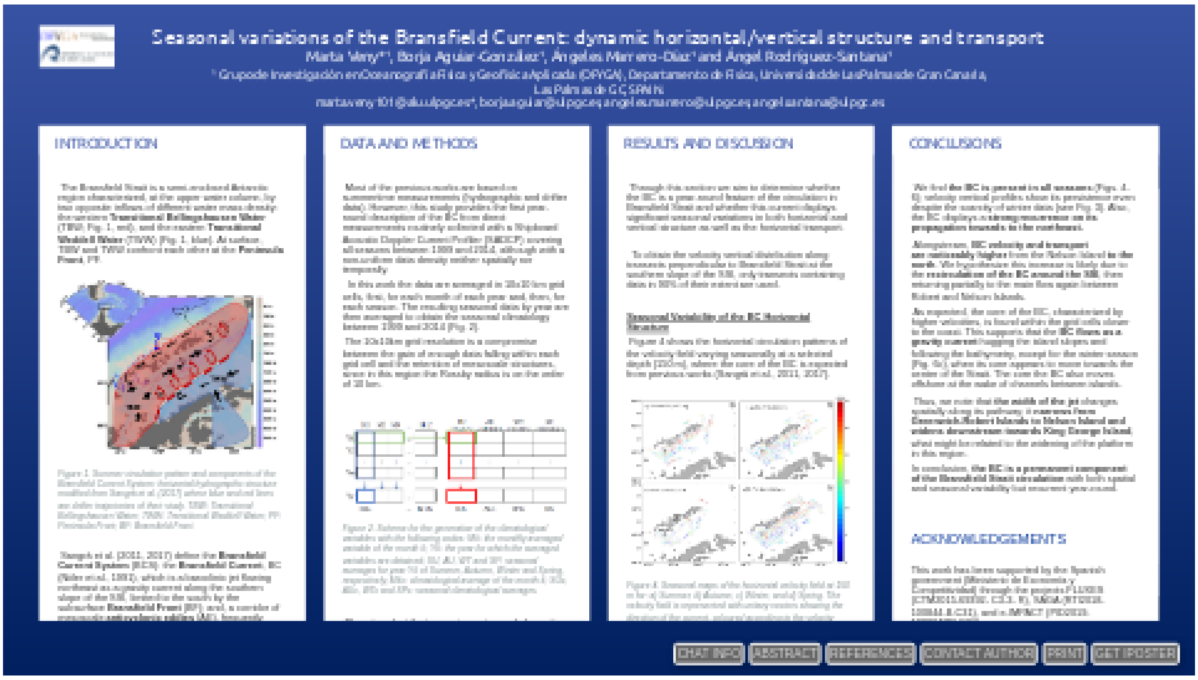
Seasonal variations of the Bransfield Current: dynamic horizontal/vertical structure and transport



Marta Veny*[1], Borja Aguiar-González[1], Ángeles Marrero-Díaz[1] and Ángel Rodríguez-Santana[1]

[1] Grupo de Investigación en Oceanografía Física y Geofísica Aplicada (OFYGA), Departamento de Física, Universidad de Las Palmas de Gran Canaria,
Las Palmas de GC, SPAIN.
marta.veny101@alu.ulpgc.es*, borja.aguiar@ulpgc.es, angeles.marrero@ulpgc.es, angel.santana@ulpgc.es

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INTRODUCTION

The Bransfield Strait is a semi-enclosed Antarctic region characterized, at the upper water column, by two opposite inflows of different water mass density: the western **Transitional Bellingshausen Water** (TBW; Fig. 1, red), and the eastern **Transitional Weddell Water** (TWW) (Fig. 1, blue). At surface, TBW and TWW confront each other at the **Peninsula Front**, PF.

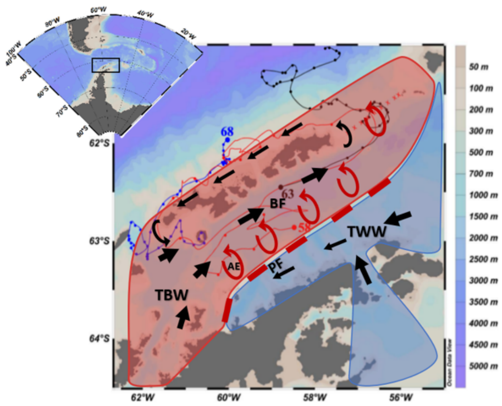

Figure 1. Summer circulation pattern and components of the Bransfield Current System: horizontal hydrographic structure modified from Sangrà et al. (2017) where blue and red lines are drifter trajectories of their study. TBW: Transitional Bellingshausen Water; TWW: Transitional Weddell Water; PF: Peninsula Front; BF: Bransfield Front.

Sangrà et al. (2011, 2017) define the **Bransfield Current System** (BCS): the **Bransfield Current**, BC (Niiler et al., 1991), which is a baroclinic jet flowing northeast as a gravity current along the southern slope of the SSI, limited to the south by the subsurface **Bransfield Front** (BF); and, a corridor of mesoscale **anticyclonic eddies** (AE), frequently observed between the PF and BF. During the recirculation of the BC around the northeastern end of the SSI, an AE also sheds off to the east of King George Island.

Because this description is based on hydrographic data of summertime oceanographic cruises, this work aims: 1) to investigate whether the BC is a permanent feature of the circulation in Bransfield Strait; and, 2) to characterize the seasonal variability (if any) of its strength and direction.

DATA AND METHODS

Most of the previous works are based on summertime measurements (hydrographic and drifter data). However, this study provides the first year-round description of the BC from direct measurements routinely collected with a Shipboard Acoustic Doppler Current Profiler (SADCP) covering all seasons between 1999 and 2014, although with a non-uniform data density neither spatially nor temporally.

In this work the data are averaged in 10x10 km grid cells, first, for each month of each year and, then, for each season. The resulting seasonal data by year are then averaged to obtain the seasonal climatology between 1999 and 2014 (Fig. 2).

The 10x10km grid resolution is a compromise between the gain of enough data falling within each grid cell and the retention of mesoscale structures, since in this region the Rossby radius is on the order of 10 km.

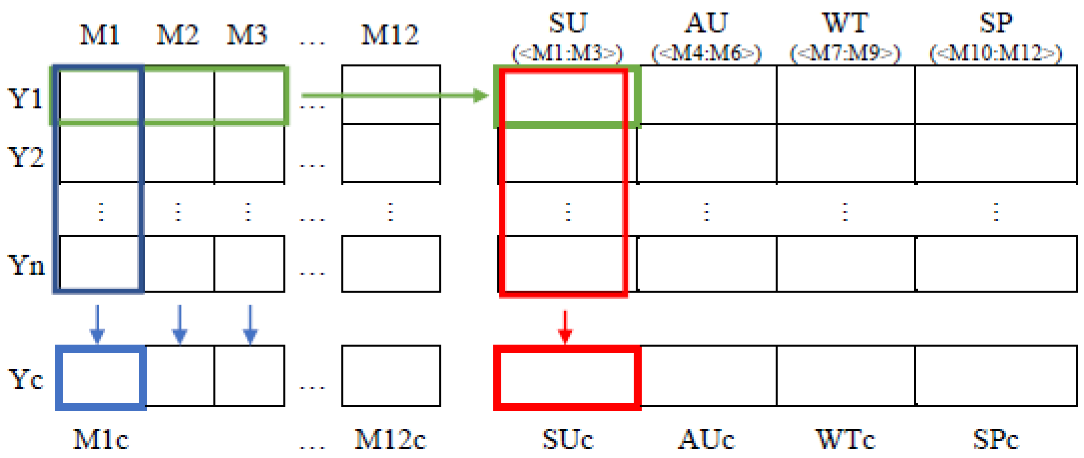

Figure 2. Scheme for the generation of the climatological variables with the following codes: M#: the monthly averaged variable of the month #; Y#: the year for which the averaged variables are obtained; SU, AU, WT and SP: seasonal averages for year Y# of Summer, Autumn, Winter and Spring, respectively; M#c: climatological average of the month #; SUc, AUc, WTc and SPc: seasonal climatological averages.

Then, to select the transects most sampled over time (gain of statistical robustness), we construct the corresponding maps of data density (Fig. 3).

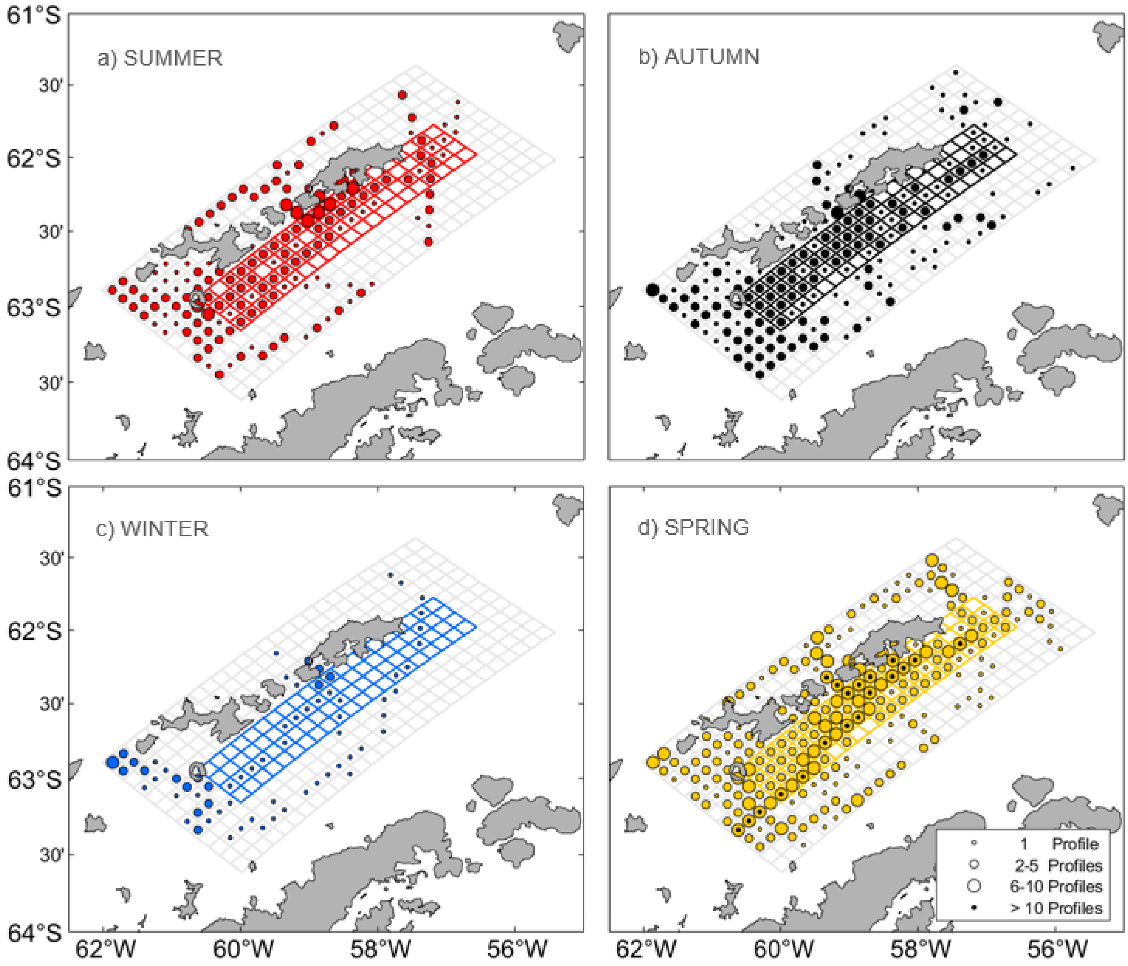

Figure 3. Maps of data density showing the amount of velocities profiles in each grid cell of the study area (see the legend). Grid cells highlighted in colours show the along-shelf and cross-shelf transects selected for further analyses. The colour code follows seasons as: a) Summer (red), b) Autumn (black), c) Winter (blue) and d) Spring (yellow).

Thus, the main analyses are focused on the horizontal and vertical structure of the BCS as well as its horizontal transport. This transport is defined as

$$U(t) = \int_{-h(x')}^{-h_0(x')} u\,(x', z, t)dzdx',$$

where h_0 is the depth of the shallowest velocity value (30 m), h is the depth of deepest velocity considered (250 m), u is the east velocity component and x' is the coordinate along the transect.

RESULTS AND DISCUSSION

Through this section we aim to determine whether the BC is a year-round feature of the circulation in Bransfield Strait and whether this current displays significant seasonal variations in both horizontal and vertical structure as well as the horizontal transport.

To obtain the velocity vertical distribution along transects perpendicular to Bransfield Strait at the southern slope of the SSI, only transects containing data in 90% of their extent are used.

Seasonal Variability of the BC Horizontal Structure

Figure 4 shows the horizontal circulation patterns of the velocity field varying seasonally at a selected depth (150 m), where the core of the BC is expected from previous works (Sangrà et al., 2011, 2017).

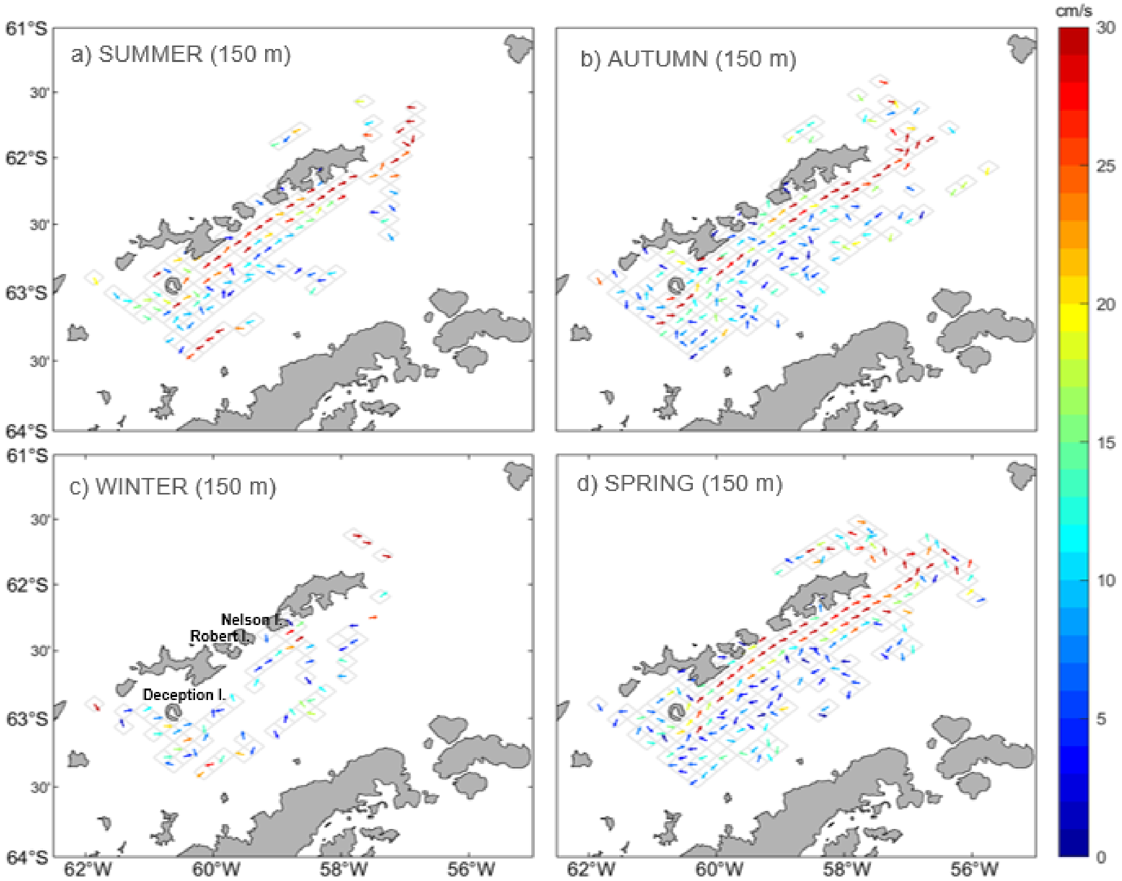

Figure 4. Seasonal maps of the horizontal velocity field at 150 m for: a) Summer, b) Autumn, c) Winter, and d) Spring. The velocity field is represented with unitary vectors showing the direction of the current, coloured according to the velocity magnitude.

The most outstanding feature is the recurrence of a northeastward-flowing jet along the southern coastline of the SSI, which signal is attributed to the BC.

Seasonally, the strength of the BC varies. From spring to summer, the BC flows as a relatively strong (~30 cm/s) and continuous jet. During autumn, the jet weakens from Deception Island to Robert Island, strengthening again downstream from this location. In winter, relatively high velocities about 30 cm/s are only found, upon data availability, south off Nelson Island.

Horizontal Transport of the Bransfield Current

The seasonal horizontal distribution of integrated volume transports (30-250 m) (Fig. 5) also show the persistence of the BC flowing northeast along the southern slope of the SSI through all seasons.

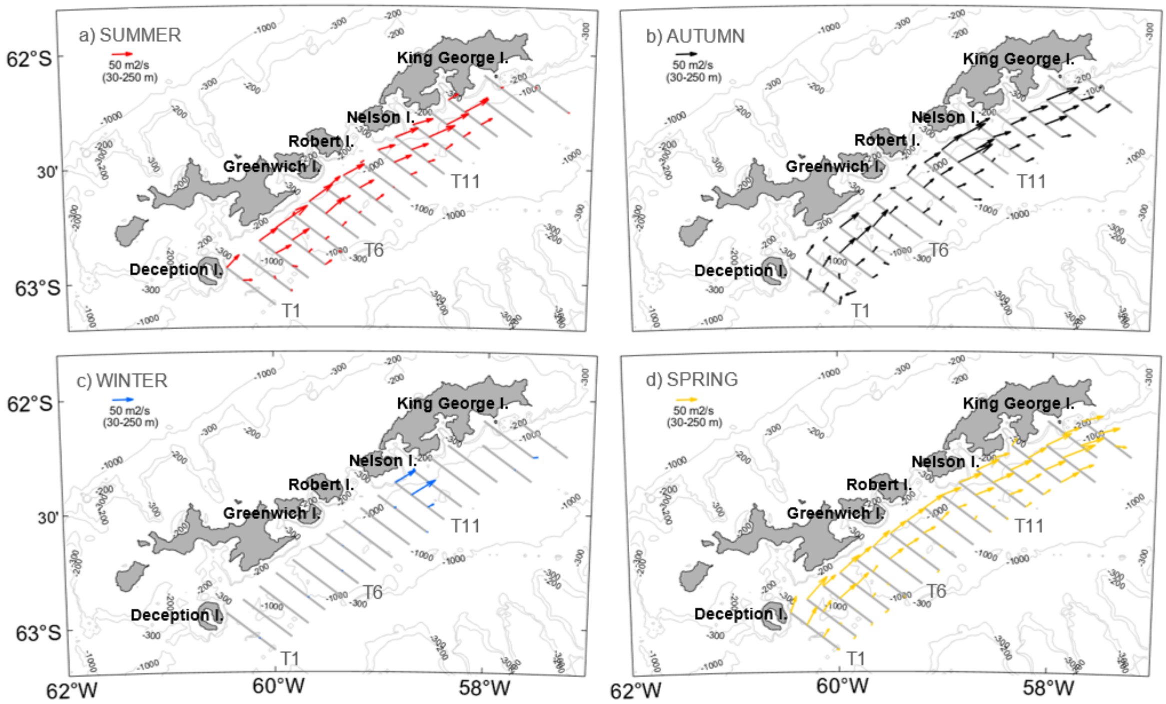

Figure 5. Map showing the transects of study and the associated seasonal horizontal transports (m^2/s) following a) summer, b) autumn, c) winter, d) spring. The four vectors along each transect originates from averaging the horizontal transport (m^2/s) driven by all available profiles and falling within each of the four cells of study (the closest to the island coastlines). Each transect covers a distance of 20 km. The magnitude of the velocity field is scaled to the vector in the upper left corner of each panel.

In agreement with results in Figure 4, the distribution of the horizontal transports over the BC domain show higher values closer to the coast and decreasing offshore, especially during summer and spring. This structure supports further the jet-like nature of the BC hugging the slope while following the bathymetry. The latter feature is especially noticeable when the BC starts its turn around the King George Island. The springtime horizontal transport also supports the BC narrows from Greenwich-Robert Islands to Nelson Island and widens downstream, contouring the bathymetry, towards King George Island. During autumn, it seems the core of the BC either widens or moves offshore along the pathway of the BC.

Seasonal Variability of the BC Vertical Structure

Vertical sections show the persistence of an eastward flow, the BC, along the southern slope of the SSI throughout the year, with changes in the shape and strength of the current core.

In terms of shape, the core appears hugging the slope of Nelson Island from spring to autumn, while the core detaches from the slope during winter. Regarding to the strength of the BC, its intensification is noticeable through autumn/winter in this transect 11 (Fig. 6).

Also, in the longest transects (autumn and spring) the PF is apparent, with TWW flowing westward. These two panels (Figure 6 b and d) are suggestive of the Bransfield Front holding the BC as a baroclinic jet and opposing the Weddell Sea Inflow.

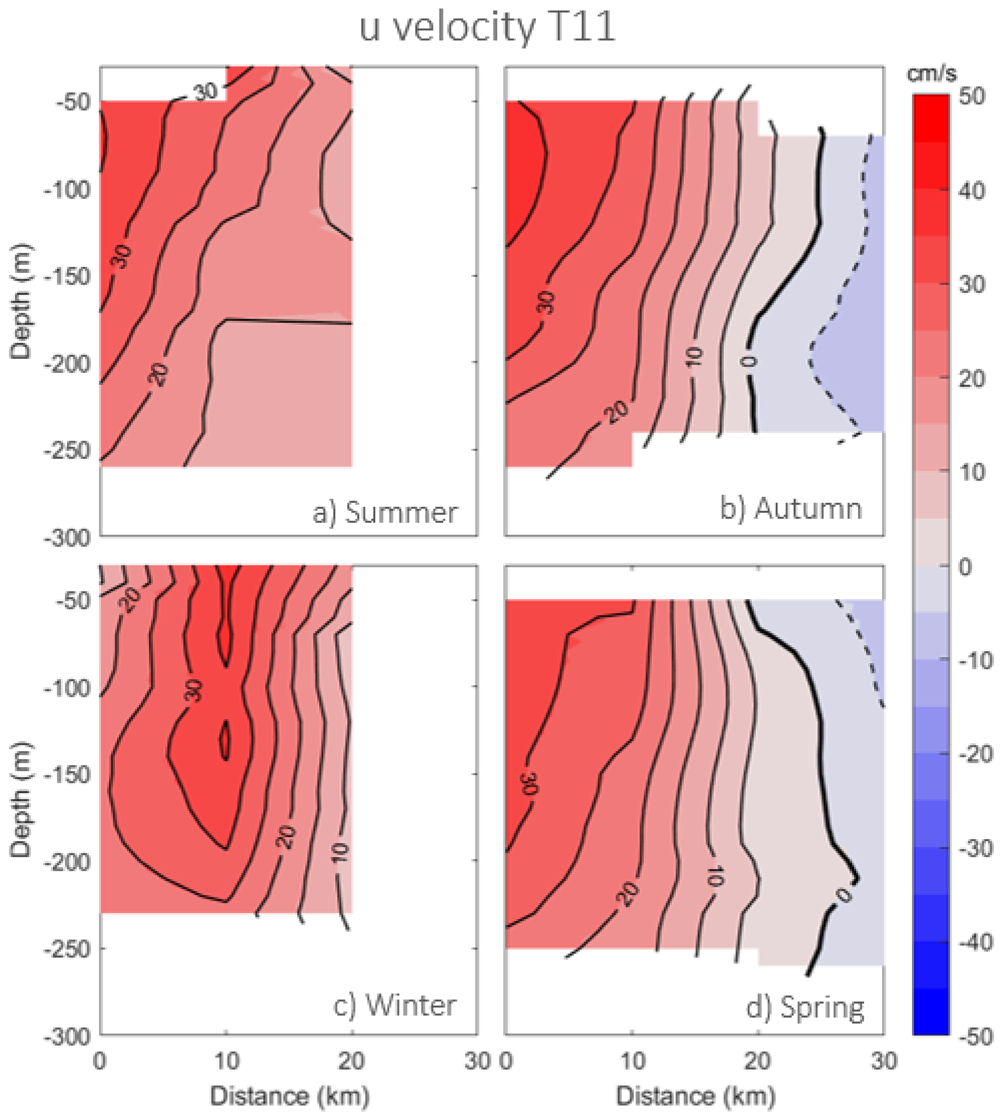

Figure 6. Vertical sections of a SADCP-based seasonal climatology for Transect 11 (see T11 in Figure 5). Distance starts at the southern SSI slope being perpendicular to the islands. Note that velocity is positive to the east; i.e., in the direction of the BC, carrying TBW. Conversely, negative velocities show westward flows; i.e. in the direction of TWW inflow.

CONCLUSIONS

We find **the BC is present in all seasons** (Figs. 4-6); velocity vertical profiles show its persistence even despite the scarcity of winter data (see Fig. 3). Also, the BC displays a **strong recurrence on its propagation towards to the northeast.**

Alongstream, **BC velocity and transport are noticeably higher** from the Nelson Island **to the north**. We hypothesize this increase is likely due to the **recirculation of the BC around the SSI**, then returning partially to the main flow again between Robert and Nelson Islands.

As expected, the core of the BC, characterized by higher velocities, is found within the grid cells closer to the coast. This supports that the **BC flows as a gravity current** hugging the island slopes and following the bathymetry, except for the winter season (Fig. 6c), when its core appears to move towards the center of the Strait. The core the BC also moves offshore at the wake of channels between islands.

Thus, we note that **the width of the jet** changes spatially along its pathway; it **narrows from Greenwich-Robert Islands to Nelson Island and widens downstream towards King George Island**, what might be related to the widening of the platform in this region.

In conclusion, **the BC is a permanent component of the Bransfield Strait circulation** with both spatial and seasonal variability but recurrent year-round.

ACKNOWLEDGEMENTS

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ABSTRACT

The Bransfield Strait is a semi enclosed region located between the Antarctic Peninsula and the South Shetland Islands (SSI), where the Bransfield Current (BC) is a relatively warm baroclinic jet (0-250 m) flowing northeastward along the southern slope of the SSI. Recent studies have shown that the BC propagates as a buoyant gravity current, recirculating around the north-eastern tip of the islands while shedding an anticyclonic eddy. However, most previous works are based on summertime measurements and a more comprehensive spatio-temporal view of the regional circulation is still lacking.

In this study we provide the first seasonal description of the BC based on an extensive dataset of direct velocity measurements. These measurements were routinely collected along ship tracks from 275 cruises between 1999 and 2014.

Seasonally, the horizontal structure of the BC flowing as a coastal jet appears more prominent during spring and summer, when its pathway extends along the island slopes over 180 km at velocities up to 45 cm/s, from Deception Island towards King George Island. During these seasons, the BC is consistently narrower at the beginning of its path (15-20 km wide), and wider before starting its recirculation around the SSI (30 km wide). Through autumn, this pattern is also apparent but less intense, especially south off Livingston-Robert Islands, where subsurface velocities (150 m) are lower at about 10-15 cm/s. The scarcity of winter data confirms the existence of a relatively strong coastal jet with mean velocities about 34 cm/s at least south off Nelson Island.

Vertically, the BC also displays a distinctive pattern. At the wake of the islands, the core of the current flows hugging the island slopes with velocities about 35 cm/s at 150 m. Differently, when located at channels between islands, the core of the current migrates offshore flowing at 30-45 cm/s. In terms of zonal volume transport (0-250 m), our estimates indicate that the BC transports about 0.85, 0.93, 0.90 and 1.01 Sv from spring to winter, respectively, at the location where all seasons are covered by data (south off Nelson Island).

These results support the BC is a recurrent feature of the circulation in Bransfield Strait, flowing northeastward all along the southern slope of the SSI not only during summer but also during spring and autumn.

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