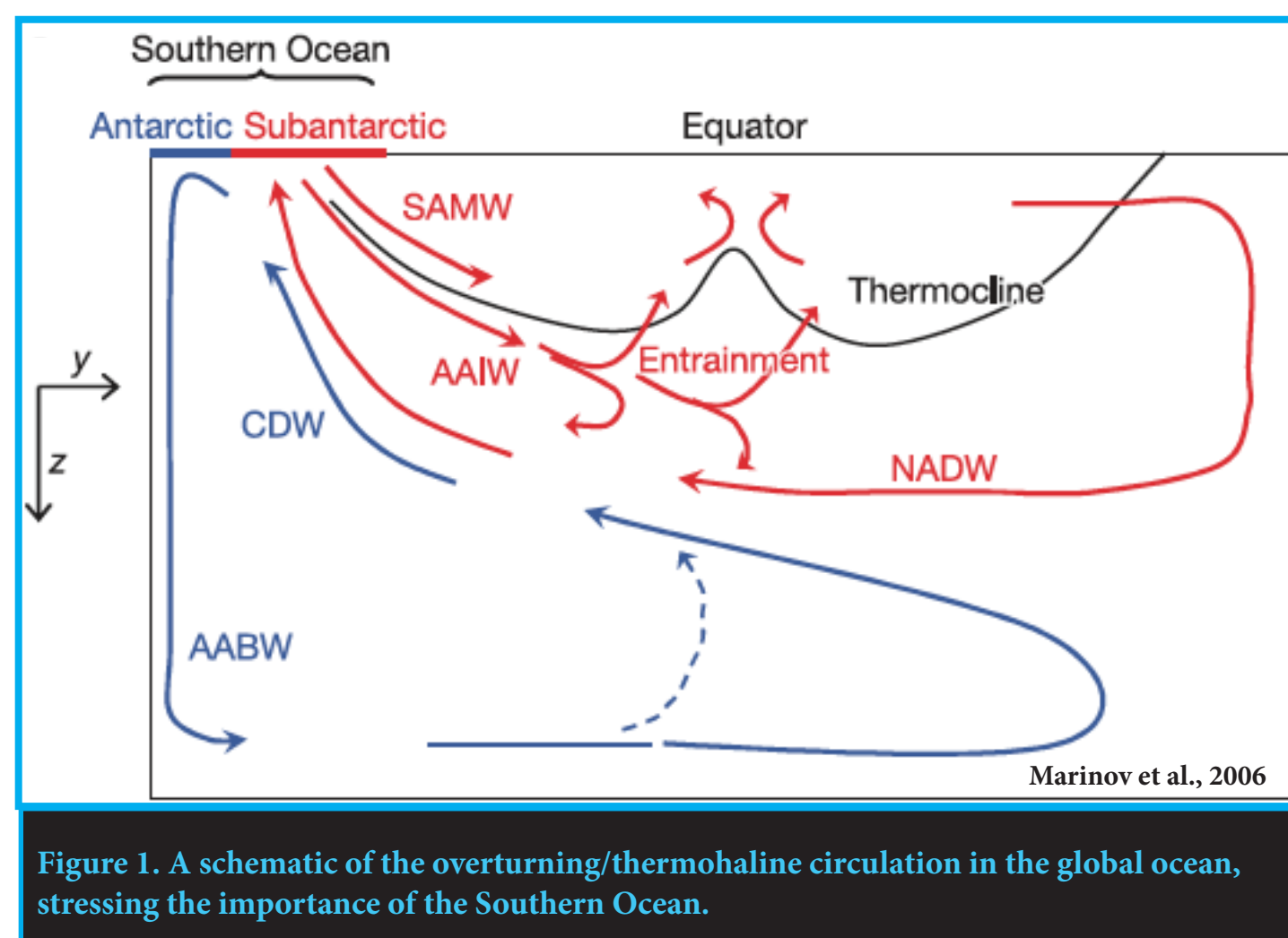


# Investigating the role that the Southern Ocean biological pump plays in determining global ocean oxygen concentrations and deoxygenation

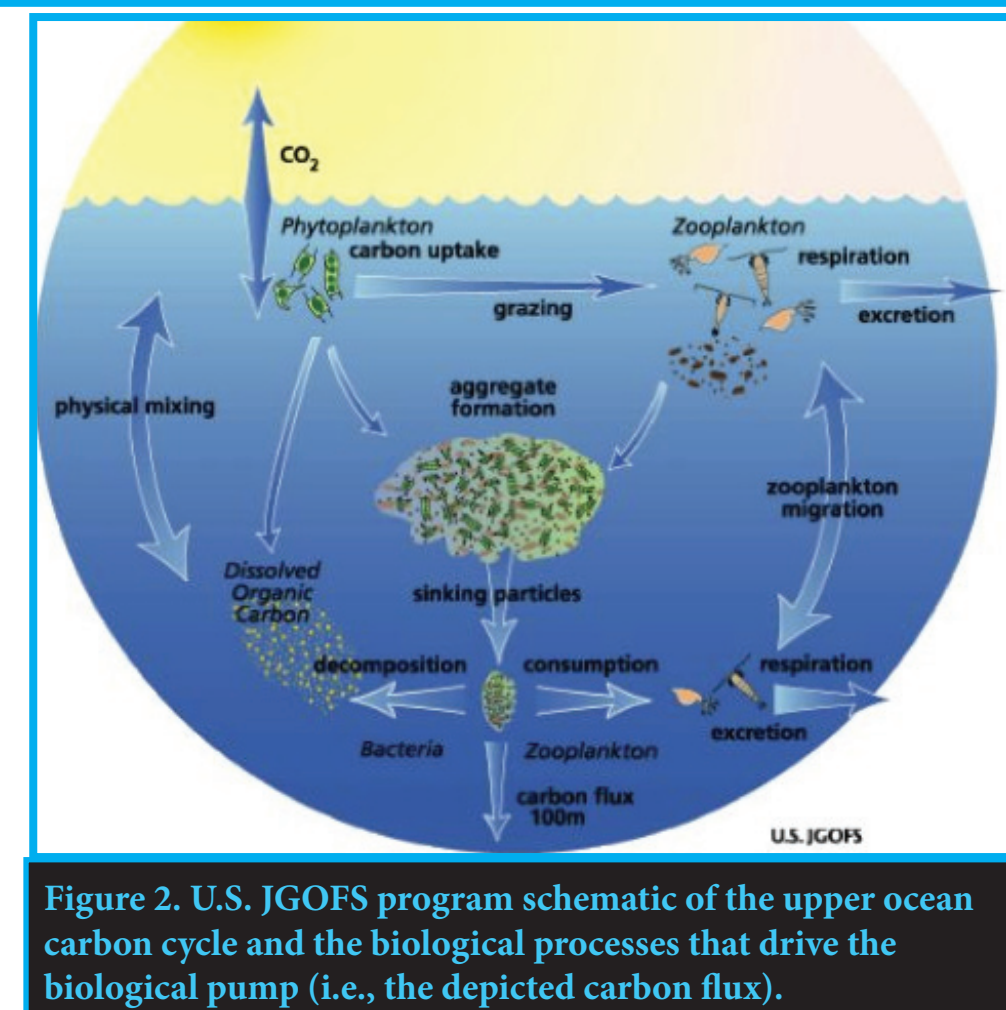
David P. Keller and Andreas Oschlies

## Why is the biological pump in the Southern Ocean so important?

The Southern Ocean plays a key role in global ocean circulation

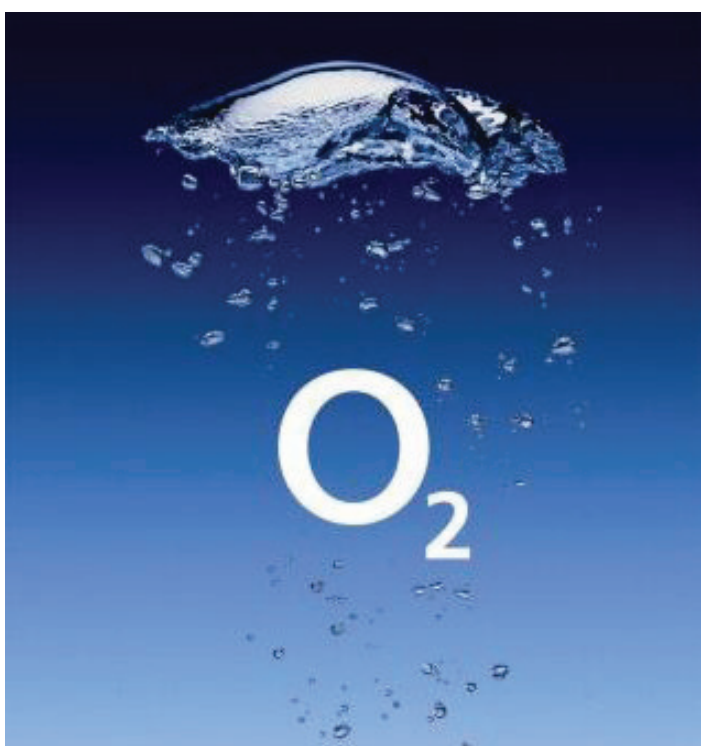


The biological pump determines how much organic matter is exported to deeper waters



## Why is oxygen important?

- There is plenty of oxygen in the Southern Ocean, but in the tropics there are areas with little to no oxygen
- In these oxygen minimum zones (OMZs) some marine organisms cannot survive and biogeochemical cycles are different from in oxygenated waters
  - » Denitrification and the production of  $N_2O$ , a powerful greenhouse gas, occur in OMZs
  - » OMZ biogeochemistry may influence the global climate system
- OMZs are predicted to become larger in the future, but are not fully understood



In combination these processes make the Southern Ocean an important driver of global biogeochemical cycles

- Previous studies have shown that the efficiency of the biological pump in the Southern Ocean plays an important role in global C, N, P and Si cycles

## Does the Southern Ocean play a role in global marine oxygen cycling?

- Polar oceans play an important role in the air-sea flux of oxygen
- Studies of other biogeochemical cycles suggest that the Southern Ocean may play an important role, but to our knowledge no focused studies have investigated the specific role that the Southern Ocean plays in global marine  $O_2$  cycling

## Objective

- To investigate how Southern Ocean biology and the efficiency of the biological pump influence global oxygen concentrations and tropical oxygen minimum zones

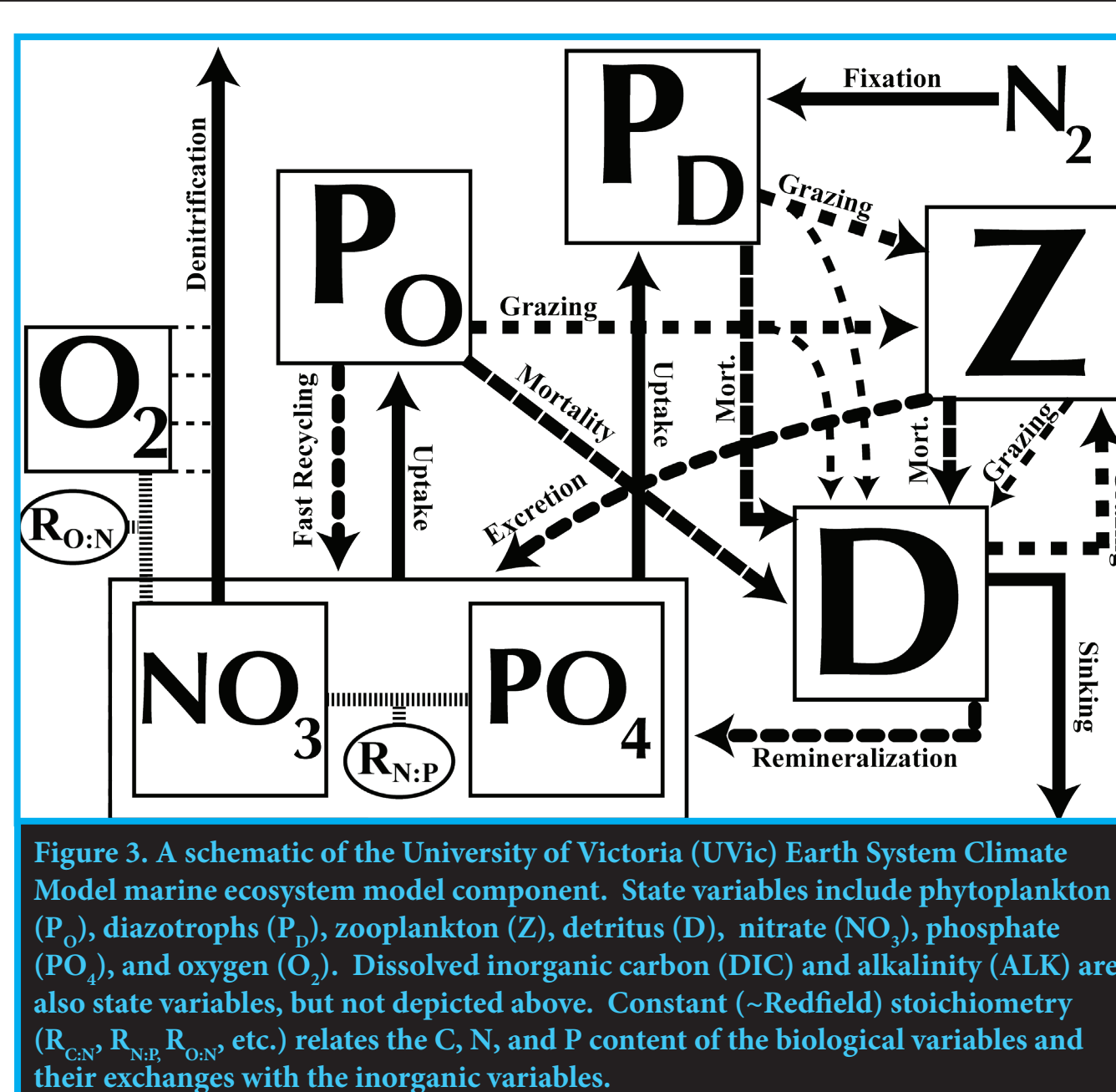
## Modelling Experiment

- Shut off biology and the biological pump south of  $40^\circ S$
- Compare how different models respond when run to steady-state

## Models

University of Victoria Earth System Climate Model (Eby et al., 2009; Keller et al., 2012)

- »  $1.8^\circ \times 3.6^\circ$  resolution, 19 ocean levels
- » Includes dynamic, coupled atmospheric, terrestrial, oceanic, and sea-ice components
- Ocean physics: Modular Ocean Model (MOM) 2
- N-based marine ecosystem model that includes C, N, P, and O cycles

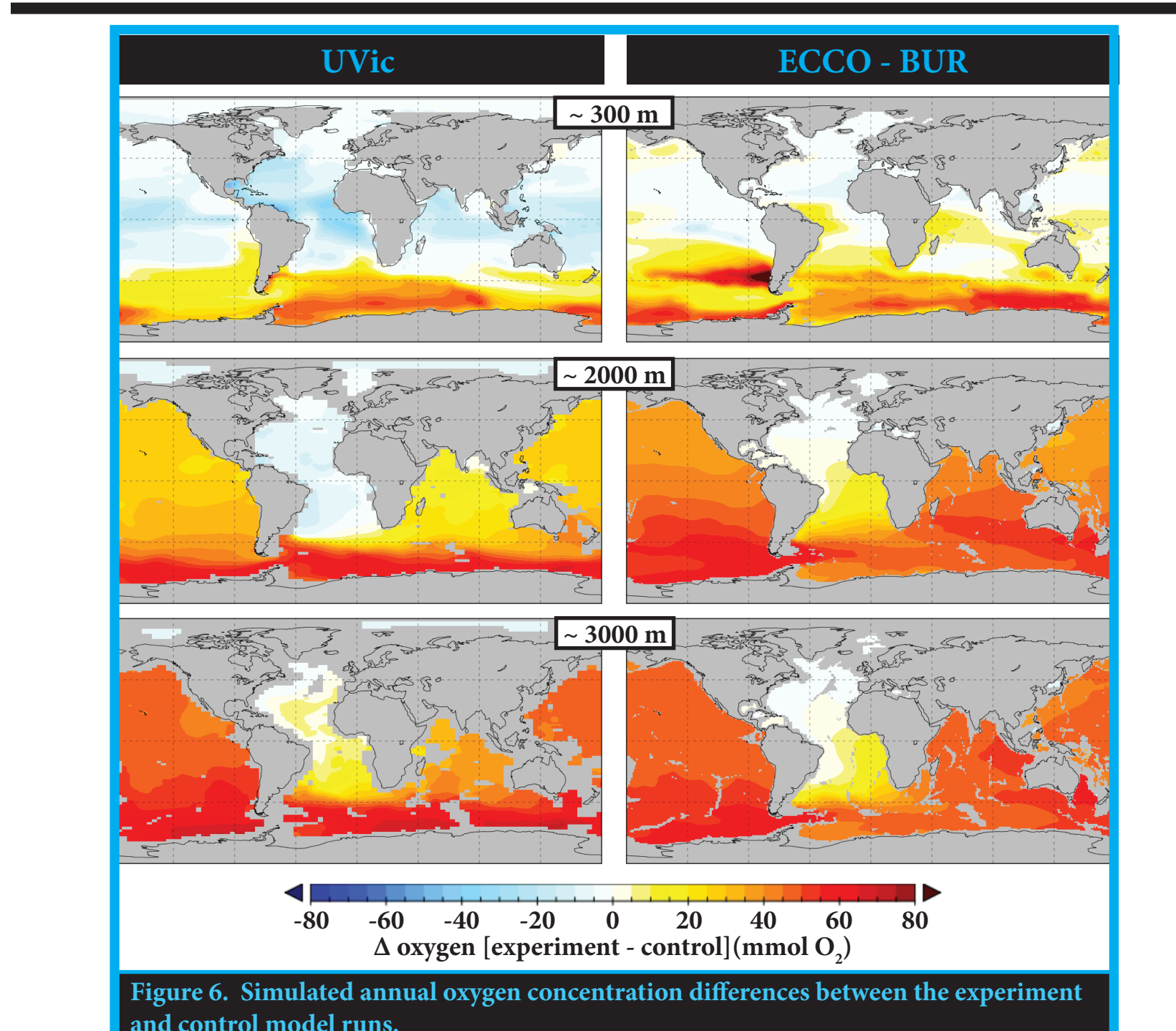
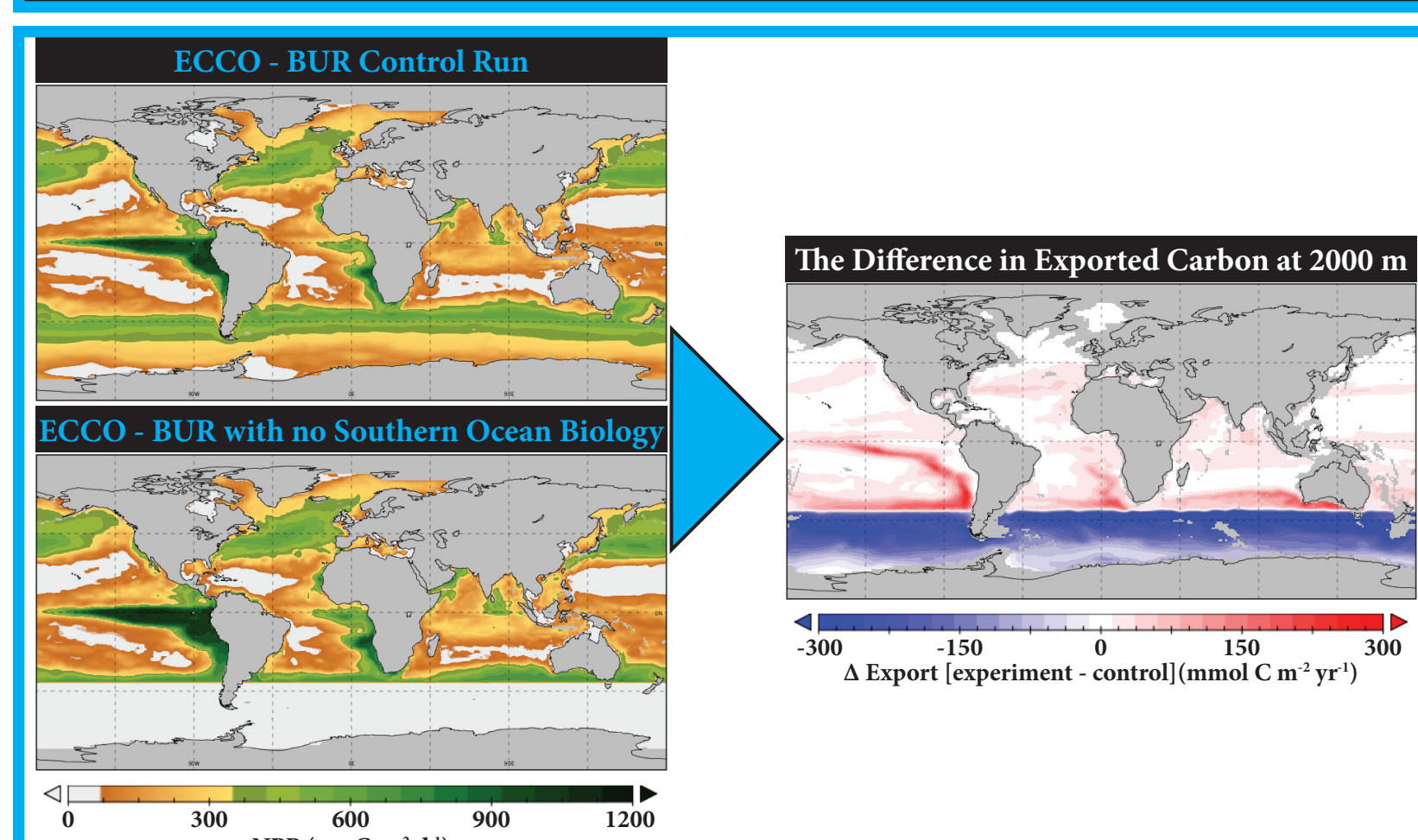
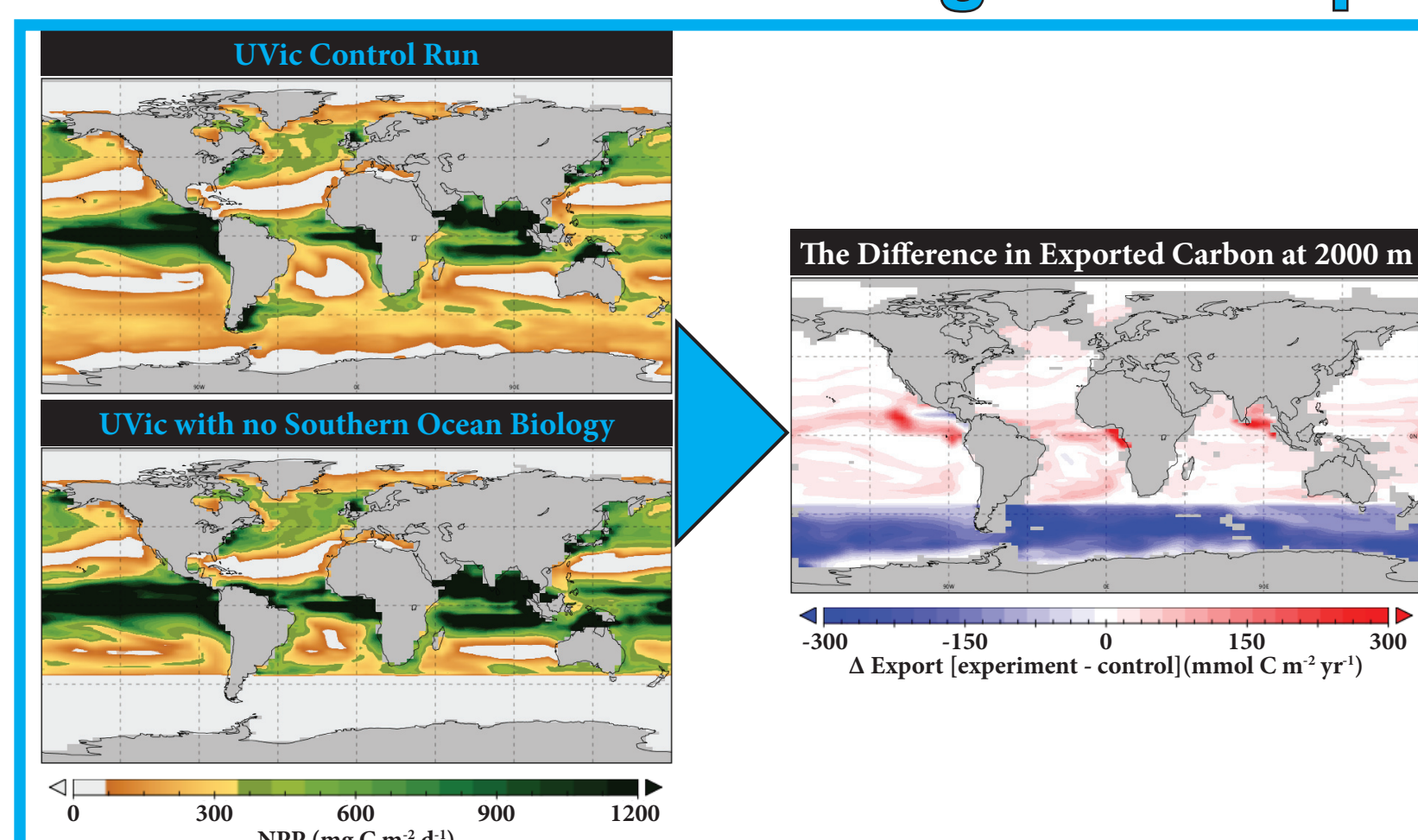


ECCO-BUR Model (Kriest & Oschlies, 2013)

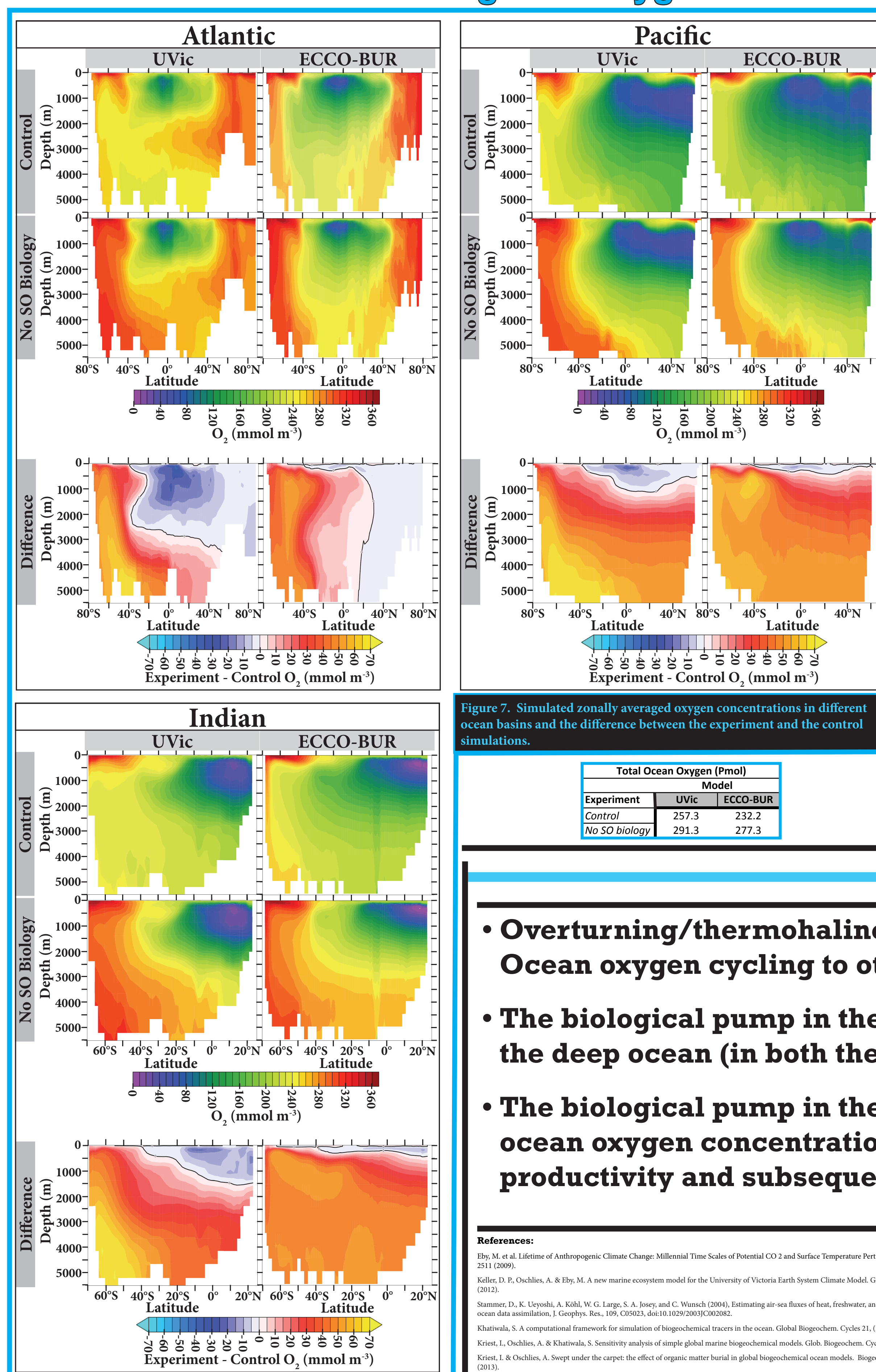
- »  $1^\circ \times 1^\circ$  resolution, 23 ocean levels
- » Transport Matrix Method derived ocean circulation field (Khatiwala, 2007)
- Ocean physics: data assimilated MIT GCM (Stammer et al., 2004)
- Phosphorus-based marine ecosystem model (Kriest et al., 2012) with benthic burial
- » State variables include  $PO_4$ , phytoplankton, zooplankton, detritus, and dissolved organic phosphate (NPZD-DOP, where N=nutrient)

## Results

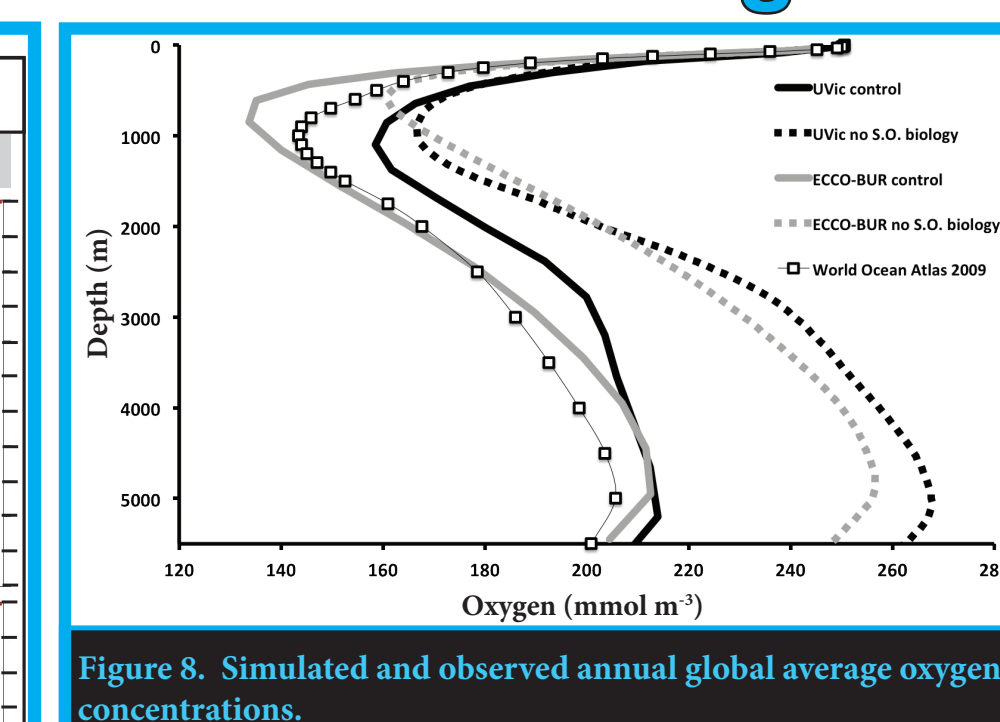
### Shutdown of the Biological Pump



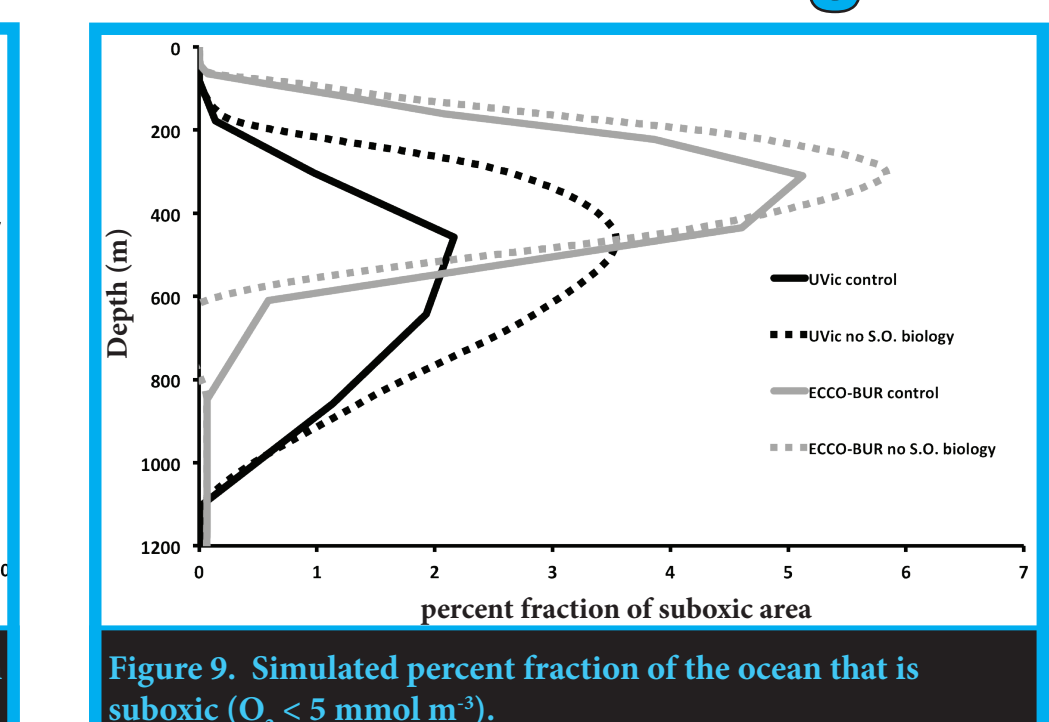
### Basin-Scale Changes in Oxygen



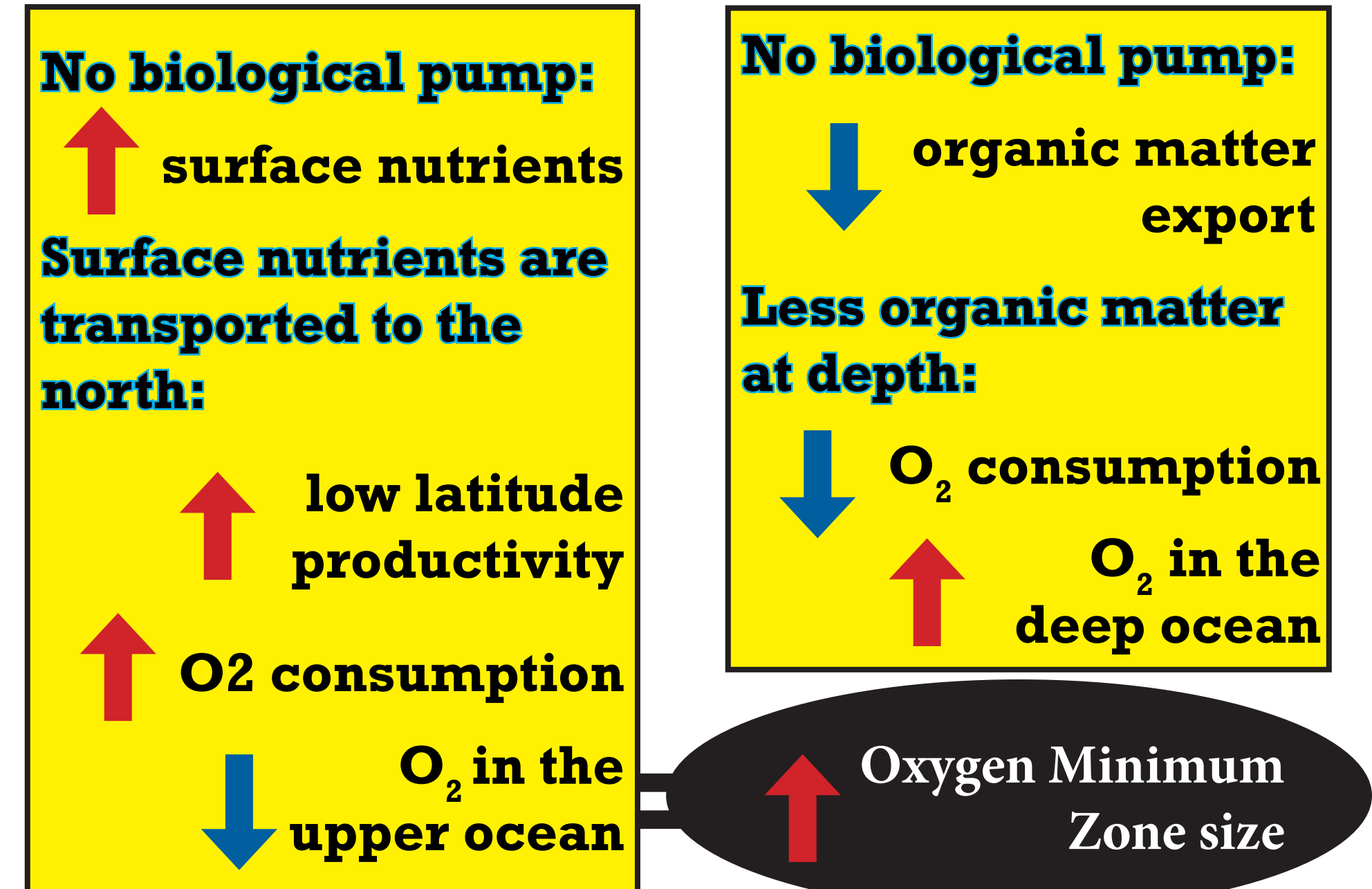
### Global Changes



### Suboxic Changes



Overturning/thermohaline circulation makes Southern Ocean biogeochemistry globally important



## Summary

- Overturning/thermohaline circulation transports the imprint of Southern Ocean oxygen cycling to other ocean basins
- The biological pump in the Southern Ocean reduces oxygen concentrations in the deep ocean (in both the Southern Ocean and other ocean basins)
- The biological pump in the Southern Ocean affects mid- to low-latitude upper ocean oxygen concentrations by trapping nutrients that would otherwise fuel productivity and subsequently reduce oxygen in these regions

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