The importance of salt fingers in diapycnal mixing parametrization in Eastern Boundary Systems: Study Case in the Oxygen Minimum Zone off Central Chile

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Abstract

Off central Chile (30-38°S), waters with very low dissolved oxygen are present at intermediate depths (between 50 m and 400 m depth) in a region where double diffusion instabilities can take place. This oxygen minimum zone (OMZ) is delimited between two water masses of southern origin that are well-ventilated, relatively fresh, and cold, namely: the Eastern South Pacific Intermediate Water (ESPIW) and the Antarctic Intermediate Water (AAIW). In this study, we analyzed the role of diapycnal mixing in the dissolved oxygen fluxes in the upper and lower oxyclines that delimit the OMZ in the water column off central Chile (~36.5°S). We use a set of observations of fine structure (1-10 m) and microstructure (<1m) obtained using CTD and a vertical microstructure turbulence profiler (VMP), respectively, along with current profiles obtained with ADCPs. We put special emphasis on evaluating the contribution of salt fingers to these fluxes. The thermohaline contrast in the ESSW-AAIW transition conditions the region for the development of double diffusion instabilities by salt fingers, which significantly contribute to the oxygen transport from the lower oxycline, thus favoring the ventilation of the OMZ from the AAIW.

Data & Methods

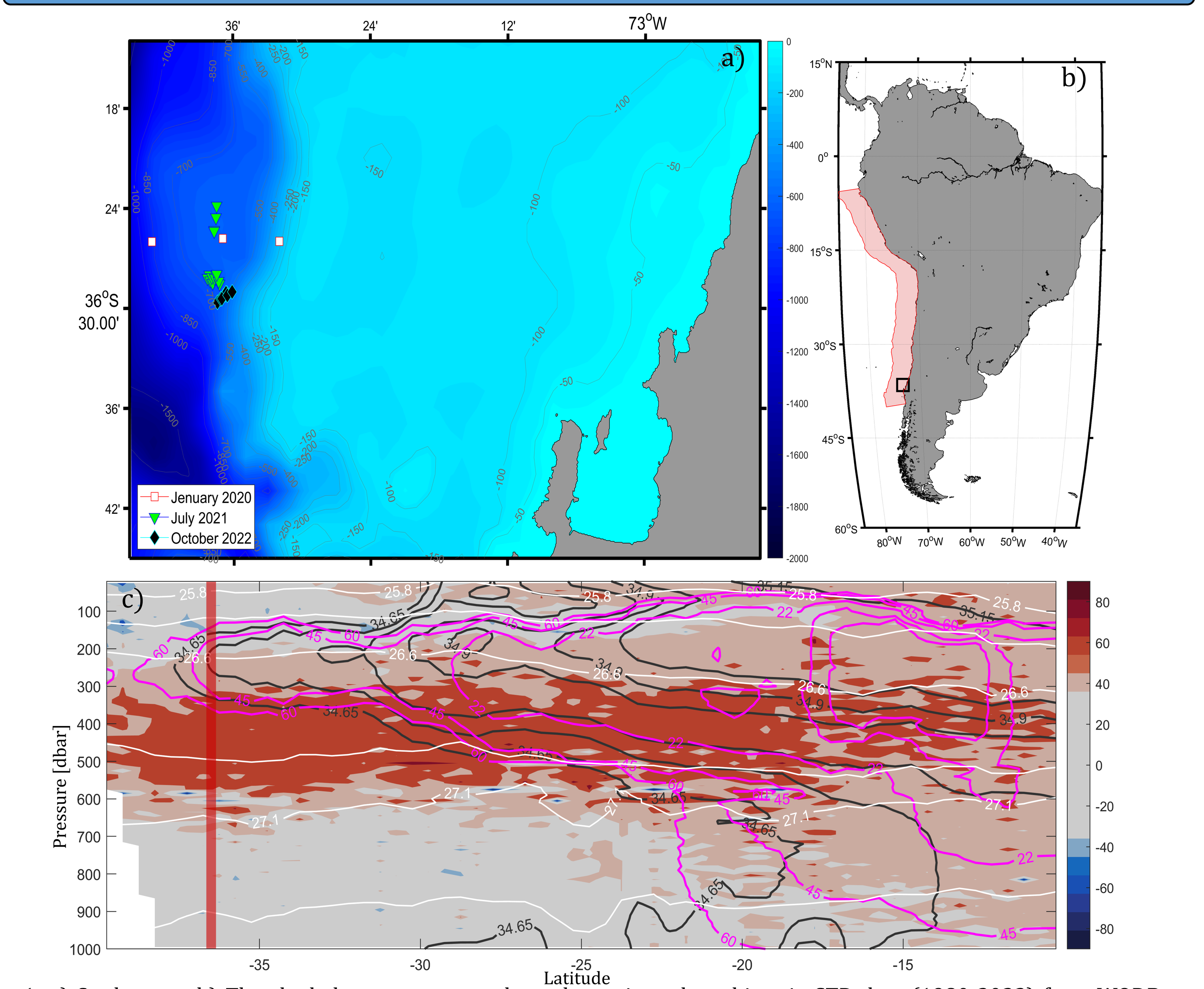


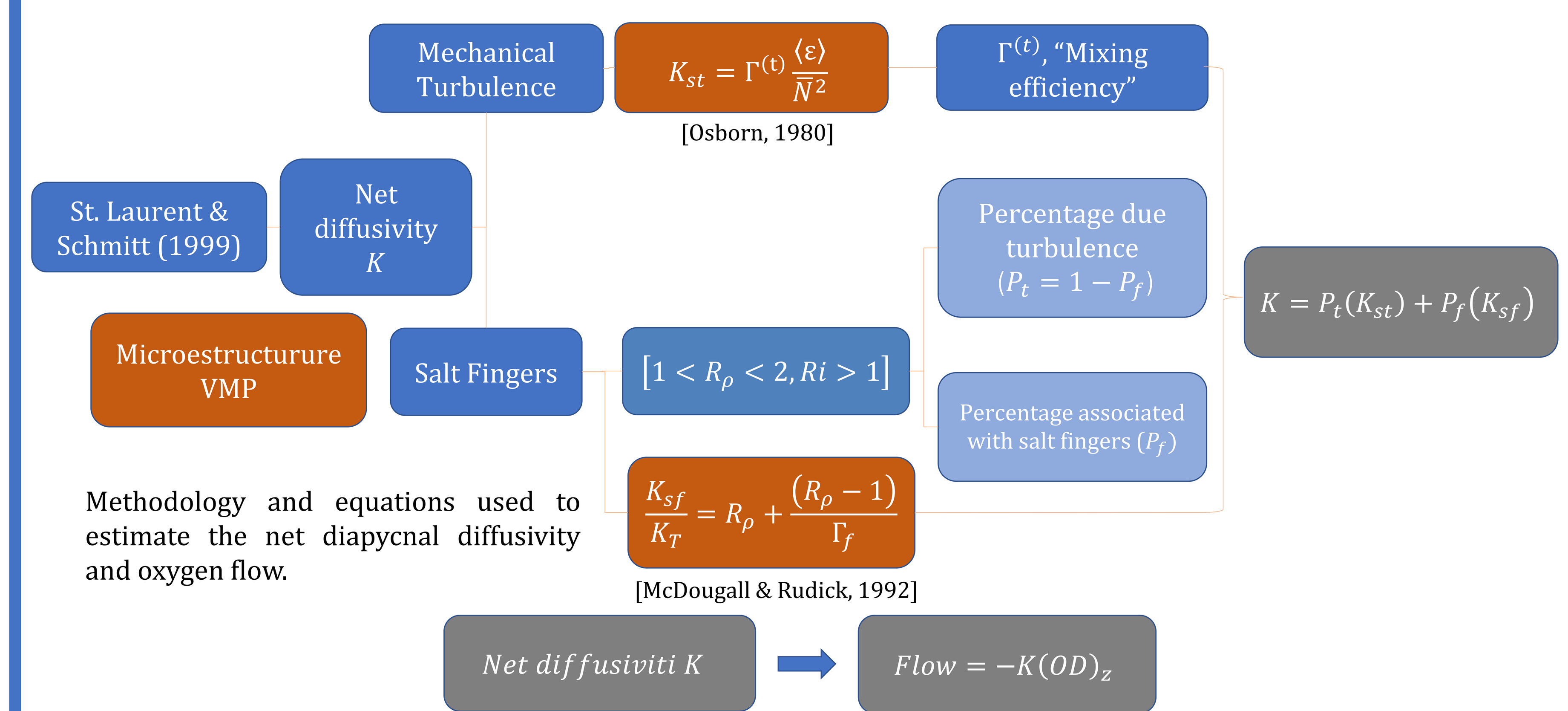
Fig. 1: a) Study zone. b) The shaded zone corresponds to the region where historic CTD data (1980-2022) from WODB was analyzed in other to explore the salt fingers occurrence in time. c) Turner Angle (degrees) map associated with the region in 1c. White lines: Isopycnic; Magenta: oxygen isopleths; Black: Isohalines.

Cruise	Total CTD profiles	Total VMP profiles	ADCP
January 2020	3	9	-----
July 2021	7	15	18 hours
October 2022	4	10	19 hours
Cell Size (m)	1	~2 (post processing)	4

Table: Data summary of the 3 cruises off central Chile (see Fig. 1a).

In the present work we are interested in mixing processes that take place below the mixed layer, that is, processes that take place under the first tens of meters of the water column. On the other hand, the contribution of the salt fingers to the net diffusivity occurs efficiently in the ESSW-AAIW transition from the saline maximum associated with the ESSW, which coincides with the core of the OMZ, towards the bottom.

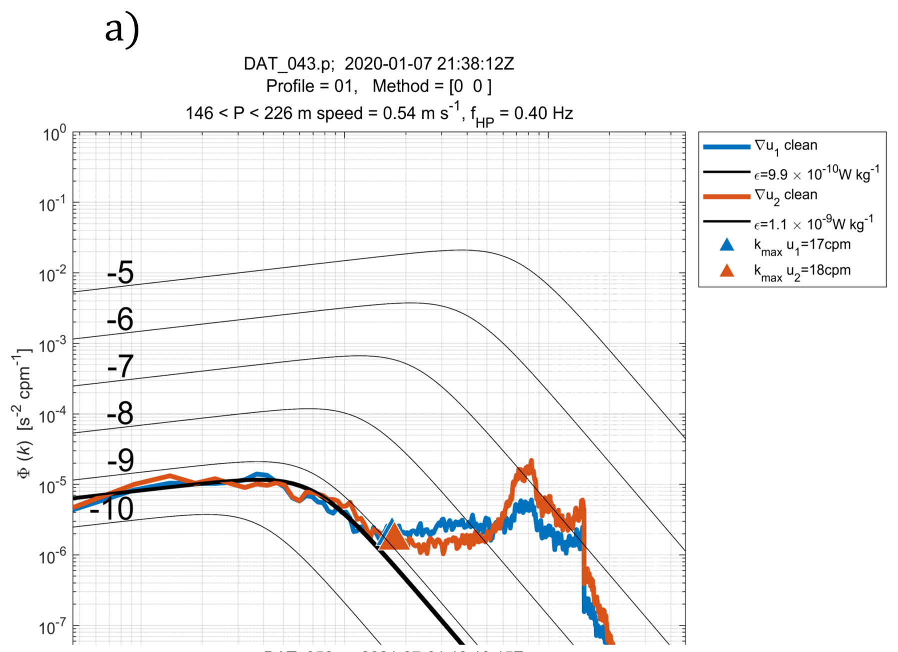
In St. Laurent & Schmitt's (1999) model, the diffusivity in the water column is calculated for the two dissipative regimes: mechanical turbulence and salt fingers. These authors carried out a detailed analysis of the conditions in which mixing by fingers of salt takes place efficiently, concluding that it occurs in the space $[1 < R_\rho < 2, Ri > 1]$ (where R_ρ is the density ratio and Ri is the gradient of Richardson number). In this way it is possible for each depth to attribute a percentage of the mixing to salt fingers (P_f) and another to mechanical turbulence ($P_t = 1 - P_f$).

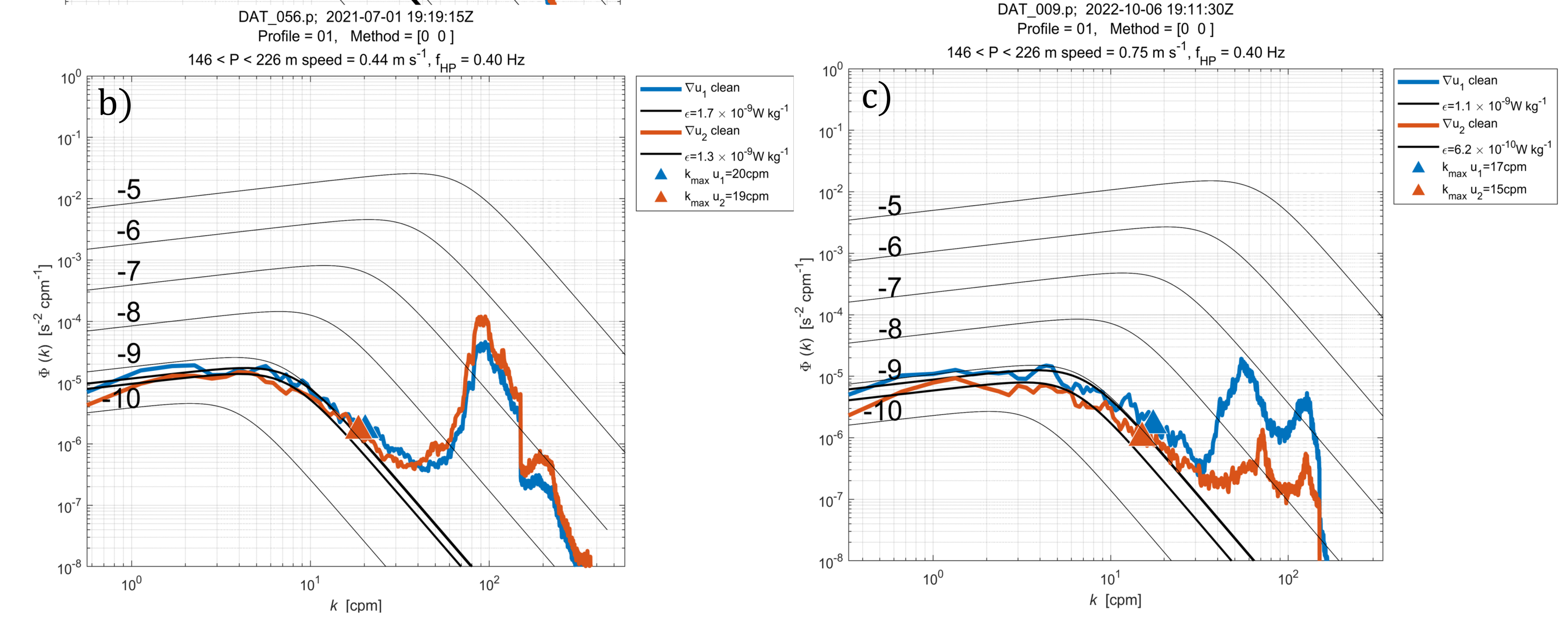


Methodology and equations used to estimate the net diapycnal diffusivity and oxygen flow.

Results

Fig. 4: Representative wave number spectrum for each cruise.





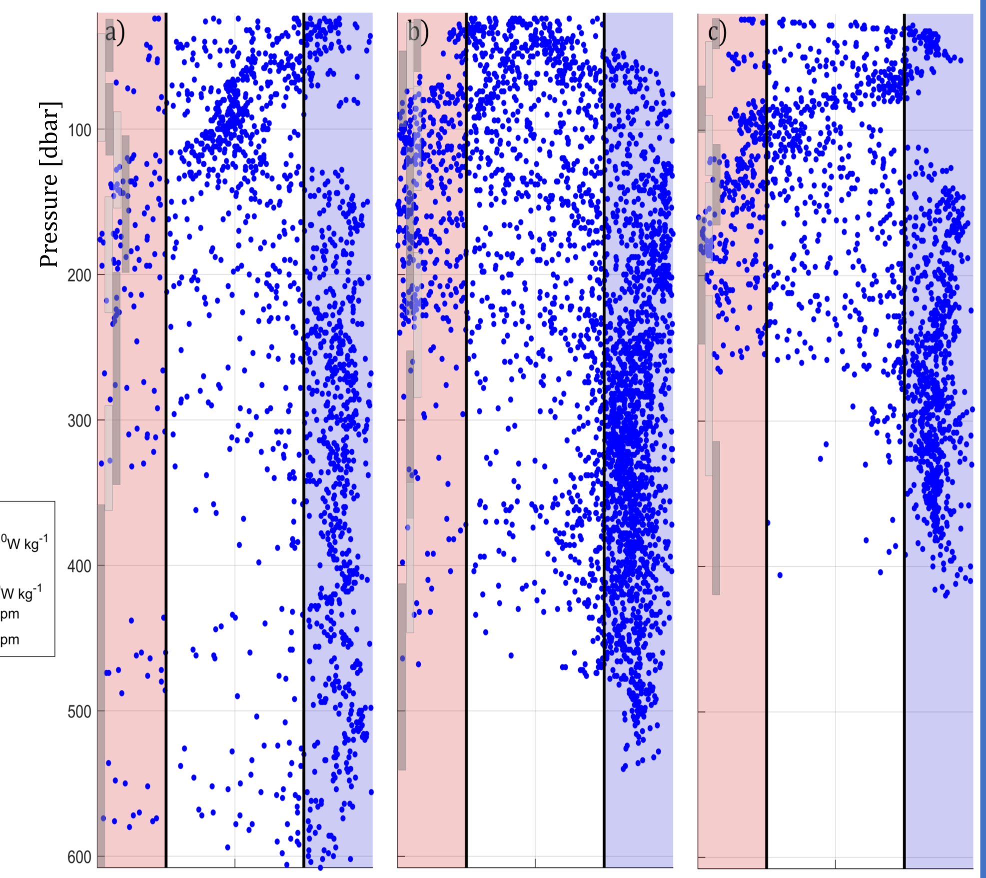


Fig. 3: Turner angle (degrees). Values >45° (<-45°) indicate that the water column has conditions favorable to the salt fingers (diffusive) mode.

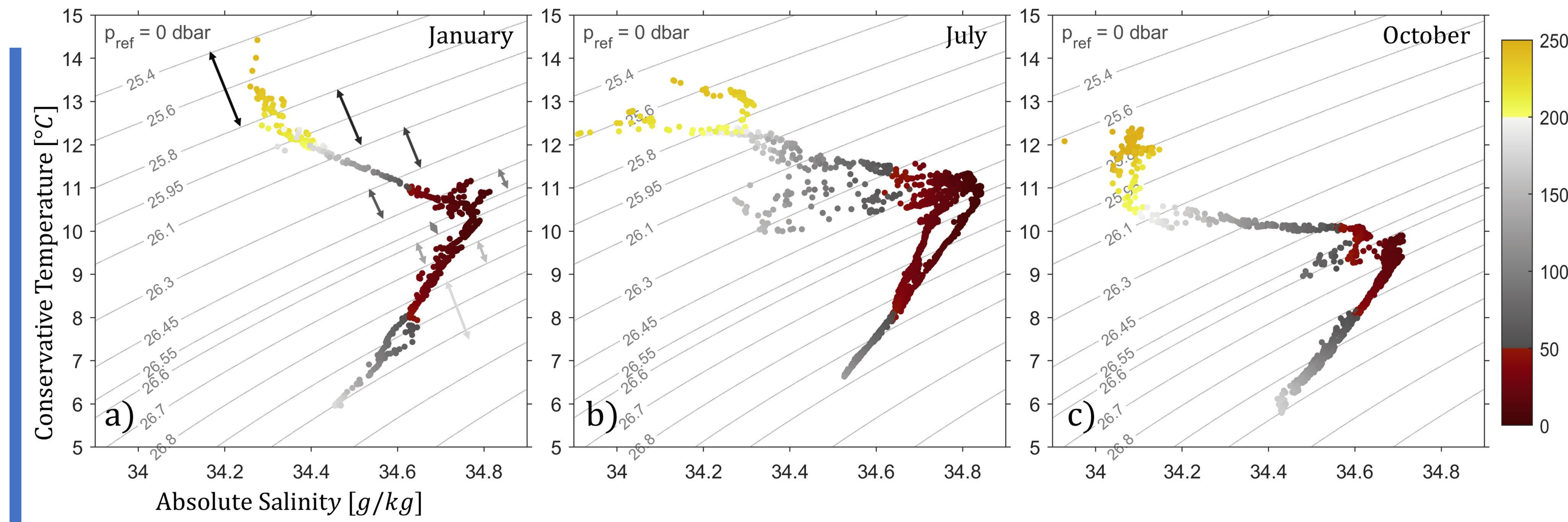


Fig. 2: T-S diagram of the 3 cruises made off central Chile. The colors show oxygen concentration. Density intervals used in the diapycnal diffusivity model are shown in (a).

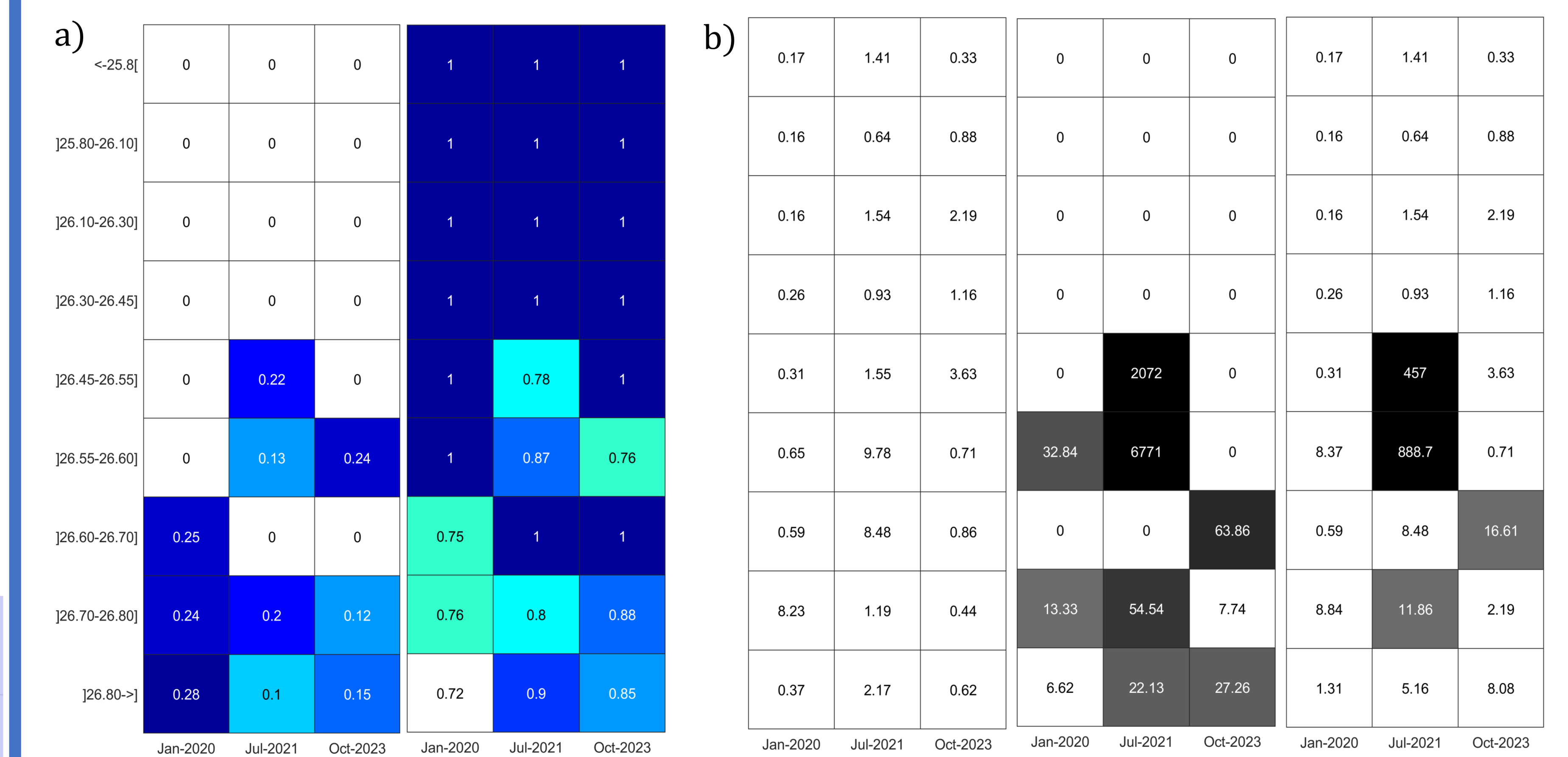


Fig. 4: a) Left (right), percentage of mixing due to salt fingers (mechanical turbulence). b) Diapycnal diffusivities associated with mechanical turbulence, salt fingers, and both contribution to net diffusivity.

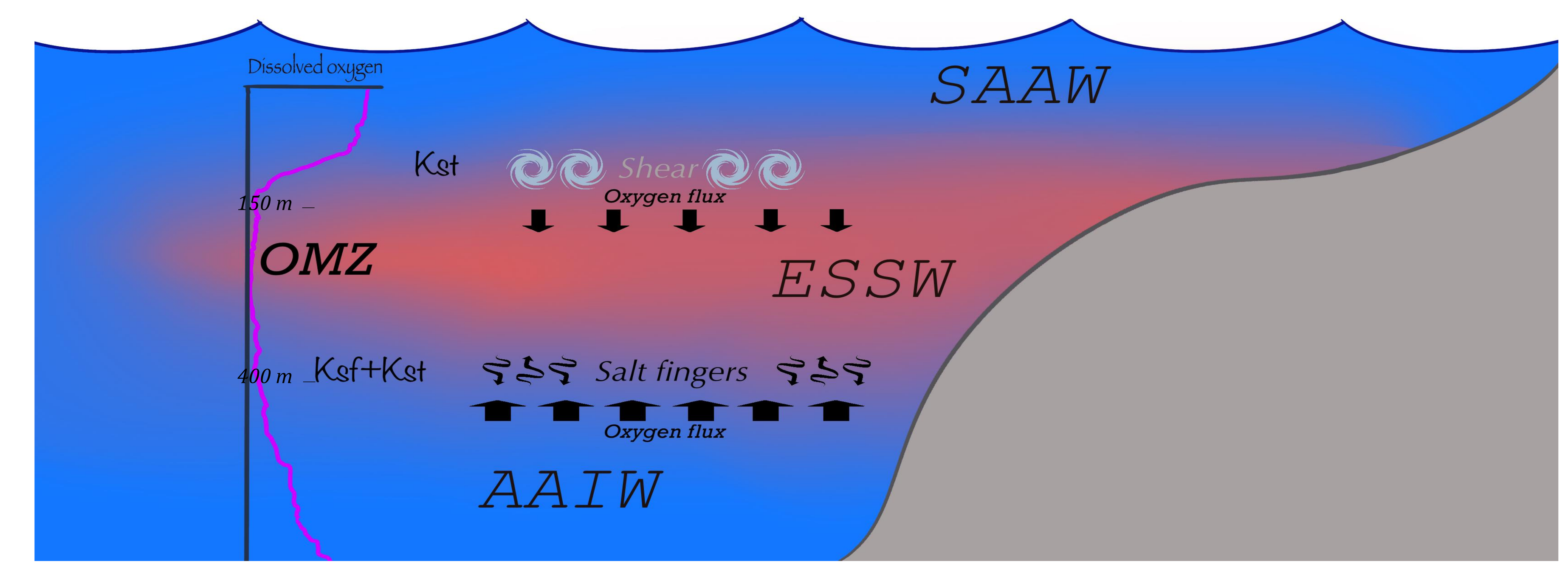


Fig. 5: Schematization of the dissolved Oxygen fluxes in the region over the slope and continental shelf off Central Chile.

The occurrence of salt fingers is limited to the region where the ESSW-AAIW transition takes place. Shear turbulence is a natural process that always occurs intermittently throughout the water column and is the dominant process in the diapycnal diffusivity above the core of the ESSW. Beneath the core of the OMZ, salt fingers may account for more than 20% of the net diapycnal diffusivity, which would produce oxygen fluxes that would contribute significantly to the ventilation of the OMZ from below. Although the diapycnal oxygen flows at the limits of the OMZ would be influenced by salt fingers and turbulence, this is one of the multiple dynamic processes that occur in the water column that would be modifying the structure of the OMZ. More studies are necessary to understand the different processes contributing to the OMZ ventilation in the region.

Acknowledgements

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