Tropical Pacific OMZ during late 20th century

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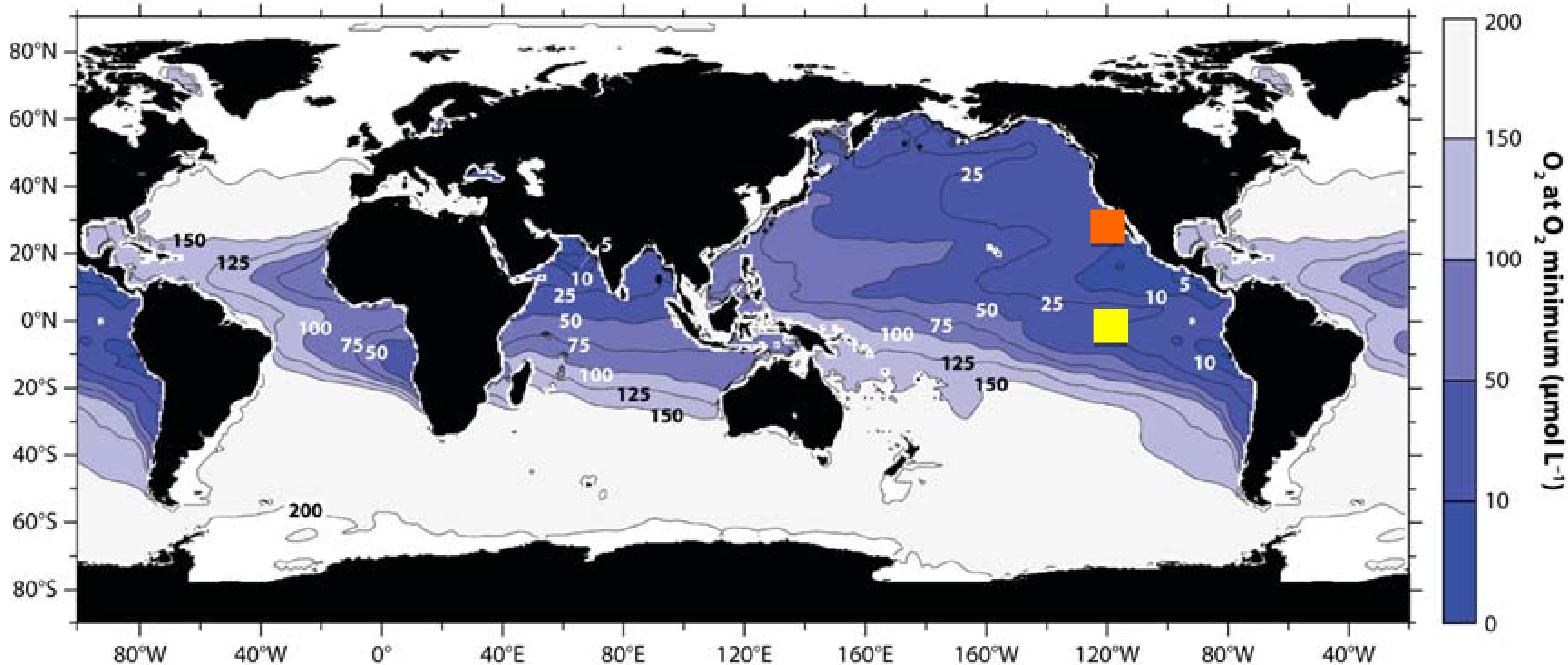
Motivation

Keeling et al. (2010)



Motivation

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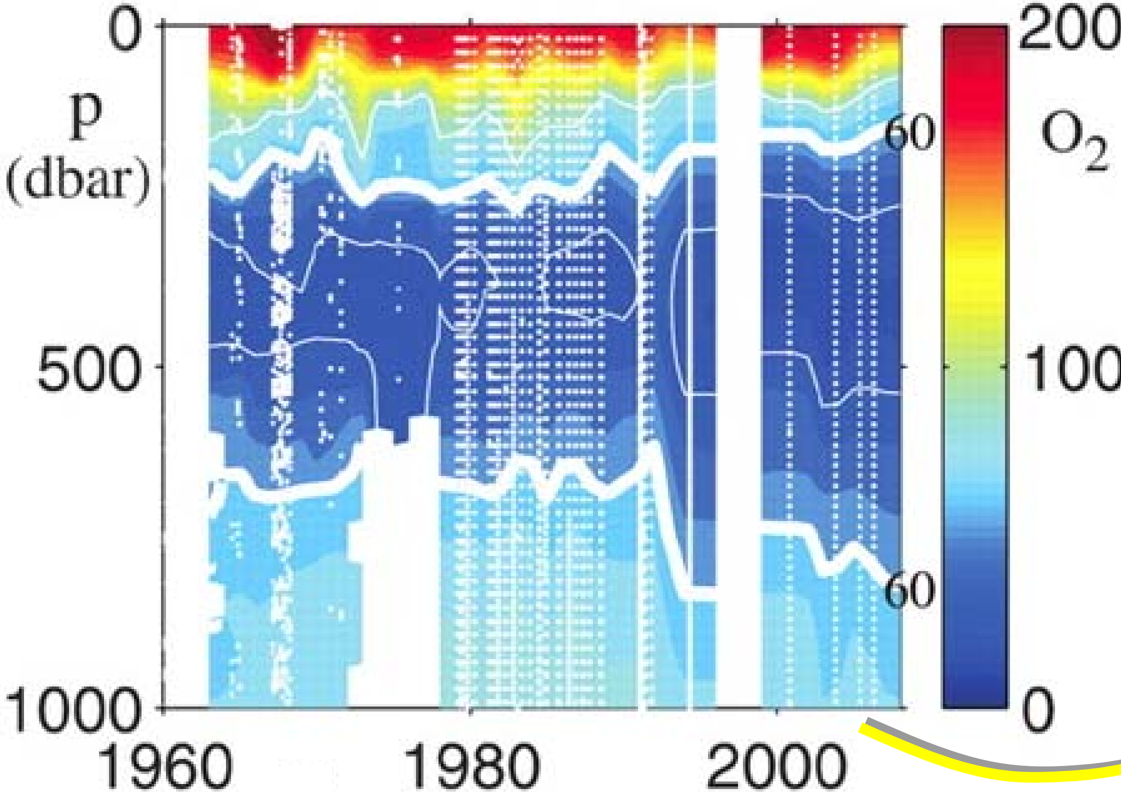
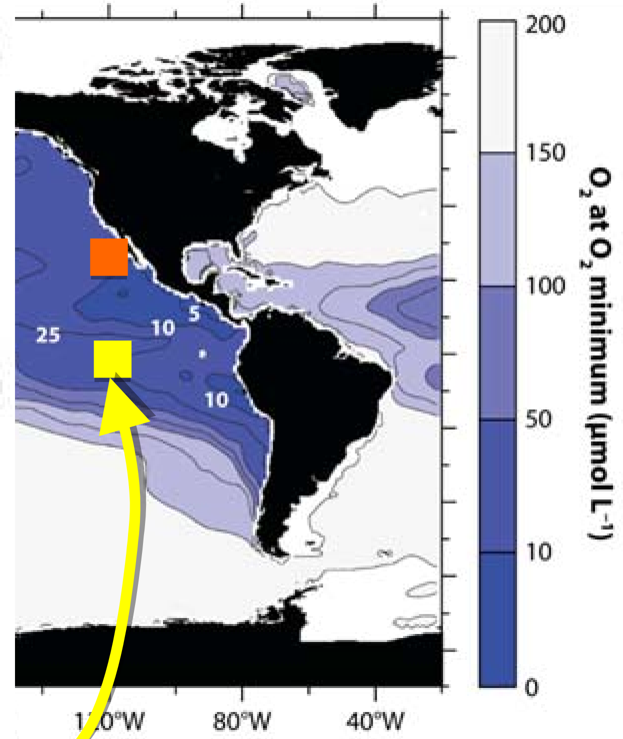


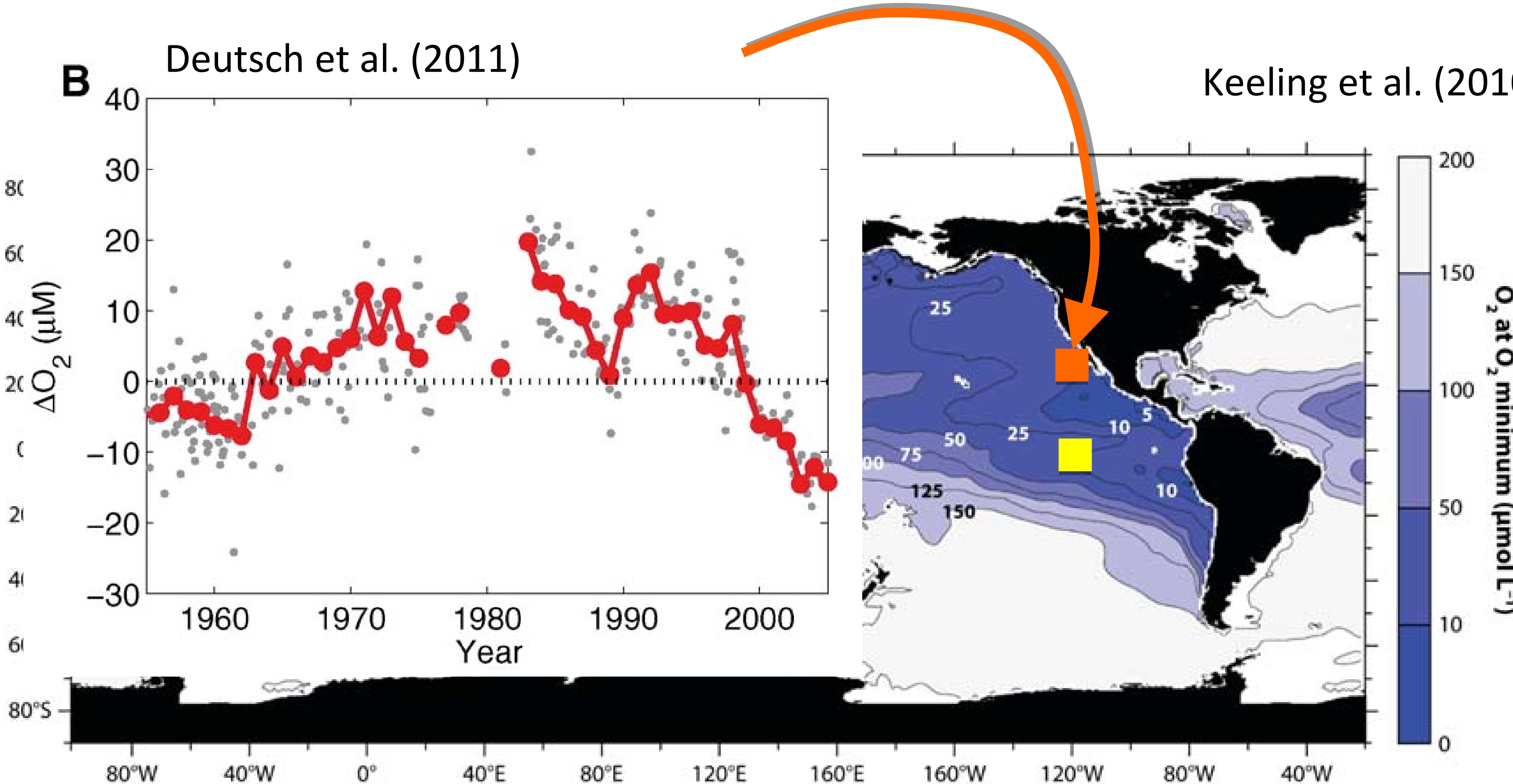


Stramma et al. (2008)

Motivation

Deutsch et al. (2011)

Keeling et al. (2010)

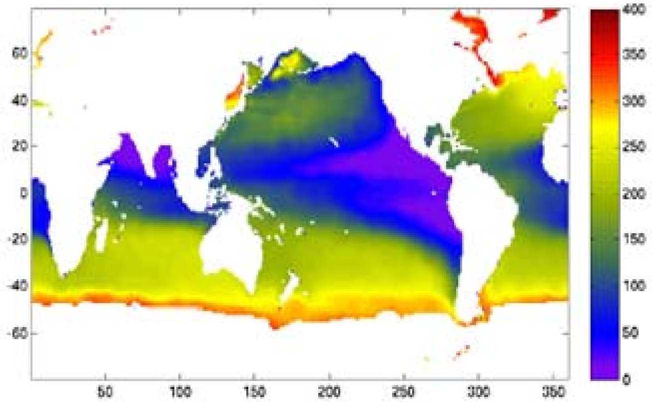


What are the underlying mechanism for the multi-decadal variability?

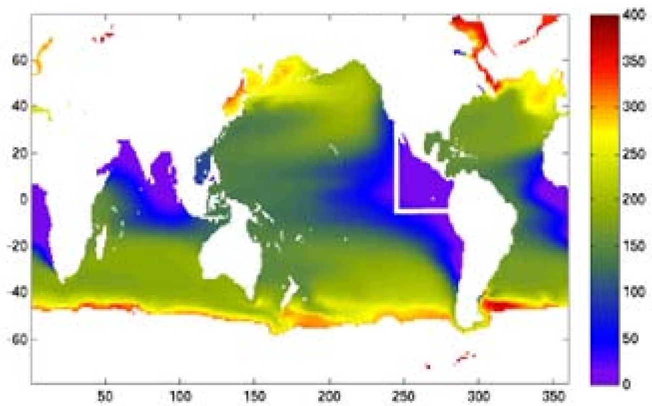
Global ocean biogeochemistry model

O_2 on $\sigma\theta$ = 26.8

Climatology



Model climatology

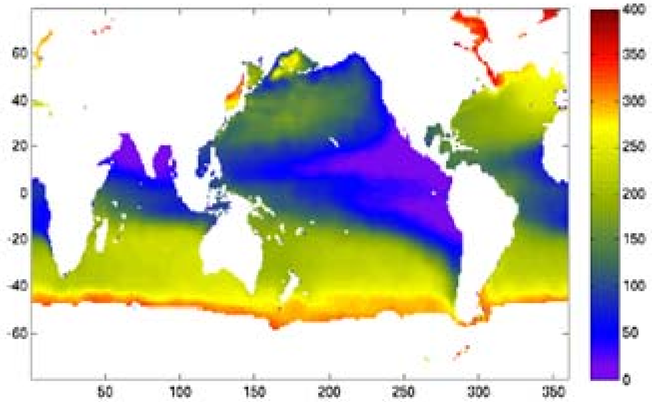


- MITgcm: global 1° x 1° resolution
  - KPP mixed layer
  - Gent-McWilliams (1990) scheme
- Simple biogeochemistry
  - Modified OCMIP-2 scheme
- Climatological spin-up for 2,000 years
- 40-year hindcast simulation using German ECCO circulation (1962-2002)

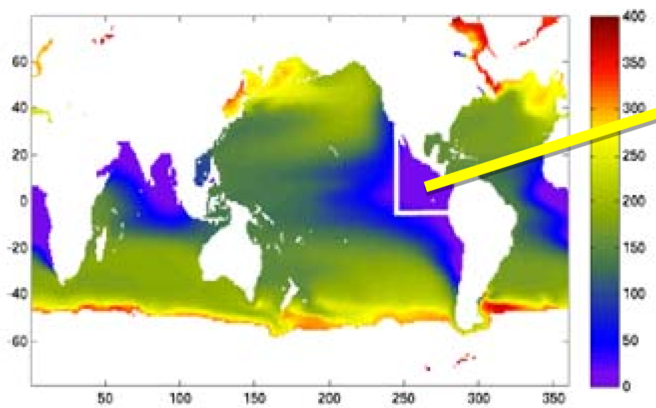
Global ocean biogeochemistry model

O_2 on $\sigma\theta = 26.8$

Climatology

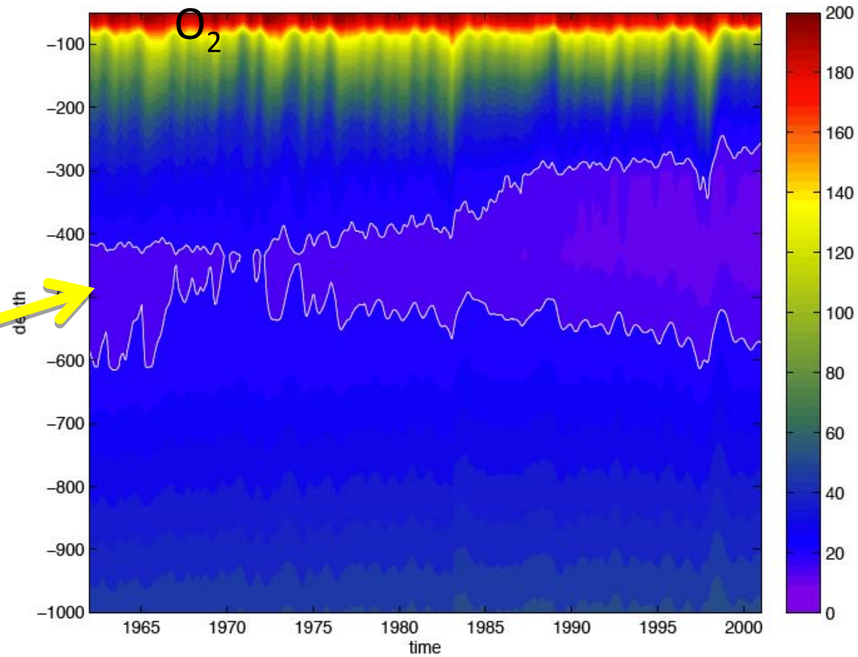


Model climatology



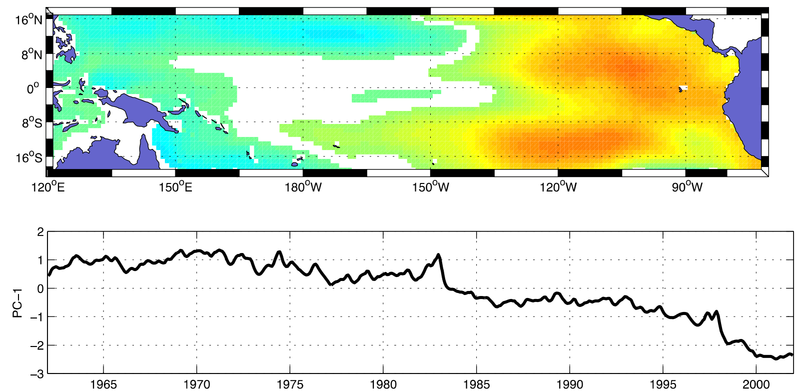
- Expansion of OMZ during late 20th century
- Minimum extent of OMZ around mid 1970s

Eastern tropical Pacific O_2

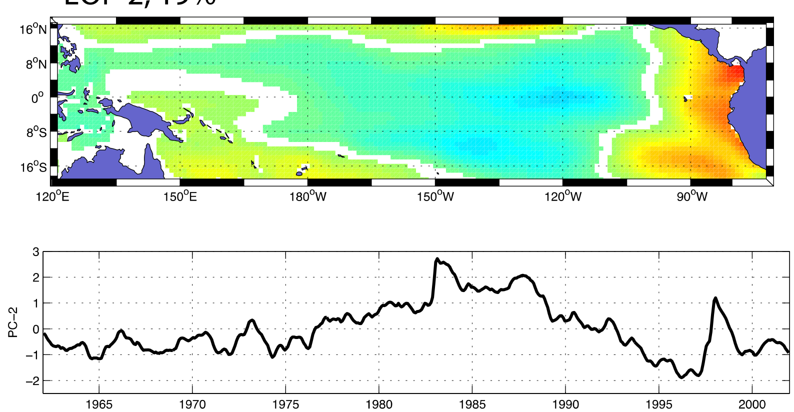


Expansion of OMZ and decadal variability

EOF-1, 31%

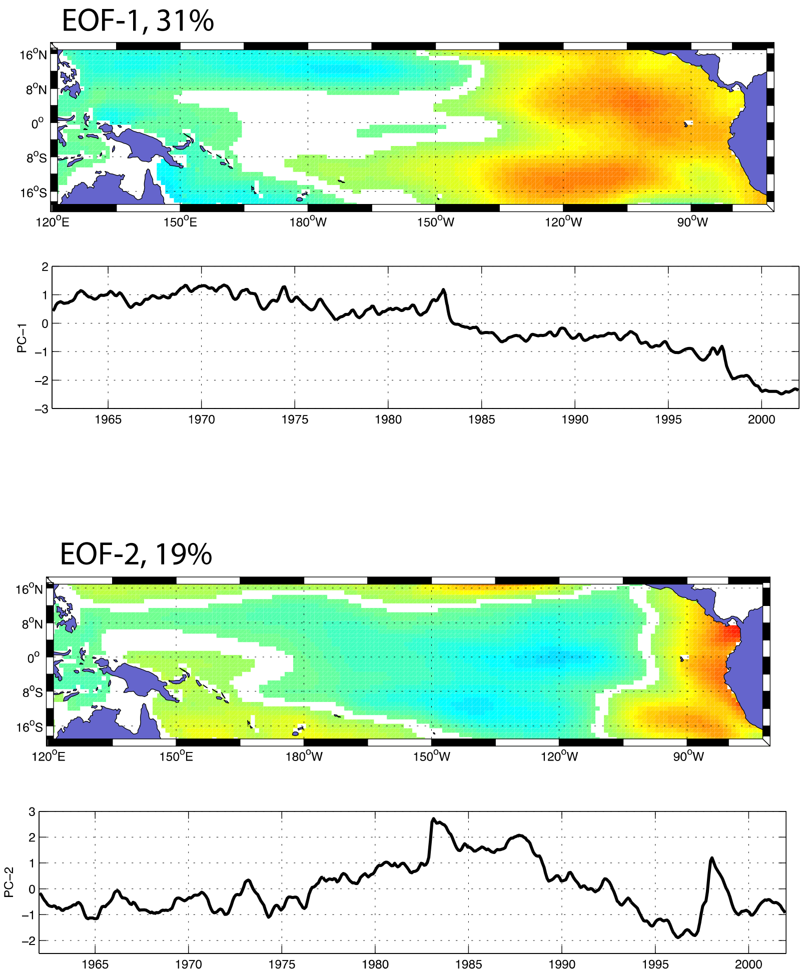


EOF-2, 19%



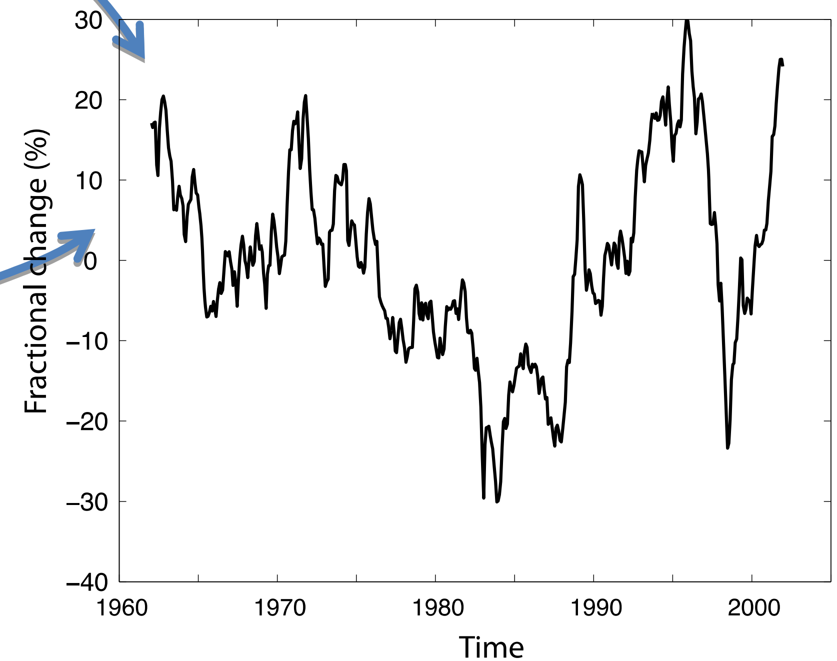
- Tropical Pacific O_2 inventory (20°S-20°N, 185m-510m, 1962-2002)
- First EOF
  - Basin-scale dipole pattern
  - Multi-decadal timescale
- Second EOF
  - Focused on eastern tropical Pacific
  - Decadal timescale
- Leading two EOFs > 50% variance

Expansion of OMZ and decadal variability



- Late 20th century expansion of OMZ is a part of multi-decadal variability

Suboxic volume ($O_2 < 5\mu M$)

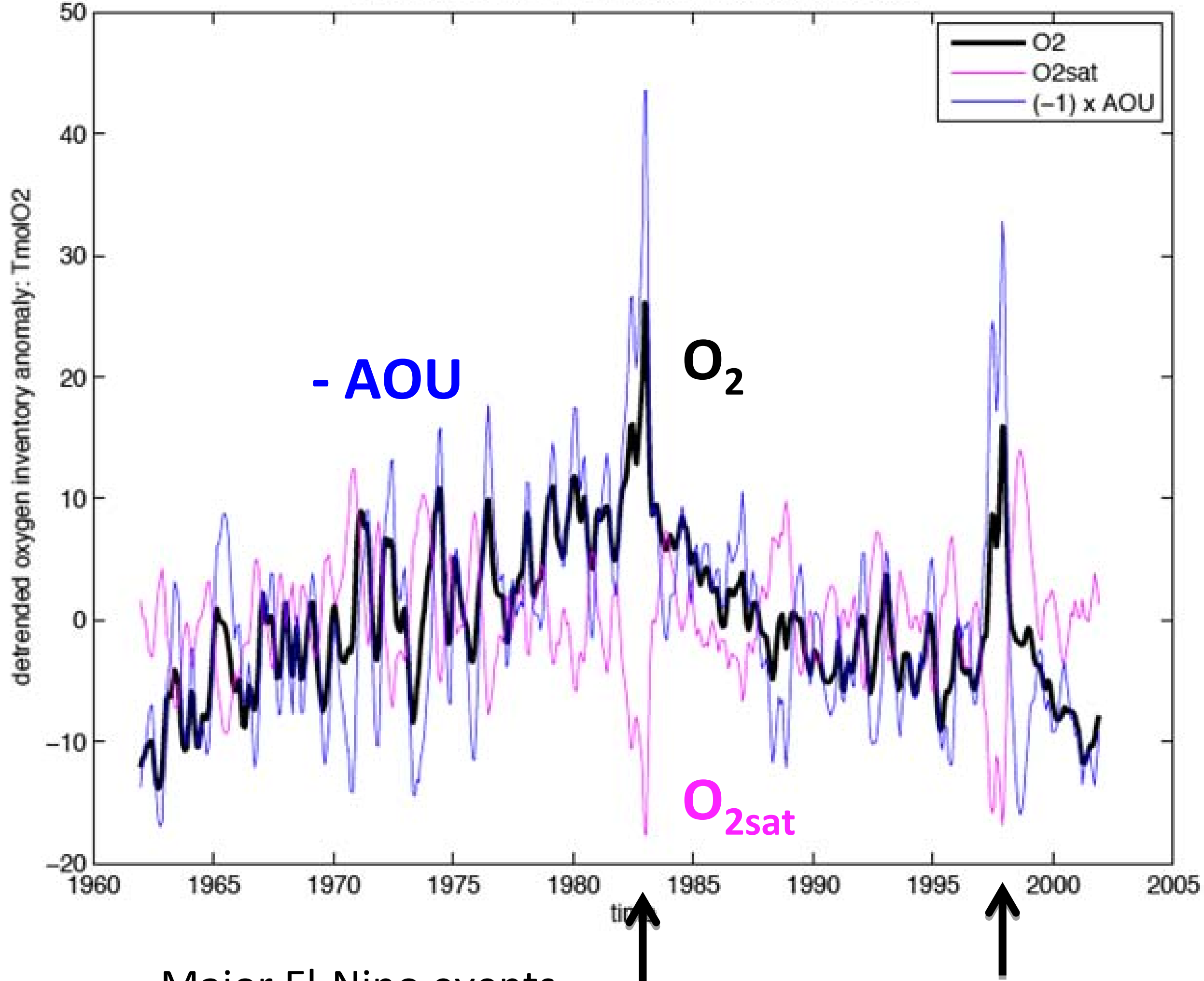


Major El-Nino events

ENSO cycle and O_2 Compensations

Regional oxygen inventory

+O_2 inventory
OMZ
contraction



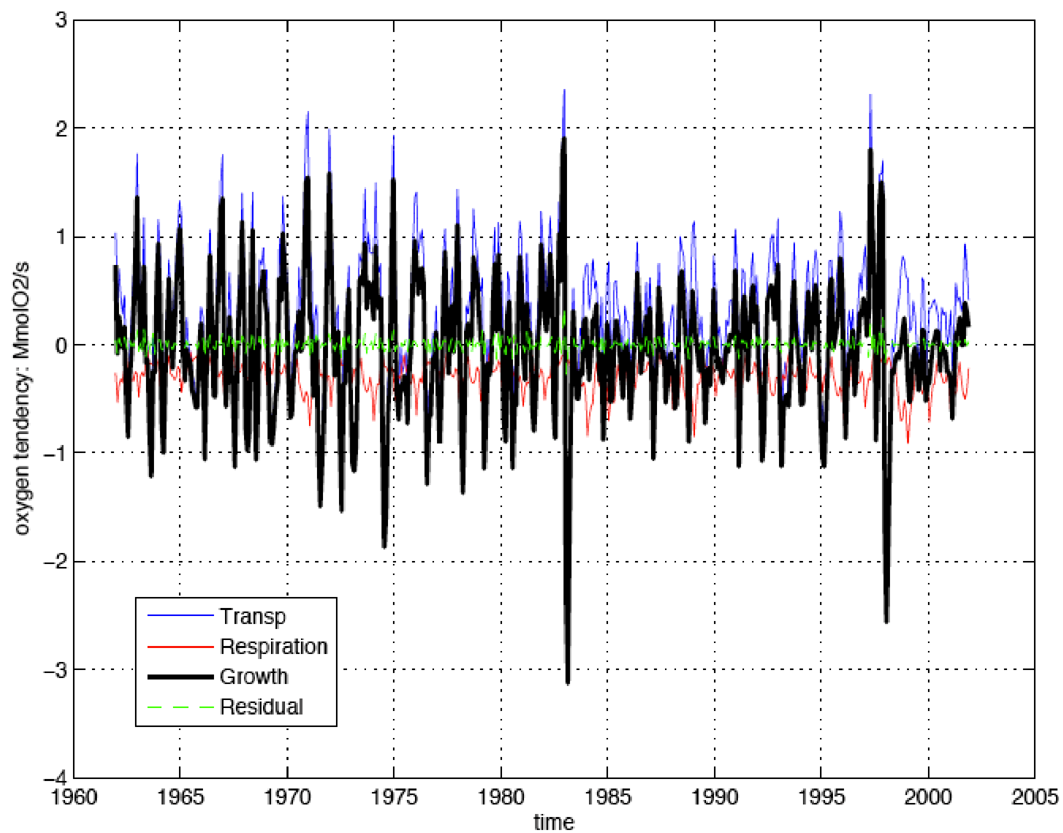
-O_2 inventory
OMZ
expansion

Major El-Nino events

Growth = Physical supply - Respiration

Growth — Transport — Respiration

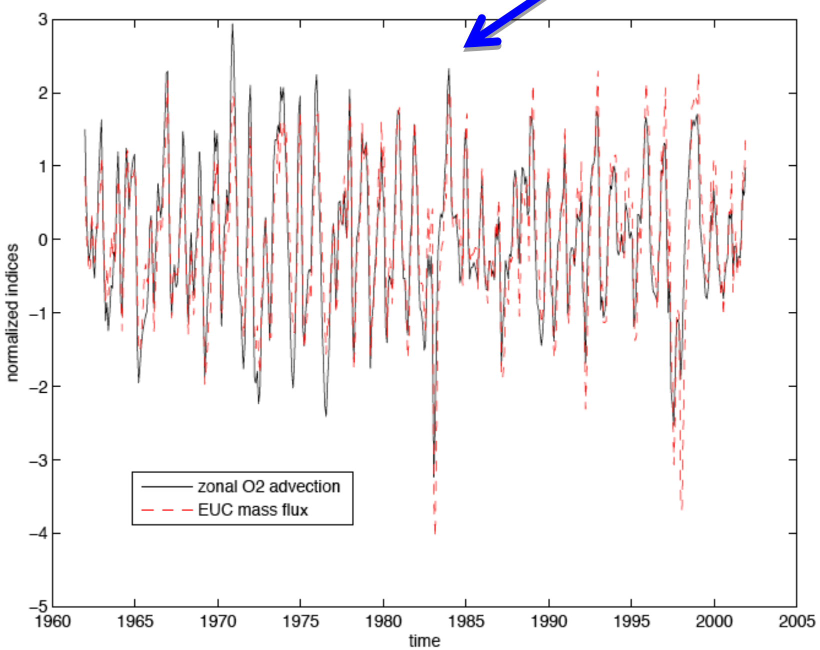
$$\frac{d}{dt}\iiint_V O_2\,dV = -\iint_\Sigma \mathbf{u}O_2\cdot\mathbf{dA} - \iint_\Sigma \mathbf{F}\cdot\mathbf{dA} - \iiint_V OUR\,dV$$



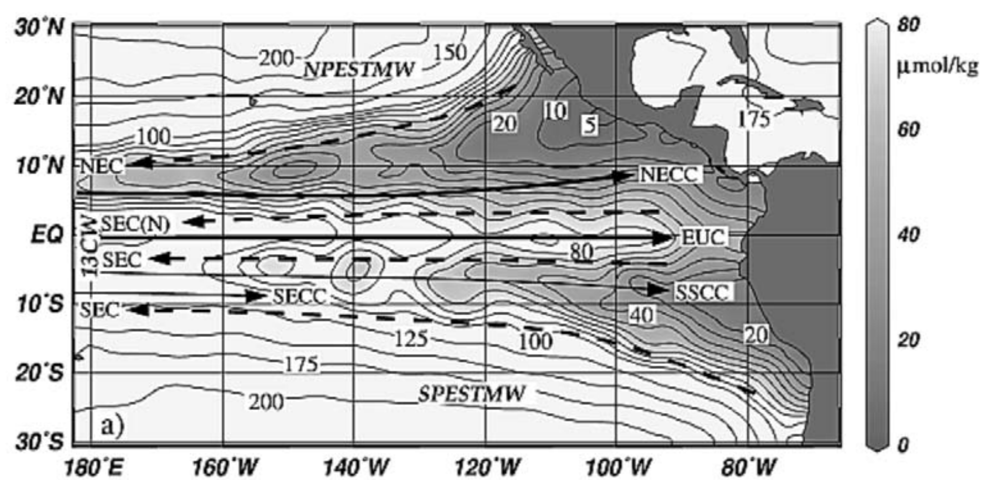
Growth = Physical supply - Respiration

Growth	Transport	Respiration

$$\frac{d}{dt}\iiint_V O_2\, dV = -\iint_\Sigma \mathbf{u}O_2 \cdot \mathbf{dA} - \iint_\Sigma \mathbf{F}\cdot\mathbf{dA} - \iiint_V OUR\, dV$$



O_2 supply by lateral advection



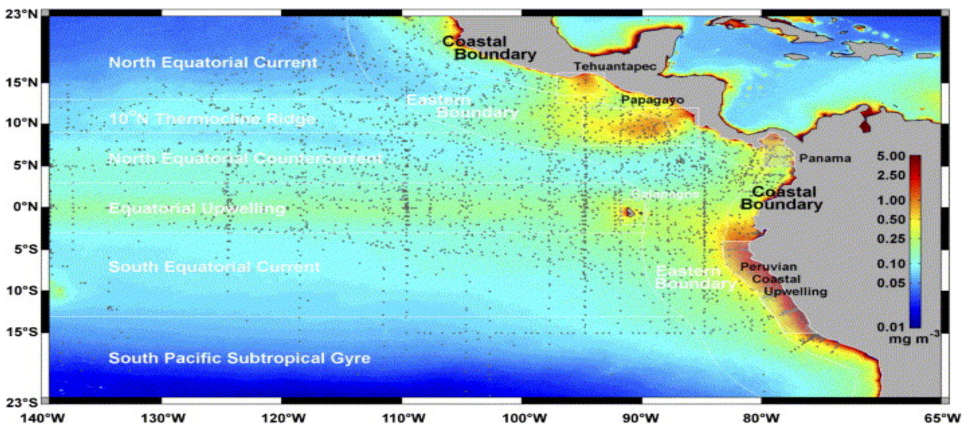
Stramma et al. (2010)

Growth = Physical supply - Respiration

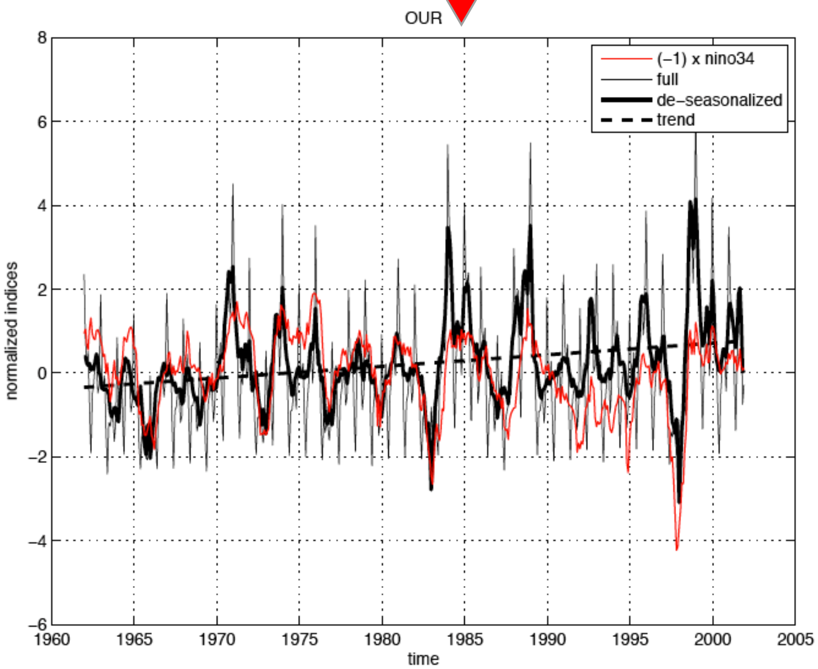
Growth | Transport | Respiration

$$\frac{d}{dt}\iiint_V O_2\,dV = -\iint_\Sigma \mathbf{u}O_2 \cdot \mathbf{dA} - \iint_\Sigma \mathbf{F}\cdot\mathbf{dA} - \iiint_V OUR\,dV$$

ENSO and biological productivity

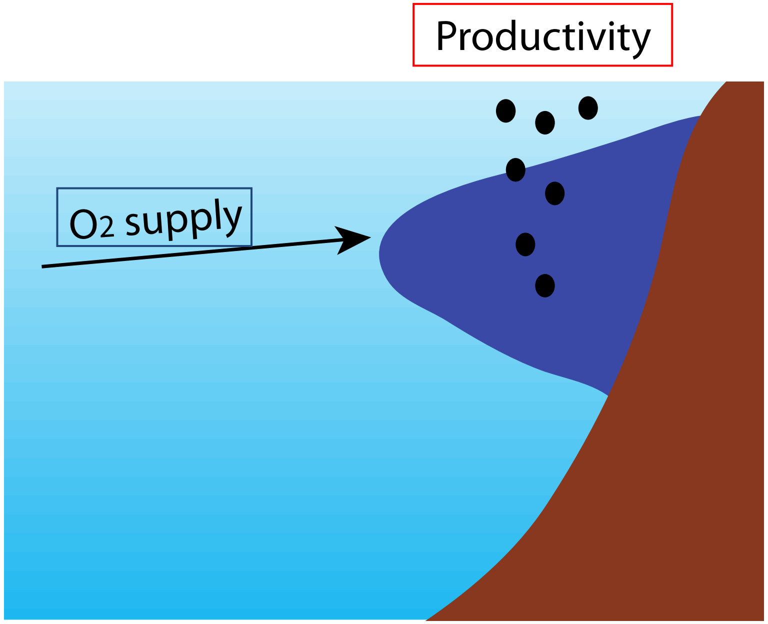


Pennington et al. (2006)



A conceptual model

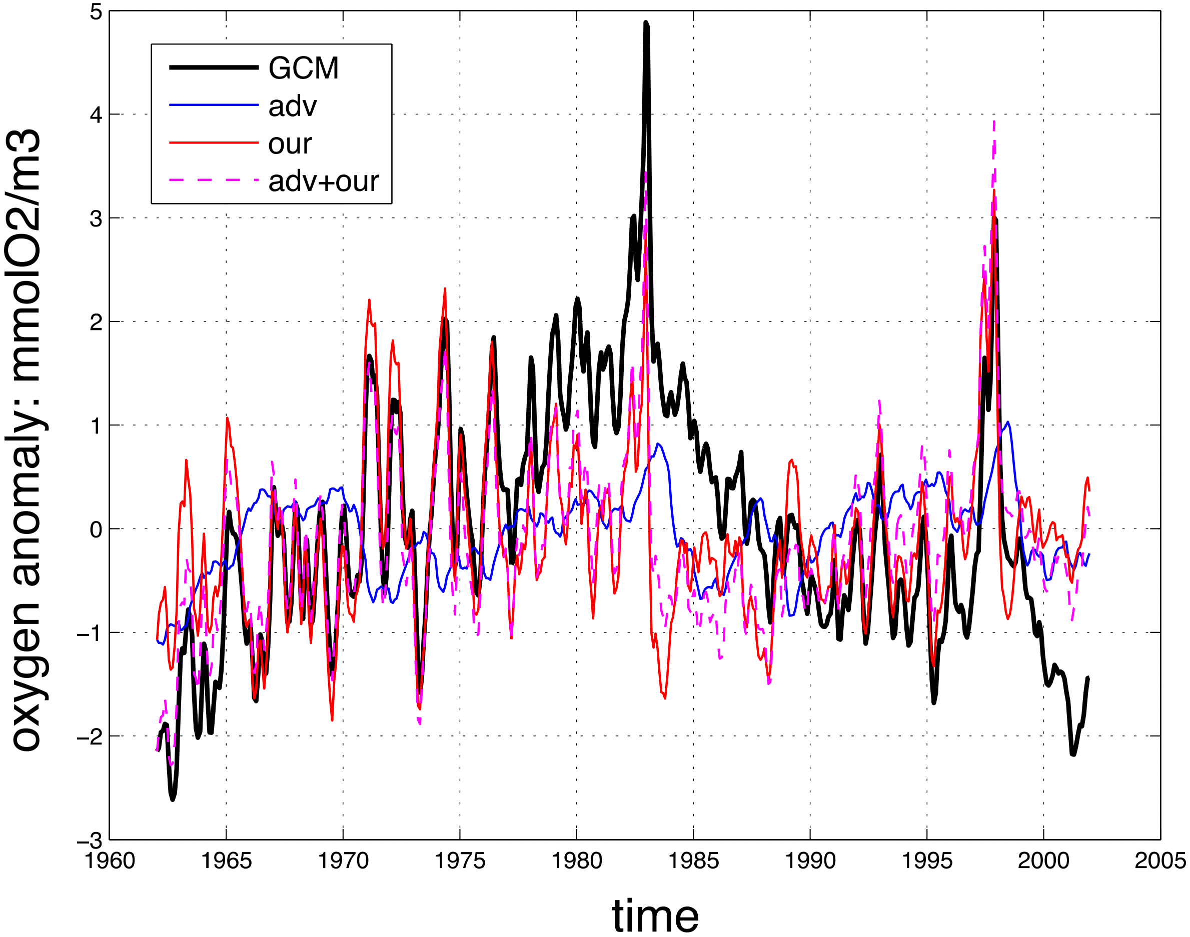
$$\frac{d}{dt}O_2' = -\lambda O_2' + \underline{f_{ADV}(t)} - \underline{f_{OUR}(t)}$$



- **Memory of thermocline waters**
  → Markov process
  → λ: lag-1 autocorrelation

- f_{ADV}(t) and f_{OUR}(t) can be diagnosed from GCM
  - Somewhat correlated with ENSO

A conceptual model



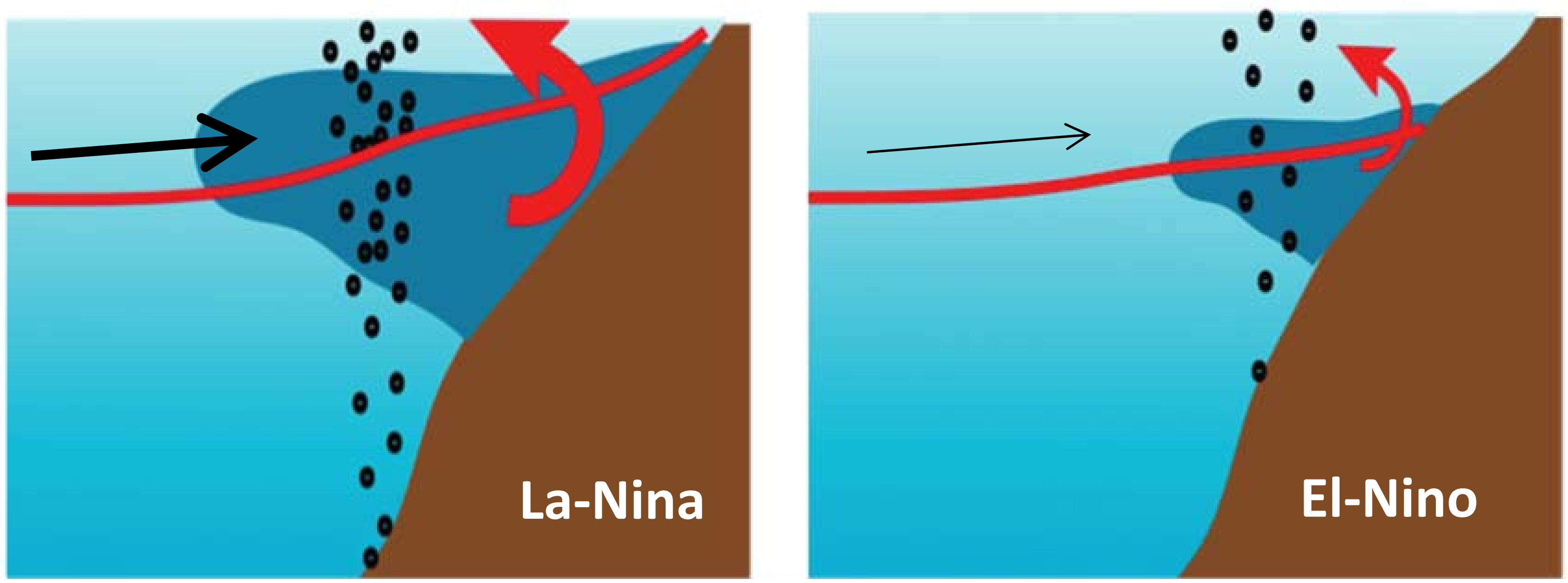
Advection only
Resolved transport convergence

Respiration only
Volume integrated OUR

The net effect is dominated by the respiration

The Mechanism: Upwelling and AOU

Deutsch et al. (2011)



- Colder and increased O_{2sat}
- Stronger lateral O_2 supply
- **Increased biological O_2 consumption**

  → OMZ expansion

- Warmer and decreased O_{2sat}
- Weaker lateral O_2 supply
- **Decreased biological O_2 consumption**

  → OMZ contraction

Take home points

- OMZ variability involves complex interactions
  - A residual between biological O_2 consumption, heat content and circulation change
- AOU dominates
  - On ENSO timescale, OMZ expands during La Nina
- Decadal variability
  - Finite memory of thermocline water
  - PDO-like behavior due to integrated ENSO signals