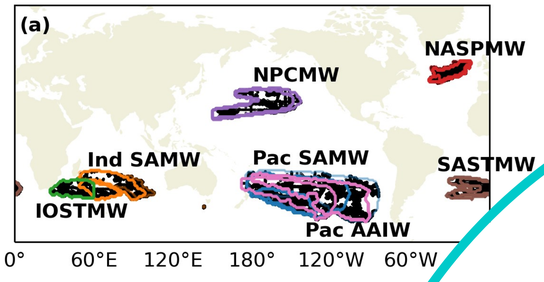
Disentangling the causes of observed changes in biogeochemical variables along ventilation pathways

Mathilde Jutras[1], Seth Bushinsky[1], Ivana Cerovečki[2]

[1] University of Hawaii at Manoa, SOEST, department of Oceanography
[2] Scripps Institution of Oceanography

Background

- Mode waters transport oxygen and carbon into the ocean's interior
- BGC variables are affected by bio activity and mixing
- Mixing is not considered in the commonly used AOU and difference to pre-formed nitrate [1,2]



Goal: Quantify the role of mixing in setting BGC properties along ventilation pathways

Method

1) Identify the ventilation pathways
   - Core Argo-derived geostrophic streamlines [3]

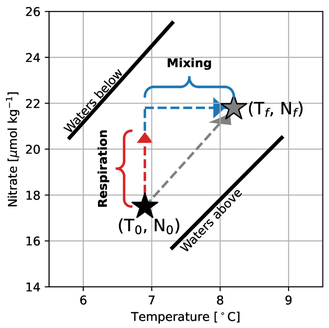
2) Evaluate the evolution of O_2 and NO_3^-
   - Average the Argo-BGC data along the pathways

3) Solve mixing equations, for distance bins along the pathways

$$\begin{aligned} f_0 C_0 &+ f_{above} C_{above} &+ f_{below} C_{below} &= C_i \\ f_0 O_{2,0} &+ f_{above} O_{2,above} &+ f_{below} O_{2,below} + R &= O_{2,i} \\ f_0 N_0 &+ f_{above} N_{above} &+ f_{below} N_{below} - r_{N:O2} R &= N_i \\ f_0 &+ f_{above} &+ f_{below} &= 1 \end{aligned}$$

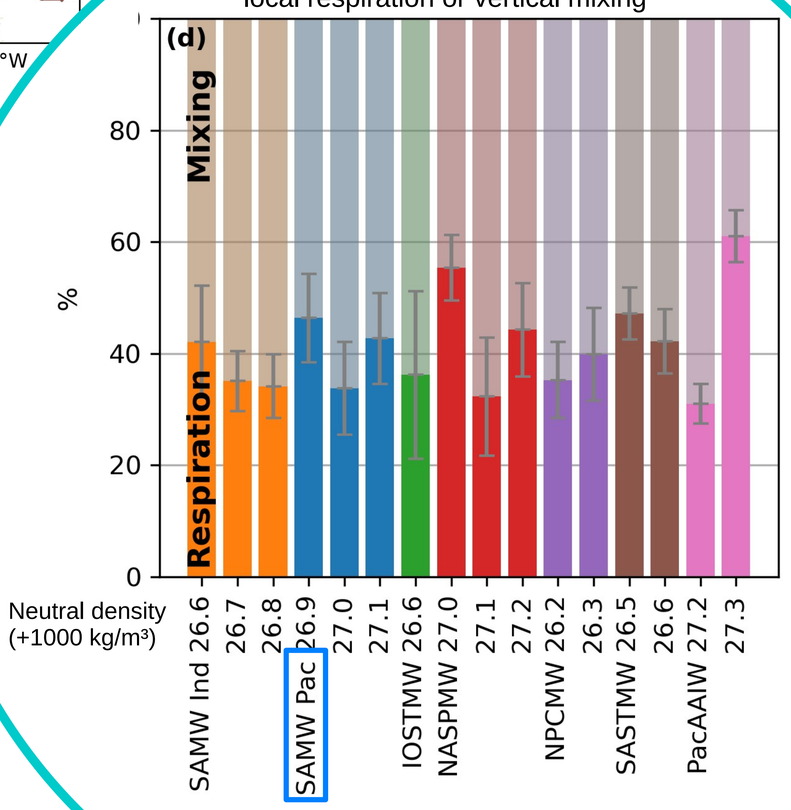
- Monte Carlo approach
- Outputs: fractions (*f*) and respiration (*R*)

4) Reconstruct the role of respiration and mixing



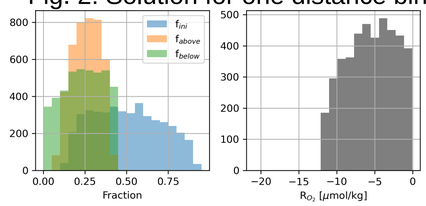
$$\begin{aligned} \Delta O_2^{respiration} &= R \\ \Delta O_2^{mixing} &= f_{above} O_{2,above} + f_{below} O_{2,below} \\ &\quad - (f_{above} + f_{below}) O_{2,i} \end{aligned}$$

Fig. 1: % of ΔO_2 and ΔNO_3 due to either local respiration or vertical mixing



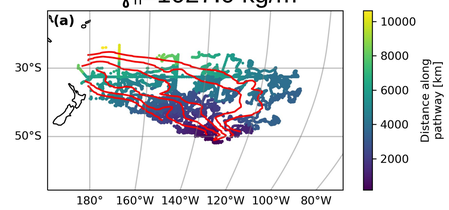
Mixing contributes to more than half of the changes in BGC variables

Fig. 2: Solution for one distance bin



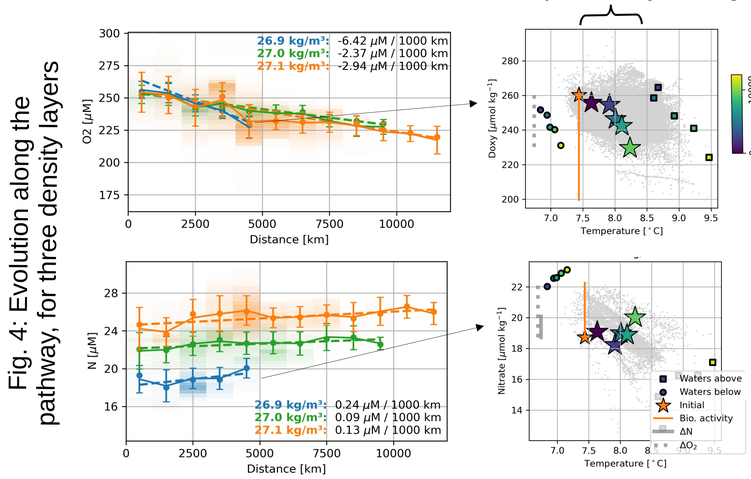
Results: Pacific SAMW

Fig. 3: Pathway for $SAMW_{Pac}$ γ^n=1027.0 kg/m³



Notice the change in temperature, which can only be explained by mixing

Fig. 4: Evolution along the pathway, for three density layers



Conclusions

- Along ventilation pathways, mode waters [O_2] decrease at a rate between 2 and 20 µmol/kg / 1000 km, and [NO_3^-] at a rate between 0.2 and 2.6 µmol/kg / 1000km (Fig. 4).
- In mode waters, mixing contributes to more than half of the changes in BGC variables (Fig. 1)
- This proportion is relatively uniform across mode waters (Fig. 1)

Future work

- How does the local respiration compare to the total respiration (including that in the waters that mix in)
- What are the implications for AOU and difference to pre-formed nitrate, and hence for calculations of respiration and remineralization rates, carbon export, and C_{ant}.

Contact: mjutras@hawaii.edu

References

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[2] Ono, T., Midorikawa, T., Watanabe, Y. W., Tadokoro, K., and Saino, T. (2001). Temporal increases of phosphate and apparent oxygen utilization in the subsurface waters of western subarctic Pacific from 1968 to 1998. Geophysical Research Letters, 28(17):3285–3288.

[3] McDougall, T. J.,and A. Klocker. (2010): An approximate geostrophic streamfunction for use in density surfaces. Ocean Modelling., 32, 105– 117.