EXPANSION OF THE EASTERN TROPICAL NORTH PACIFIC OMZ AND IT'S ASSOCIATED DENITRIFICATION REGIME

Introduction

The eastern tropical North Pacific (ETNP) is one of the three, large water-column oxygen deficient zones (ODZs) where oxygen concentrations are reduced to undetectable levels and water-column denitrification takes place. These ODZs are responsible for about 50% of the marine fixed nitrogen loss annually. It is currently though that Marine oxygen concentrations are decreasing i.e., ocean deoxygenation[1]. We seek to answer the question "Is there a concomitant increase in denitrification?". To address this question we looked at a 50 year time series along 110° W (shown in red in Figure 1).

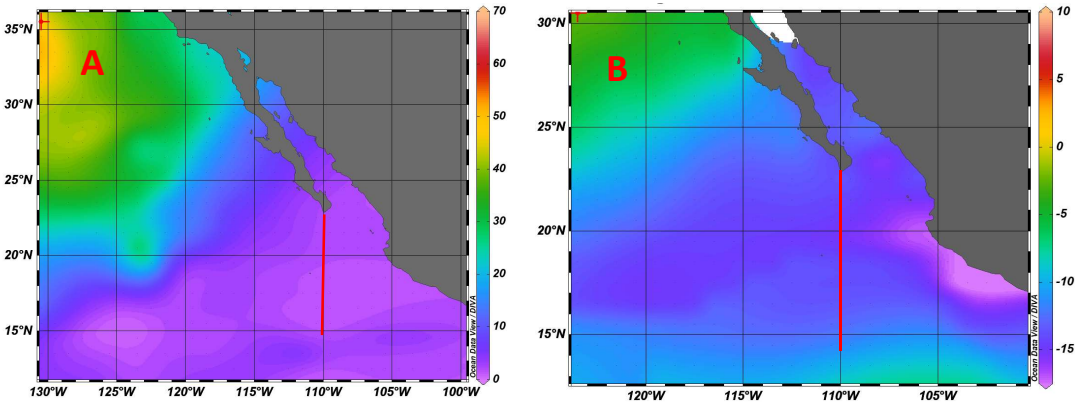

Figure 1. oxygen concentration (A, μM) and measure of denitrification, N (B, μM) on the 26.55 σ_θ surface in the ETNP. The more negative the N* the more N_2 produced by denitrification. Figures made with ODV; Schlitzer, R. (2014), Ocean Data View. http://odv.awi.de*

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Methods

Our analysis used high quality nutrient and hydrographic data from 6 cruises spanning a ~50 year period: TT 66 (1971), WOCE-P18 (1994), CLIVAR-P18 (2007), TN 278 (2012), RB 16-06 P18 (2016-17), and RR 1804/5 (2018). To ensure consistency of data we conducted a secondary QC by cross-over analysis[2,3]. This analysis assumes deep water values remain constant over the timescale of interest. The analysis produces correction factors which adjust for systematic biases in individual data sets. After adjustment we calculated N* as a measure of denitrification. N* is a measure of fixed nitrogen excess or deficit relaive to Redfield stoichiometry ($N^* = 16PO_4 - (NO_3+NO_2;)$[4]. All cruises were objectively mapped onto the section and individually integrated from the 24.75 density surface to 1000 m and along over the entire section.

Table 1. Adjustment factors from the secondary QC corss-over analysis

Cruise	O_2 (mmol kg^{-1})	NO_3^- (mmol kg^{-1})	PO_4^{-3} (mmol kg^{-1})
1971 TGT66	**1.02**	1.01	1.01
1994 WOCE	0.99	1	1
2007 CLIVAR	**1.09**	1.01	0.99
2012 TN278	**1.04**	1.01	**1.04**
2016 P-18	1.01	1.01	0.90
2018 RR 1804	**0.95**	**1.05**	1.00

Results

The sections of dissolved oxygen and N* are shown below in figure 2. The oxygen concentration appears to decrease during the time series. Even more clearly seen is an increase in the negativity of N* indicating an intensification of the denitrification regime.

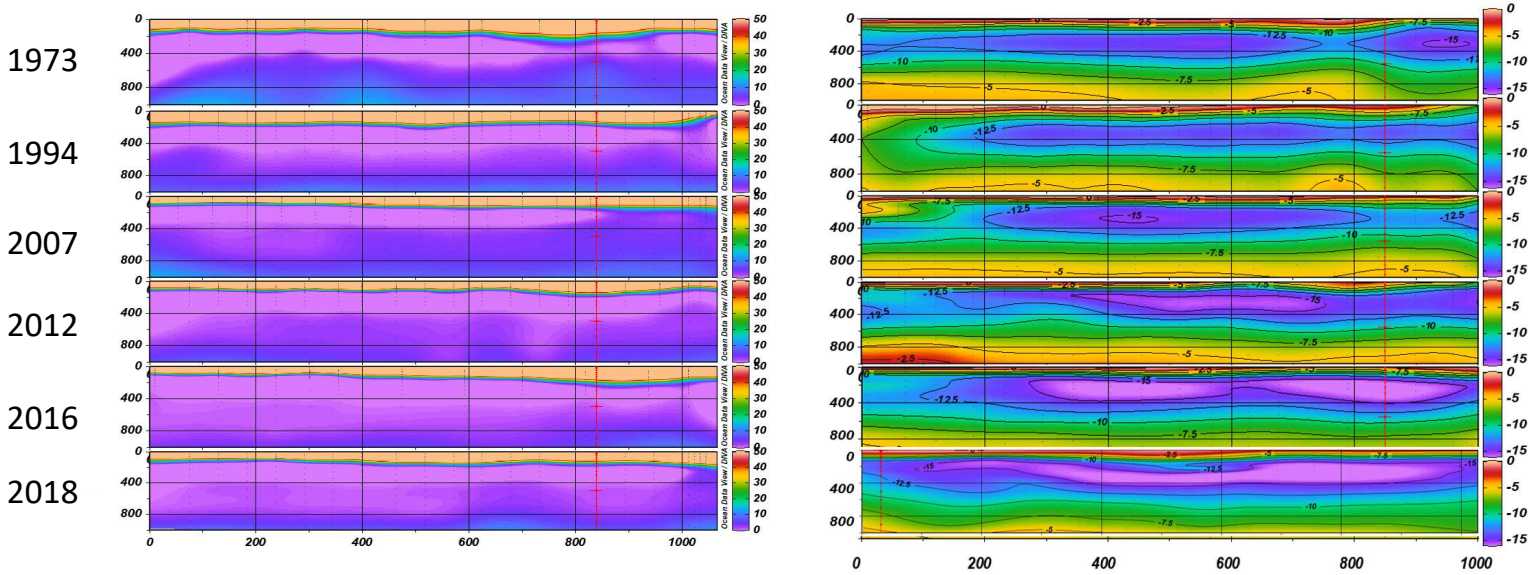

Figure 3. Sections of oxygen (left) and N (right) units = μM*

A.H. Devol, W. Ruef

Results continued

Integrations of oxygen and N* across depth and section distance show clear patterns. Dissolved oxygen decreases from about 7.8 x 10^6 to 4 x 10^6 moles while –N* increases from about 8.3 x10^6 to 9.4 x 10^6 moles.

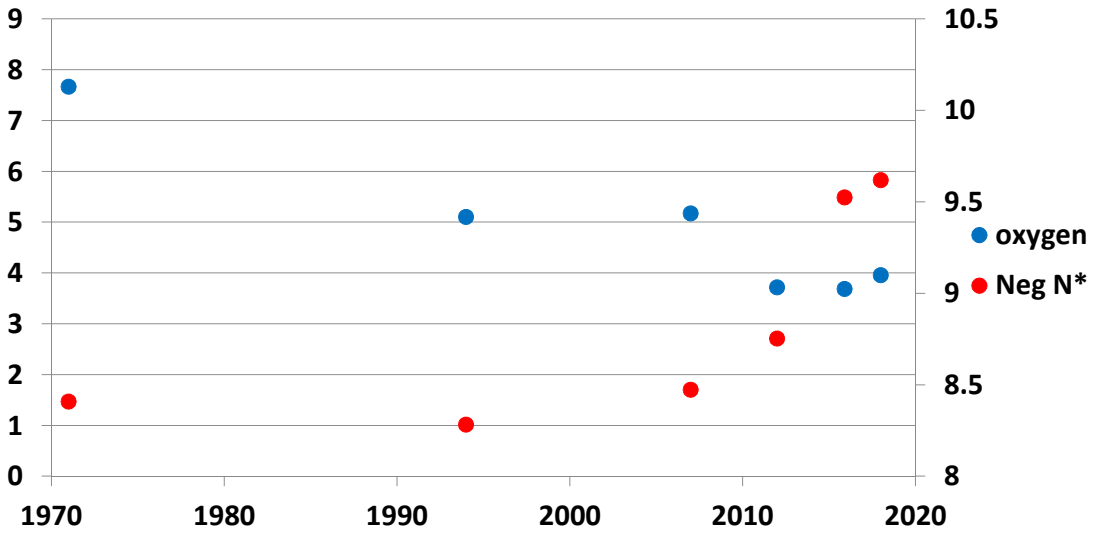

Figure 4. Integrated oxygen and negative N along 110 W°. The oxygen axis is on the left and the negative N* is on the right, both with units of 10^6 moles. Negative N* indicates the amount of nitrogen gas produced by denitrification.*

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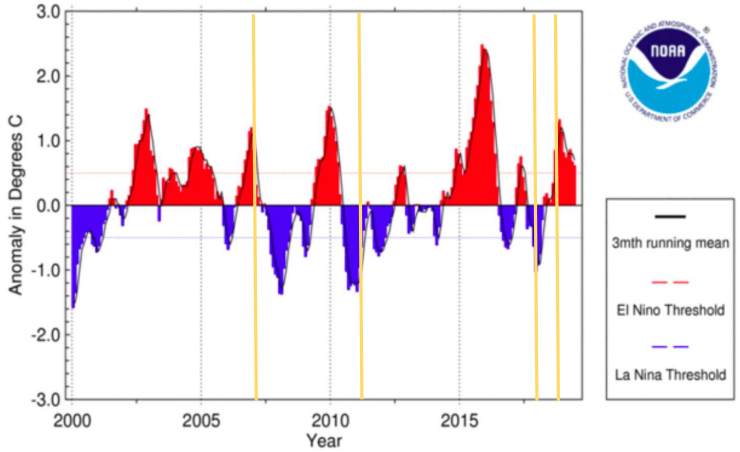
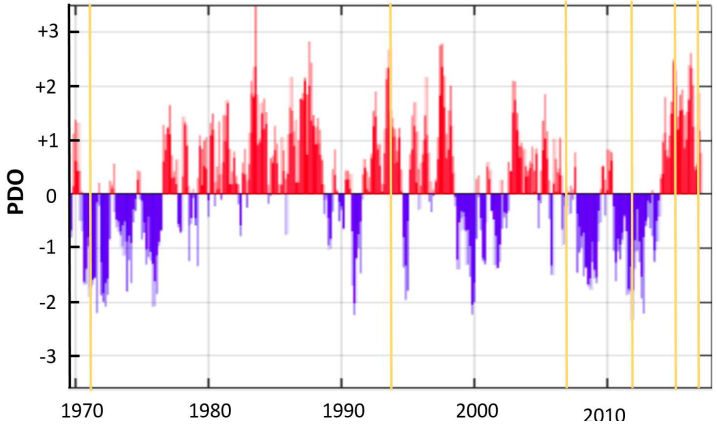
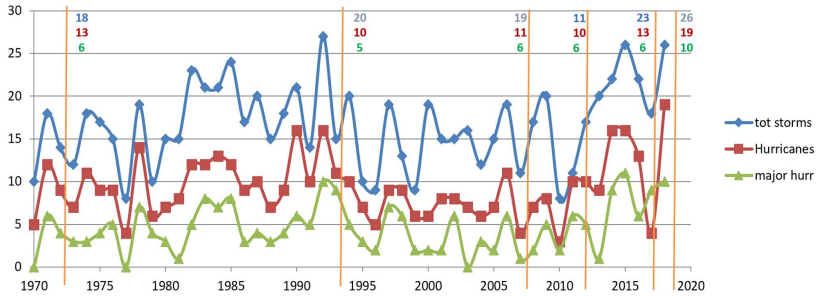
Expansion of the eastern tropical North Pacific OMZ and it's associated denitrification regime







Discussion

The results suggest a decrease in oxygen and an increasing negative value for N*. We instigated three potential mechanisms. The graphs on this slide show: **A**, SST Anomaly in Nino 3.4 region; **B**, Pacific Decadal Oscillation; and **C**, Storm frequencies in the ETNP. In all panels the vertical yellow lines show timing of the cruises. In **A** only the period of the last four cruises are shown, during which the O_2 and denitrification increased continuously but the SST anomaly oscillated. Similar lack of correlation can be seen in both other indices. Thus, these indices are not driving the observed Changes.

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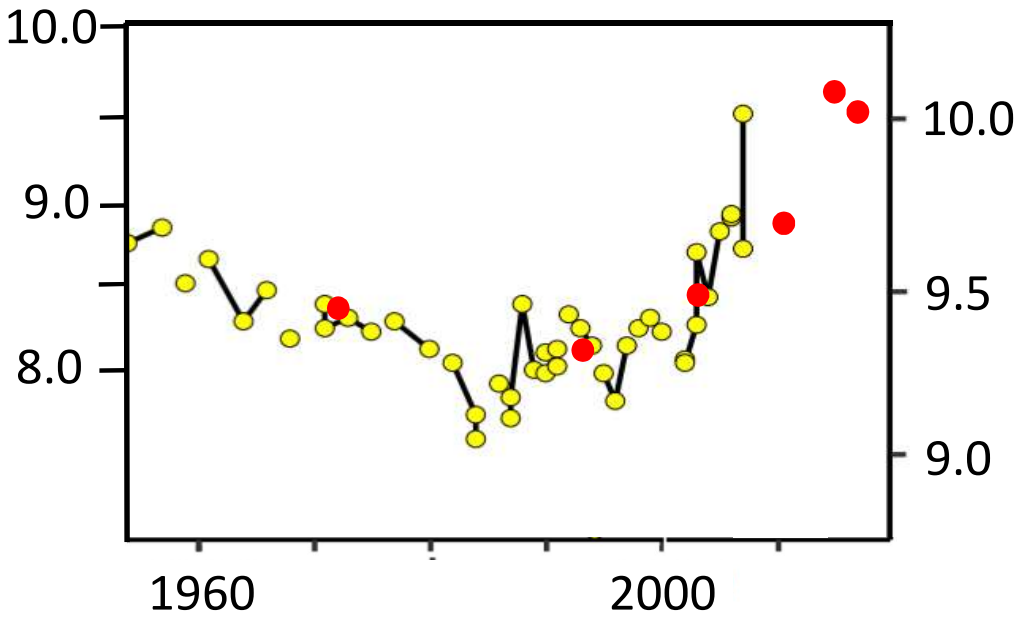

Discussion continued

Although there are no obvious relationships between the decrease in oxygen and increase in denitrification in the ETNP these is some evidence to support our observations. Davis et al. 2019[4] show that bulk surface sediment $\delta^{15}N$ values increased in continental shelf basins off Southern California and Baja California beginning 2000. Denitrification increases $\delta^{15}N$ the of the remaining nitrate. The Upwelling in the California current system source from the California Under Current, which originates in the ETNP. The figure on the left shows top $\delta^{15}N$ from the Soledad Basin(yellow symbols, right-hand axis) overlain by the integrated negative N* from this study (red symbols, left hand axis). The core top data are from the supplemental information in Davis et al. 2019.

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Conclusions

Data from 6 cruises spanning a 50 year period shows that in the ETNP ODZ oxygen concentrations have decreased and denitrification has increased.

These changes do not seem to be related to El Nino/La Nino cycles in Nino region 3.4, the Pacific Decadal Oscillation, or tropical storm/hurricane activity in the area.

They are, however, related to changes is sediment core top $\delta^{15}N$ values on continental shelf basins fed by the California Undercurrent.

Refrences

1) Breitburg, D., Levin, L. A., Oschlies, A., Grégoire, M., Chavez, F. P., Conley, D. J., et al. (2018). Declining oxygen in the global ocean and coastal waters. *Science*, 359(6383), 1475-1476

2) Key, R., et.al. (2010) The CARINA data synthesis project: Introduction and overview. *Earth Syst. Sci. Data*, 2, 105-121.

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4) Deutsch, C., et al. (2001) Denitrification and nitrogen fixation in the Pacific Ocean. *Global. Biogeochem. Cycles*, 15(2), 483-506.

5) Davis, C., et al. (2019) Ongoing increase in the eastern tropical North Pacific denitrification interpreted through the Santa Barbara sedimentary $\delta^{15}N$ record. *Paleoceanography and Paleoclimate*, 34, 1554-1567.