Biogeochemical Applications for Intense Oceanic $O_2$ Minimum Zones

- Small portion of oceanic volume, but have a central role for key biogeochemical cycles; e.g. N cycles
- Important influence on ocean release of trace gases; e.g. $N_2O$, $CH_4$
- Overlay high accumulation rate, organic C-rich sediments which hold important paleo-climate archives
- Impact the population and ecology of regionally important living marine resource species
- Concern over future expansion of both natural and anthropogenic low $O_2$ zones. Occur in climate sensitive regions; e.g. ETP (ENSO), Arabian Sea (Monsoon)
Global distribution of low O$_2$ zones

- High surface productivity and downward OM flux
- Poor subsurface water mass ventilation
- Closed regional circulation (shadow zone)
- Remote surface (outcrop) ventilation zone
A1: Monitoring future changes in extent and intensity.

Distinguish natural vs. anthropogenic climate forcing.
Temporal Variability: 1996-2004

Oxygen (mL/L)

Callao (12°04' S - 77°35' W)

Temperature (°C)

IMARPE - JESUS LEDESMA

El Nino

Oxygen (mL/L)
Past large changes in suboxic zone intensity off Peru. Centennial version of ENSO?

![Graph showing changes over time in suboxic zone intensity off Peru.](image)

**Diagram Description:**

- **δ¹⁵N** vs. Time (Cal yr BP)
- **Grayscale** vs. Time (Cal yr BP)
- **Ti (%)** vs. Time (Cal yr BP)
- **Si/Ti** vs. Time (Cal yr BP)
- **N(%)** vs. Time (Cal yr BP)

**Axes:**

- **Y-axis:** Depth (cm)
- **X-axis:** Time (Cal yr BP)

**Legend:**

- **Sub-surface denitrification**
- **Surface productivity**

**Data Points:**

- Various data points are plotted across different axes, indicating changes over time.

**Graph Annotation:**

- **Time (Cal yr BP):** 0, 1000, 2000, 3000, 4000, 5000
- **Depth (cm):** 0, 20, 40, 60, 80, 100, 120, 140, 160, 180
- **δ¹⁵N:** 4.5, 6.0, 7.5
- **Grayscale:** 80, 160, 240
- **Ti (%):** 0.6, 0.4, 0.2
- **Si/Ti:** 100, 200, 3000.4
- **N(%):** 0.8, 1.2

**Key Observations:**

- Significant changes in suboxic zone intensity are observed over time.
- Centennial version of ENSO is indicated through the data patterns.

**Conclusion:**

- The study highlights past large changes in suboxic zone intensity off Peru, suggesting a possible centennial version of ENSO.
A2: Resolve current questions regarding N cycling microbial pathways and stoichiometry


Fig. 3: Schematic of major and possible suboxic zone N cycle pathways and associated $^{15}$N fractionation factors (see text). NO and N$_2$O intermediates are not shown. POM originates from surface productivity and produces NH$_4^+$ with little isotopic fractionation. Ultimate sources for excess biogenic N$_2$ must be from either sediment fluxes or POM remineralization in the water column.

Canonical Denitrification

$$(\text{CH}_2\text{O})_{106}(\text{NH}_3)_{16}\text{H}_3\text{PO}_4 + 94.4\text{HNO}_3$$

$$= 106\text{CO}_2 + 55.2\text{N}_2 + 177.2\text{H}_2\text{O} + \text{H}_3\text{PO}_4$$

Anammox

$$\text{NH}_4^+ + \text{NO}_2^- \rightarrow \text{N}_2 + 2\text{H}_2\text{O}$$
Property Relationships along $\sigma_\theta$ 26.3 to 26.5 in S. Pacific

- Slope ~ 8
- Slope ~ 1.3
Restrict to Peru suboxic zone; no increase in DIC with NO removal!
Needs and Feasibility

1. A1; stable, accurate O₂, ready now, existing deployments (examples at end)

2. A2; novel combination of measurements using existing sensors
   a. [NO₃⁻] ± 1 µmol/kg (ISUS)
   b. [NO₂⁻] ± 1 µmol/kg
   c. [N₂] ± 1 µmol/kg (~ GTD Pₜ - P₀₂)
   d. [DIC]org ± 2 µmol/kg (pH & pCO₂)
O₂ on Argo floats
data available on-line

The Eastern South Pacific
Oxygen Minimum Zone

Profiler Trajectories
20 day glider deployment during Meteor 77 leg 4 in Jan. 2009
20 day glider deployment during Meteor 77 leg 4 in Jan. 2009