Circulation and wind-driven processes in the Yaganes area

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Introduction

The northern sector of the Drake Passage-Scotia Sea system connects the Southeast Pacific and the Southwest Atlantic and is shaped by complex water masses and strong oceanic fronts such as the Northern Boundary and the Sub-Antarctic Front of the Antarctic Circumpolar Current (ACC). At the southern tip of South America, steep bathymetry and the Sloggett Canyon interact with major currents, including an along-shelf-break flow (Figure 1). These features promote vertical motions, mixing, and biological hotspots, yet remain poorly studied. **OBJECTIVES: 1) Characterize** the main circulation in the transitional Yaganes area (between Southern Chilean and Southern Argentinian Patagonian regions). **2) Assess** the influence of wind forcing and bathymetry on vertical motions in the upper Sloggett Canyon. **3) Explore** implications of these processes for biological productivity.

Material and methods

Observational data:
Oceanographic expedition aboard R/V *Austral* (Nov 3–22, 2022).
46 CTD/Rosette profiles collected in NW Scotia Sea (Figure 2 and 3).
Two transects across the upper Sloggett Canyon: **T2** and **T1**.
Reanalysis data:
GLORYS12V1 ocean reanalysis (0.5–454 m depth) for currents and SSH.
ERA5 reanalysis for wind stress (Figure 4).
Combined EOF analysis of SSH and wind stress intensity to assess synoptic variability.
Ekman transport and pumping estimated; absolute vorticity computed during T1 and T2.

Results

EOF analysis of SSH and wind stress (Nov 2022) revealed strong variability along the Northern Boundary and Sub-Antarctic Front (Figure 5 and 6), with significant changes at the canyon rim (Figure 7). Wind forcing was a key driver of coastal variability through Ekman dynamics. Two phases were identified: **Relaxation (Nov 12):** calm winds, weak coastal current (~45 cm s^{-1}), and mesoscale eddies south of the region. **Intensification (Nov 25):** strong NW winds (>0.3 N m^{-2}), intense coastal current (>80 cm s^{-1}), and enhanced meander activity. In the **Sloggett Canyon**, contrasting wind regimes shaped vertical motions (Figure 7 and 8): **T2 (calm winds):** weak downwelling upstream and limited upwelling downstream. **T1 (strong winds):** significant upwelling across the canyon, uplifting isotherms and increasing fluorescence, indicating nutrient supply to the euphotic zone.

Conclusions

- **Three oceanographic domains** were identified, linked to the Northern Boundary and Sub-Antarctic Front of the ACC, separating coastal, intermediate, and subpolar regions.
- **Upper-ocean circulation** revealed two phases of the along-shelf-break flow: relaxation (weak Ekman convergence) and intensification (strong Ekman convergence).
- During intensification, an **episodic upwelling event** was observed in the Sloggett Canyon, despite its classification as a downwelling canyon.
- This variability suggests the canyon may acts as a **by-pass zone** between the Chilean and Argentinian Patagonian shelves.
- The study provides the **first daily-scale evaluation** of this coastal current and its link to canyon dynamics and upwelling.

Graphical Information

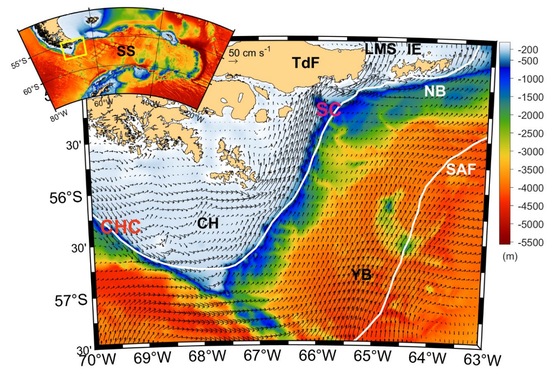

Figure 1. Bathymetry of the northwestern Scotia Sea (yellow polygon, inset). Main fronts (NB, SAF) are shown in white. Black vectors indicate mean November depth-averaged circulation (GLORYS12V1). Key features: Cape Horn Current (CHC), Yaghan Basin (YB), Tierra del Fuego (TdF), Isla de los Estados (IE), Le Maire Strait (LMS), Cape Horn (CH), and Sloggett Canyon (SC).

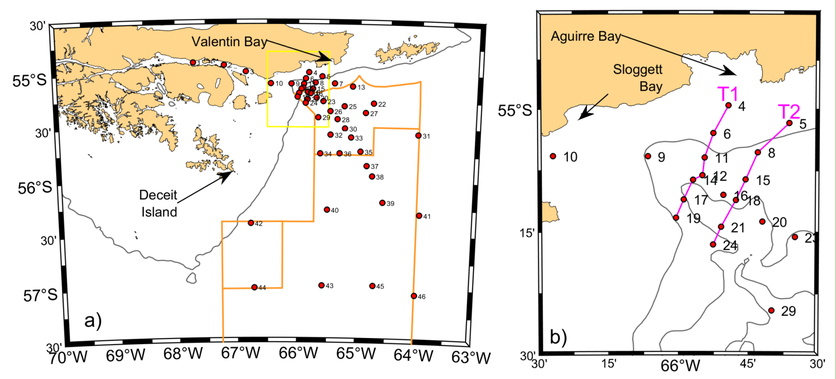

Figure 2. CTD/Rosette casts during the oceanographic expedition (red dots). (a) Northwestern Scotia Sea showing the 200-m isobath (grey) and the Yaganes Marine Protected Area (orange). (b) Upper Sloggett Canyon (yellow polygon in a) with 200, 1000 and 2000-m isobaths (grey). Transects T1 and T2 are indicated in magenta.

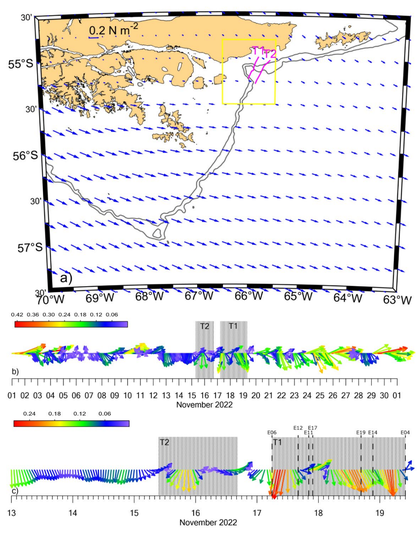

Figure 4. Wind stress vectors in the northwestern Scotia Sea (ERA5, November 2022). (a) Time-averaged wind stress with 200-m and 500-m isobaths. (b) Time series of area-averaged wind stress in the Sloggett Canyon (yellow polygon). (c) Zoom of (b) during transect days.

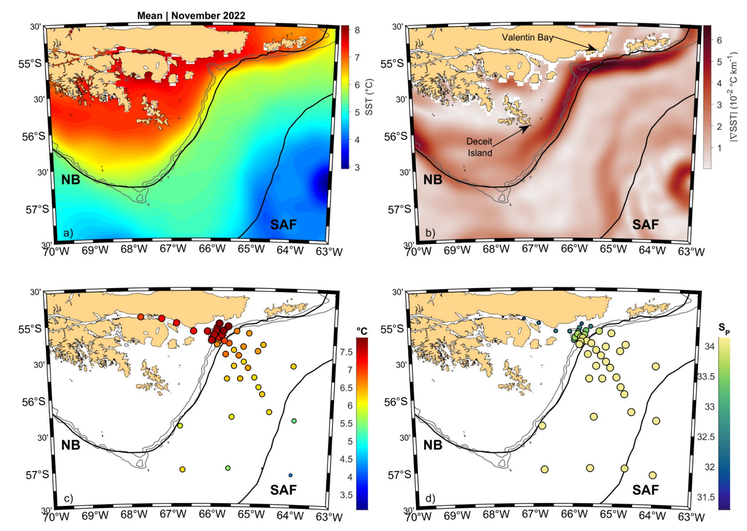

Figure 3. (a) Mean sea surface temperature (SST) in November 2022 from OSTIA. (b) Mean SST gradient magnitude. (c) Surface potential temperature and (d) practical salinity from CTD profiles at 10 m depth. Grey lines show 200-m and 500-m isobaths; black lines mark main fronts (NB, SAF).

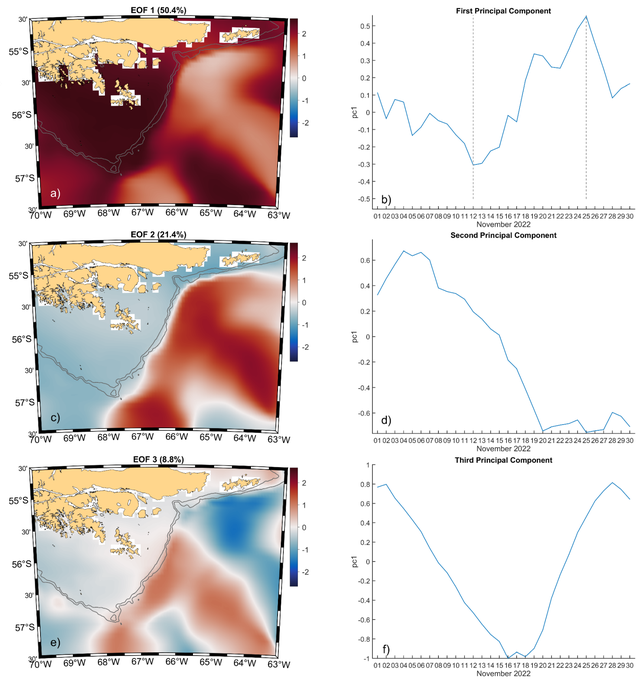

Figure 5. Combined EOF modes of sea surface height (SSH) and wind stress intensity, with associated time series. (a–b) EOF1, (c–d) EOF2, (e–f) EOF3. Dashed grey lines in (b) mark extreme scenarios of PC1.

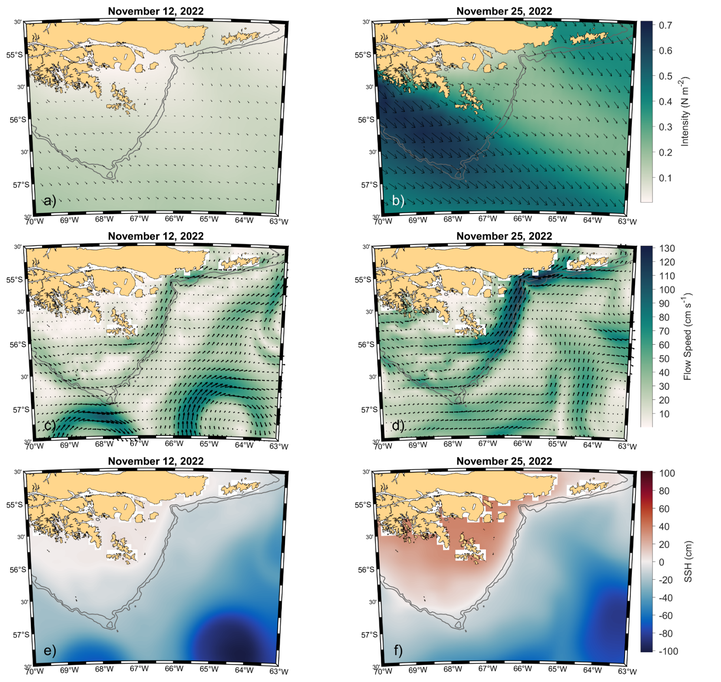

Figure 6. Extreme scenarios from the PC1 time series: November 12 (minimum) and November 25, 2022 (maximum). Panels show wind stress (a–b), upper-ocean circulation (c–d), and sea surface height (e–f).

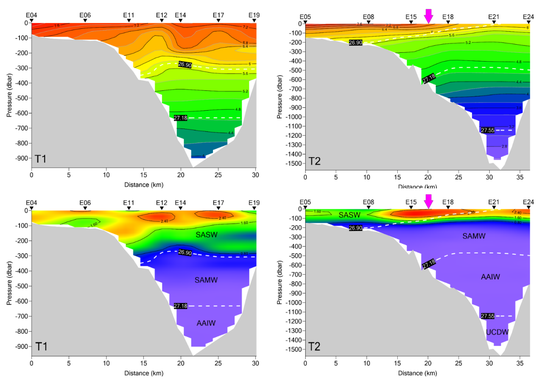

Figure 8. Vertical sections of Conservative Temperature (Θ) and calibrated fluorescence along transects T1 and T2. Neutral density thresholds are shown as dashed white lines. Water masses are labeled in bottom panels.

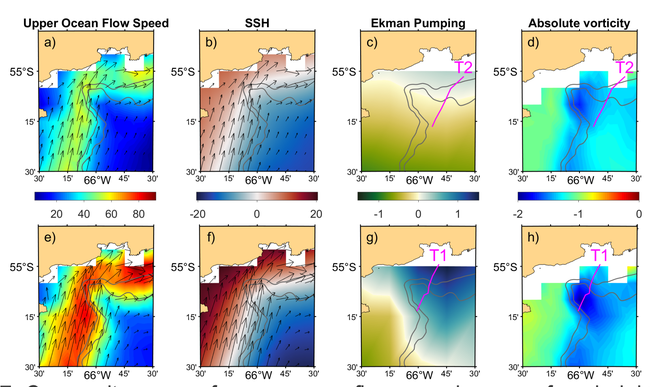

Figure 7. Composite maps of upper-ocean flow speed, sea surface height (SSH), Ekman pumping, and absolute vorticity in the Sloggett Canyon during transects T1 and T2. Grey lines show 200-m and 500-m isobaths.

Take Action

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