Representation of Oxygen Minimum Zones in NEMO PISCES. Comparison with WOA and UVic

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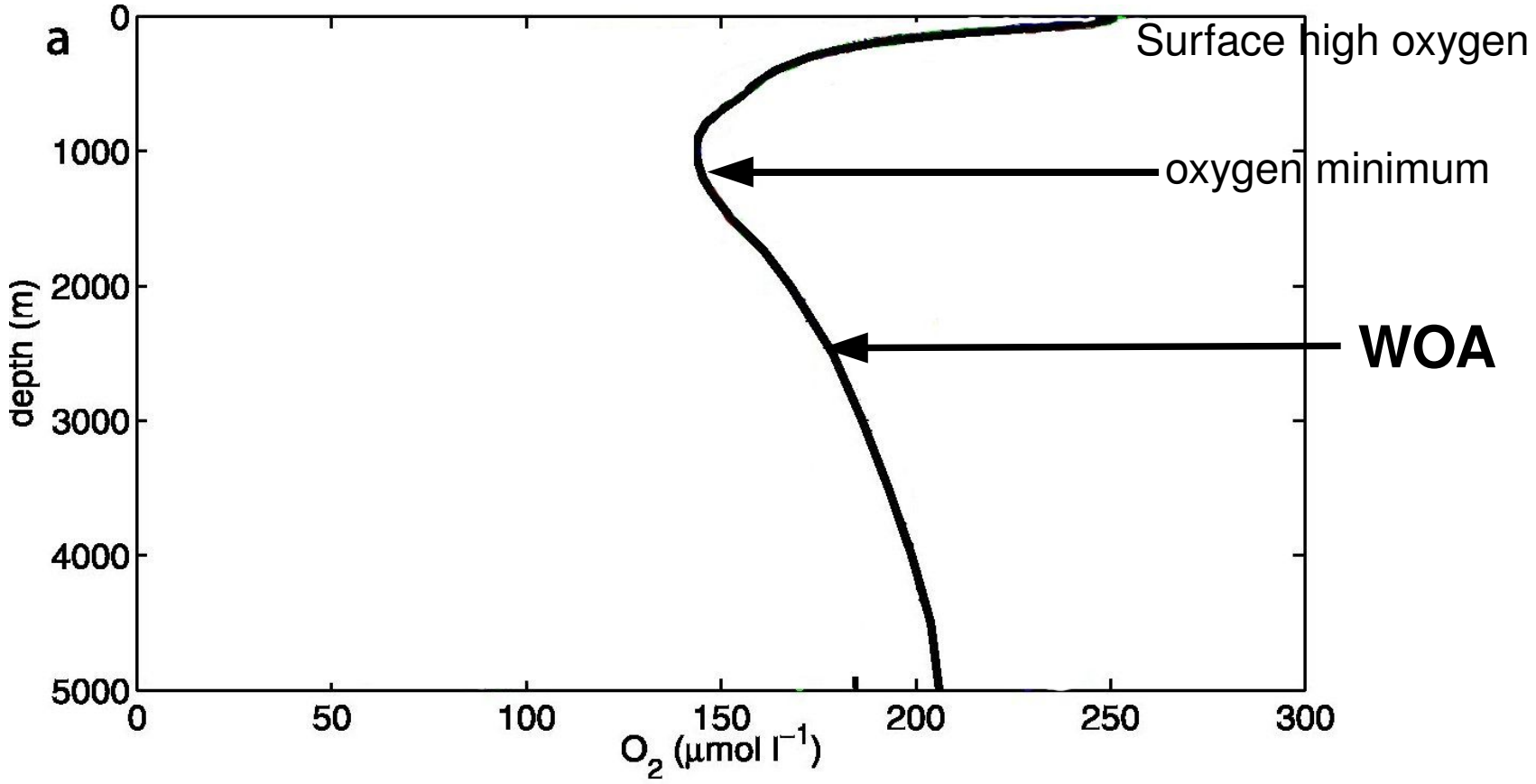
What are OMZs ?

OMZ: regions presenting low oxygen values
located at intermediate depth of tropical oceans

-> poor ventilation

-> high export production

-> likely to increase under global warming (Stramma et al., 2008; Oschlies et al., 2008)



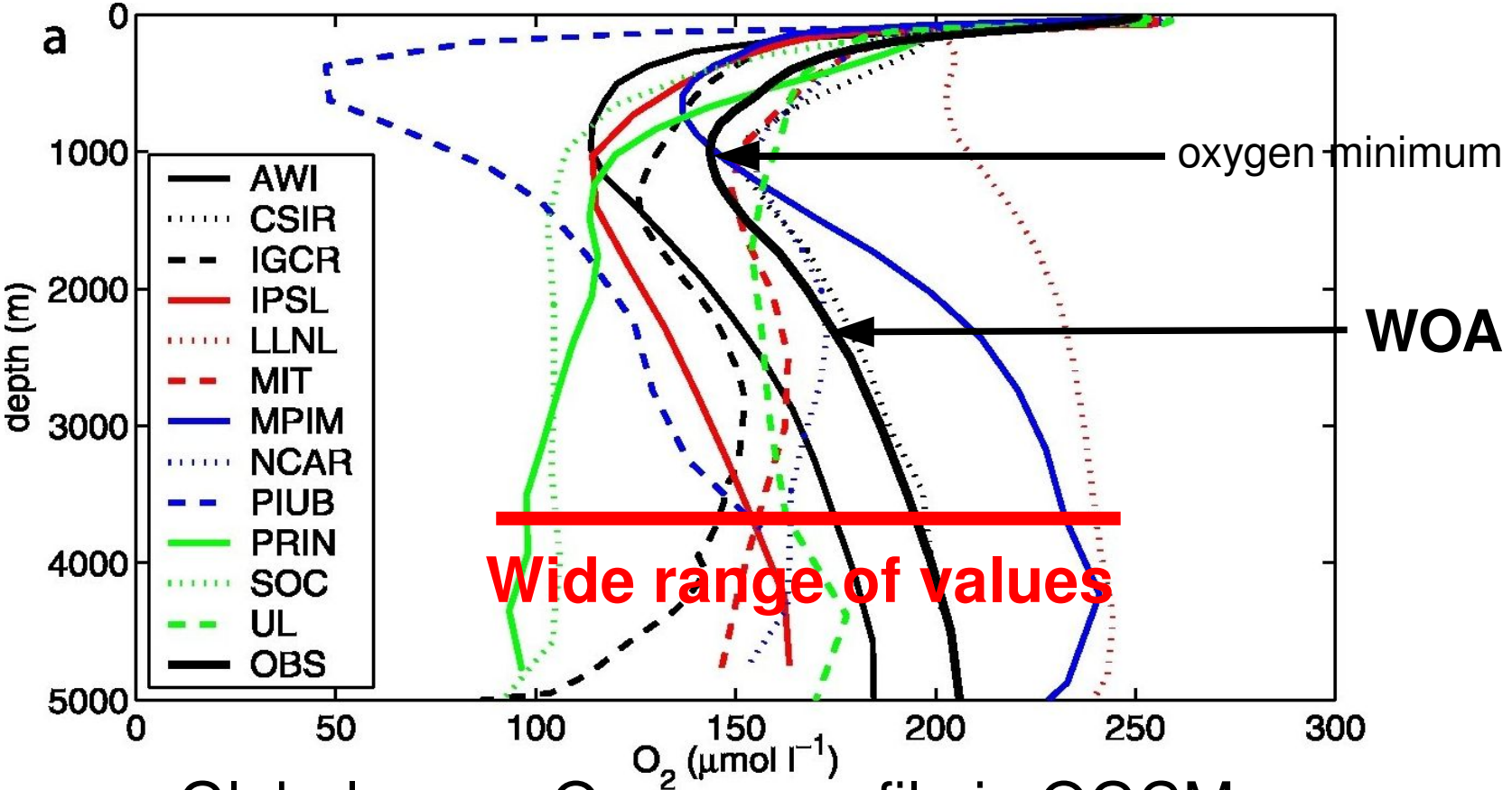
Global mean Oxygen profile

What are OMZs ?

-> need OGCMs to understand better OMZ formation and future evolution

-> but: not well represented in most OGCMs

(Matear et al, 2007)



Global mean Oxygen profile in OGCMs

Models overview

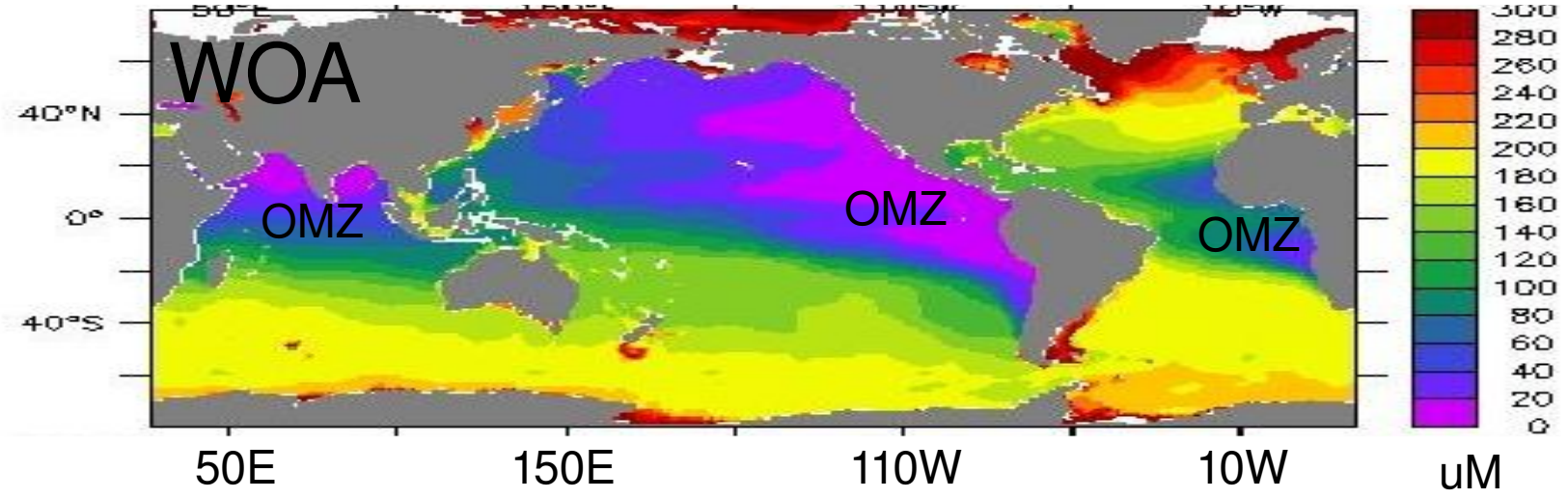
NEMO (ORCA2) PISCES

- 31 vertical levels
- horizontal resolution of 2 degrees with equatorial refinement
- forced by CLIO bulks
- coupled to PISCES model (24 compartiments)
- offline spinup of 3000 years starting from analytical initialisation
- configuration used by Bopp et al., 2006

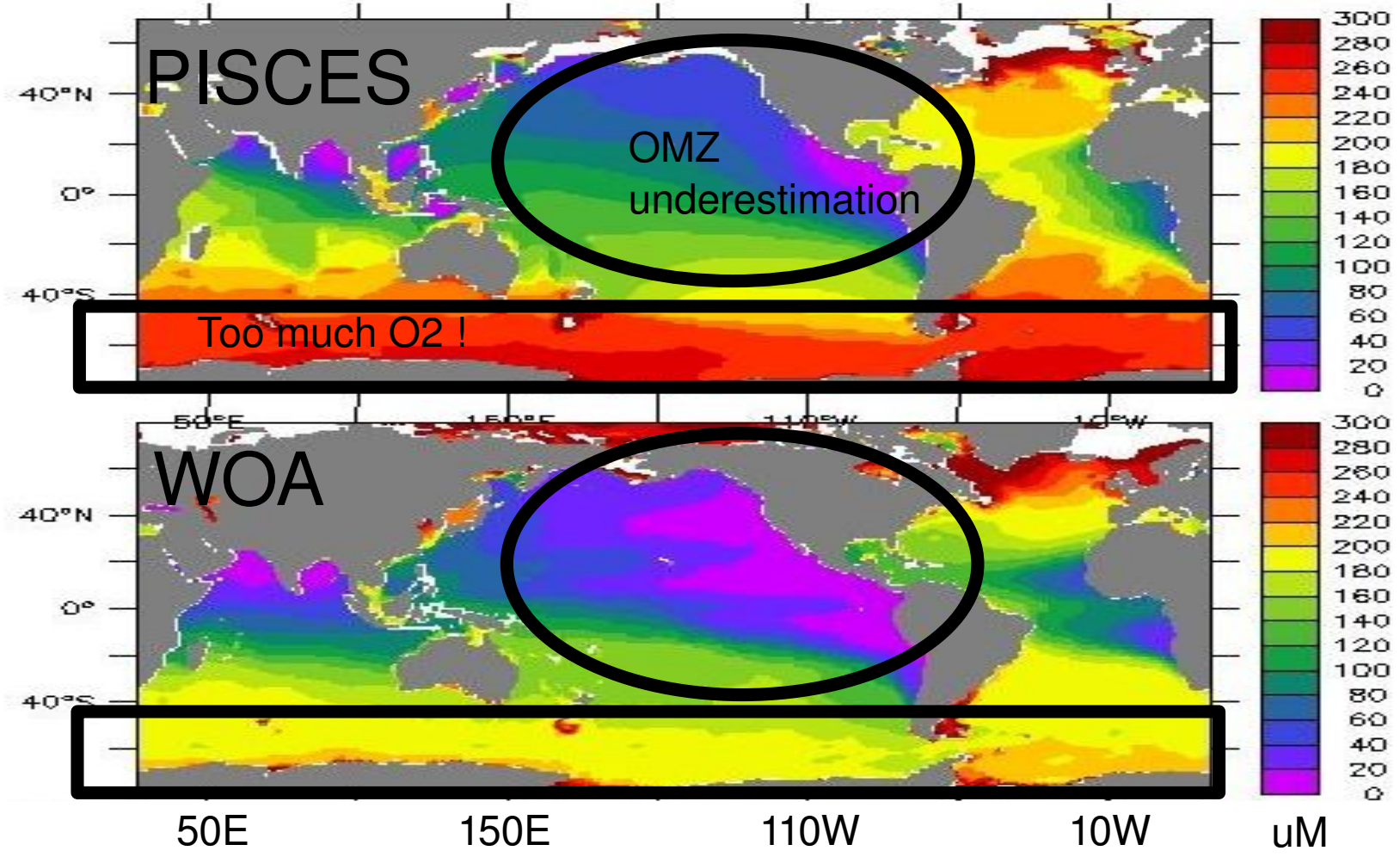
UVic

- based on MOM2 coupled with a one box atmosphere
- 19 vertical levels
- horizontal resolution of 4 * 2 degrees
- includes a land model
- coupled to a simple biogeochemical model: NPZD, DIC, O2, ALK
- spinup of 10000 years starting from analytical initialisation
- configuration used by Oschlies, 2008

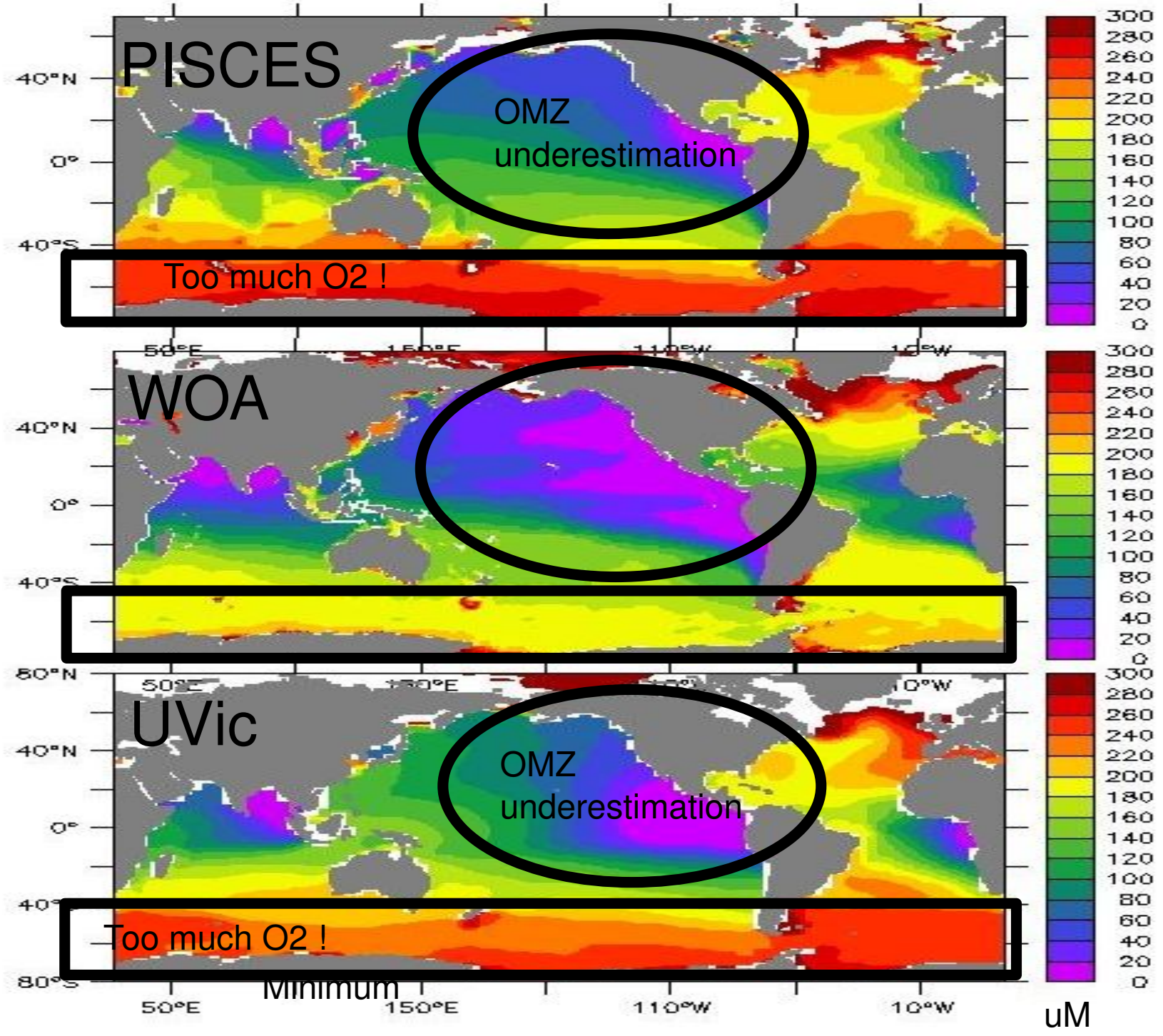
Oxygen distribution: minimum concentration



Oxygen distribution: minimum concentration

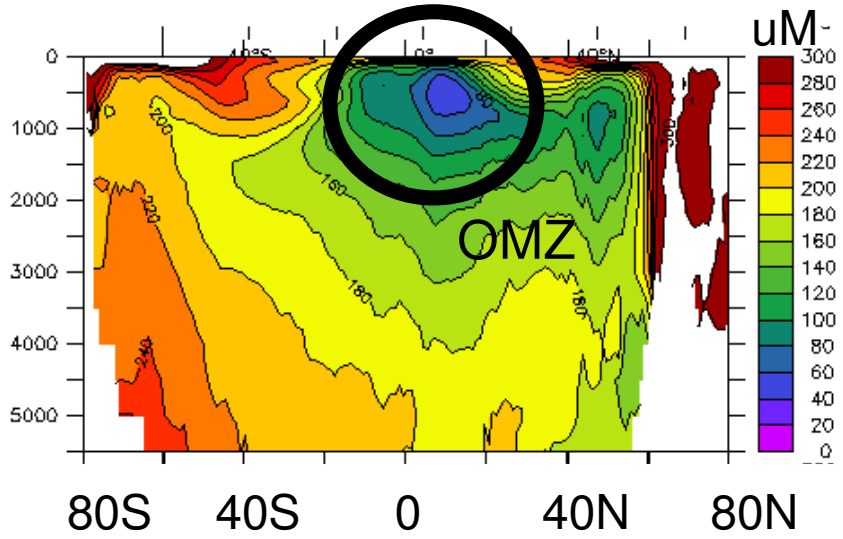


Oxygen distribution: minimum concentration



Oxygen distribution: zonal mean

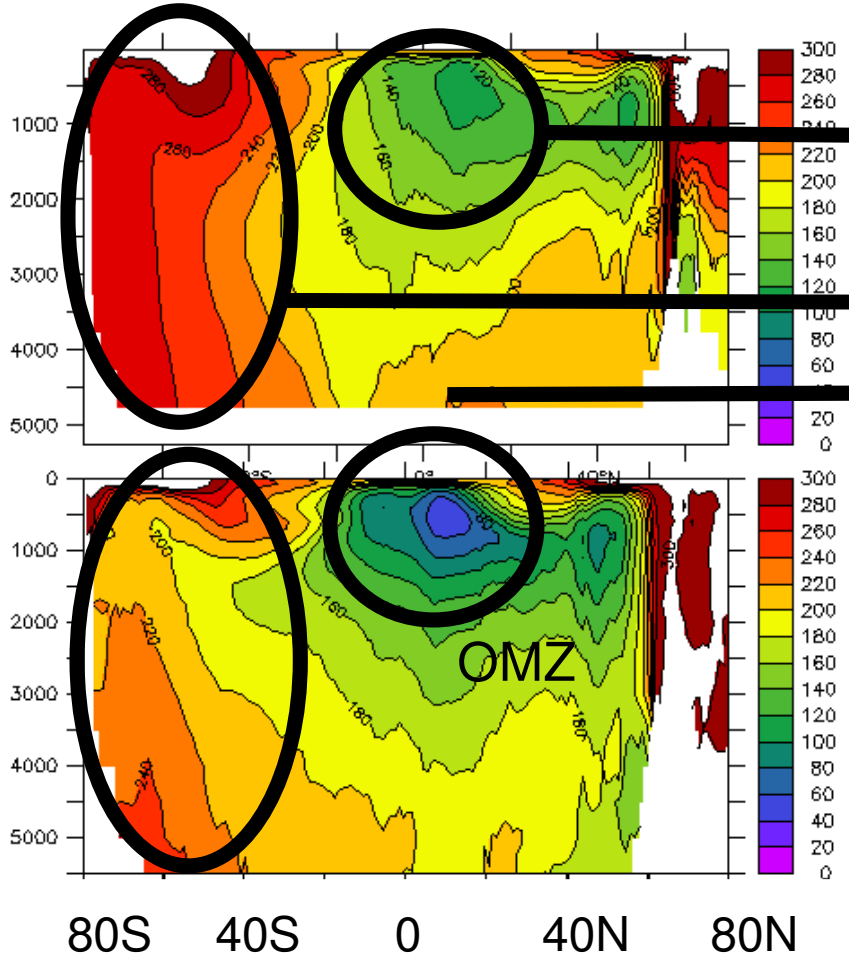
WOA



Oxygen distribution: zonal mean

PISCES

WOA



OMZ underestimation

O2 overestimation in Southern Ocean

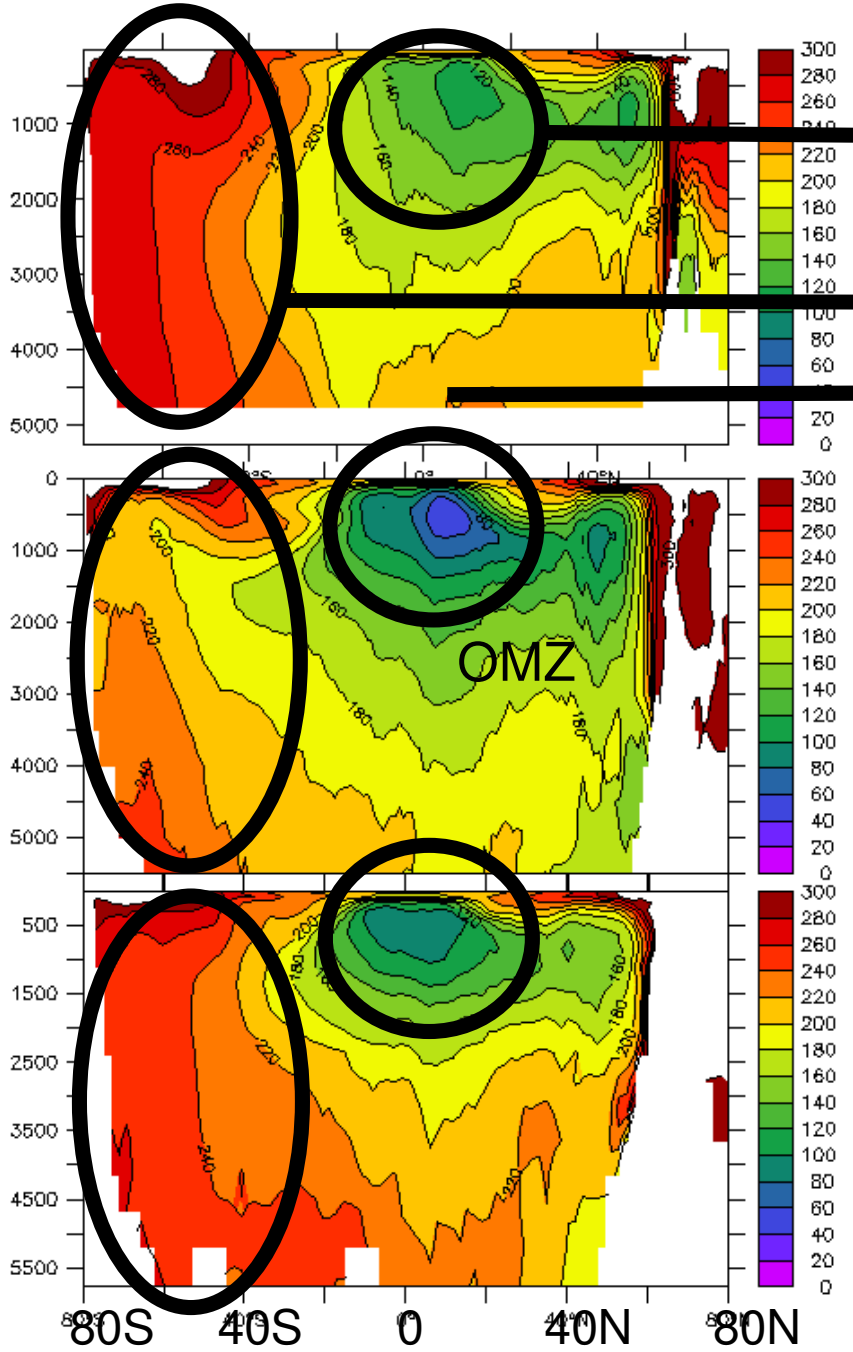
O2 overestimation at bottom

Oxygen distribution: zonal mean

PISCES

WOA

UVic



OMZ underestimation

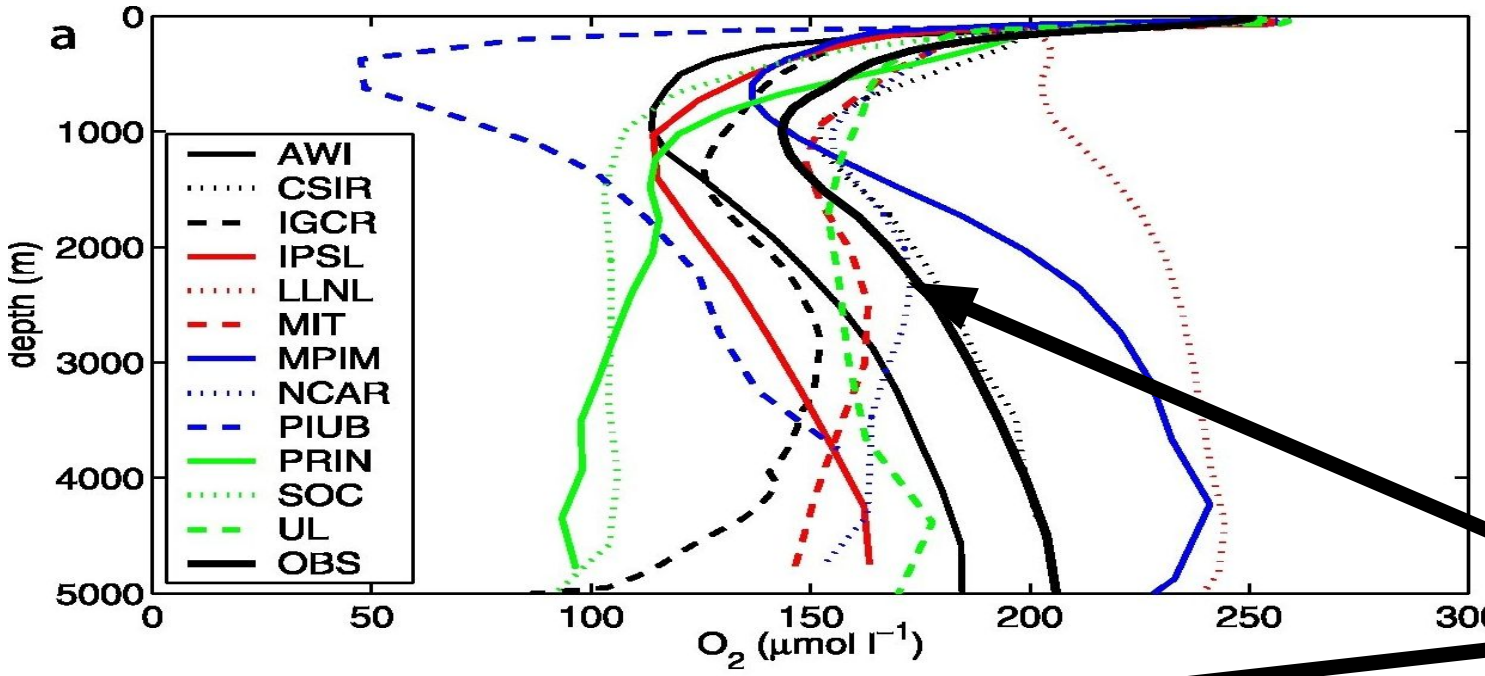
O2 overestimation in Southern Ocean

O2 overestimation at bottom

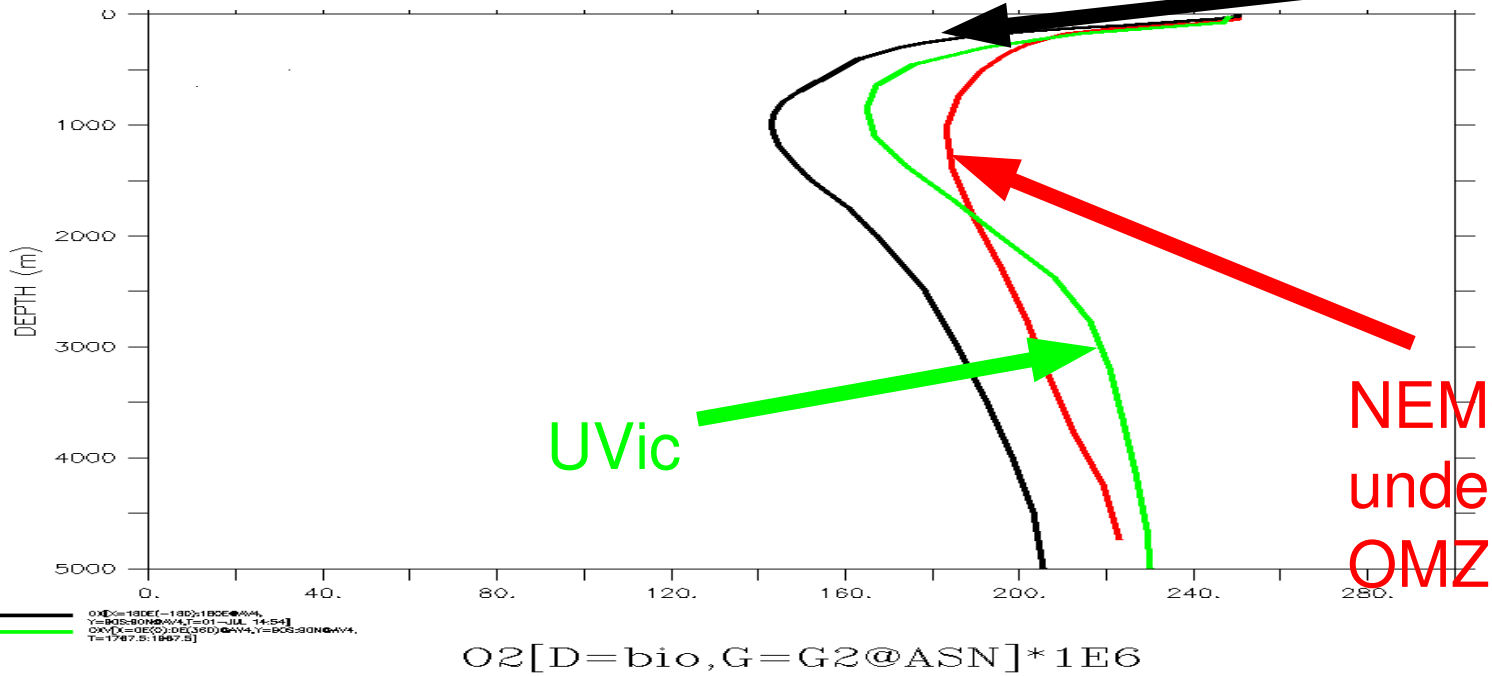
Same biases than in PISCES but
-better OMZ
-less O2 in Southern Ocean

Oxygen distribution: global mean

(Matear et al., 2007)



WOA



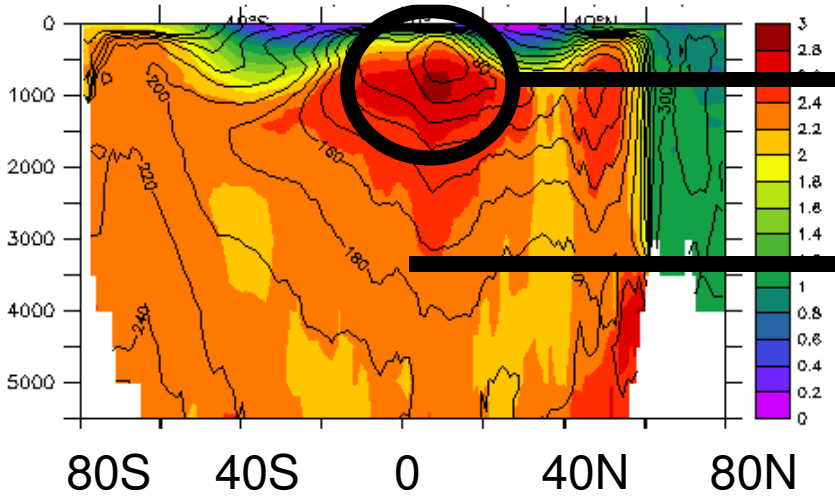
UVic

NEMO PISCES: underestimates OMZs

Phosphates distribution: zonal mean

$$(CH_2O)_{106}(NH_3)_{16}(H_3PO_4) + 138O_2 \underset{\text{Photosynthesis}}{\overset{\text{Respiration, decomposition}}{\rightleftarrows}} 106CO_2 + 16HNO_3 + H_3PO_4 + 122H_2O$$

WOA



PO4 maximum

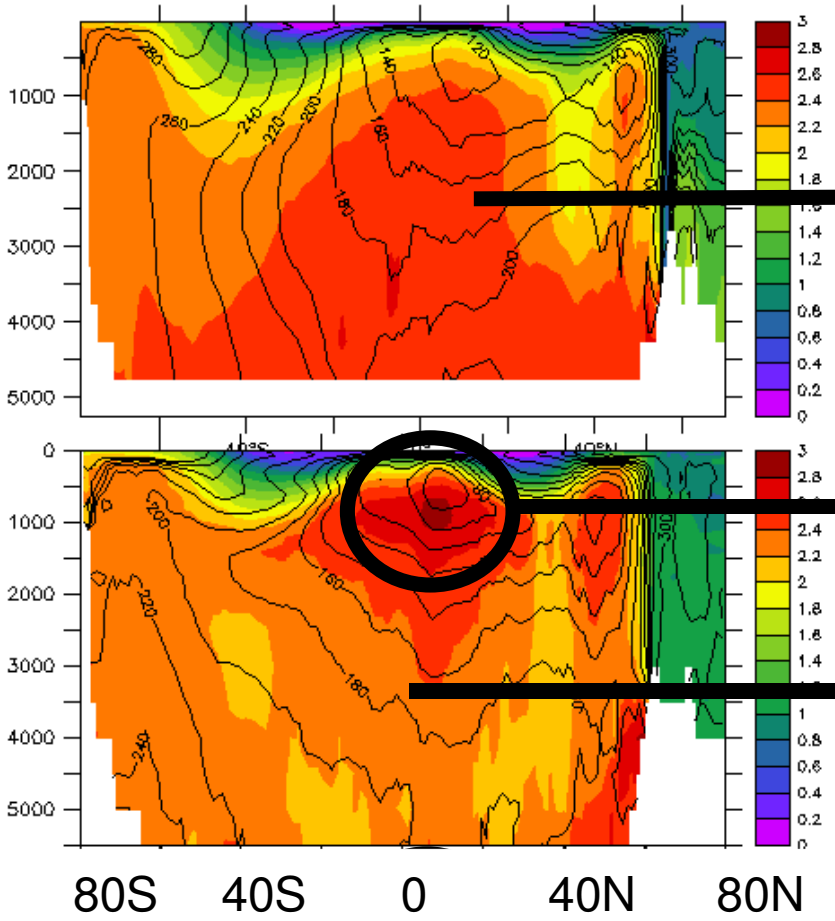
- remineralisation = oxygen consumption

Less PO4 in ocean interior

Phosphates distribution: zonal mean

PISCES

WOA



Too much PO4 at depth

- remineralisation rate too low ?
- particules sinking speed too fast ?
- not enough production ?
- mixing ?
- circulation (MOC) ?

PO4 maximum

- remineralisation = oxygen consumption

Less PO4 in ocean interior

Phosphates distribution: zonal mean

PISCES

WOA

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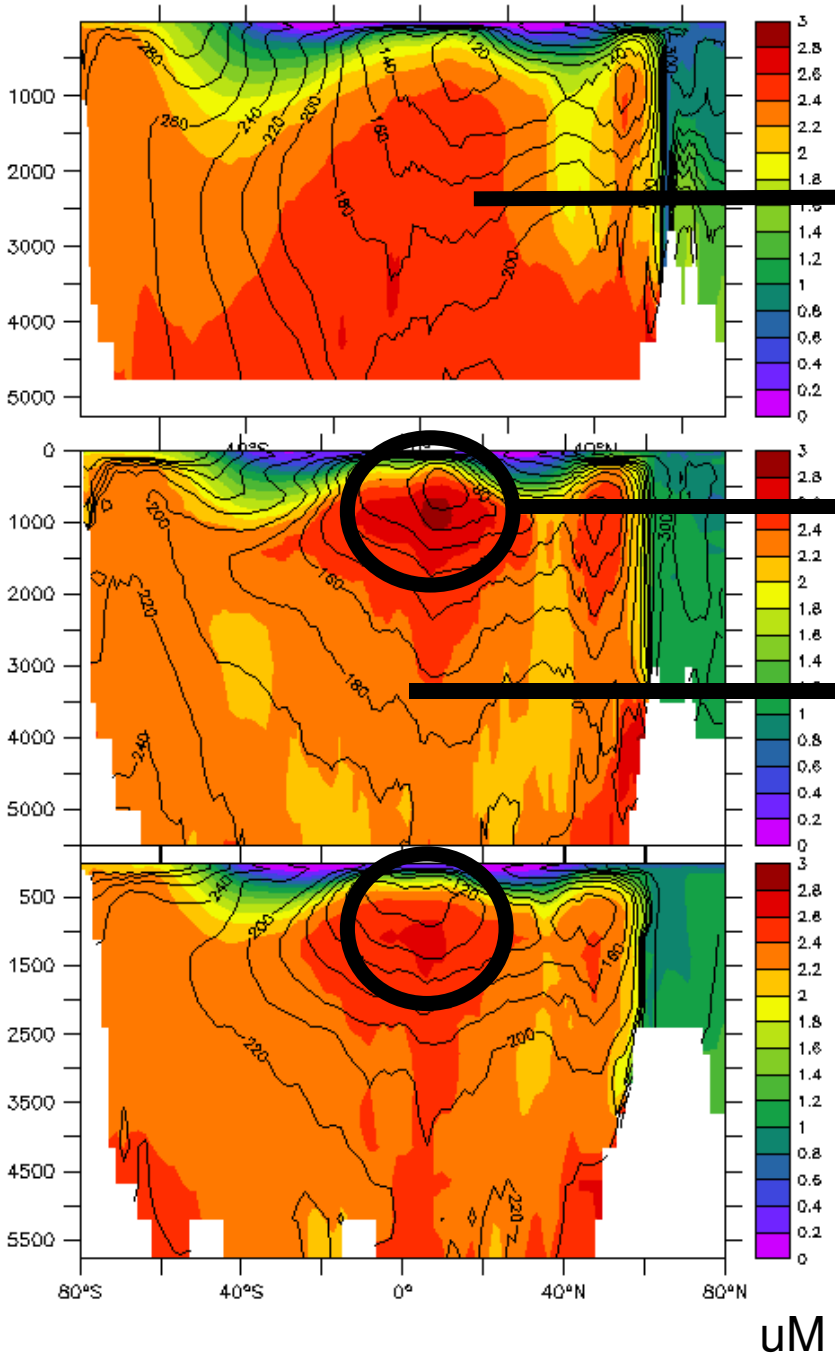

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PO4 maximum

- remineralisation = oxygen consumption

Less PO4 in ocean interior

Why is there so much difference between WOA / PISCES / Uvic ?

- **Is it due to the biogeochemical model ?**
  *Is remineralisation rate correct ? -> preformed and regenerated nutrients

- Is it caused by circulation ?
  *residence time -> Radiocarbon
  *MOC

Preformed nutrients: better assess biology / physics

$$X_{total} = X_{preformed} + X_{regenerated}$$

Unitilised nutrients are subducted in ocean interior during water formation

Fraction regenerated by respiration

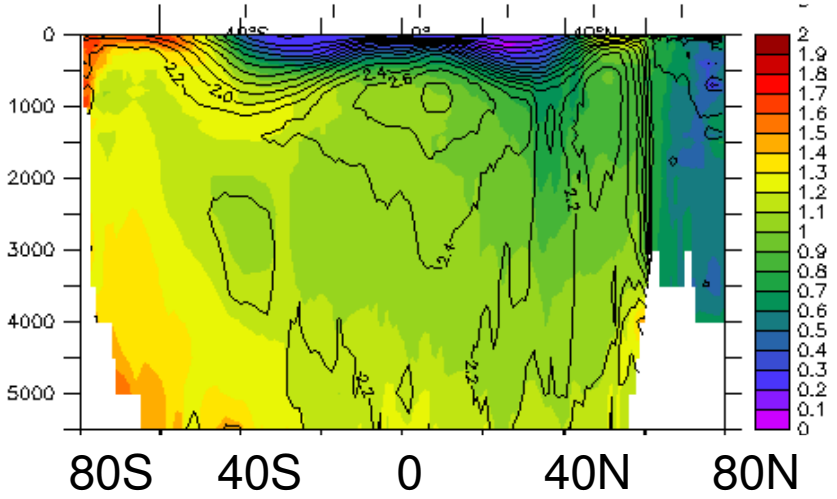
related to the surface concentration at the outcrop of isopycnals (Broecker et al., 1985)

$$X_{pref} = X_{tot} - Ratio\ X{:}O_2\ (O_{2sat} - O_2)$$

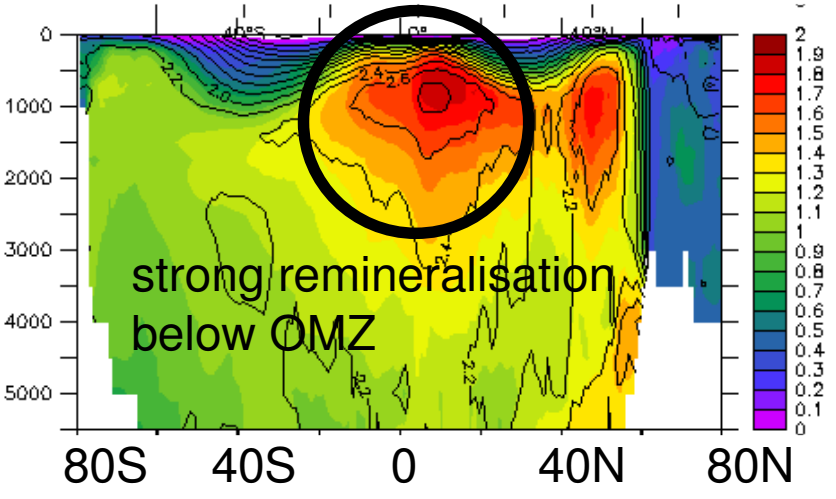
P:O2 = 135
N: O2 = 9
...

Preformed and regenerated phosphates: zonal mean

WOA



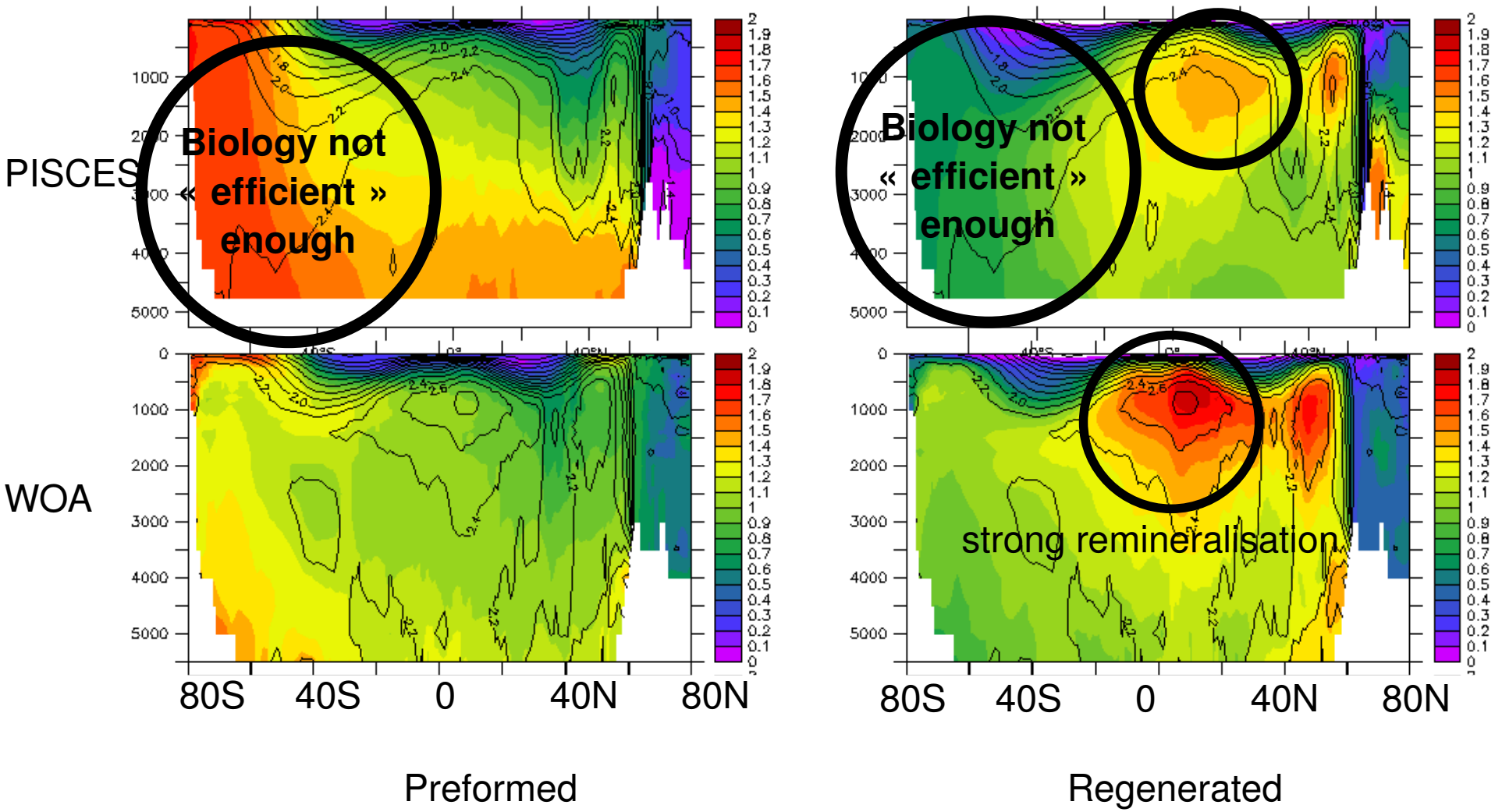
Preformed



Regenerated

uM

Preformed and regenerated phosphates: zonal mean

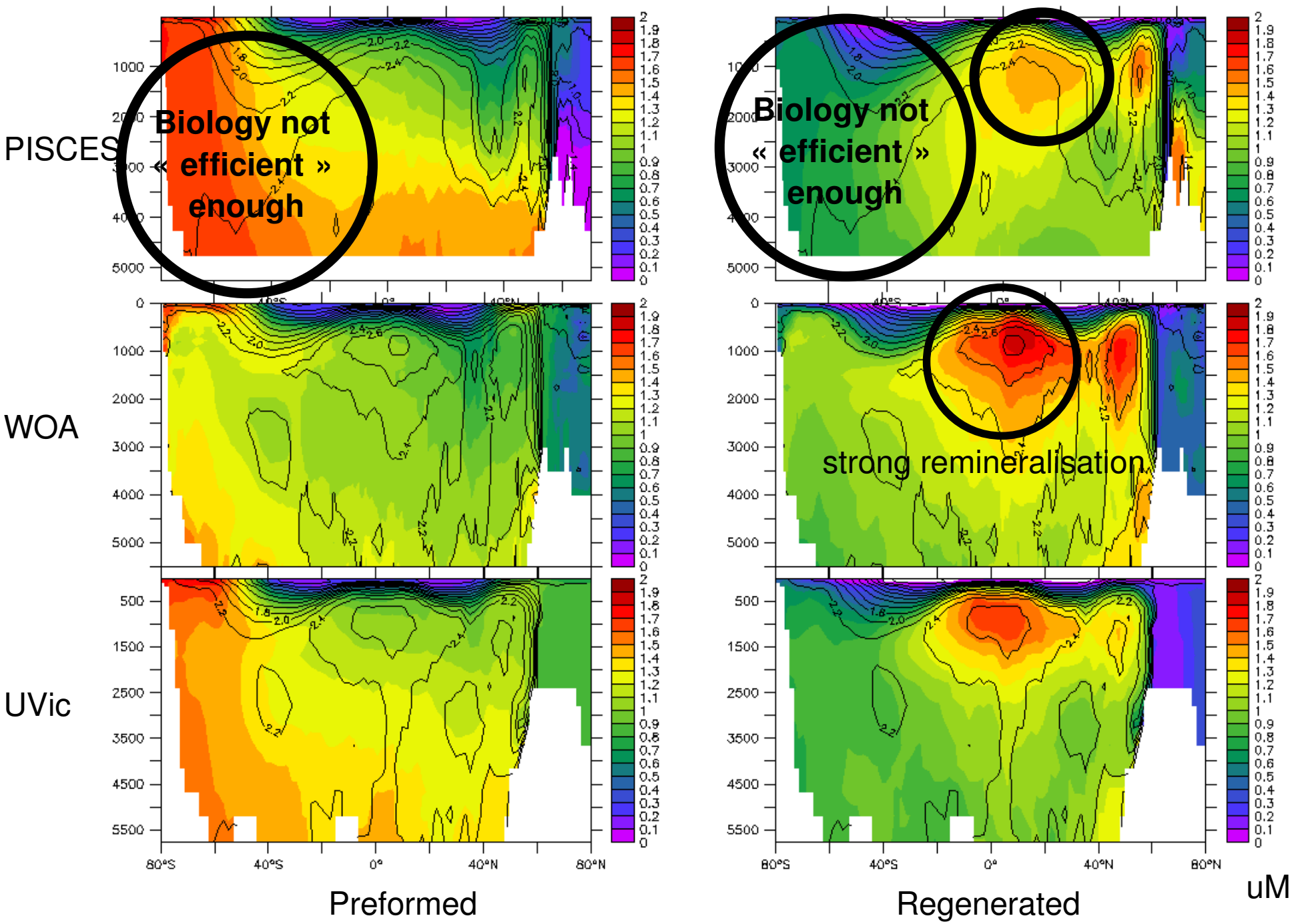


Biology not « efficient enough » : remineralisation too low

-> remineralisation rate too low in OMZ (Paulmier et al. 2006)

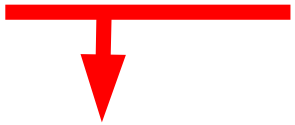
-> nutrient transport is too important (water residence time too low)

Preformed and regenerated phosphates: zonal mean



Radiocarbon

Surface: concentration of C14 equilibrate with atmosphere
Depth: radioactive decay



Measuring C14/C12 assess the water mass age till ventilation

Biases:
- emission of CO2 in atmosphere due to fossile combustion
- nuclear tests since 1950

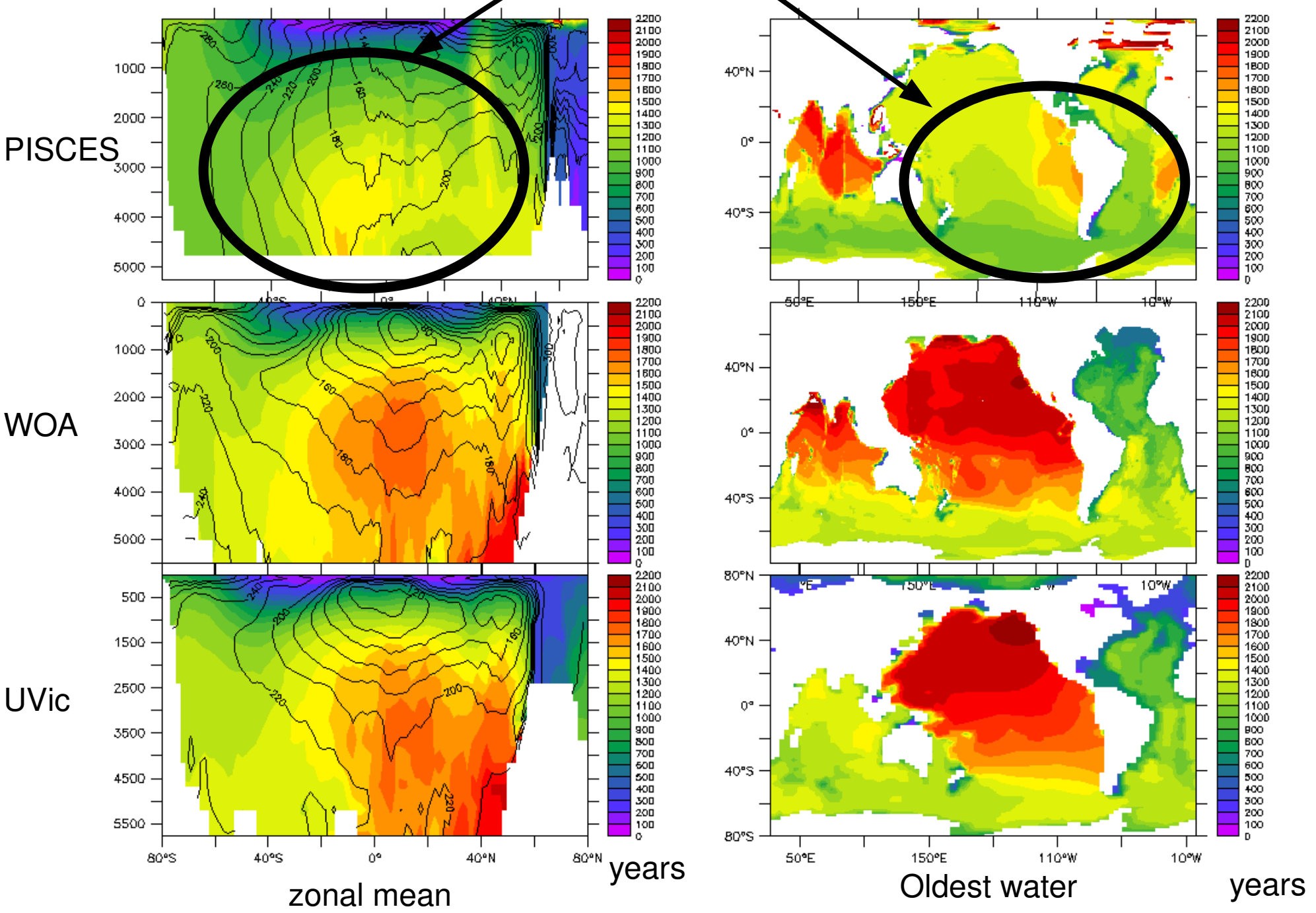
It is however possible to assess « natural » C14:

Natural C14 = -59 – 0.962 (PALK – 2320)
*PALK = (ALK + NO3) * 35 / S*

(Rubin and Key, 2001)

Residence time

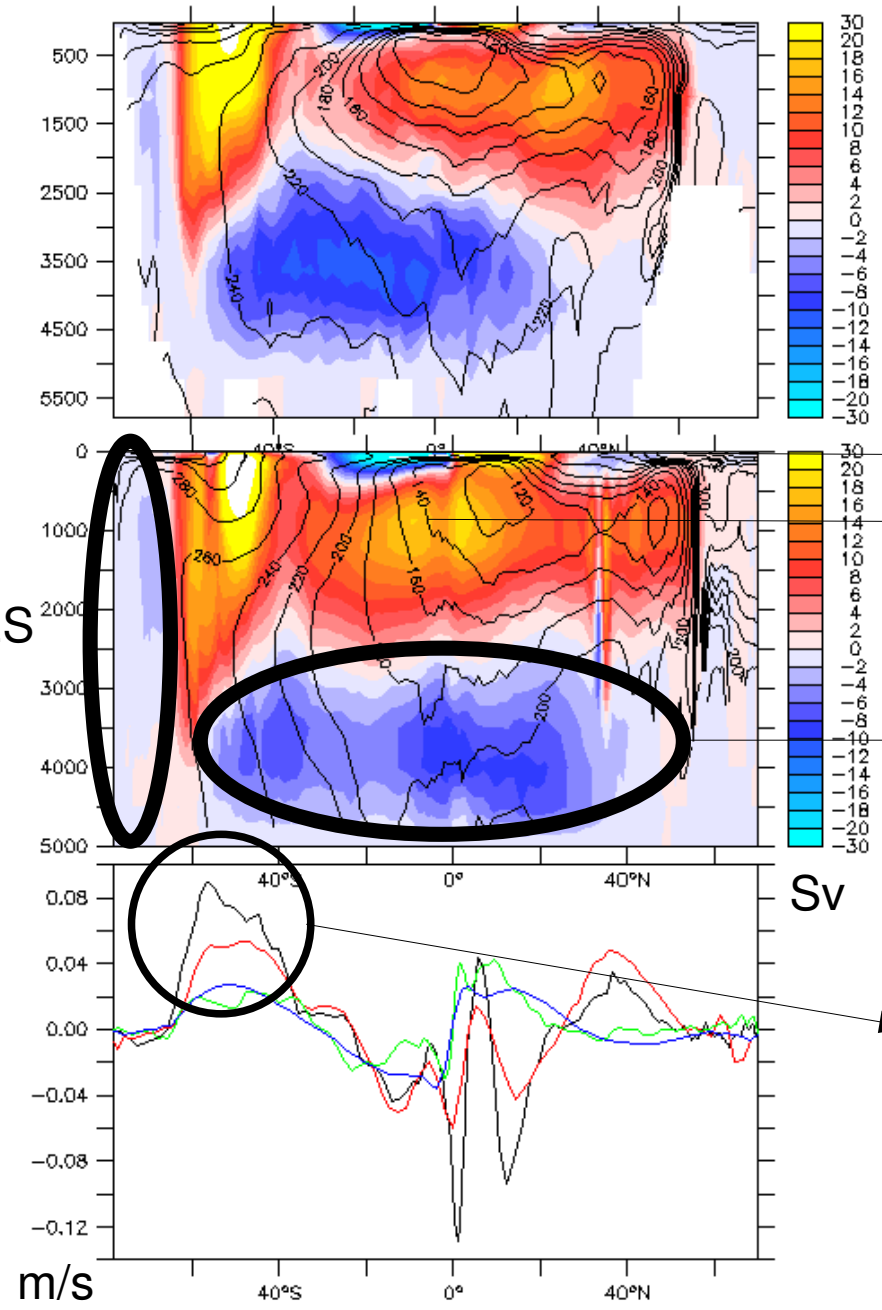
Water too young in
PISCES ! = MOC too fast ??



Possible explanation of difference Uvic / PISCES

UVic

PISCES



Downwelling too fast

Intense tropical ventilation (OMZ ?)
mixing too important ?

MOC lower recirculation is going much northward

Surface zonal velocities much important in PISCES than Uvic

- make some spinup using other forcing

Conclusions

- OMZ underestimated in PISCES

- Too much O2 in southern ocean in PISCES, Uvic

- PISCES water too young: ventilation too important

- sensibility tests : diffusivity ? C:N Redfield ratio ? Remineralisation rate ? Use of PO tracer to assess pathway between southern ocean / OMZ ?