

Physical and biogeochemical processes in the Antarctic Marginal Ice Zone: observations and modelling

The Southern Ocean is the home of the largest sea-ice biome on the planet. Covering approximately 16 million km² during the winter growth (Rintoul, 2011), Antarctic sea-ice plays a pivotal role in climate regulation, deep water formation and the uptake of atmospheric greenhouse gasses (Dieckmann and Hellmer, 2010; Rintoul, 2011). The dynamic interactions between the ocean, atmosphere and sea ice that occur in the region and the freezing and thawing of sea-ice transforms waters from one density to another, thus contributing to the formation and renewal of deep water in the oceans and the redistribution of heat and moisture throughout the connected ocean basins, thus influencing global temperature and rainfall patterns.

The marginal ice zone (MIZ) is the boundary region between the sea-ice covered ocean and the open ocean, it is here that the air-sea interactions are at their maximum (Muench, 1989), due to the abrupt change from 100% ice cover to 100% open ocean (Smith, 1987). The variability in the sea-ice cover in the MIZ is affected by the interaction of the atmosphere and the ocean (Muench, 1989). The structure and shape of the floes that form in the MIZ are heavily influenced by the wind and wave activity due to the intense air-sea interactions present in the region. Bordering open water; small, irregular ice crystals develop and accumulate to form brash ice. As the brash ice grows, grease and pancake ice begin to form and eventually consolidate into pack ice (Muench, 1989). The influence of the rapidly changing atmosphere results in a dynamic MIZ with no defined position, where changes occur over various time scales; some as small as a few hours up to larger effects over days or even weeks (Lange et al., 1989).

The MIZ is an important region to study as our understanding of the MIZ and sea-ice cycle influences the data and accuracy of models developed, both physical and biogeochemical. These models rely on accurate data to produce optimum results (Smith, 1987). Often a bias towards pack ice exists in the data due to under sampling of the MIZ, attributed to the volatile nature of the MIZ (Smith, 1987). The extent of the MIZ is inaccurately estimated by satellite data and it is therefore necessary to validate and support the satellite data with direct observations (Worby and Comiso, 2004). The physical and biogeochemical characteristics of the MIZ have indicated features that have significant physical and biogeochemical importance for the Polar oceans (Smith, 1987).

The sea ice environment in the Marginal Ice Zone (MIZ) of the Southern Ocean is characterized by a combination of pancake ice, frazil ice and

more consolidated ice conditions. The process of pancake ice formation usually occurs at the very boundary with the open ocean, but also in the interior of the MIZ, as recently observed during a South African winter cruise in July 2017. The semi-consolidated state of the surface covered ocean is the result of the action of strong air-sea interactions and waves. Pancake ice is therefore shaped by the typical thermodynamic processes occurring at the interface with the atmosphere and the ocean, but also by the action of waves and surface washing. Ice growth leads to the entrapment of nutrients and biological components in the sea ice, which may develop into a sympagic community and eventually bloom. However, very little is known about the internal vertical structure of pancake ice, the distribution of biogeochemical constituents and the biogeochemical cycling that occurs both within the ice and between the ice and underlying ocean. Data from the SA Agulhas II 2017 winter cruise are available to obtain an initial understanding of the concentration and gross distribution of nutrients and phytoplankton in the growing pancake ice. These data will be combined with numerical modelling with the main objective of explaining the processes leading to the accumulation of chemical and biological components in the MIZ and their evolution as the ice season advances. A model for sea-ice biogeochemistry has been proposed by Tedesco et al. (2009, 2010), and can be expanded to include features that are specific to the Antarctic pancake ice field.

The thesis work will focus on the following aspects:

1. Analysis of the existing literature concerning physical and biogeochemical conditions of the Antarctic MIZ, with special attention on non-summer conditions
2. Extension of a numerical model of sea-ice thermodynamics and biogeochemistry originally developed by Tedesco et al. (2009, 2010) to incorporate the specific features of pancake ice as described by Doble et al. (2003)
3. Characterization of the biogeochemistry (nutrients and chlorophyll) in winter pancake ice using samples collected during the winter cruises
4. Simulation of sea-ice biogeochemistry equilibria during the freezing season and validation of the model results with the available data. Prognostic simulation of the evolution of sea-ice nutrients and algae along the seasonal pathway determined by means of the ice-tethered buoys deployed during the cruise.

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Thesis proposal
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