Deep ventilation process in Patagonian fjord, Chile.

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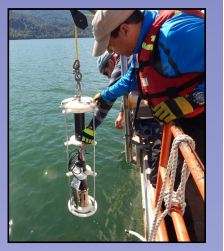

ABSTRACT

The Puyuhuapi Fjord (44.6° S) has previously been reported as one of the hypoxic fjords in Chilean Patagonia (dissolved oxygen -DO below 2 mL L^{-1}). Hydrographic sampling between 1995-2016 confirmed hypoxia below 100 m depth, down to the bottom (250 m). A line of sensors at an oceanographic mooring in Puyuhuapi were deployed to continuously record the temporal-vertical behaviour of water column temperature and salinity from the surface down to ~120 m, from February to July 2015. A multi-Parameter water quality sonde was deployed at the bottom of the line, with a DO optical sensor. From February to mid-May, hypoxia was sustained (1.4-1.6 mL L^{-1}). However, from May until the end of June, DO values increased (2.8 mL L^{-1}), exceeding the hypoxia threshold. This was the first event of deep ventilation reported in a Chilean Patagonian Fjord. During this time period, deep water temperatures increased by ~1.3 °C, coinciding with the decreased in salinity from 33.6 to 32.8. The main cause of this event was attributed to the arrival of a new volume of mixed oceanic water into the fjord, transported by Modified Subantartic Water, with warm temperatures, lower salinities and slightly higher DO values, given its origin in the surface layer of the outer oceanic region.

A new experiment was carried out during January-November, 2016 in order to corroborate the ventilation process and its connection with the adjacent ocean. Temperature, salinity and DO sensors were deployed in the outside fjords region close to the ocean (Melinka Channel) and in Puyuhuapi Fjord, to record the data at very high temporal resolution. The distance between both stations was 150 km. In the oceanic mooring the DO time series collected at ~150 m depth showed hypoxia in summer related to the position of the Equatorial Sub-surface water, but from fall DO started to increase registering high values in August and September (4-5 mL/L) when the Subantartic Water arrive. The DO records in Puyuhuapi at ~120 m showed a similar behaviour but with lower magnitude, confirmed the 2015 results. Winds and internal wave, registered with acoustic current profilers, contributed to this connection. The deep ventilation recorded in Patagonian Fjords would be helping to maintain their environmental health avoiding dead zones due to the increasing input of organic matter from salmon aquaculture.

I-INTRODUCTION

The Puyuhuapi fjord (Figure 1a), has been described as one of the hypoxic fjords in Northern Patagonia, Chile, with dissolved oxygen (DO) levels below 2 mL L^{-1} (~30 % saturation) between 100-250 m depth (*Schneider et al., 2014; Silva & Vargas, 2014*). According to these values, deep hypoxia conditions have been attributed to the presence of the southern and northern sills, which impede circulation (*Schneider et al., 2014*), and to the input of low-oxygen Equatorial Subsurface Waters (ESSW). Generally, DO measurements are carried out using CTD instruments with DO sensors, and by on board chemical analyses with the Carpenter (1965) modification for the Winkler titration method. Since 1995, deep DO values have shown minima of 1.14 mL L^{-1} in the central zone of Puyuhuapi, with similar records in 2015 (*Pérez-Santos et al., 2015*). Despite hypoxia having been permanently recorded, DO values have never dropped down to anoxia, indicating that the fjord is ventilated at a certain point in time, keeping the DO levels above 1 mL L^{-1}. In this study, we present the temporal evolution of DO within the hypoxic layer of the Puyuhuapi fjord and Gulf of Corcovado. Temperature and salinity was also recorded. The occurrence of some ventilation events is reported.

II-DATA SET AND METHODOLOGY

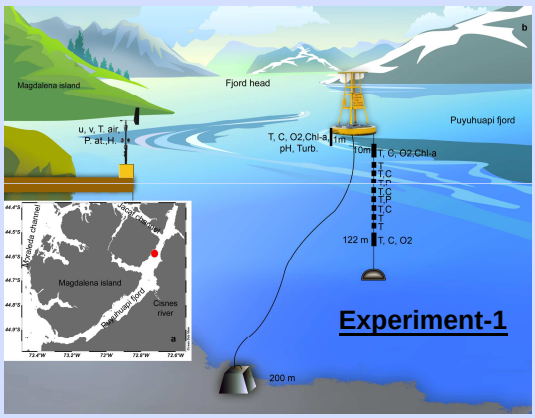

Figure 1. a) Location and b) design of the oceanographic observation system installed in the Puyuhuapi fjord, Aysén Region. The red circle in a) showed the buoy position.

III-RESULTS

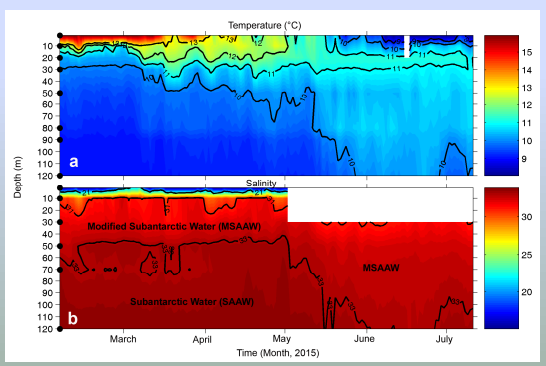

Figure 2. Time series of the vertical distribution of temperature and salinity at the oceanographic buoy installed in Puyuhuapi fjord from February to July 2015. The black dots represent the vertical position of temperature and conductivity sensors.

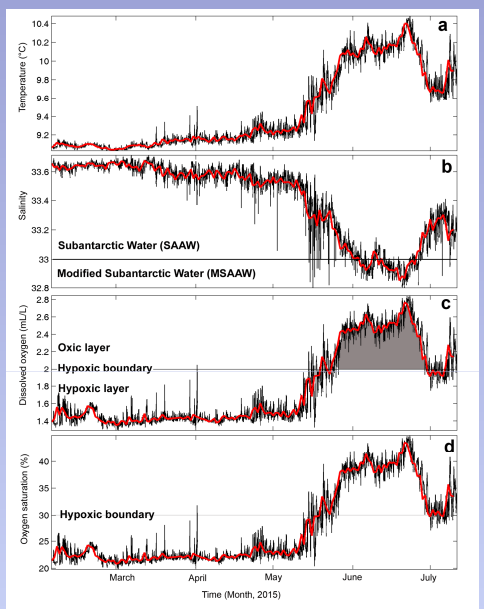

Figure 3. Time series of a) water temperature, b) salinity, c) dissolved oxygen and d) oxygen saturation, obtained at 123 m depth at the oceanographic buoy installed in Puyuhuapi fjord. The black line represents hourly records and the red line shows the daily average.

Experiment-2

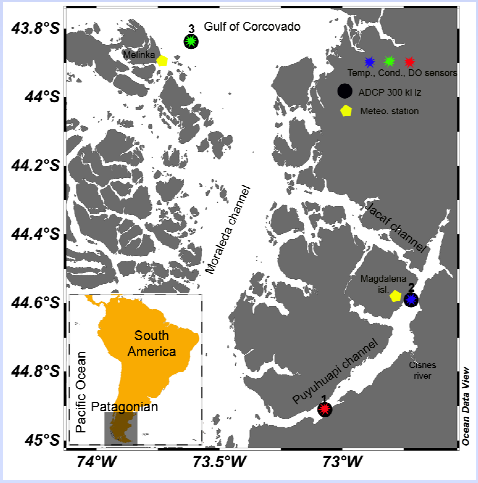

Figure 4. Study area of the experiment 2 in northern Patagonia.

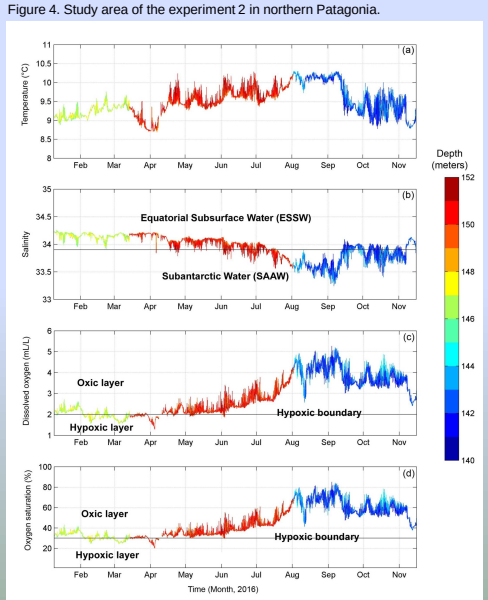

Figure 5. (a-d) Oceanographic variables registered close to bottom in Gulf of Corcovado during months of 2016.

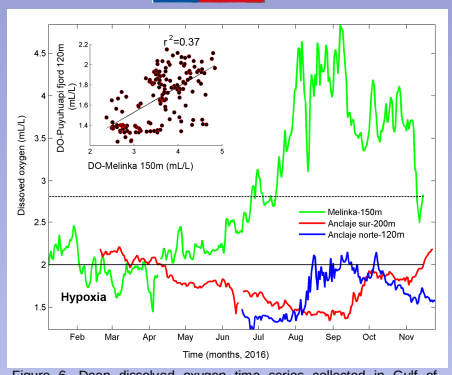

Figure 6. Deep dissolved oxygen time series collected in Gulf of Corcovado (green line) and in Puyuhuapi fjord (red and blue lines). Data was registered hourly and average daily during months of 2016.

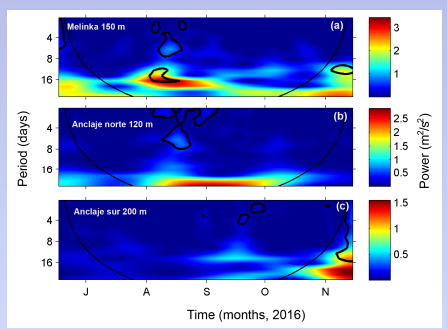

Figure 7. Morlet wavelet analysis to the deep dissolved oxygen time series presented in figure 6.

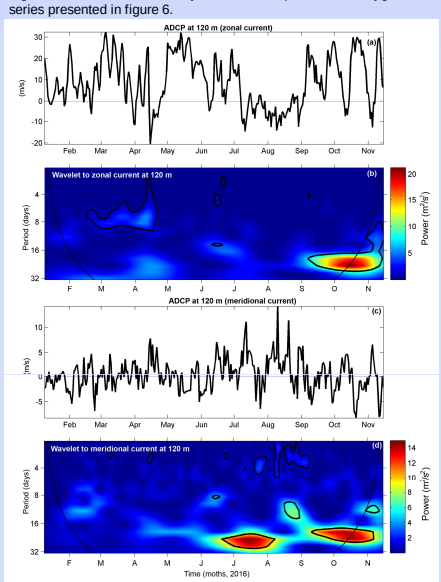

Figure 8. Morlet wavelet analysis to the ADCP data extracted from 120 meter depth in Gulf of Corcovado mooring during months of 2016.

IV-CONCLUSION

1. Hypoxia condition in study area was not permanent. Deep layer of Gulf of Corcocado ventilated from fall to spring but high dissolved oxygen (DO) was observed in winter of 2016.
2. Deep ventilation event recorded during fall-winter 2015 in Puyuhuapi Fjord was again registered in winter 2016.
3. Ventilation events coincided with the presence of Subantartic (SAAW) and Modified Sabantartic (MSAAW) water masses. In the meantime, Equatorial Subsurface water mass (ESSW) was observed mostly in hypoxic layer.
4. Deep increase of DO occurred at the same time in the adjacent ocean and interior of fjord but the physical mechanisms (local-remote) that forced this event remain unknown and need to be more investigate.

ACKNOWLEGMENT

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