An inventory of salty and warm subsurface intrusions in the South Brazil Bight (SBB)

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Introduction

Intrusions are found all over the world and they are attributed to strong lateral fluxes and enhanced vertical gradients (Ruddick and Richards, 2003), also affecting the air-sea interactions and larvae exchanges between shelf and shelf-slope. Therefore, they can potentially affect the thermodynamics and biogeochemistry of the shelf. In the South Brazil Bight (SBB), a tongue-shaped pattern of salty and warm waters penetrating the inner continental shelf was found in observational datasets and numerical outputs. However, no special attention was paid to these features and theirs characteristics, like occurrence, vertical position or even the salinity anomaly associated with them. In this work we address the occurrences of salty intrusions and their characteristics, as their implications for thermohaline motion.

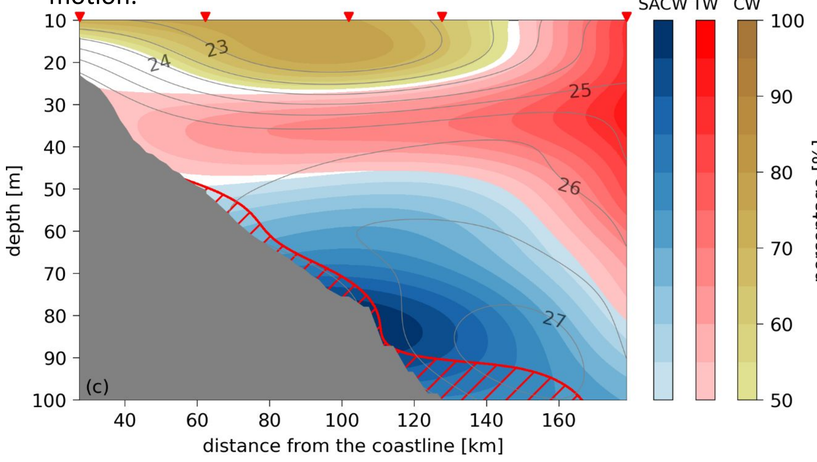
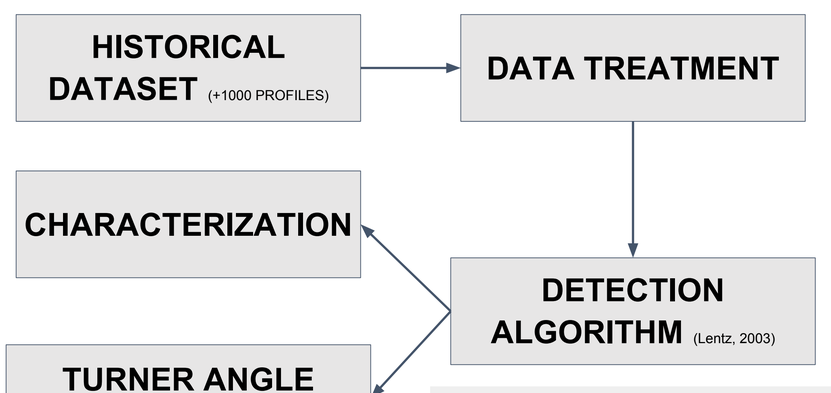


Figure 1 – Water mass transect. The colors represent the water masses: red is the Tropical Water (TW), blue is the South Atlantic Central Waters (SACW) and yellow is the Coastal Water (CW). White regions are places where there was no dominance of a specific water mass.

Methods



Applied nonparametric statistics:

- Spearman correlations @ 95% CL
- Mann-Whitney to evaluate alongshelf differences and seasonality (@ 95% CL)

Results

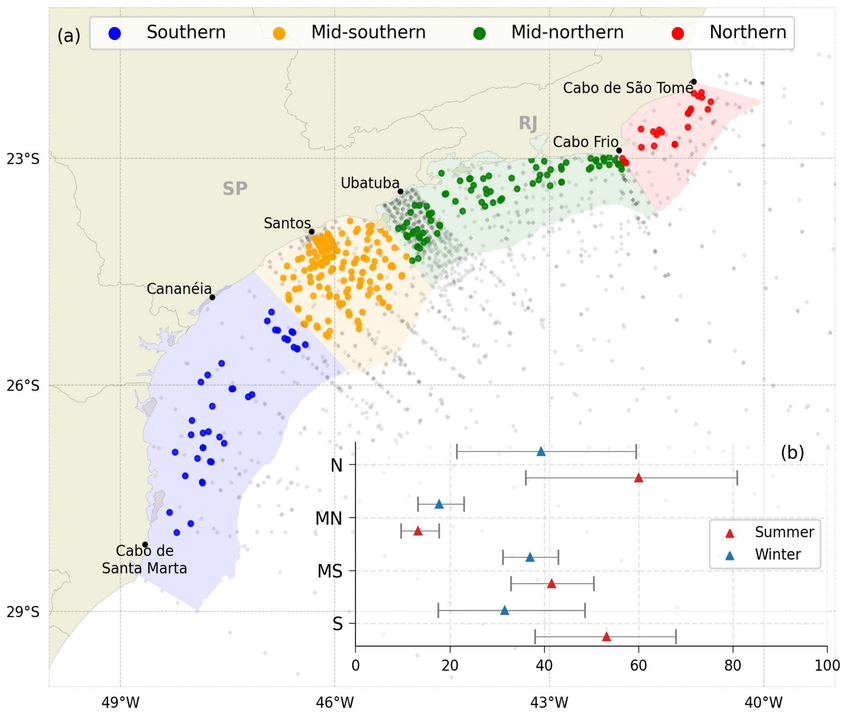


Figure 2 – Intrusive vertical profiles geographically distributed (a), separated by colors for each compartment. The inner bar graph in (b) shows the relative seasonal occurrence of intrusions in each compartment.

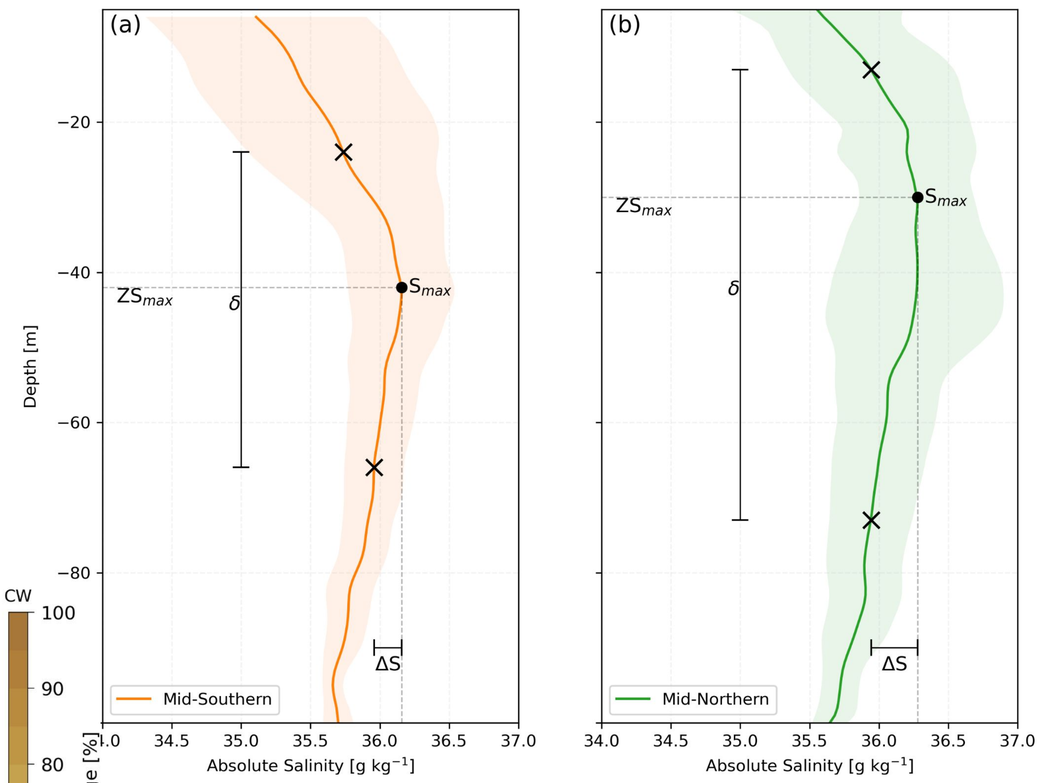


Figure 3 – Average absolute salinity vertical profile and envelope with observations with subsurface thermohaline intrusions. In (a) shows a typical intrusion for Mid-Southern and (b) for Mid-Northern area. Check Figure 2 for reference of these regions.

How intrusion thickness relates to the stratification?

Spearman correlation of [-0.39; -018] suggest an anti correlation between intrusion thickness and stratification. Which means intrusions are thinner when the stratification is strong. The same relationship was found by Lentz (2003), for the Mid-Atlantic Bight. In the SBB, intrusions will be thinner when the three water masses from this region are found at the same time (see Figure 1 for an example).

Our thickness values are consistent with intrusions thickness found around the world (Ruddick and Richards, 2003).

Are these intrusions double-diffusively driven?

The inverse relation between stratification and intrusion thickness suggest that double diffusion processes may be associated with intrusions, since the intrusions develop thermohaline structures favorable for these mixing processes. From this analysis, we found that double diffusion activity in the region is independent of intrusions, since the susceptibility for the region doesn't change with or without intrusions (not shown). Moreover, the comparison of our thickness values are one order of magnitude higher than theoretical thickness (Ruddick and Turner, 1979) for double-diffusively driven intrusion, supporting the hypothesis that intrusions in the SBB are not developed for these processes. Therefore, intrusions might no be double-diffusively driven, even though its effects cannot be neglected.

Double-diffusive processes within intrusions

The Tu analysis shows that the water mass structure during intrusive events favors the formation of different double diffusion processes at the upper and lower layer of the intrusion.. Therefore, it is expected that these processes might affect the mixing between intrusions with surrounding waters (Figure 4) and it is expected that these processes affect the mixing of intrusions. Thus, shear-driven mixing also can be responsible for mixing the intrusions and both processes can coexist in the same region (Ruddick and Richards, 2003). The turbulence role over mixing within intrusions was quantified through the Bulk Richardson number (Ri_b) and we found that the stratification actually suppress the shear-driven mixing. Therefore, double diffusion processes have the higher potential for mixing intrusions with continental shelf waters and the different processes may affect the intrusion dynamics (growth, stability or erosion).

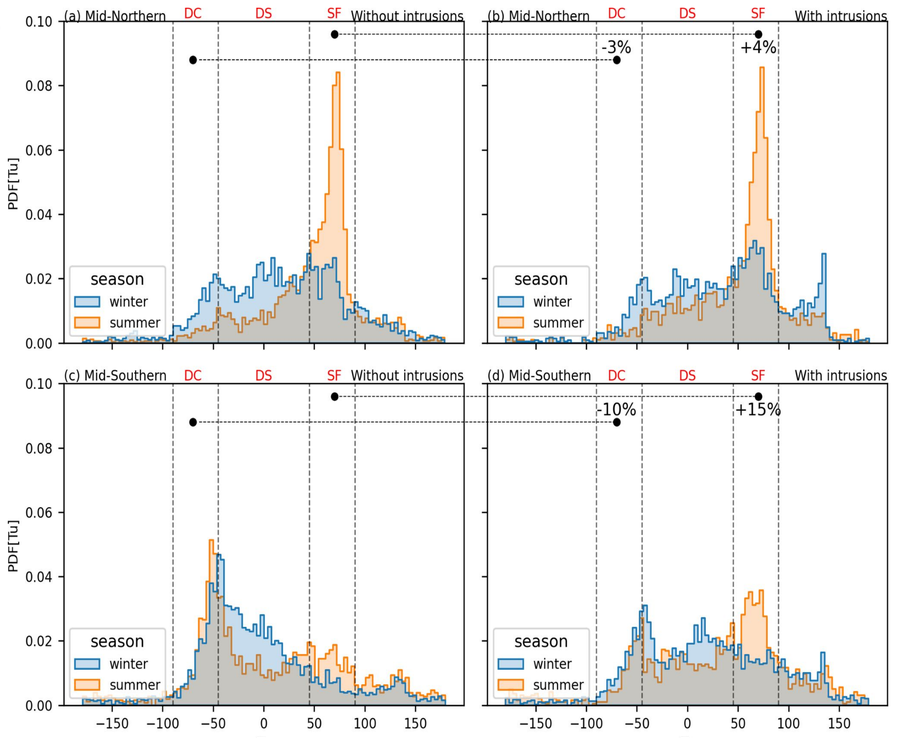


Figure 4 –Turner angle probability density function for the top and bottom layers of intrusions for Mid-Northern (a) and Mid-Southern (b), separated by summer (light orange) and winter (light blue).

General description

In general, intrusions were found in 27% of the profiles evaluated in the entire domain (Figure 2). However, the Mid-Southern (38%) presents significantly more intrusions than Mid-Northern (15%). In general, intrusions were found to be saltier and shallower (21m and 36.42 g kg^{-1}) to the north of São Sebastião Island (SSI) when compared to intrusions occurring to the south of SSI (25m and 36.19 g kg^{-1}, respectively).

Alongshelf differences are possibly related to different topography and freshwater influence

At the MN region, narrow shelf and absence of larger continental runoff, region susceptible to wind-driven cross-shelf transport (Ekman Transport). During downwelling-favorable winds, Tropical Waters are transported shoreward, which is displaced downwards by low freshwater presence nearshore, reflecting in only 15% of occurrences. While for the MS, quasi-permanent low-salinity strip nearshore develops a cross-shelf density gradient which appears to favors intrusions to occur, resulting in 38% of occurrences in this region (Castro, ,2014; Cerda and Castro, 2014).

Seasonality

Were found significant differences between summer and winter in terms of vertical position of the intrusion, thickness and salinity anomaly. These seasonal differences reflects the seasonality of the processes mentioned above. For MN and MS, intrusions are shallower and saltier in summer. Only for MS, it was found that intrusions are thicker in summer due to the upward displacement of the lower limit of the intrusion. This is possible related to the presence of SACW below the intrusions (see Figure 1 for an example).

Conclusions

- Intrusions have a relatively higher occurrence (27%) along the shelf, with higher occurrence at the MS (38%) compared to the MN (15%);
- Intrusions are saltier and shallower to the north of São Sebastião Island (SSI) and fresher and deeper south of SSI;
- Alongshelf differences are related to occur due to the continental runoff (CW) and the SACW near-bottom presenc ;
- There are evidences to suggest that these intrusions are not double-diffusively driven, even though the effects of these processes could be significant in mixing intrusions with surrounding waters;
- More studies are needed to understand the triggering mechanisms and how intrusions behave inside the shelf.

References

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