Evaluating variability of interior ocean regenerated carbon using observationally constrained data products

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Introduction

- The biological carbon pump (BCP) plays a key role in transporting carbon from the surface to deep ocean, sequestering a fraction of the organic carbon produced by photosynthesis in the mesopelagic.
- Many studies assess changes in the BCP in terms of export flux, however investigating regenerated carbon (C_{reg}) – inorganic carbon of biological origin – in the ocean interior has fewer uncertainties and integrates other forms of carbon export in addition to sinking particle flux.[1]
- Here, we show preliminary results of observationally derived changes in the mesopelagic (200 m – 1000 m) pool of C_{reg}, including seasonal variability.
- The expanding global array of biogeochemical Argo floats has made this work possible, along with the creation of the GOBAI-O_2 data product.

Gridded Ocean Biogeochemistry from Artificial Intelligence – Oxygen (GOBAI-O_2)

- GOBAI-O_2 is an algorithm-driven 4D gridded oxygen data product trained with BGC-Argo float data and discrete ship-based measurements.[2]
- It has a 1° x 1° horizontal resolution, 58 depth levels from 0 dbar – 2000 dbar, and a monthly temporal resolution (2004 – 2022).[2]
- Temperature and salinity fields for GOBAI-O_2 come from the Roemmich-Gilson Argo Climatology.[3]

AOU as a metric of the biological pump

GOBAI-O_2

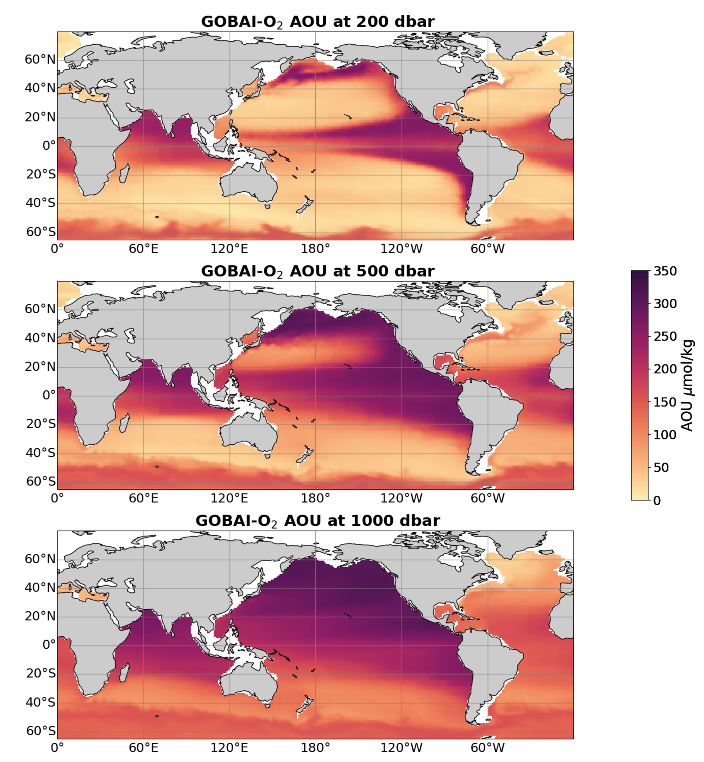

Figure 1. GOBAI-O_2 climatological average (2004-2022) apparent oxygen utilization at 200 m, 500 m, and 1000 m. Apparent oxygen utilization: AOU = $[O_2]_{saturated} - [O_2]_{observed}$

GLODAPv2

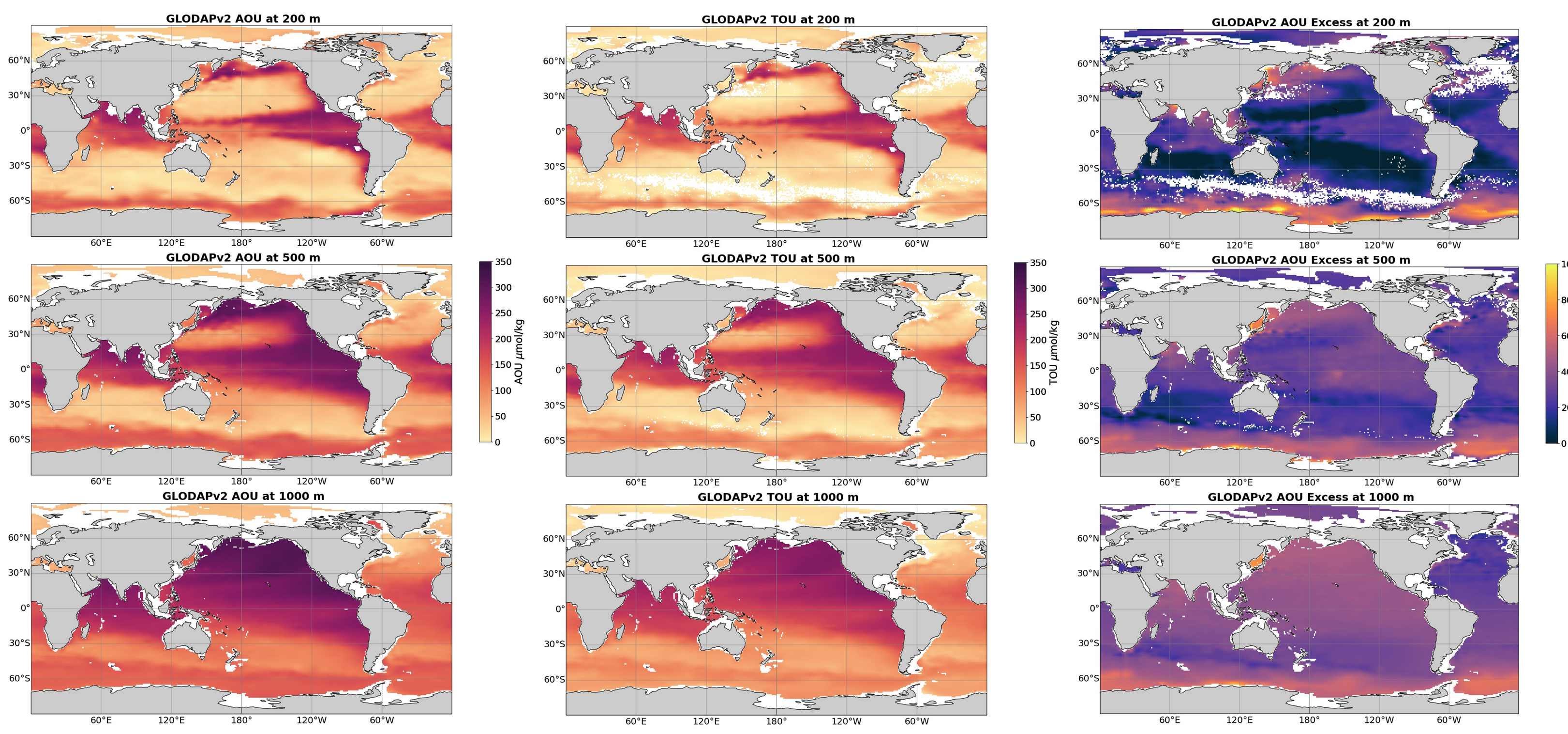

Figure 2. GLODAPv2.2 Mapped Product apparent oxygen utilization (AOU), true oxygen utilization (TOU), and the AOU excess relative to TOU at 200 m, 500 m, and 1000 m. AOU assumes that seawater O_2 is in equilibrium with the atmosphere before it is transported to depth, however this is not always the case. True oxygen utilization (TOU) uses estimates of preformed oxygen to account for this disequilibrium.[4]

- Spatial patterns of AOU agree well between GOBAI-O_2 and GLODAPv2 Mapped Product[5].
- For the purposes of quantifying changes in the total pool of regenerated carbon, AOU is a better metric than TOU because it integrates remineralization that has occurred over the lifetime of a water parcel, not just since it was last at the surface.

Regional patterns and global change in mesopelagic regenerated carbon

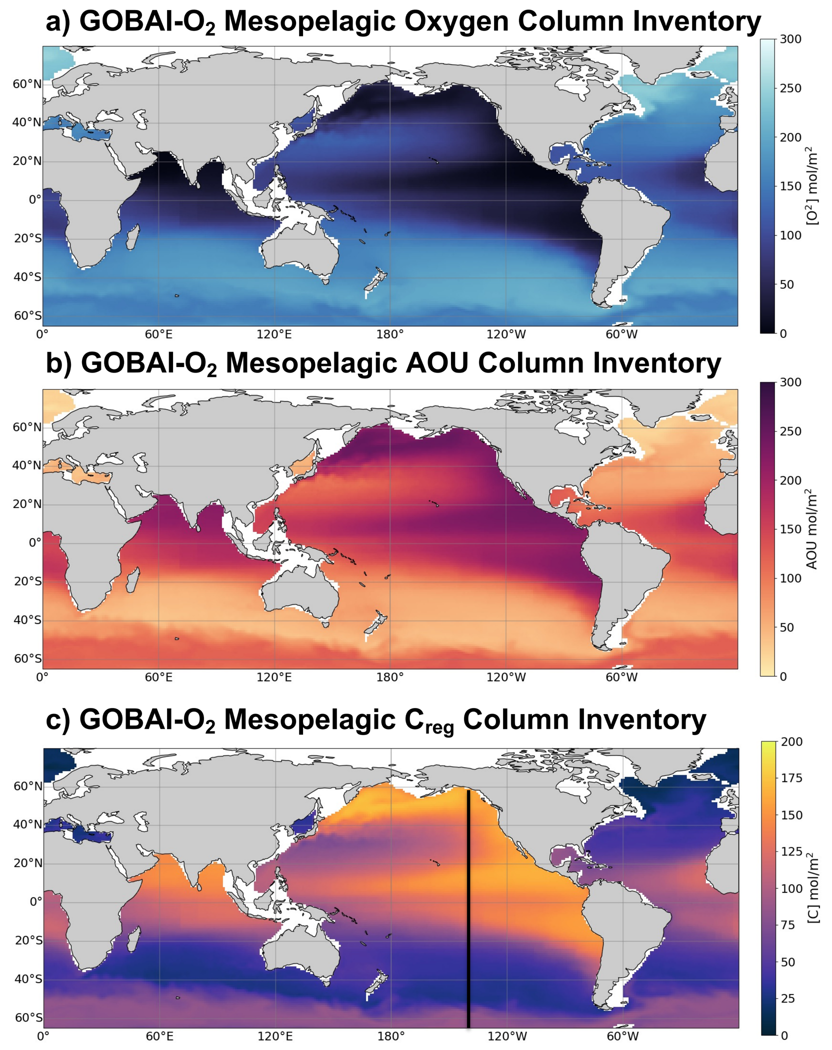

Figure 3. GOBAI-O_2 climatological average (2004-2022) mesopelagic column inventories of a) oxygen, b) apparent oxygen utilization (AOU), and c) regenerated carbon (C_{reg}), integrated from 200 m to 1000 m. Panel c shows the location of the transect in Figure 5. Oxygen and carbon are stoichiometrically related through the respiratory quotient (O_2:C, 170/117).[6]

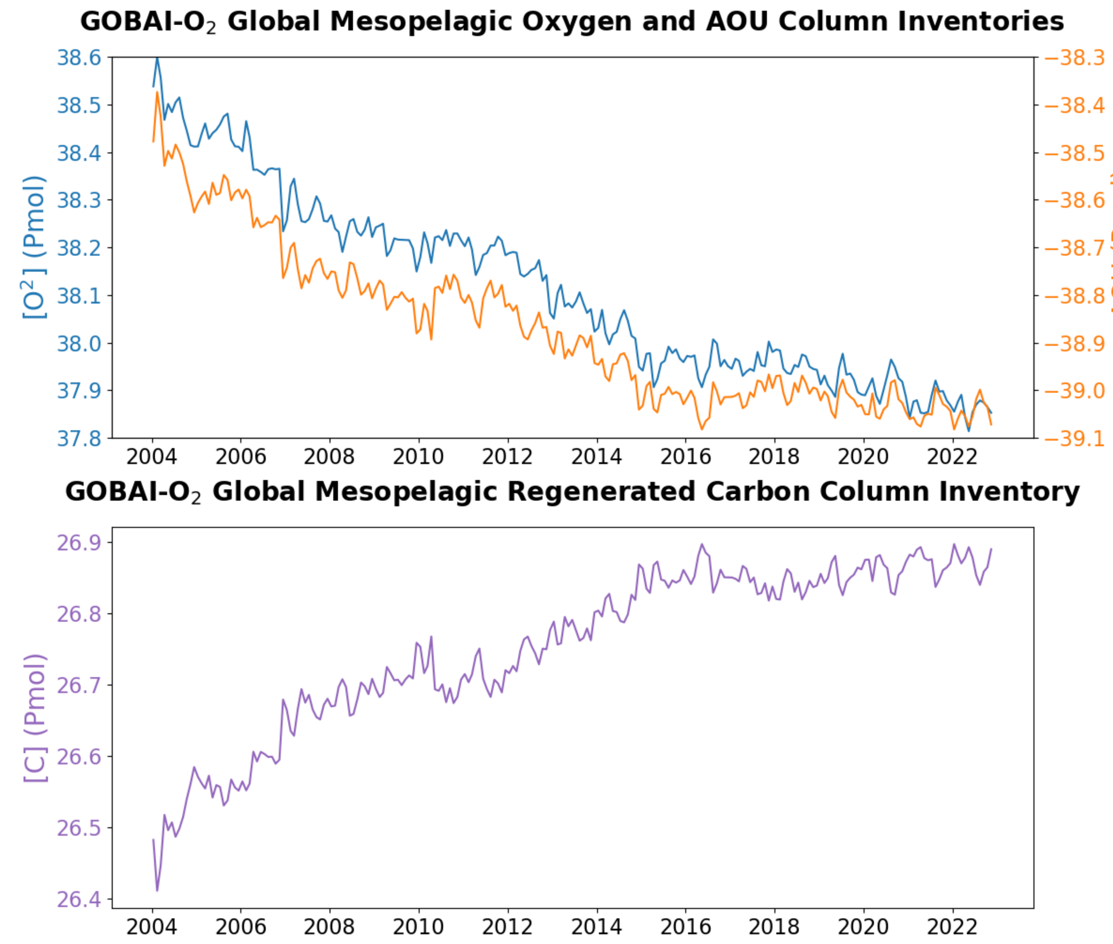

Figure 4. GOBAI-O_2 globally integrated change in oxygen, AOU, and C_{reg} mesopelagic column inventories (200m – 1000 m). Mesopelagic oxygen inventory is decreasing by 340 Tmol/decade. AOU inventory is increasing by 282 Tmol/decade (note that AOU is represented as -AOU). C_{reg} inventory is increasing by 193 Tmol/decade.

- The amount of oxygen used (AOU) is proportional to the amount of carbon generated by biological respiration in the ocean interior.
- Low oxygen areas, such as the Equatorial Pacific, correspond with high AOU and high C_{reg}, since these water masses are older and respiration has had more time to occur.
- These water masses are characterized by some combination of old age, allowing more time for respiration to occur, and high overlying production, providing more organic material to be respired.
- The increase in AOU accounts for the majority (~83%) of the oxygen decrease in the mesopelagic, with solubility changes accounting for the remaining 17%.
- A circulation slow down combined with increasing stratification would mean less oxygen is being exchanged with the atmosphere, and more oxygen being utilized.[7]
- AOU changes might also reflect isopycnal movement, with different water masses shifting into and out of the 200 – 1000 dbar depth interval.

Case study: Regenerated carbon during "The Blob"

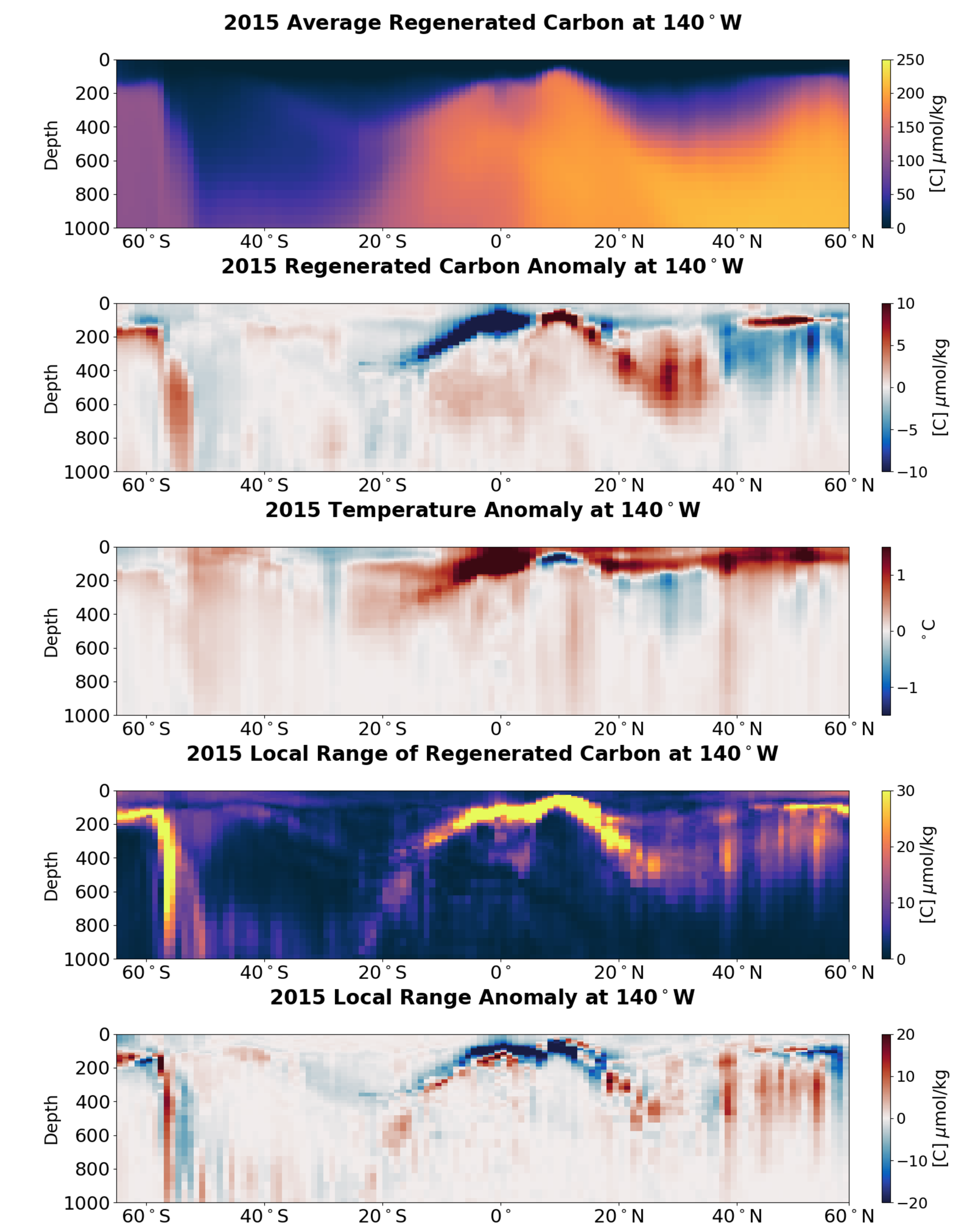

Figure 5. GOBAI-O_2 transects at 140 °W (see location on Figure 3) of a) 2015 average C_{reg}. b) 2015 C_{reg} anomaly relative to the climatological (2004-2022) average. c) 2015 temperature anomaly relative to 2004- 2022 climatological average from the Roemmich and Gilson Argo Climatology. d) 2015 local range of C_{reg}. Local range is defined as the maximum annual range of C_{reg} in every grid cell. e) 2015 local range anomaly of C_{reg} relative to the climatological average of the annual ranges.

- The 2013 – 2016 marine heat wave in the NE Pacific, "The Blob", increased water column stratification, inhibited mixing, and led to persistent subsurface temperature anomalies.[8]
- Variability of C_{reg} is anomalously high in the mesopelagic N Pacific during 2015. Perhaps this is connected to a temperature dependent increase in respiration rates in warmer waters.[7]

References

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Conclusions and next steps

- Global observational data products are enabling new methodologies of quantifying regenerated carbon inventories and exploring seasonal and interannual variability with a high spatial and temporal resolution.
- We will investigate changes within isopycnal ranges for comparison with the analysis in a depth framework.
- We will evaluate global regenerated carbon increases in different ocean basins and assess patterns of seasonal and interannual variability in AOU and regenerated carbon derived from GOBAI-O2.