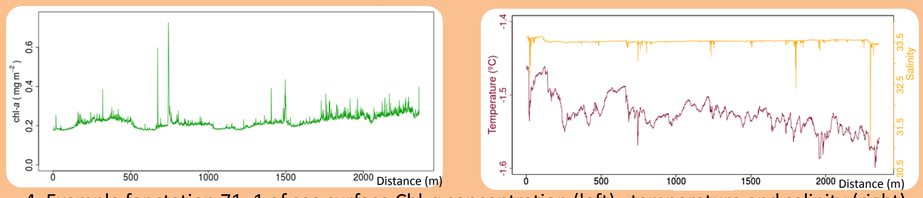


Sensor: AMSR2

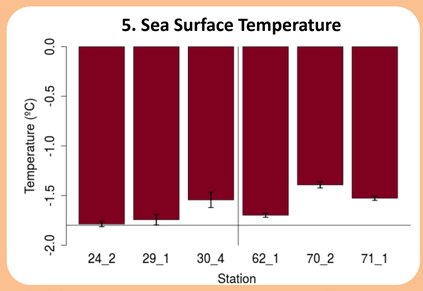
Sea ice concentration data were obtained from http://www.meereisportal.de (grant: REKLIM-2013-04)

2. SEA SURFACE PROPERTIES

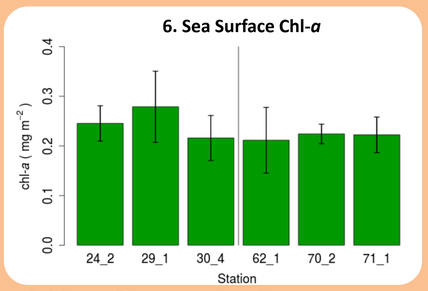
Along-profile variability in sea surface properties (Fig. 4) is large. Figure 5 shows that the western stations have higher mean temperature, this agrees with the advanced melting stage as seen in the ice concentration (Fig. 3). Lower, but not significantly different, Chl-*a* concentration in surface sea water was registered in the western stations (Fig. 6).



4. Example for station 71_1 of sea surface Chl-*a* concentration (left) , temperature and salinity (right)

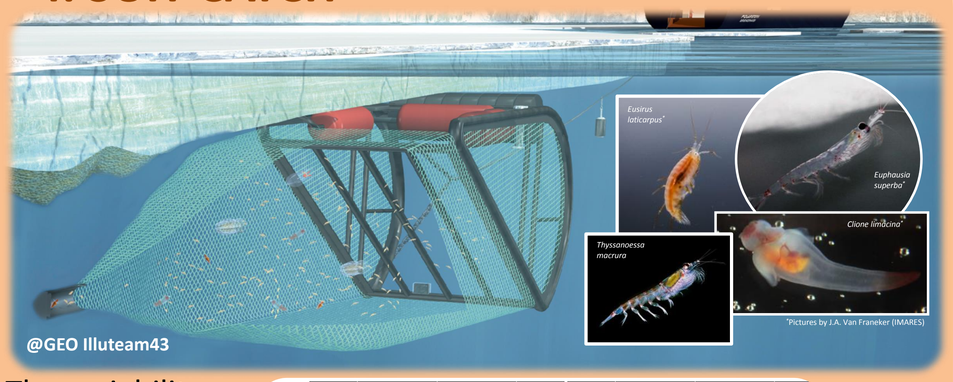


5. Mean temperature per station. Bars represent mean ± stand deviation

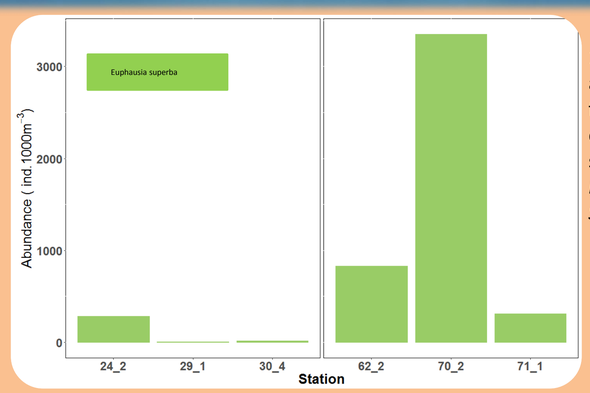


6. Mean chl-*a* per station. Bars represent mean ± stand deviation

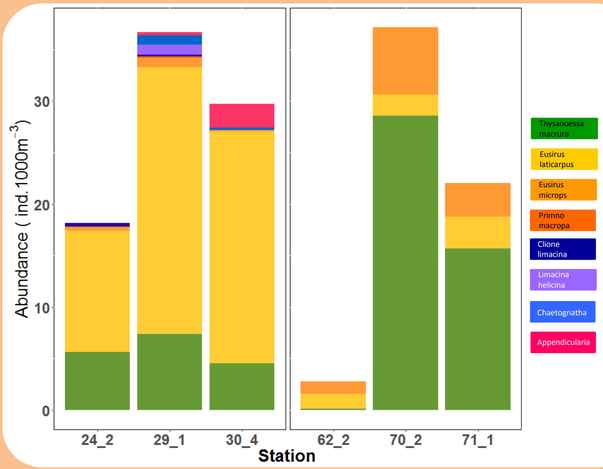
4. SUIT CATCH



The variability found in sea surface and sea-ice properties is reflected in the species abundances and composition (Fig. 13 and 14).



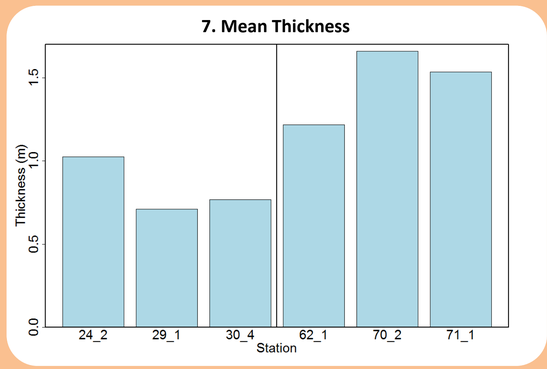
13. Catch abundances for the dominant specie *Euphausia Superba*

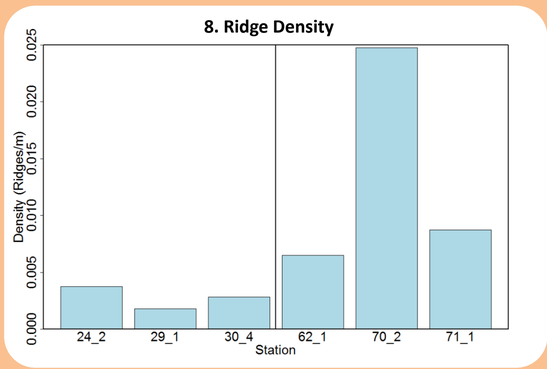


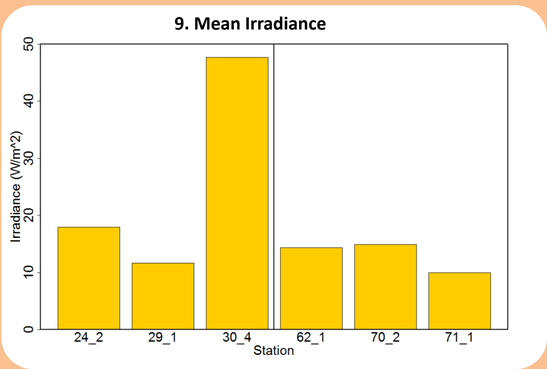
14. Catch abundances for other species

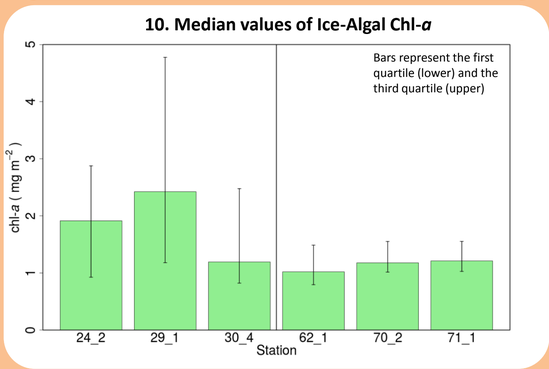
Species diversity also differs between transects. Krill *Euphausia superba, Thysanoessa macrura*, and the amphipod *Eusirus microps* were abundant in the western stations, the amphipod *Eusirus laticarpus* in the eastern ones.

3. SEA-ICE PROPERTIES

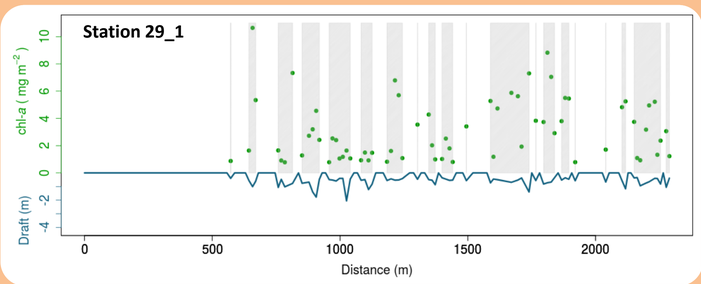




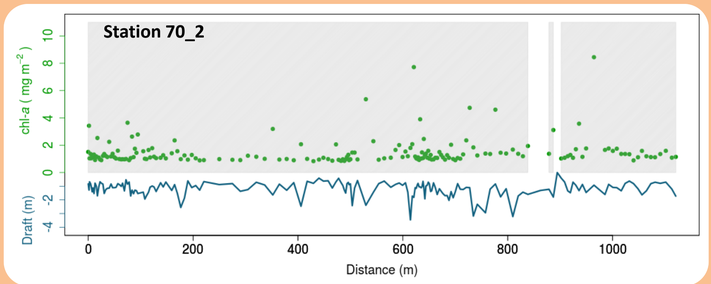




A clear separation between eastern and western stations is seen in all sea-ice properties. The ice is thicker (Fig. 7) in the western stations, and has more ridges (Fig. 8), detected as in *Castellani et al. (2015)*. This is reflected in the light availabe under the ice (Fig. 9). Sea-ice algae (Fig. 10), retrieved as in *Melbourne-Thomas et al. (2015),* are more abundant in the eastern stations.



11. Sea-ice draft and sea-ice chl-*a* content for station 29_1 (eastern transect). Shaded areas are ice covered regions



12. Sea-ice draft and sea-ice chl-*a* content for station 70-2 (western transect). Shaded areas are ice covered regions

Sea-ice algae show a large variability along profile (Fig.11 and 12). They are very low in regions where very thin ice is found. They are high in areas with thick ice and sometimes show peaks close to ridges, similar to what was observed by *Lange et al. (2015*) in hummocks.

CONCLUSION

- Sea-ice physical properties in the Antarctic MIZ can vary drastically, showing two completely different environmental regimes
- The structure of under-ice communities clearly follows the strong contrast in sea-ice properties
- The general knowledge of the MIZ as a very productive area is, in half of the case studies presented here, not confirmed
- High abundances of Antarctic krill were associated with thick deformed ice and low chl-*a* in both sea ice and water, indicating that krill distribution under sea ice reflects other traits of the environment than food availability, such as predator avoidance
- Low Chl-*a* in surface water and sea ice could, on the other hand, be a consequence of grazing

REFERENCES

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-Lange et al, (2015) *Comparing springtime ice-algal chlorophyll a and physical properties of multi-year and first-year sea ice from the Lincoln Sea.* PLoS One.

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Corresponding author:
Dr. Giulia Castellani
Giulia.castellani@awi.de