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Southern Giant Petrels *Macronectes giganteus* as indicators of ocean surface currents

Megan A Cimino[1*] & *Carlos Moffat*[2]

[1]*Institute of Marine Science, University of California Santa Cruz, 1156 High St, Santa Cruz, CA 95064, USA.*

[2] *School of Marine Science and Policy, University of Delaware, 210 South College Ave., Newark, DE 19716, USA.*

**mecimino@ucsc.edu*

Abstract

A Southern Giant Petrel *Macronectes giganteus* was satellite tracked during a long foraging trip. While at rest on the sea surface, the giant petrel drifted in a counterclockwise corkscrew pattern that is characteristic of an inertial oscillation in the Southern Ocean. This note demonstrates that tracking data from resting seabirds can be used as passive drifters to estimate ocean surface currents in a notoriously stormy environment where data near the air-sea interface are difficult to obtain.

Introduction

Seabirds are well–known ocean sentinels that can provide unique information on atmospheric, ocean, and food web processes, especially species capable of traveling long distances (Hazen et al. 2019, Ellis-Soto et al. 2023). An exemplary species is the Southern Giant Petrel *Macronectes giganteus*, which is a long-lived, widely distributed predator in the Southern Ocean. Giant petrels can have long foraging trips during both the breeding and non-breeding seasons, where they can be at sea for days to weeks and cover distances of 100s to 1000s of kilometres (e.g., Finger et al. 2023). Therefore, their foraging behaviour across multiple spatio-temporal scales can provide information on their surrounding environment in intriguing ways as shown here.

Observation

As part of the Palmer Long-Term Ecological Research (LTER) program, Southern Giant Petrels nesting on small islands near Anvers Island (64.076°W, 64.769°S), West Antarctic Peninsula, were satellite tracked using Axy-Trek Marine devices during the incubation phase in 2022. The trackers record GPS coordinates (longitude, latitude, and time) every 15 minutes, which can be used to estimate statistics such as distance traveled and speed. One male giant petrel traveled to Peter I Island in the Bellingshausen Sea (~1200 km away from its nest) before returning to its nest and finishing its ~3200 km journey in about 14 days (8-22 December) (Figure 1).

When we examined the petrel's trajectory, we found several instances of a counterclockwise corkscrew pattern (Figure 2A) that coincided with low speeds and displacements, indicating the bird was sitting on the sea surface, presumably foraging or resting, and thus tracking the movement of the surface ocean water. Counterclockwise surface circulation can be evident in the surface ocean after strong winds suddenly stop. The currents that are forced by the wind, and that continue after the wind stops, are influenced by the earth's rotation and friction, veering to the left and forming a characteristic counterclockwise corkscrew pattern called an inertial oscillation. In the northern hemisphere, this motion would be clockwise.

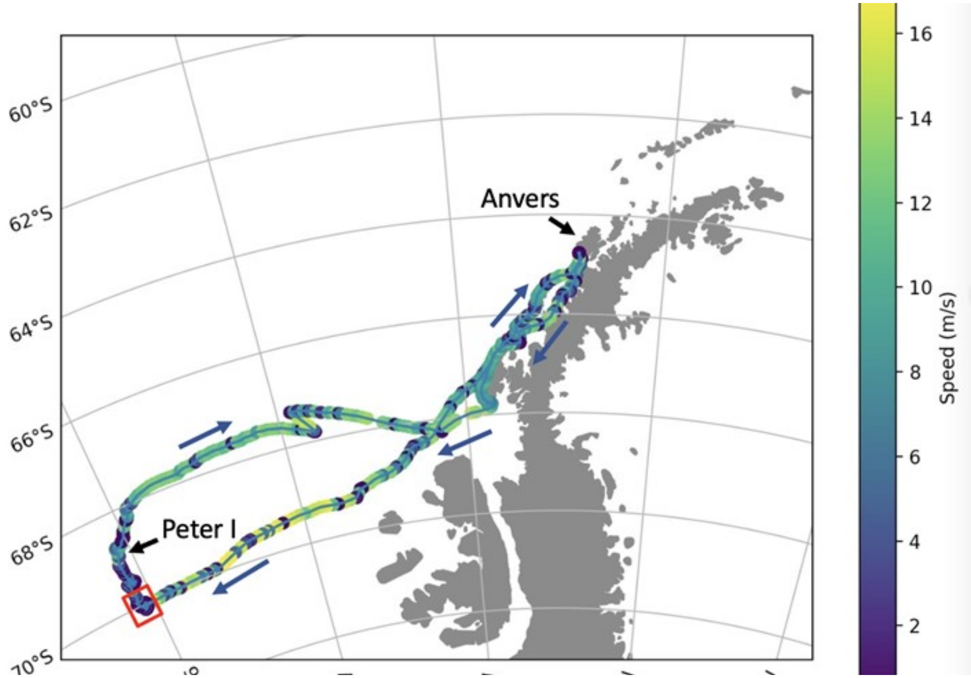

Figure 1: A Southern Giant Petrel foraging track coloured by speed. The track begins and ends near Anvers Island. The direction of travel is indicated by the blue arrows. The region within the red box is shown in Figure 2 .

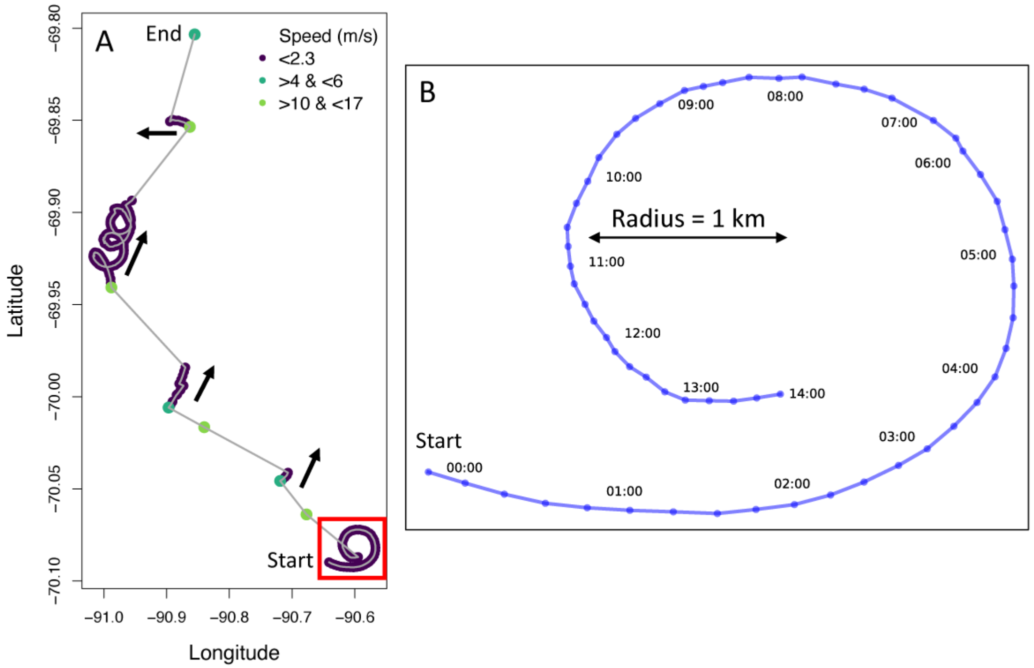

Figure 2: A) Zoomed-in giant petrel track within the red box in Fig. 1. Arrows represent the direction of drift. With the addition of flight at higher speeds, the bird travelled ~34 km north. The start and end points are marked, 13 December at 00:00 and 15 December at 13:00. **B**) Zoomed-in counterclockwise "corkscrew" located within the red box in (A) with the hour and radius of the corkscrew. The track started at approximately 00:00 and ended at ~14:00 .

If what we observed was indeed an inertial oscillation, theory predicts the time for the trajectory to complete a full circle to be T = 2**π**/f (the inertial period), where **π**=3.1416 and f is the Coriolis parameter, which depends on the latitude. At the latitude of 70°S where the inertial oscillations appeared to have been tracked by the petrel, T is 12.7 hours. This expected value is broadly consistent with the observations, which showed the petrel finishing a complete circle every 12 hours or so several times (Figure 2AB). The radius of the circle scales like V/f, where V is the velocity of the surface current. Typical speeds are of the order of 0.15 m/s, which should result in "corkscrews" with a radius of 1 km or so, which is again broadly consistent with the observations (Figure 2B).

Discussion

The Southern Ocean is a notorious harsh environment with strong winds and large waves. During rare and prolonged calm periods, seabirds may take advantage of these conditions for resting, sitting, or foraging for prey near the sea surface. Sleeping and resting are an important part of an animal's daily time budget and can provide an opportunity to digest food during long foraging trips, and these long resting bouts may be more common than realized (Ropert-Coudert et al. 2004). Additionally, the cost of flying without strong winds may make it energetically favourable for a bird to sit and wait for wind speeds to increase to continue its journey (Thorne et al. 2023).

Ocean surface winds are a critical factor for understanding ocean and atmospheric interactions. In polar environments, obtaining high-resolution and continuous in situ meteorological measurements or data at the air-sea interface can be challenging. It has been previously shown that flying birds take advantage of winds and vertical air motion (Treep et al. 2016) and tracking birds with instruments measuring elevation and air pressure allow for the calculation of wind speed and direction (Yonehara et al. 2016, Goto et al. 2017, Ellis-Soto et al. 2021). Seabirds resting on the sea surface can also be used as passive drifters to estimate ocean currents or tides (Yoda et al. 2014, Shamoun-Baranes et al. 2011, Cooper et al. 2018), and such drift observations that represent geostrophic currents (not wind-driven components) have been assimilated into ocean forecasts (Miyazawa et al. 2015).

The observations shown here suggest Southern Giant Petrels may also be an indicator of atmospheric and oceanic processes at the sea surface. It is possible that some biologists and ecologists have overlooked drift patterns in tracking data because these small-scale movements are not always noticeable when viewing tracking data over a large spatiotemporal scale and/or current/tidal patterns (including, inertial oscillations) may not be known or of interest when the goal is to answer major research questions on climate or human impacts, predator-prey interactions, or physiology (Watanabe, Papastamatiou 2023). With the availability of large, long-term tracking databases on numerous seabird species (Hindell et al. 2020, Bernard et al. 2020), the drift patterns of resting seabirds could be used as another fine-scale biomonitoring tool by turning ocean wanderers into ocean drifters.

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FitzPatrick Institute of African Ornithology,
Department of Biological Sciences,
University of Cape Town