Predicting ocean oxygen: capabilities and potential

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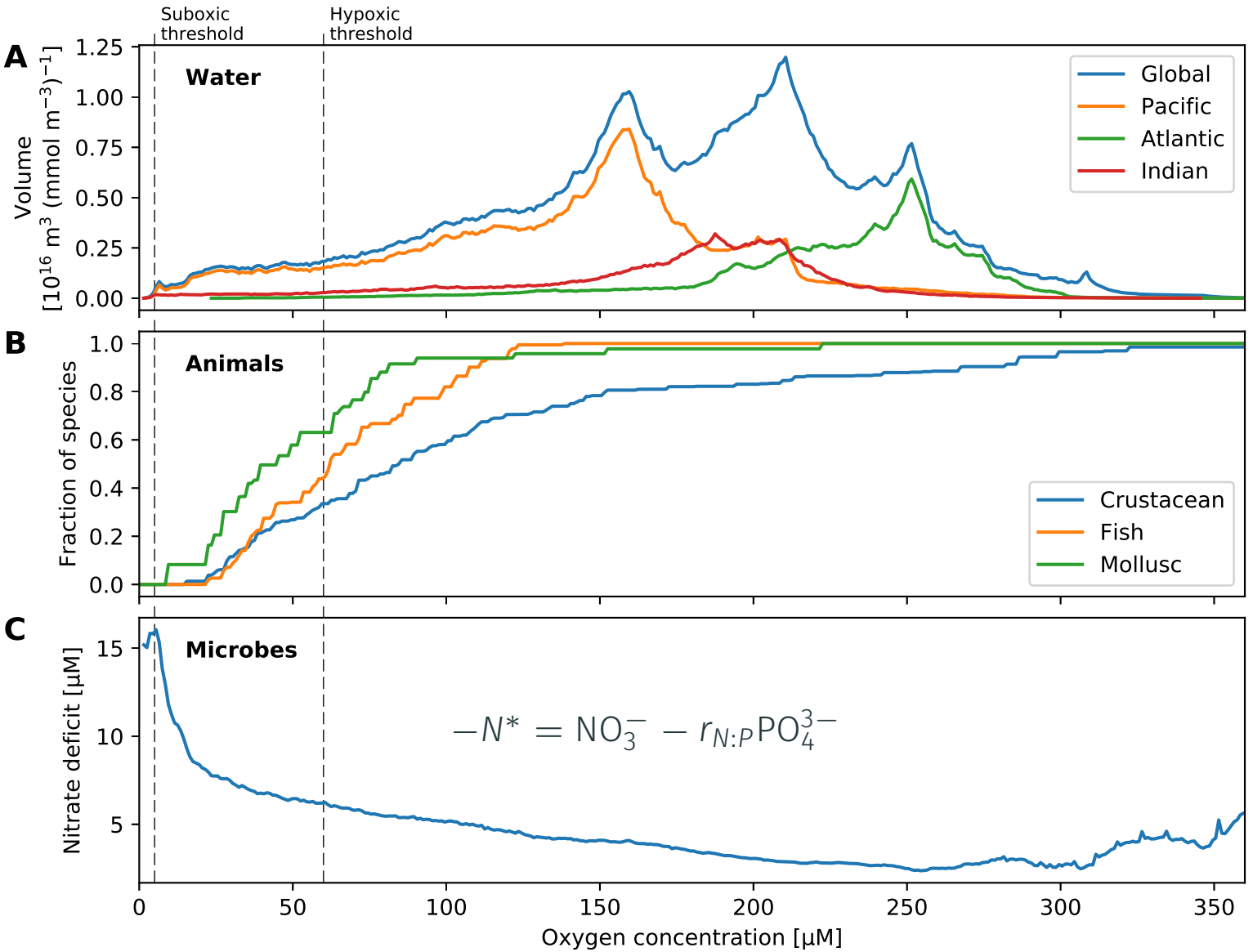
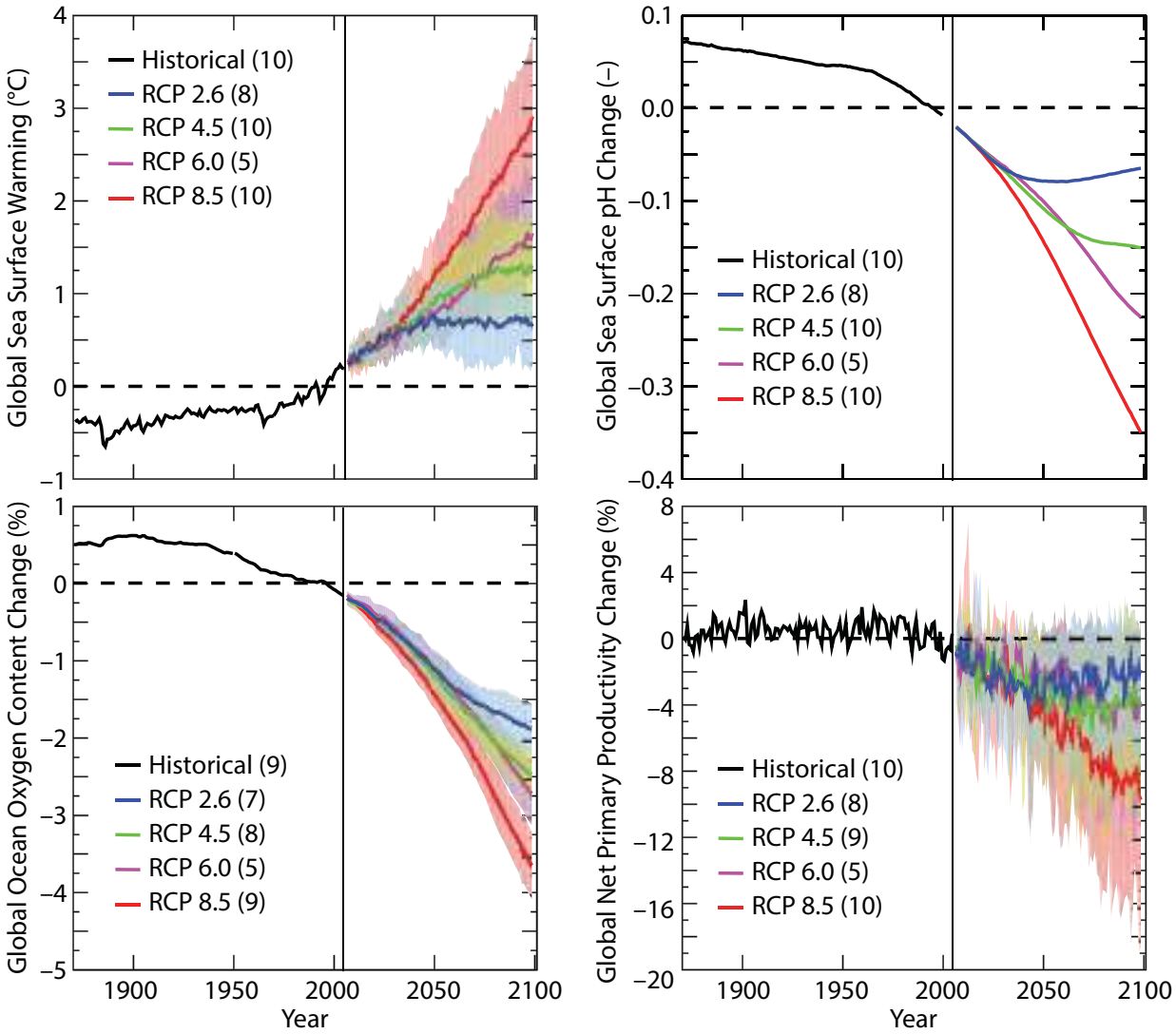
Oxygen is a fundamental environmental constraint



Warming up, turning sour, losing breath*

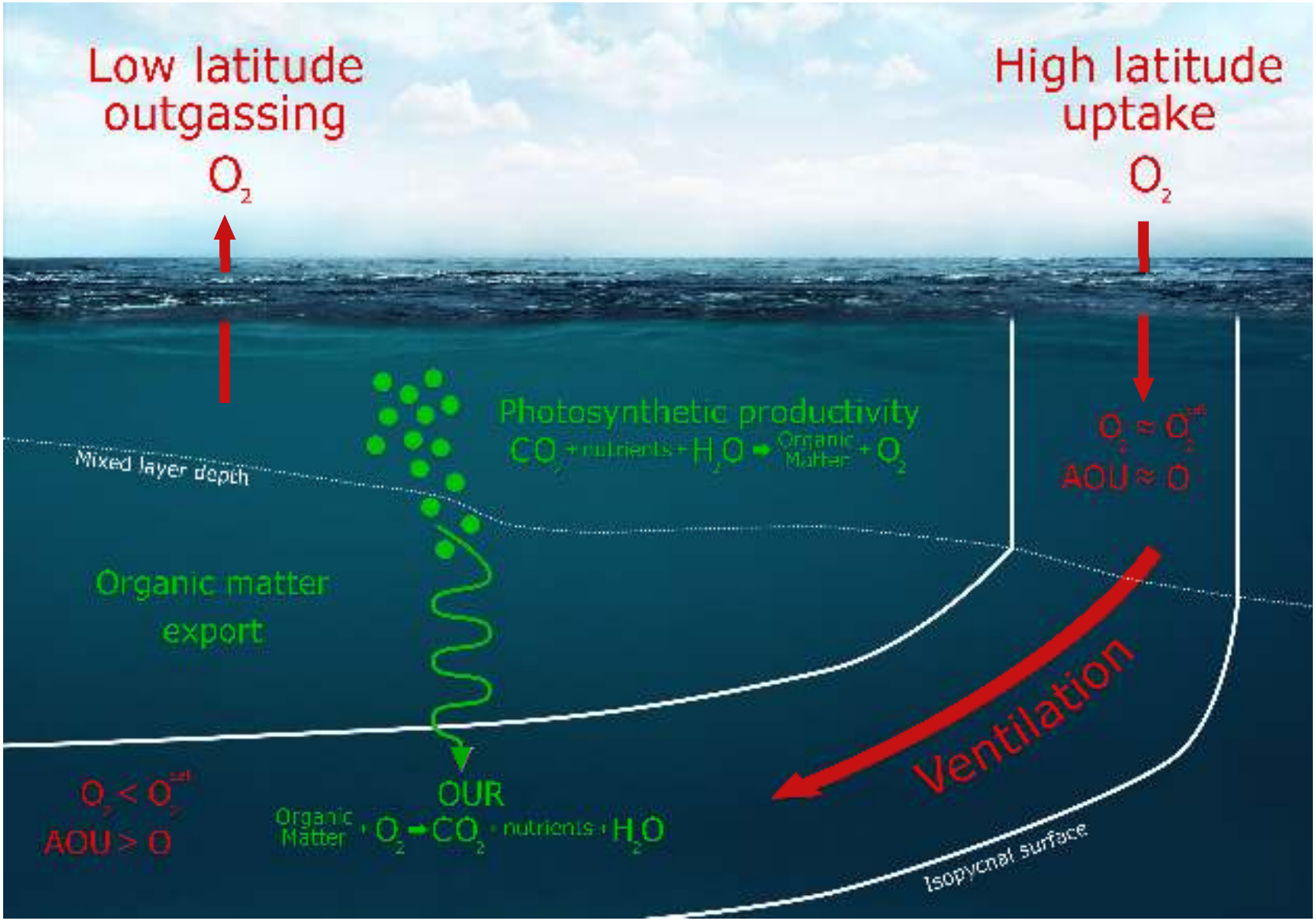
CMIP5 multi-model global-mean projections



Doney, Bopp, & Long, 2014

* *Gruber, 2011*

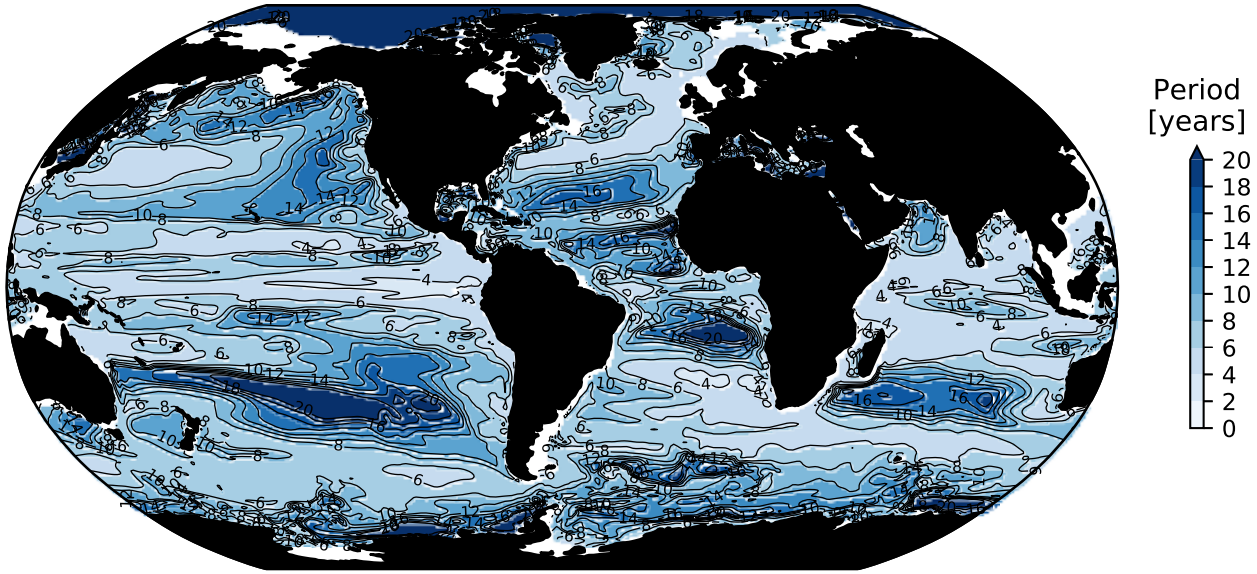
Physical & biological controls on interior oxygen



Graphic credit: M. Long and R. Johnson (NCAR)

Timescales of natural variability in thermocline O_2

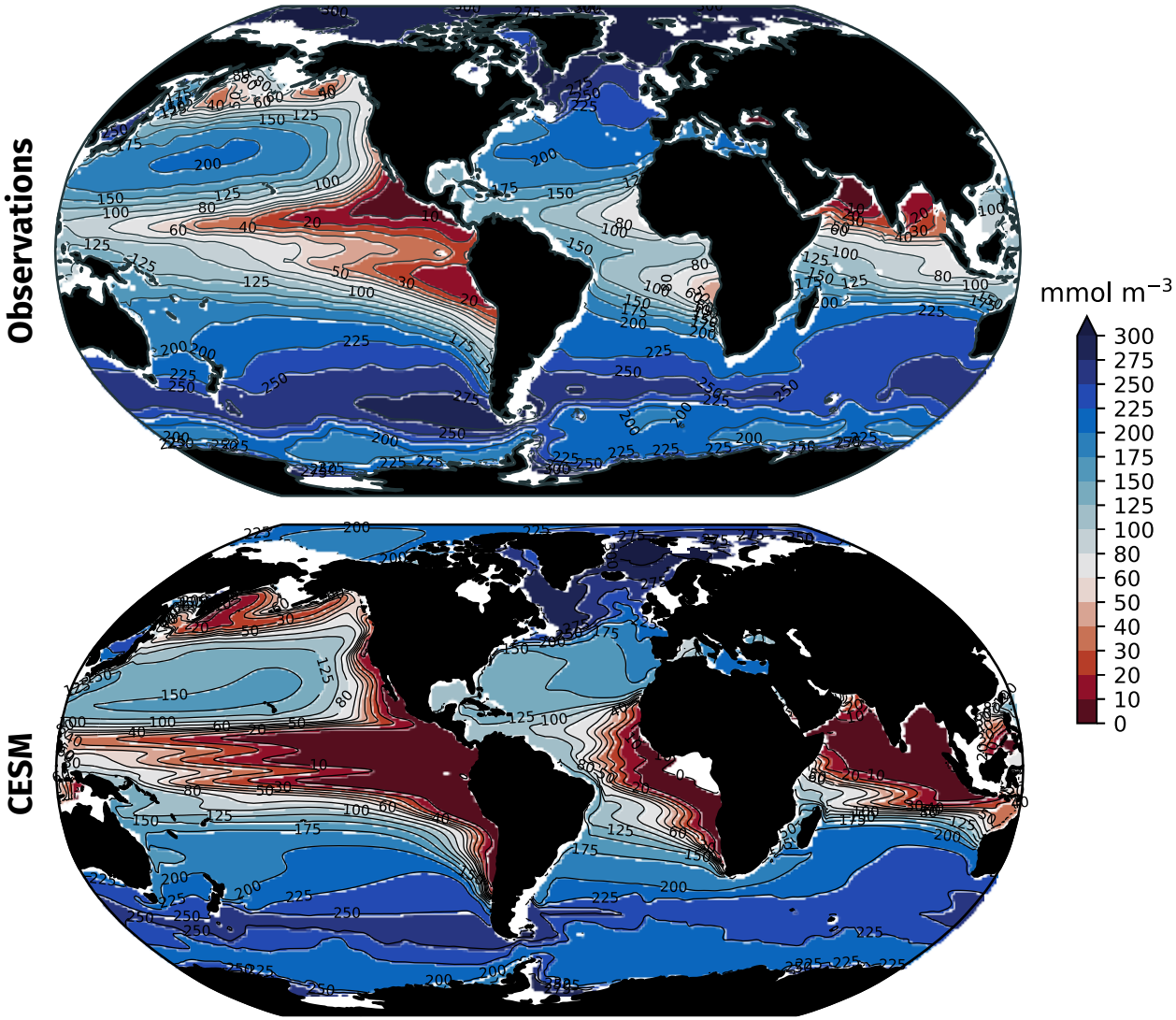
Variance-weighted mean period (CESM 1850-control)



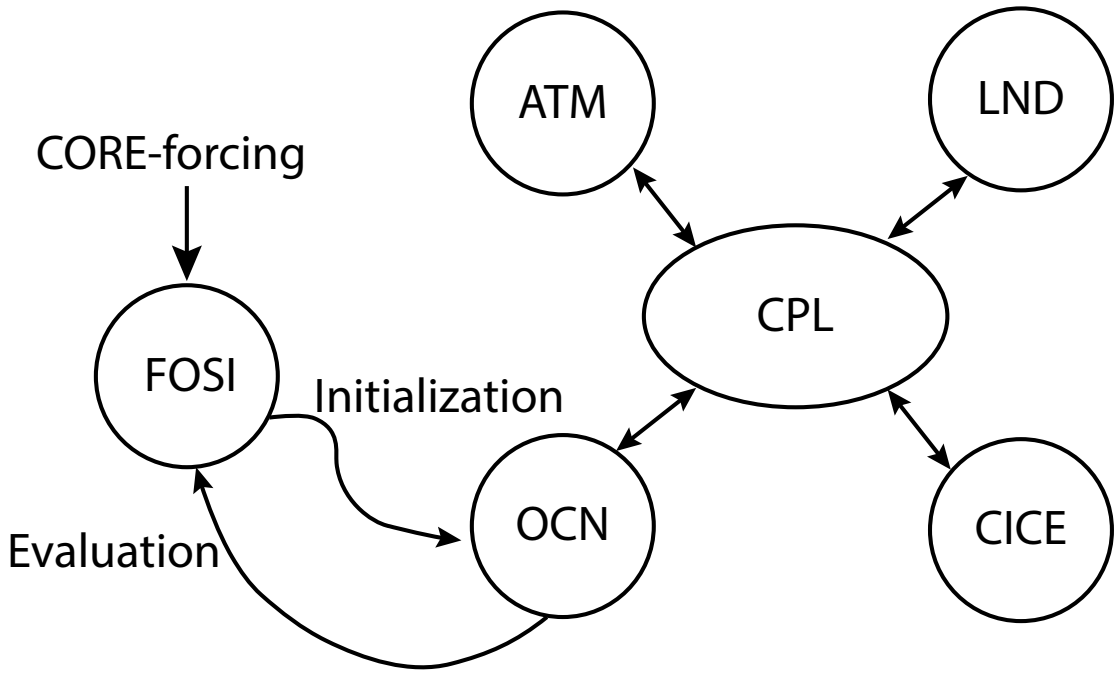
$$T_x = \sum_k V(f_k, x) / \sum_k f_k V(f_k, x)$$

A persistent bias in Earth system models: Extensive OMZs

Thermocline (400–600 m) O_2 distributions

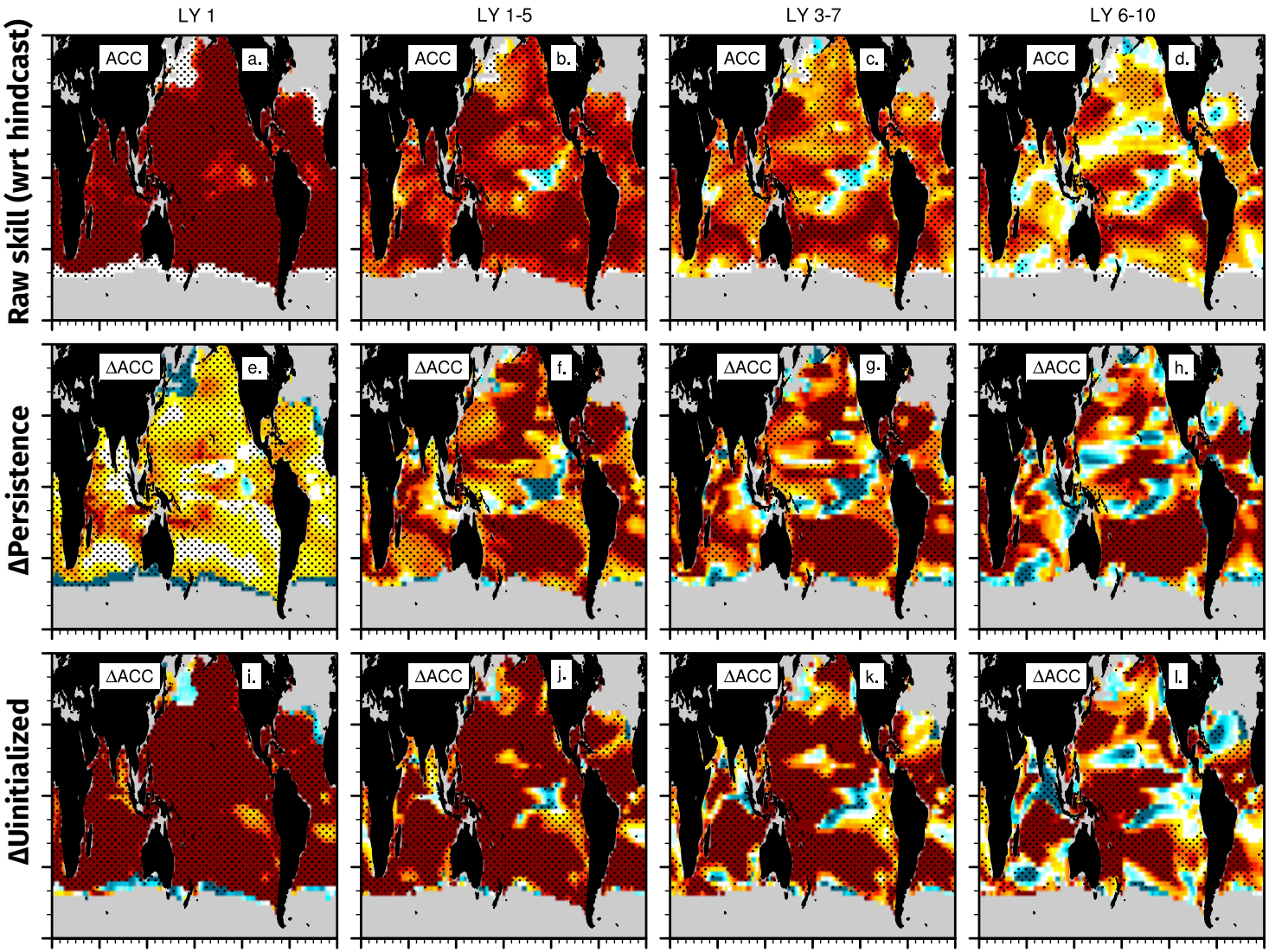


CESM Decadal Prediction Large Ensemble



Thermocline oxygen concentrations look to be highly predictable

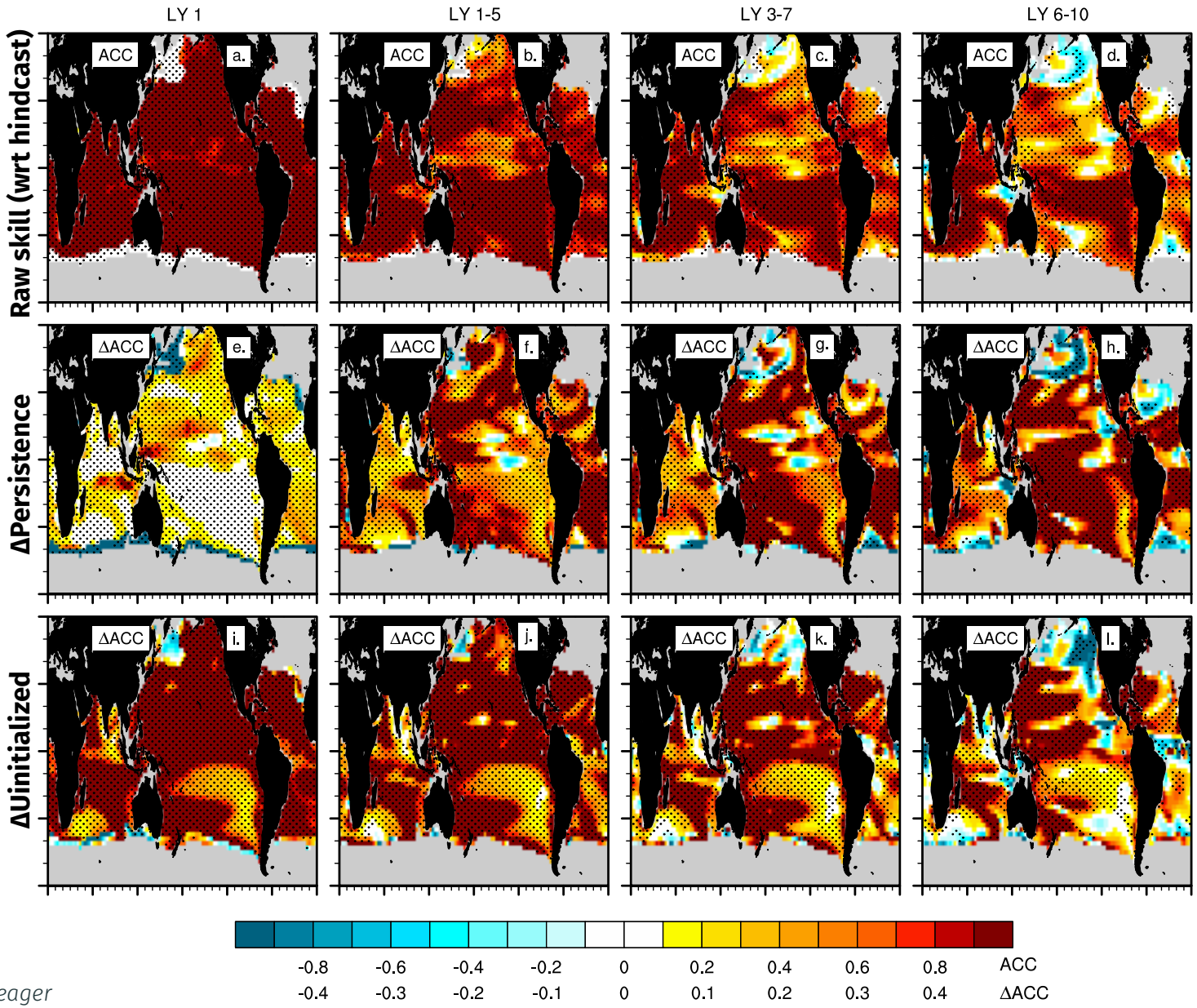
Anomaly correlation coefficient: O_2 on $\sigma_\theta = 26.5$



courtesy of S. Yeager

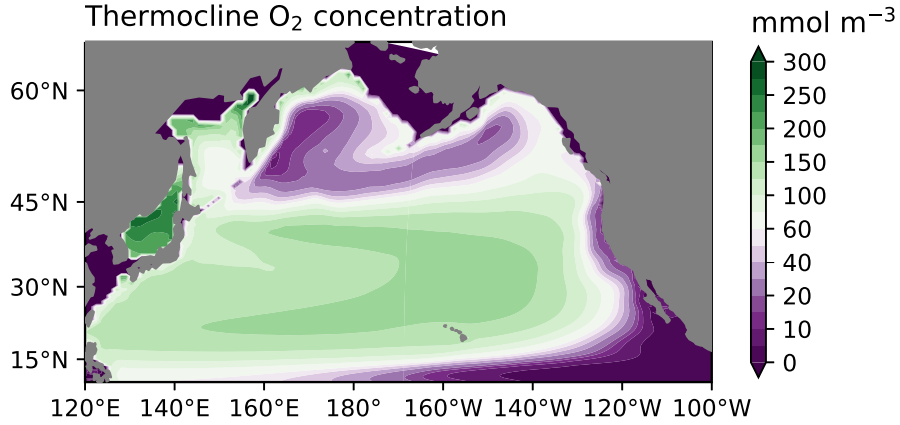
Thermocline oxygen concentrations look to be highly predictable

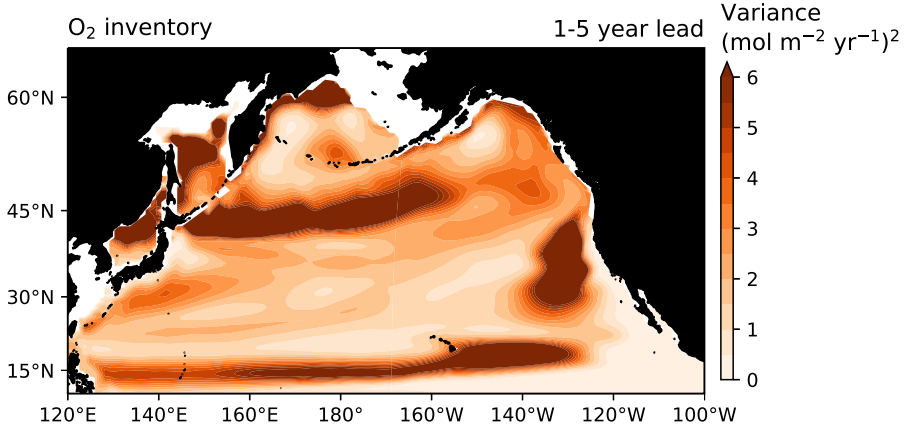
Anomaly correlation coefficient: Salinity on $\sigma_\theta = 26.5$

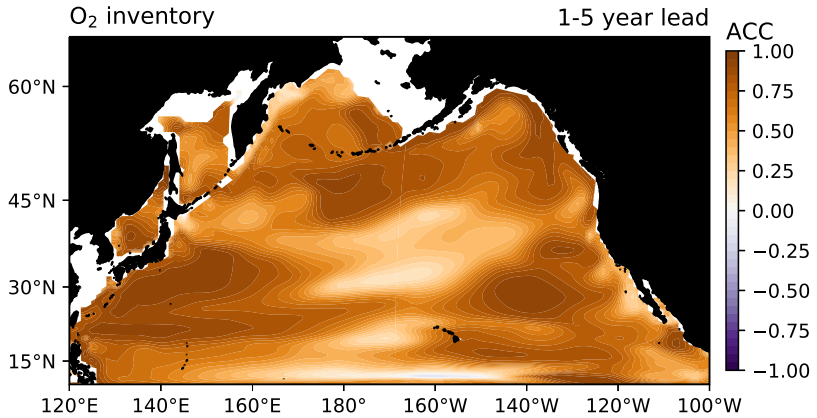


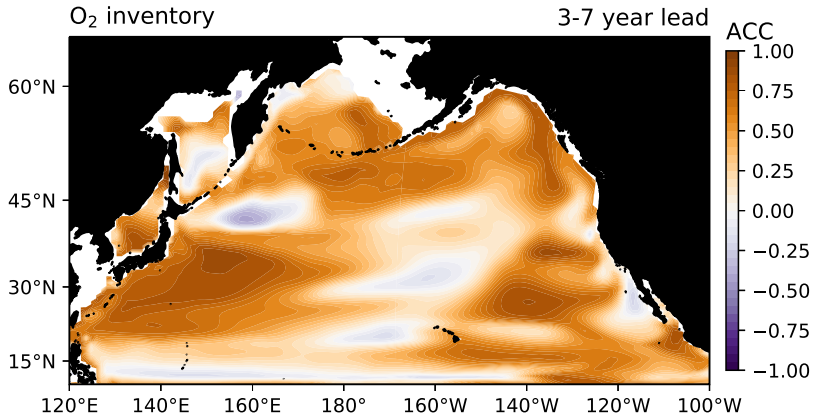
courtesy of S. Yeager

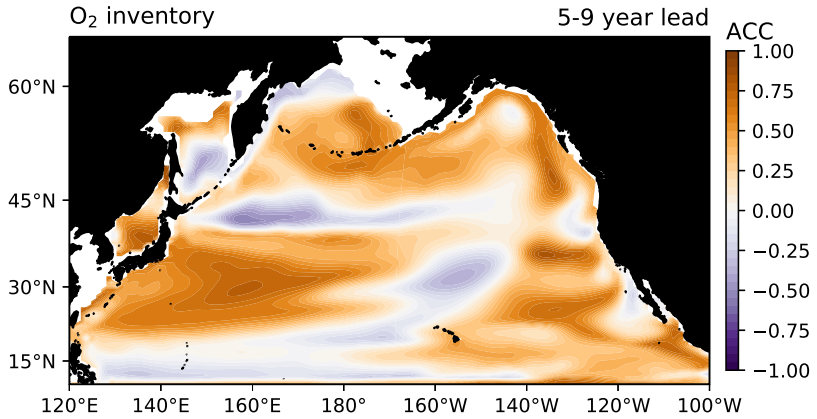
North Pacific dissolved oxygen is skillfully predicted







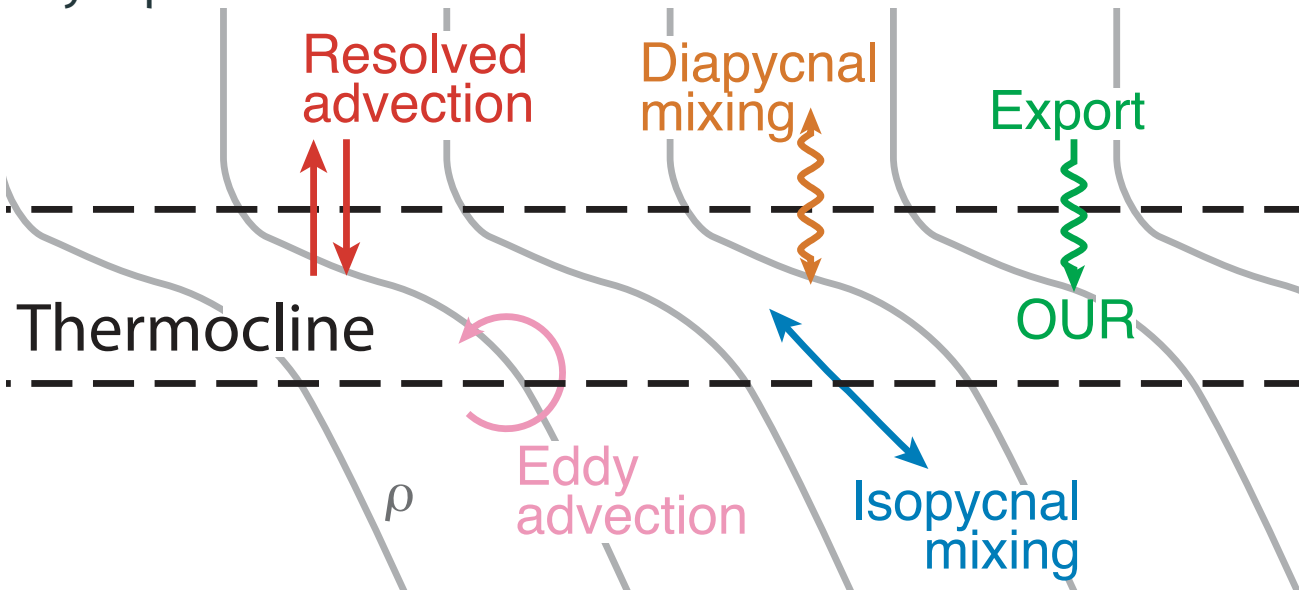




"Thermocline" := 200–600m mean

What mechanisms provide predictability for O_2?

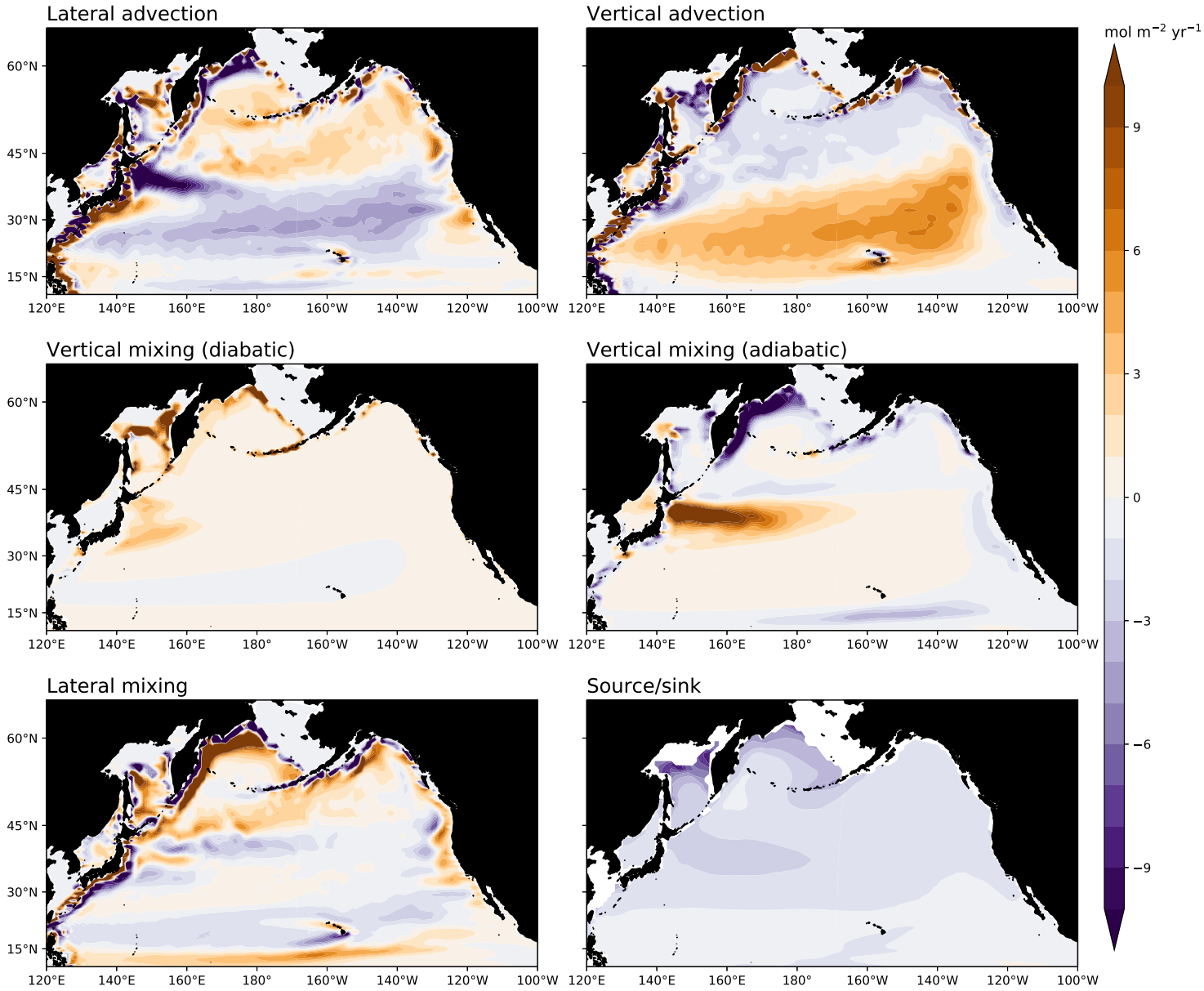
Tracer tendency equation



$$\frac{\partial O_2}{\partial t} + (\mathbf{u} + \mathbf{u}^*) \cdot \nabla O_2 = \mathcal{D}_{iso}(O_2) + \mathcal{D}_{dia}(O_2) + \mathcal{J}_{bio}(O_2)$$

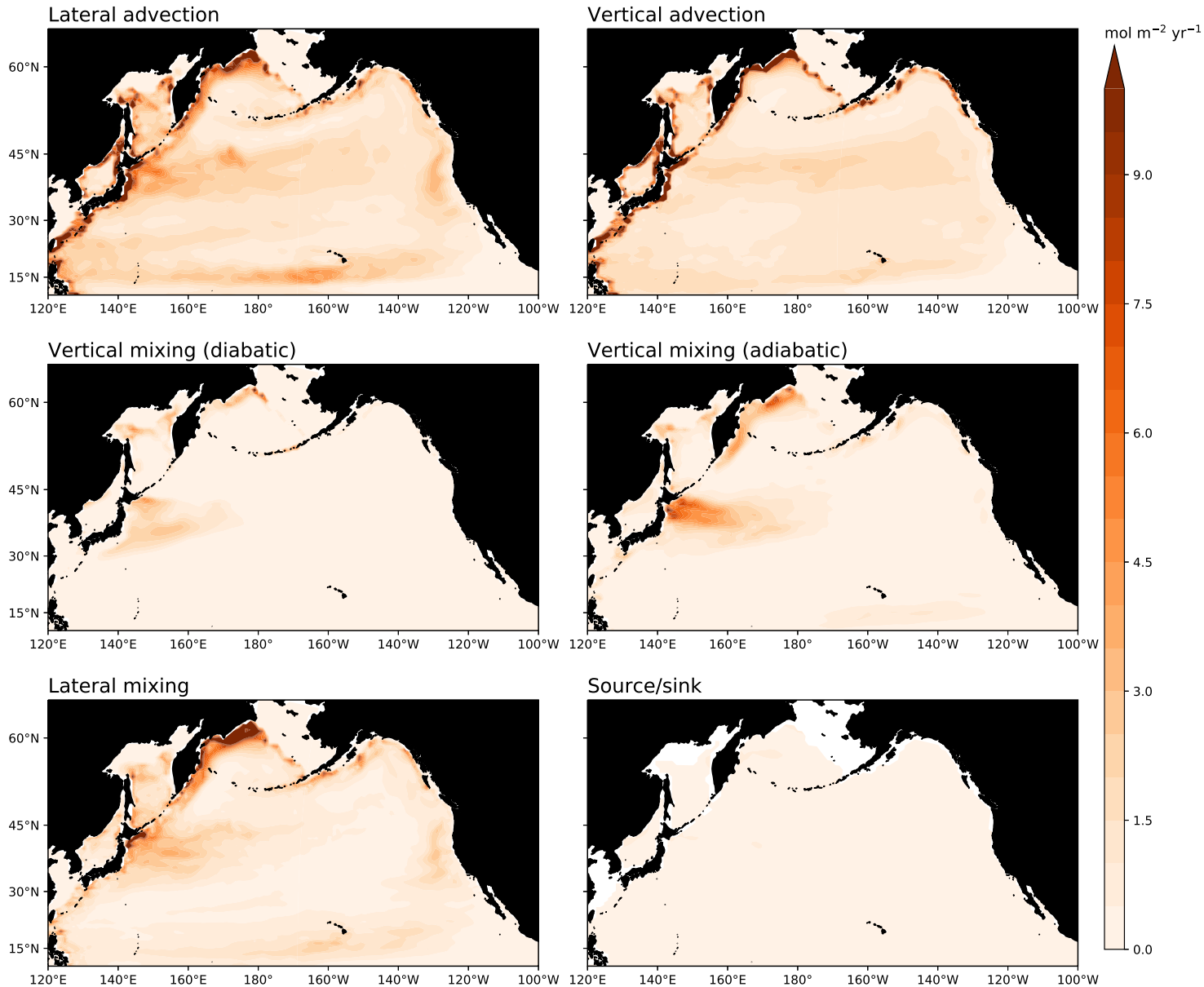
What mechanisms provide predictability for O_2?

O_2 term balance: annual mean



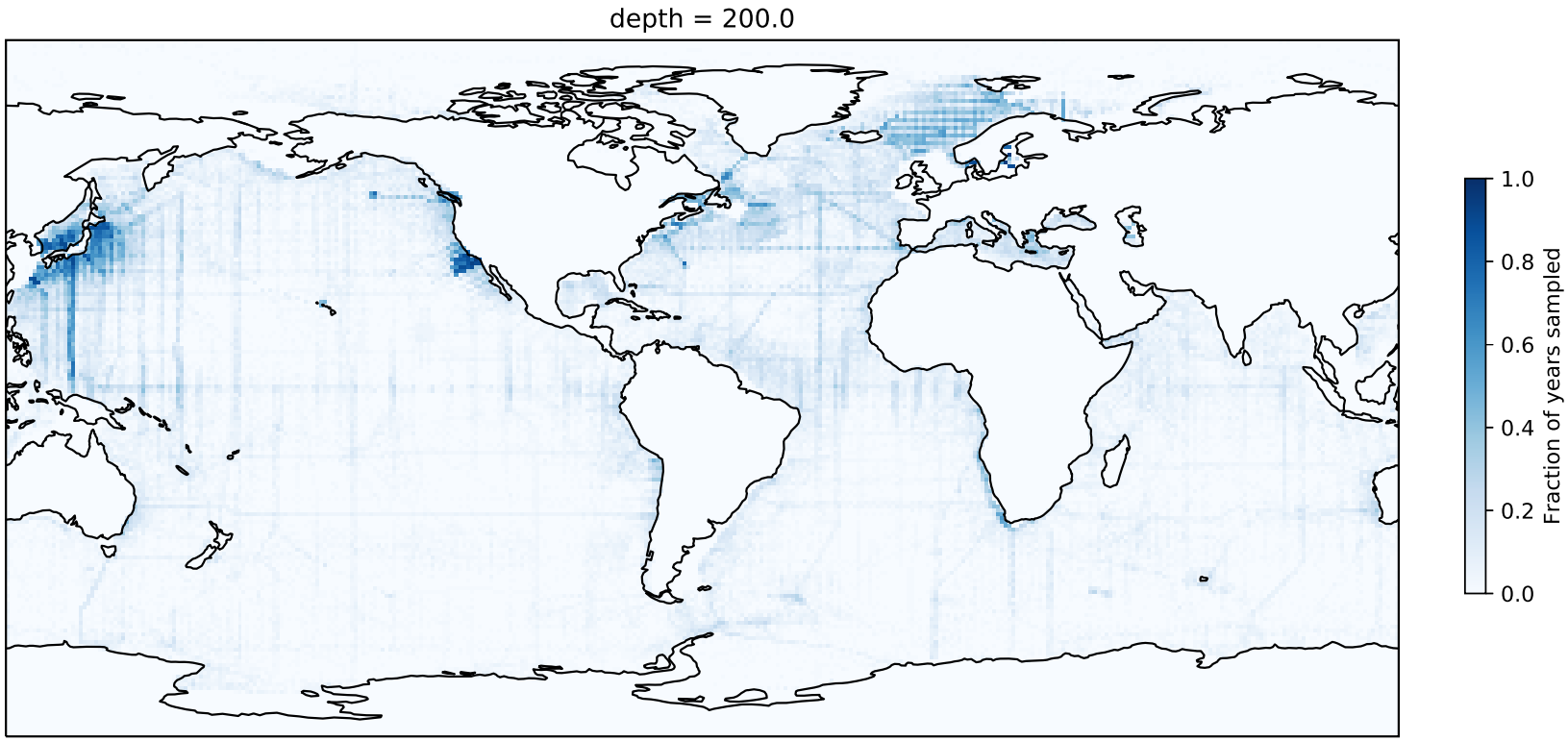
What mechanisms provide predictability for O_2?

O_2 term balance: interannual variability (std. dev.)



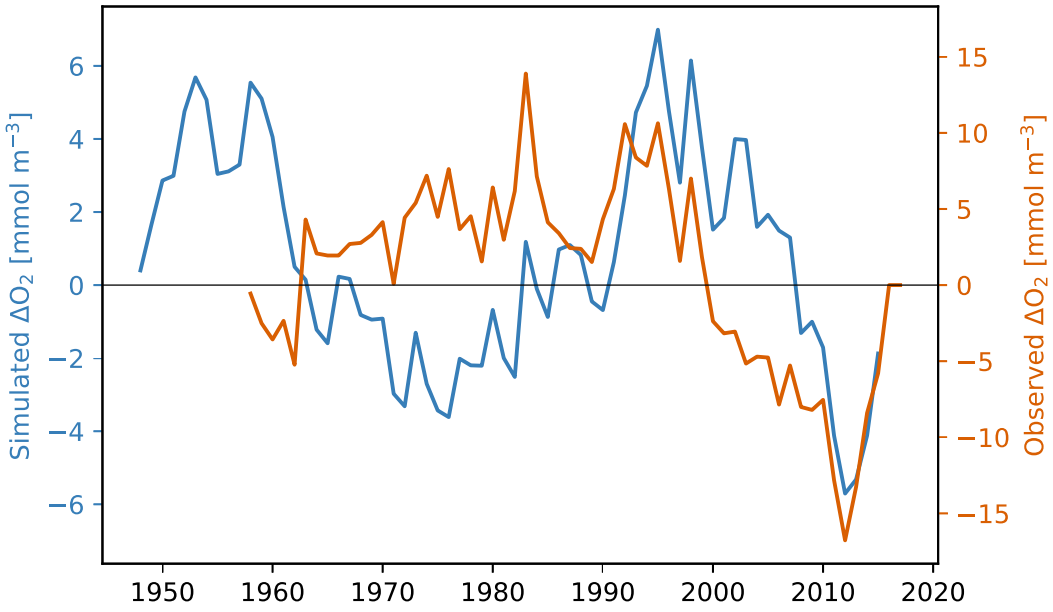
Timeseries observations of oxygen are sparse

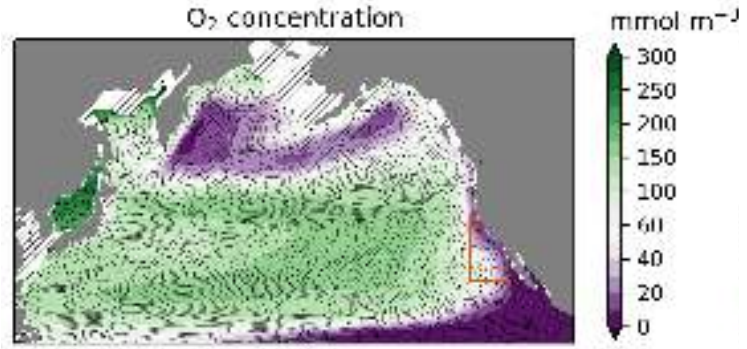
World Ocean Database 2013: Fraction of years sampled (1958–2015)



Model skill in CalCOFI* region: questionable

Thermocline O_2

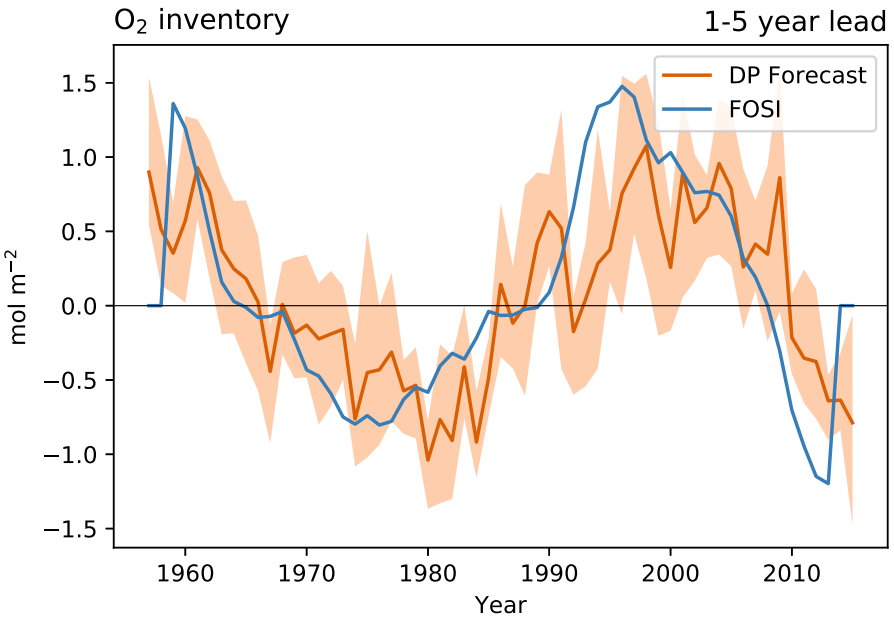




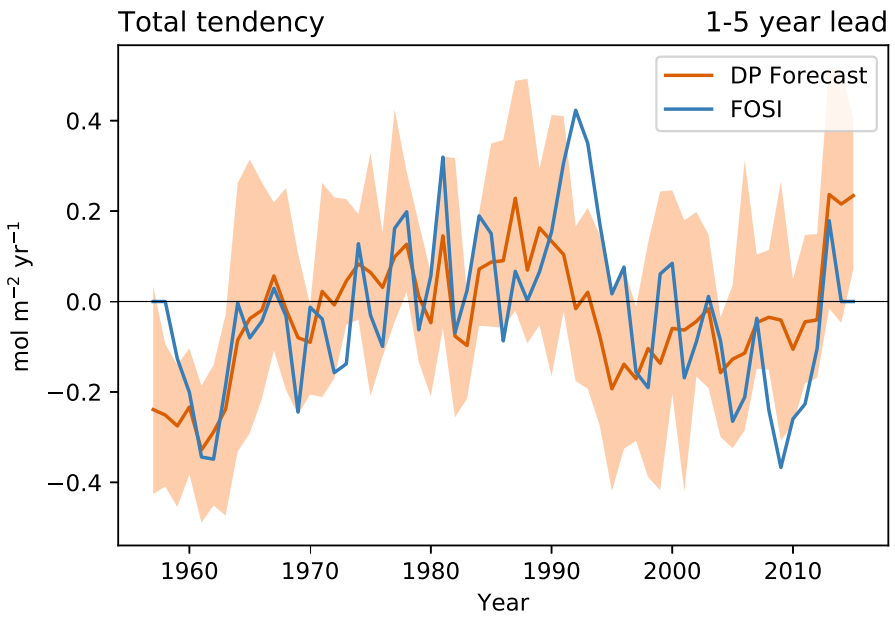
* California Cooperative Oceanic Fisheries Investigations

CalCOFI dissolved oxygen is skillfully predicted

Thermocline O_2 in CalCOFI region

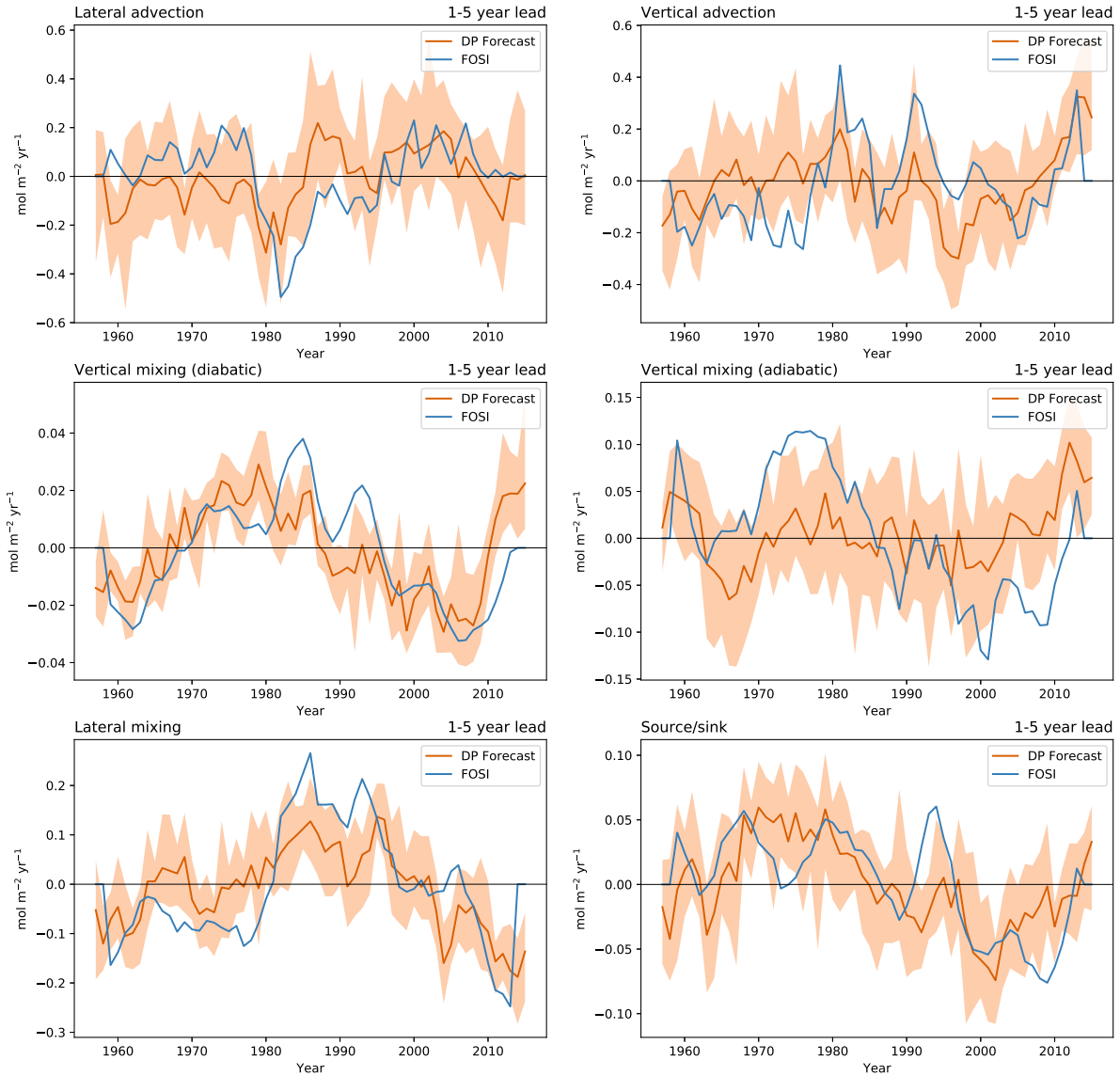


Thermocline O_2 tendency



What mechanisms provide predictability for O_2?

O_2 term balance: annual mean



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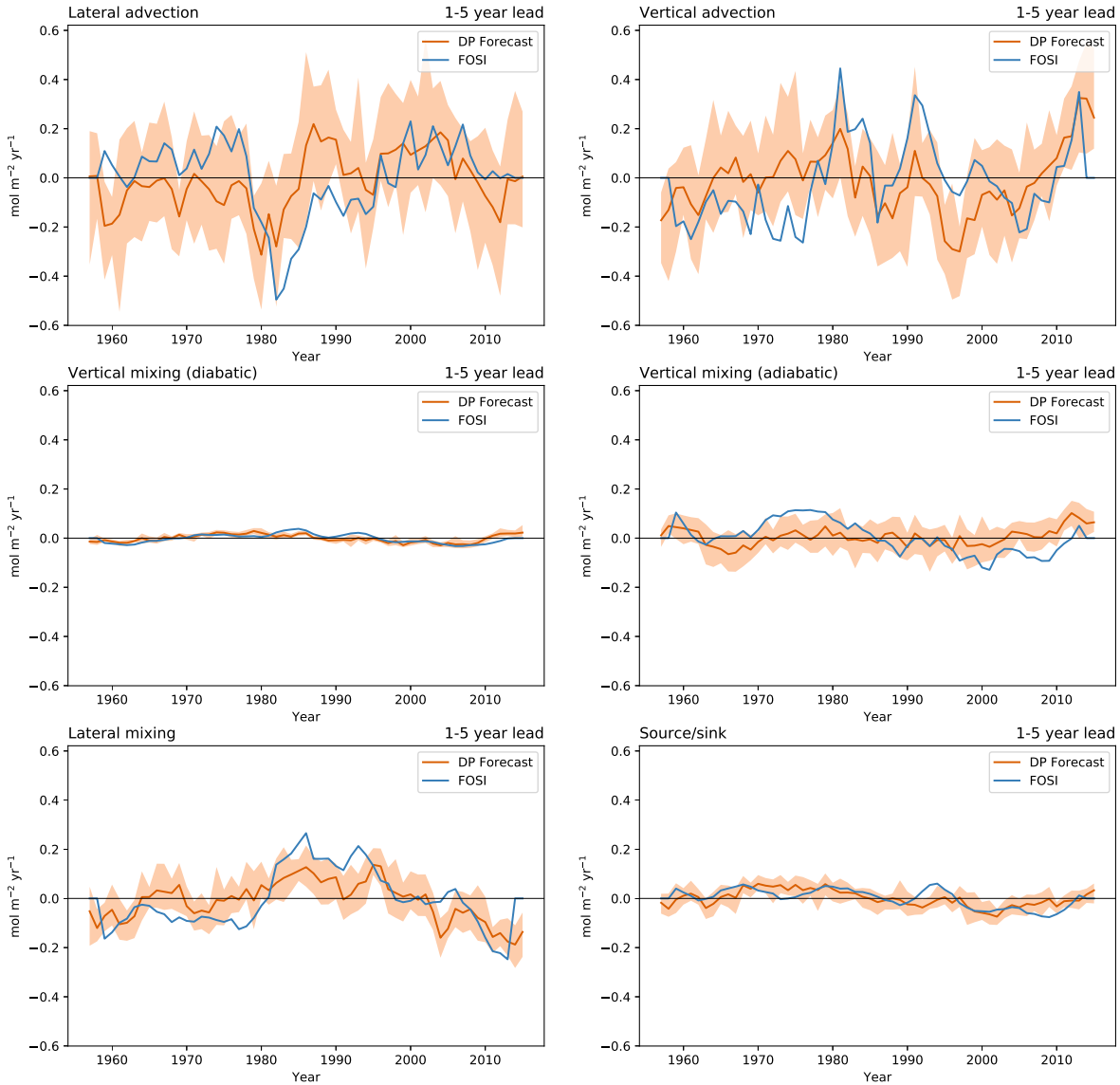
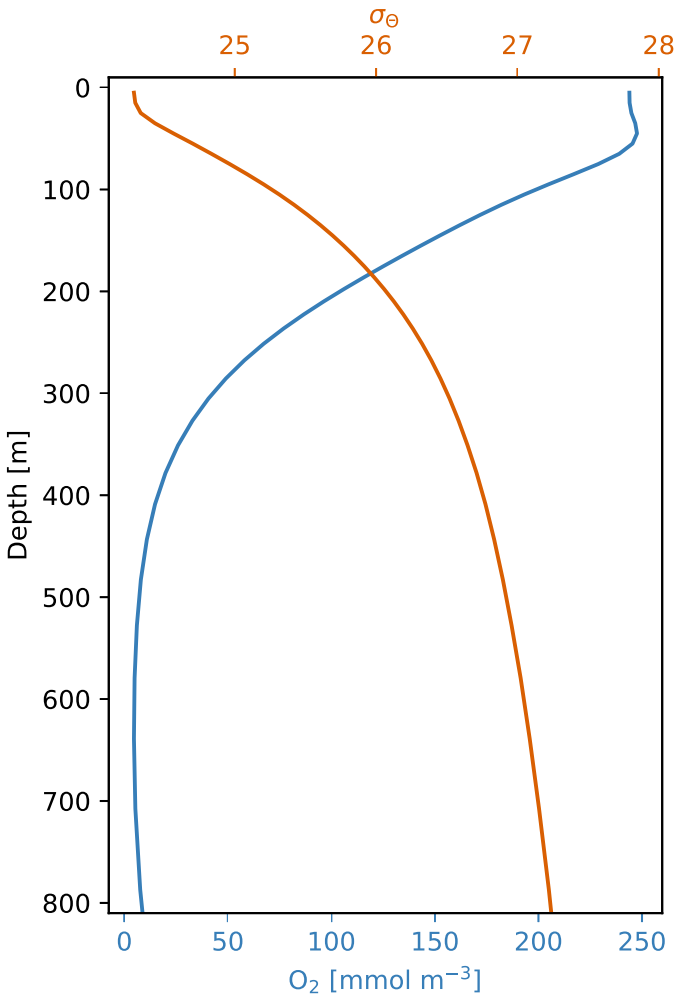


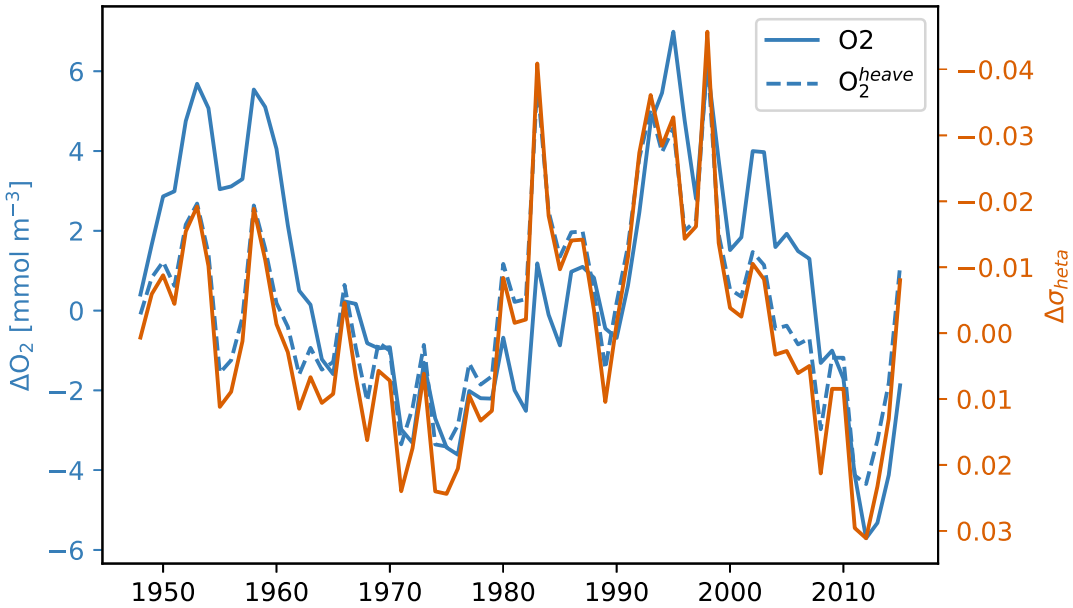
What mechanisms provide predictability for O_2?

Mean vertical gradients



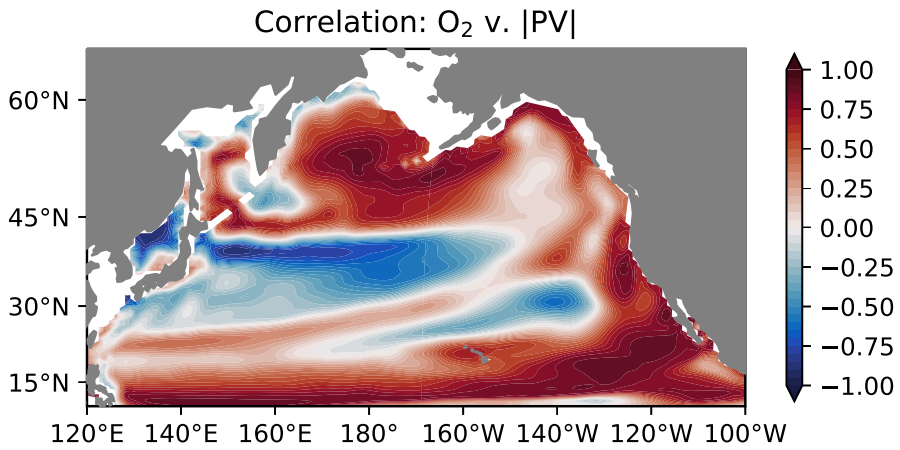
"Heave"

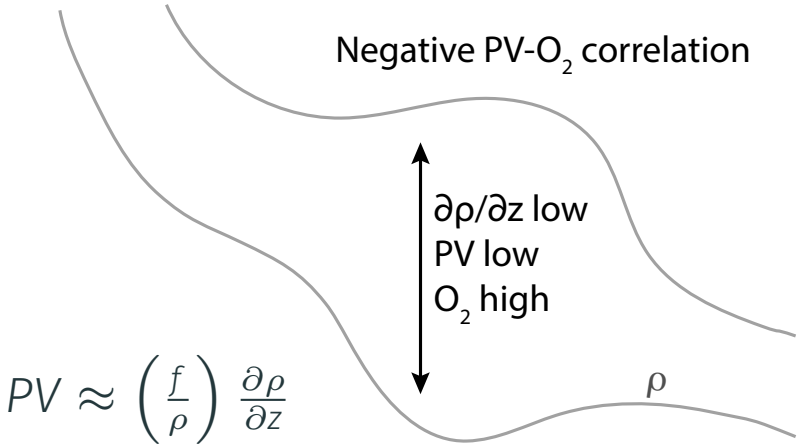
$$O_2^{heave} = \left(\frac{\partial \overline{O_2}}{\partial z}\right)\left(\frac{\partial \overline{\rho_\theta}}{\partial z}\right)^{-1} \rho'_\theta$$



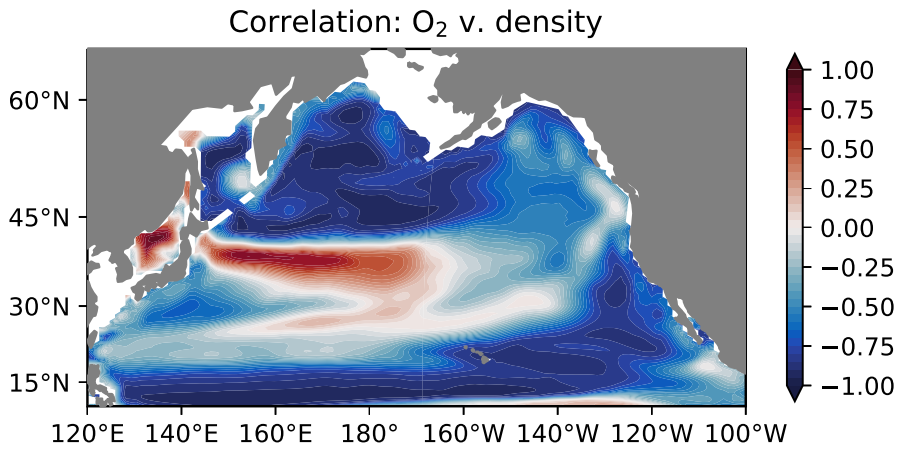
East-west difference in anomaly generation mechanism

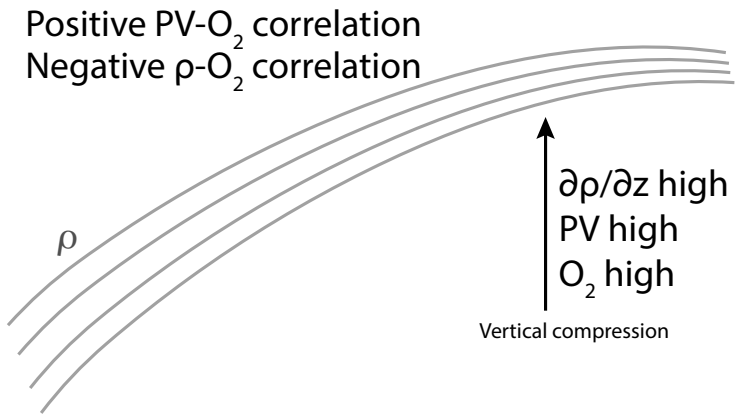
“Ventilation regime”





“Heave regime”





Summary

- Thermocline dissolved oxygen concentrations are highly predictable on multi-annual timescales.
- Vertical displacement of isopycnals in response to basin-scale thermocline adjustment explains much of the variance in simulated CalCOFI O_2.
- The “heave” regime of the eastern Pacific contrasts with a “ventilation” regime of the west, indicated by differing correlations with PV.
- Model skill remains a challenge.

Questions?

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