

Abstract

My PhD dissertation investigates the hydrodynamics of Antarctic glacial bays, using Admiralty Bay (AB), King George Island, as a representative example of other glacial bays in the West Antarctic Peninsula (WAP) region. The research aims to address existing knowledge gaps regarding the roles of glacial meltwater influx and wind forcing in shaping coastal water circulation and primary productivity.

My dissertation comprises three publications (two published, one after first round of reviews) that collectively address six research goals. These were achieved using a combination of high-resolution *in situ* measurements and 3D numerical modeling to provide a holistic understanding of the investigated system. A comprehensive dataset of AB's water properties measurements was collected from December 2018 to March 2023, reflecting seasonal variability in physical, chemical, and biological water properties. Numerical modeling, using Delft3D, was employed to simulate AB's hydrodynamics under various glacial influx and wind scenarios. A Lagrangian particle model was coupled to the hydrodynamic model to track the transport of suspected primary sources of iron, a productivity-limiting factor in AB, and the penetration of open ocean waters into AB.

The research identified a general circulation pattern in AB, characterized by a strong inflow current along the western boundary and an outflow current in the east, transporting glacially modified waters out of the bay. Two cyclonic circulation cells regulate water exchange between AB and the ocean. The results showed that ocean forcing consistently acts as the primary driver of AB's circulation. However, significant glacial influx can induce a shift in circulation within the smaller inlets.

This study provides the first high-resolution estimate of seasonal variability in glacial water input to an Antarctic bay. The AB contribution to freshwater input to the Southern Ocean ranges from 0.434 to 0.632 Gt/year, with peak values during late summer and minimal input in winter and spring.

The most common winds in AB are westerly, the strongest storms tend to originate from the east; both directions are perpendicular to the main axis of the bay. This research highlights the role of these cross-bay winds in shaping AB hydrodynamics. While increased wind magnitude elevates energy levels and reduces water column stratification, wind direction was found to have a previously underappreciated significance. Westerly winds promote water mass retention within AB, generating submesoscale eddies that concentrate particles suspected to be primary sources of iron, creating areas conducive to biological hotspot formation. Conversely, easterly winds rapidly flush all tracked water types from the bay, likely

limiting primary production. While measurement data and satellite-derived chlorophyll-a estimates offer supporting evidence, the influence of cross-bay winds on primary production remain incompletely validated due to observational constraints. However, the results indicate that cross-bay winds can either enhance or inhibit biological productivity in broad glacial bays, depending on their orientation relative to the bay's main axis.

The results of my PhD dissertation have significant implications for understanding the dynamics of Antarctic glacial bays and their response to climate change. As the volumes of glacial meltwater increase and wind regimes shift, the insights gained from AB can inform predictions of future changes in WAP coastal waters and their capacity to sustain productive ecosystems. The study also underscores the importance of considering local geomorphology and wind forcing when assessing glacial bay hydrodynamics. The developed approach that combined an observational dataset, a hydrodynamic model, and a detailed bathymetry provide valuable tools for future research in this critical region.