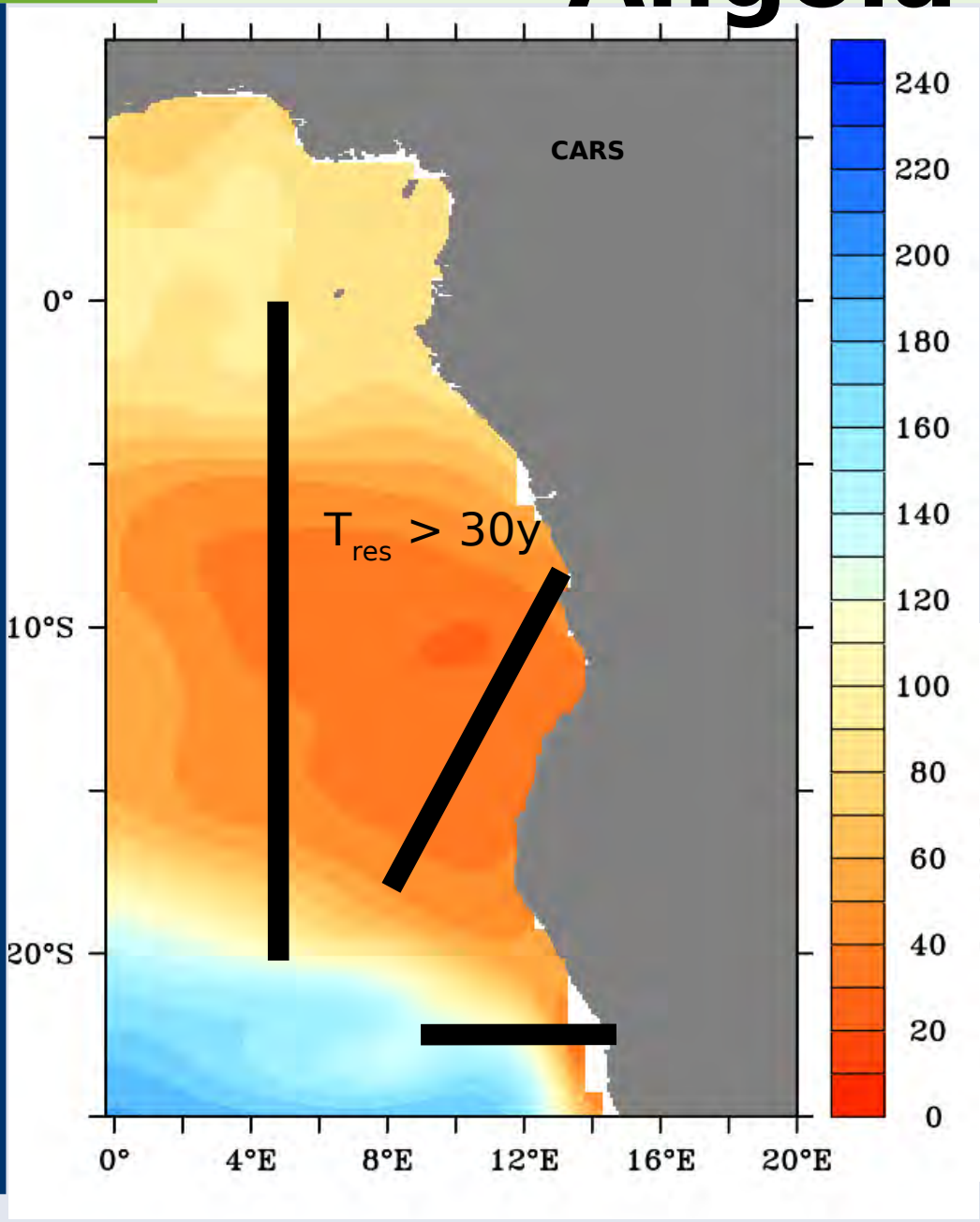
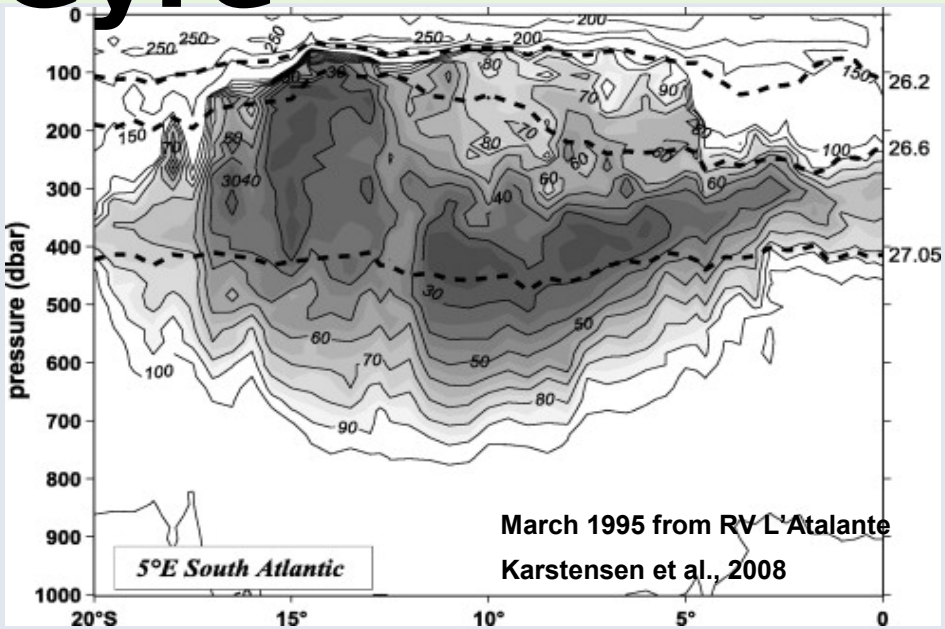
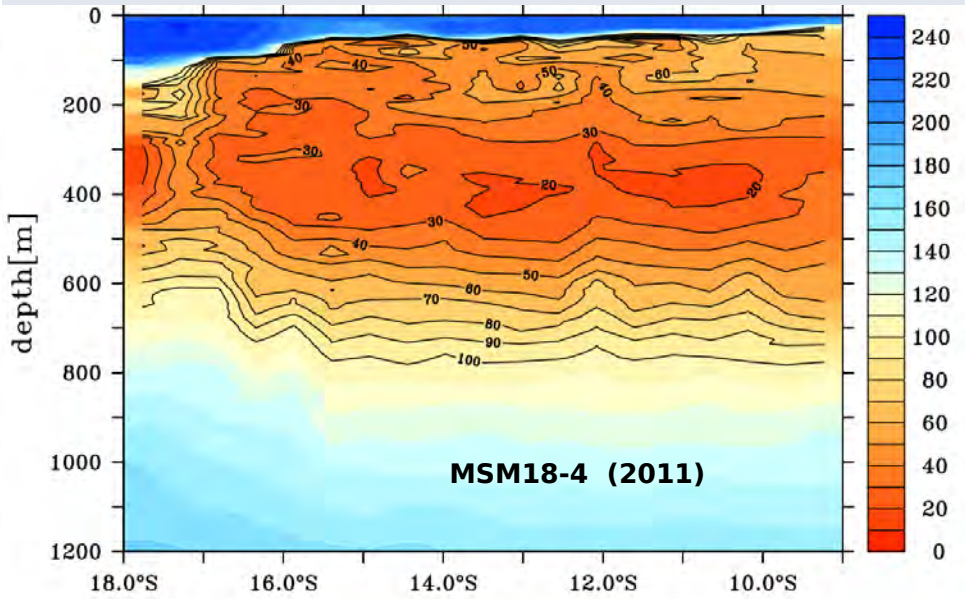
Is Zooplankton able to stabilize the oxygen content of oceanic oxygen minimum zones?

Martin Schmidt, Anja Eggert
Leibniz-Institute for Baltic Sea Research
Rostock-Warnemünde, Germany
Contributions from Tim Junker, Volker Mohrholz

Angola Gyre


CARS
T_{res} > 30y
0°
10°S
20°S
0°
4°E
8°E
12°E
16°E
20°E
240
220
200
180
160
140
120
100
80
60
40
20
0


pressure (dbar)
5°E South Atlantic
March 1995 from RV L'Atalante
Karstensen et al., 2008
26.2
26.6
27.05
20°S
15°
10°
5°
0

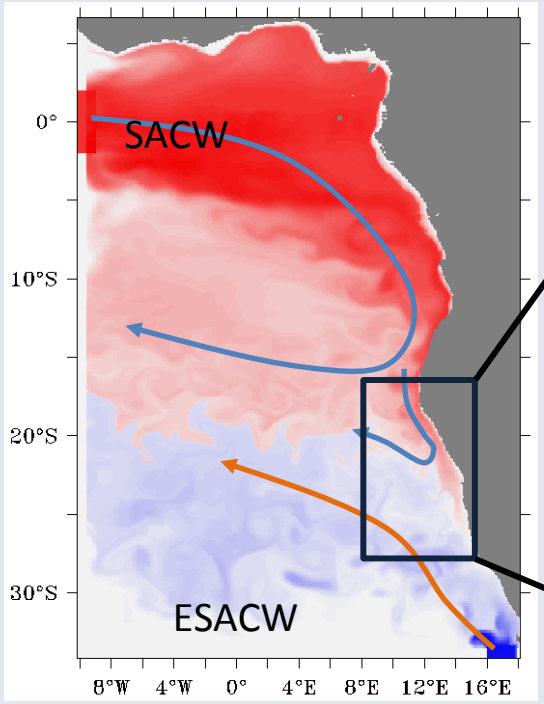

depth[m]
MSM18-4 (2011)
18.0°S
16.0°S
14.0°S
12.0°S
10.0°S

Convergence of SACW and ESACW in the Northern Benguela

SACW : high nutrients, low oxygen

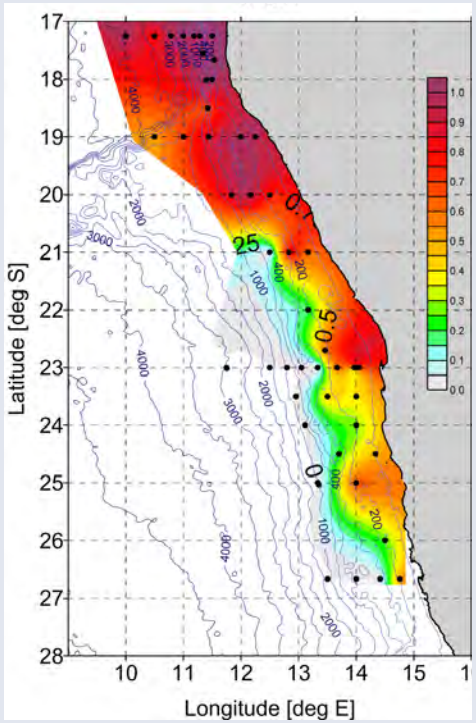
ESACW : low nutrients, high oxygen

Equator tracer (SACW)
Cape basin tracer (ESACW)



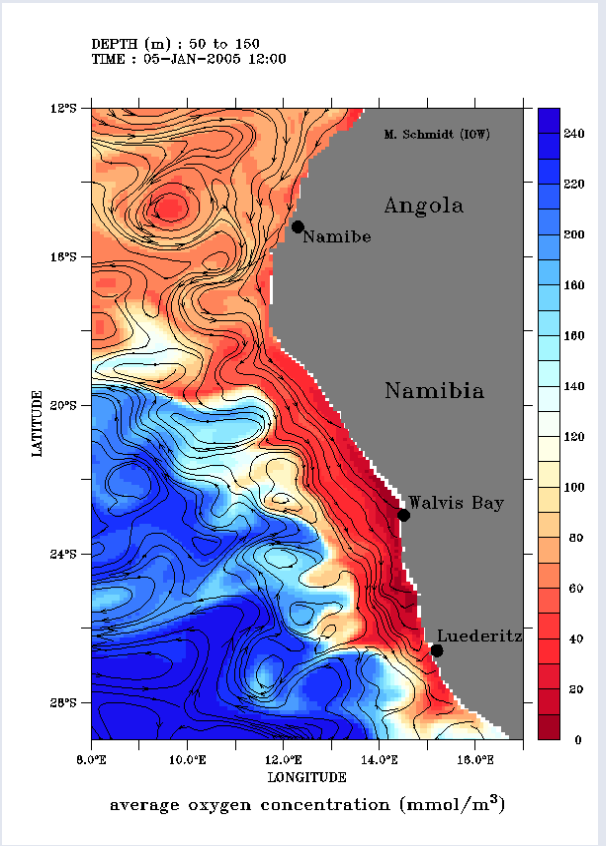
Tracer experiment with numerical model

SACW fraction
February 2011

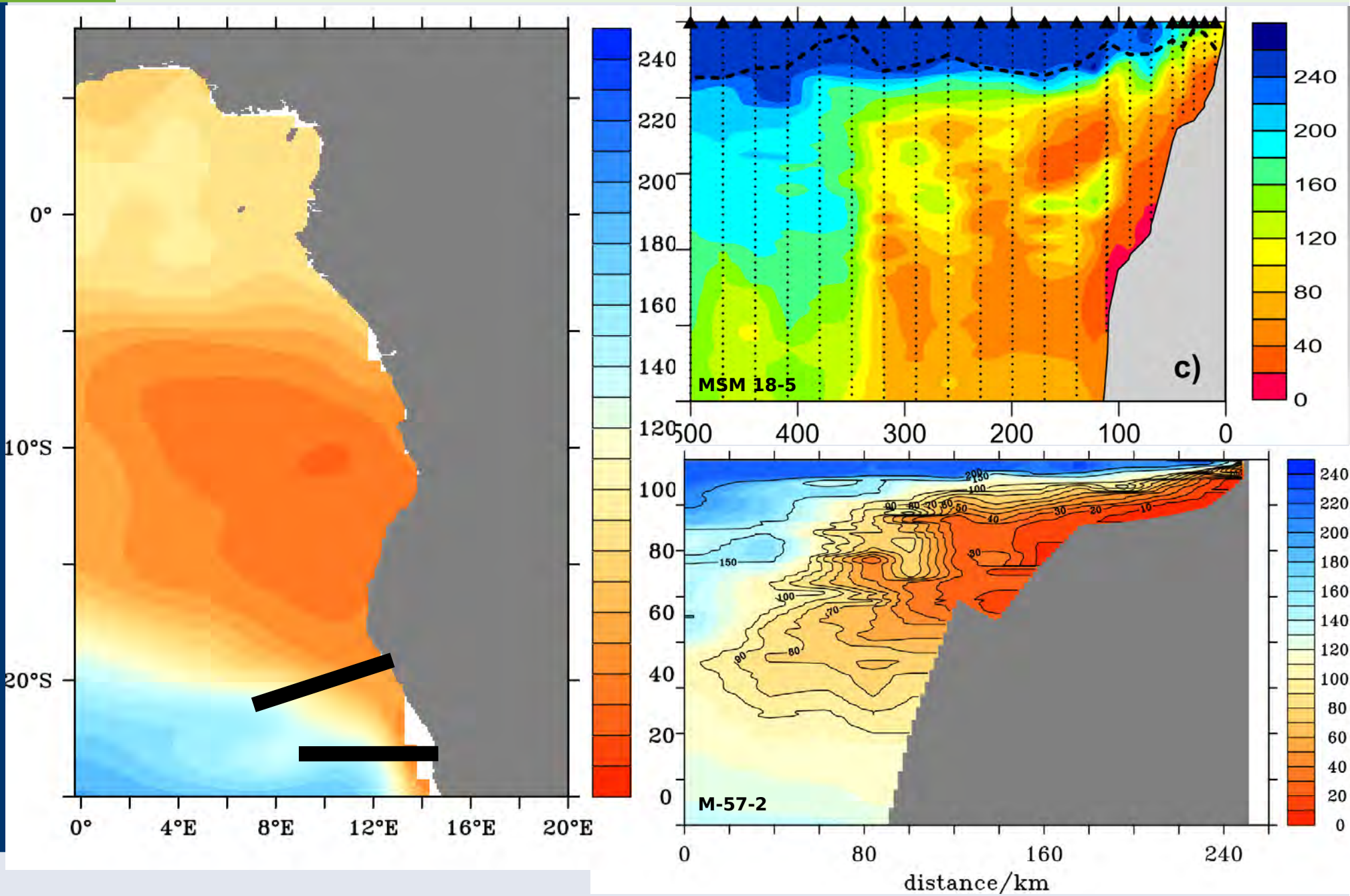


SACW fraction based on field data

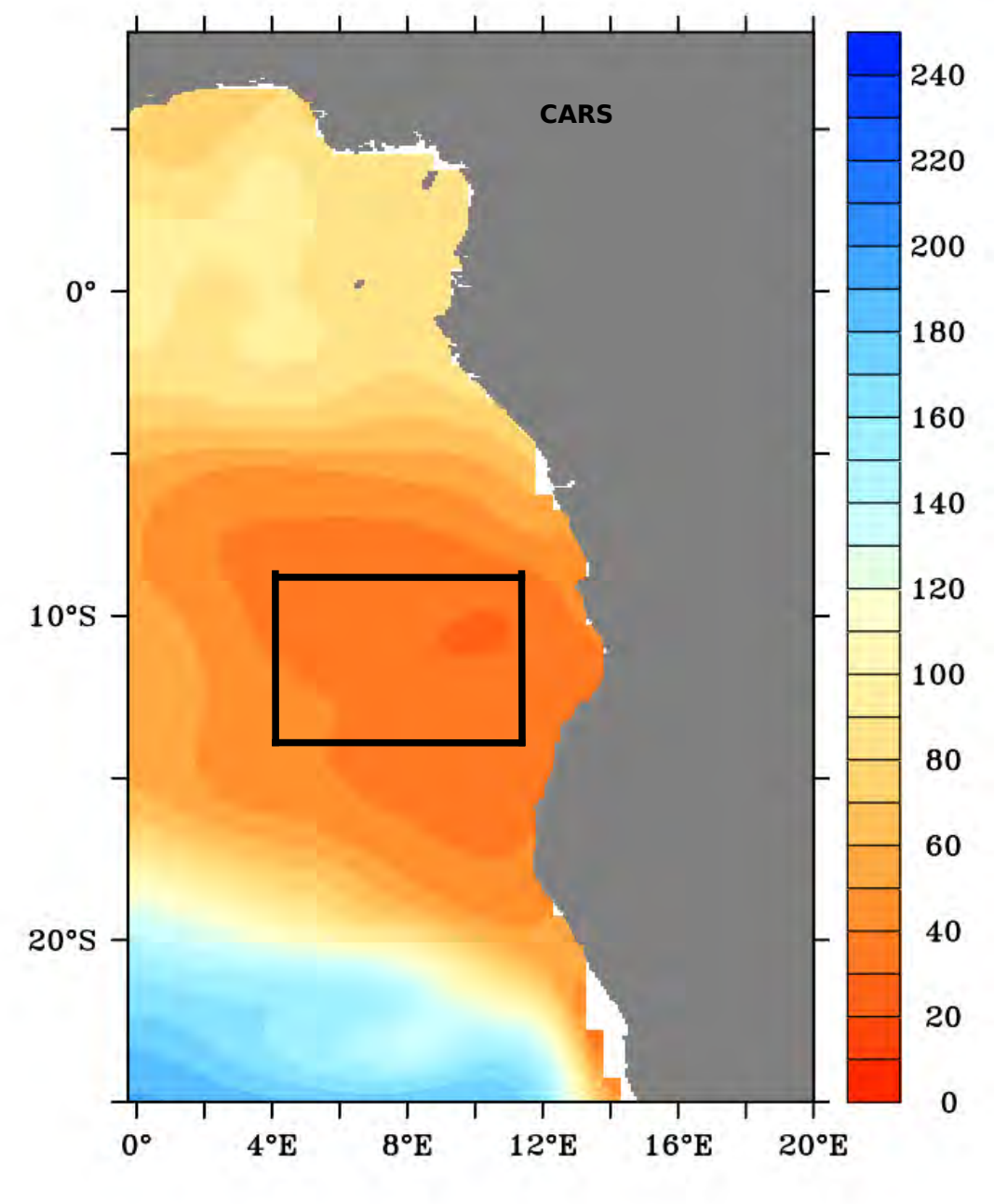
(Fennel et al., 2012)

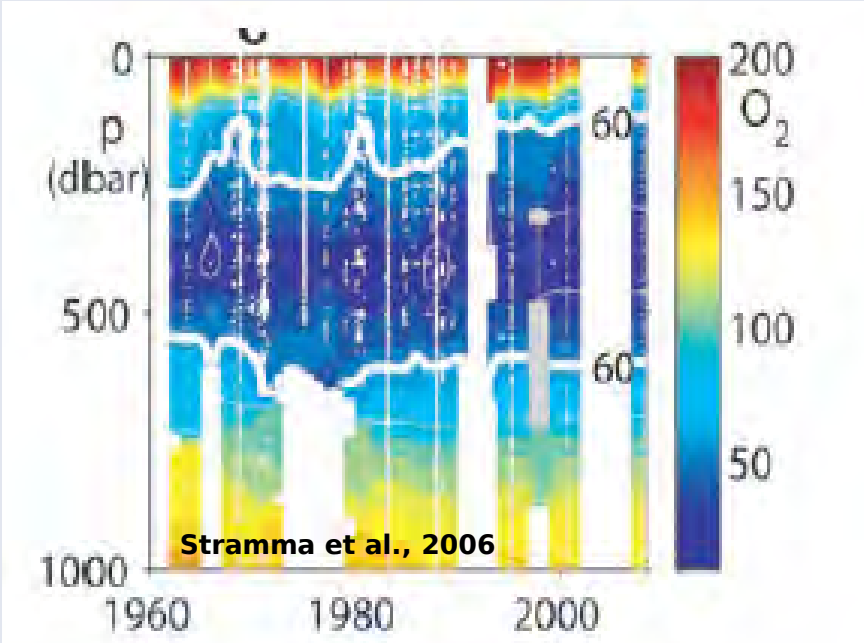


Northern Benguela



Long term evolution





Long lasting oxygen depletion.

Never anoxic.

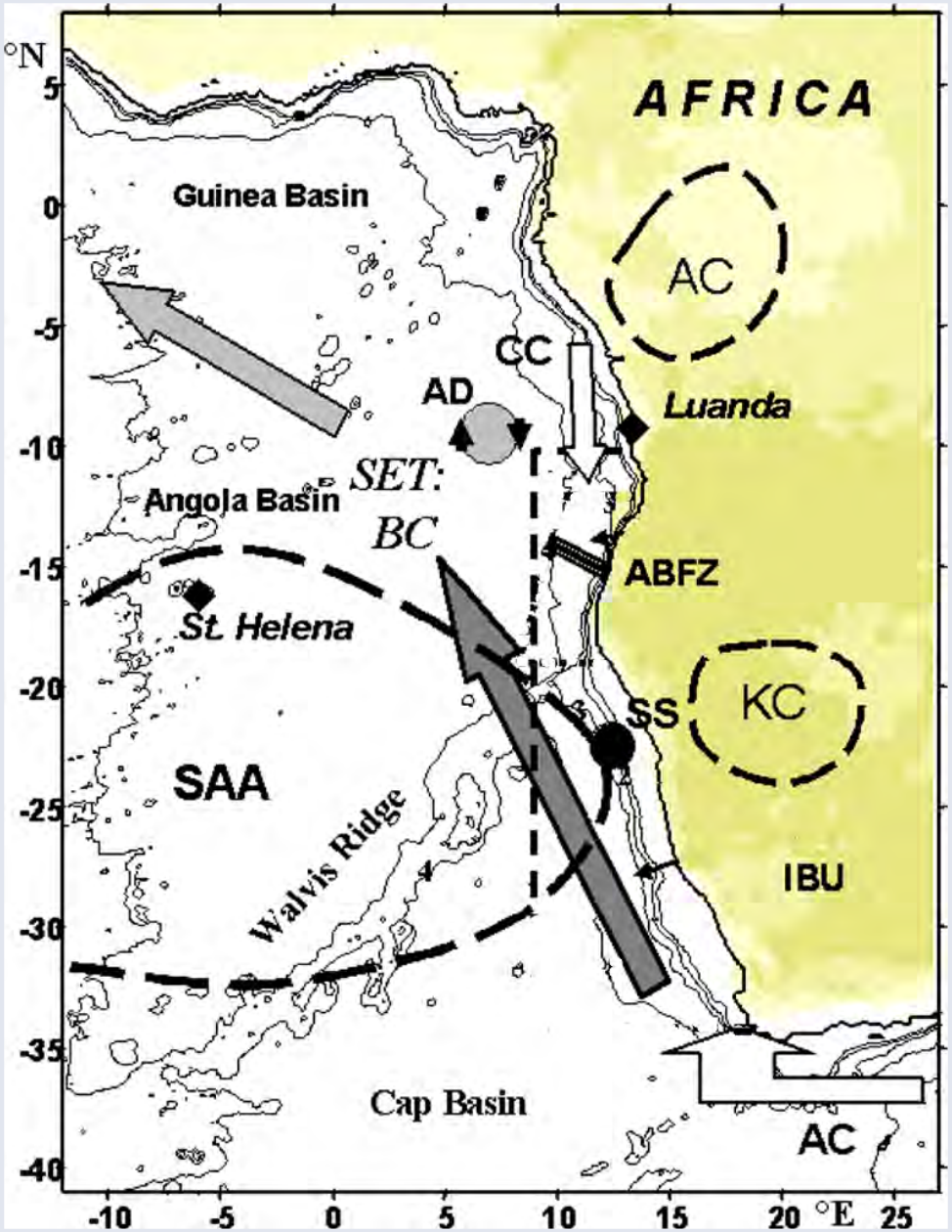
Accidental balance between consumption and ventilation?

„Regulation“ from feedbacks within the ecosystem?

Investigation method

- **simulation, coupled biochemical model**
- **comparison with field data**
  - oxygen concentration
  - zooplankton abundance
- **physiological data**
  - oxygen tolerance
  - respiration rates

The circulation model



Circulation model

→ MOM

Atmospheric drivers

→ QuikSCAT/ASCAT

NCEP

Open boundaries

→ ECCO, WOA

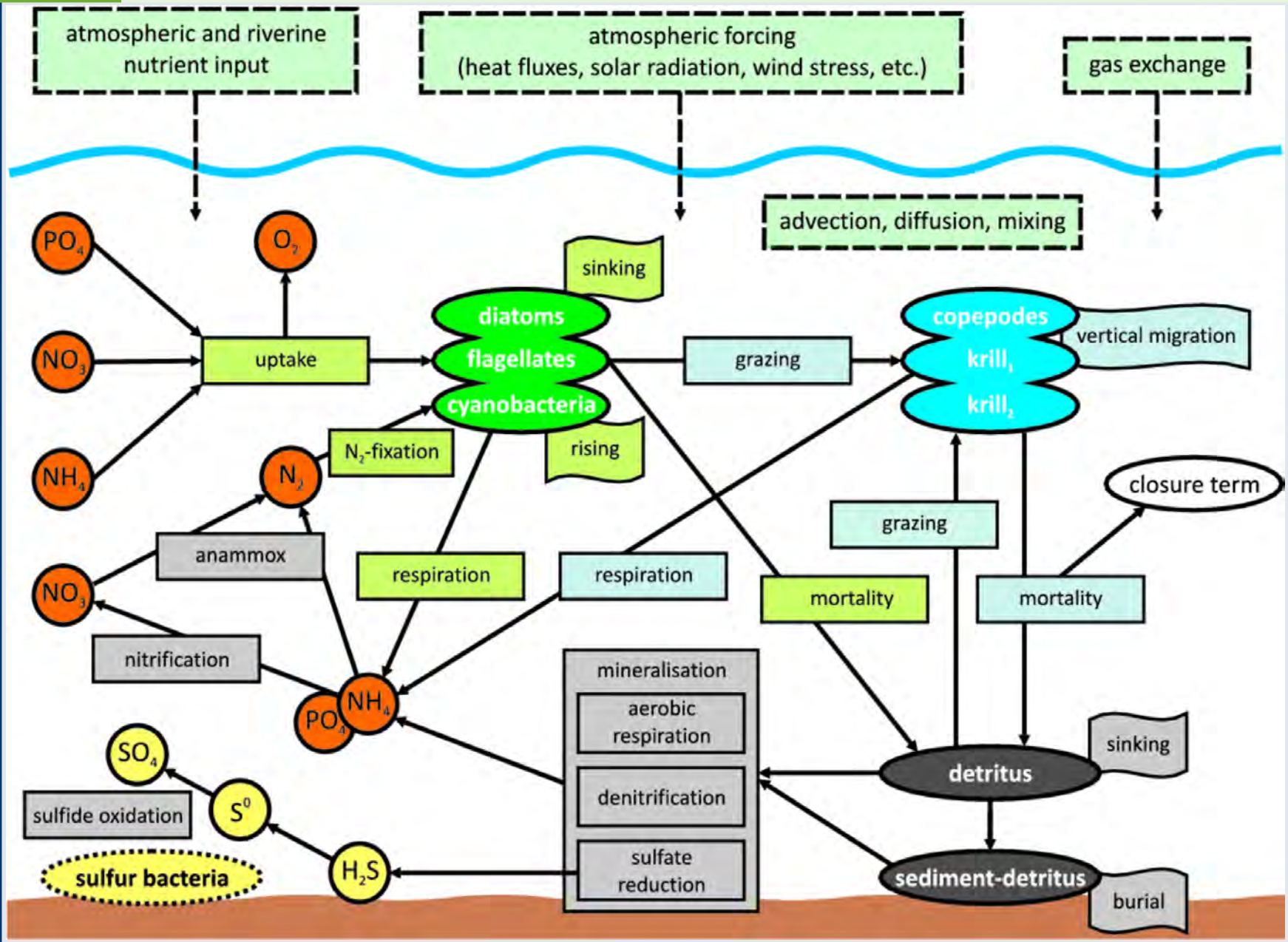
Resolution

→ 7km .. 15 km

→ 2m .. 300m

Atmospere circulation (Hagen et al. 2005)
SAA : South Atlantic Anticyclon
KC : Kalahari Cyclon
AC : Angola Cyclon

The ecosystem model



Ecosystem model → ERGOM (modified for specifics of the South-Eastern Atlantic)

The ecosystem model

Zooplankton representation:

- Grazing (preferences, food, T, O_2)
- Respiration (grazing, movement, T, O_2)
- Mortality (food, O_2)

$$(Resp, graz) = I(food)\,G(T)\,F(O_2)$$

Food preference Ivlev limitation

Optimum Temperature (Blanchard)

Minimum ambient oxygen concentration
- reduced activity
- enhanced mortality

The ecosystem model

Zooplankton representation: vertical migration

Does zooplankton know a “map” of the ocean?

Assume only „local rules“!

$$mig = L(light)\,F(O_2)\,G(T)\,I(food)$$

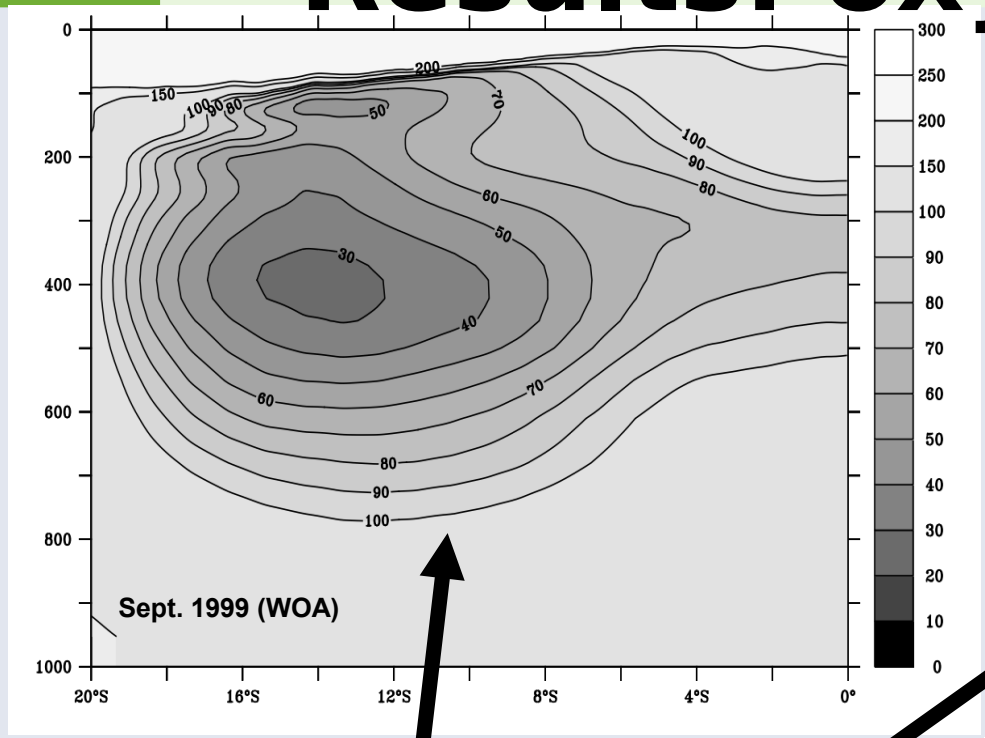
Avoid light

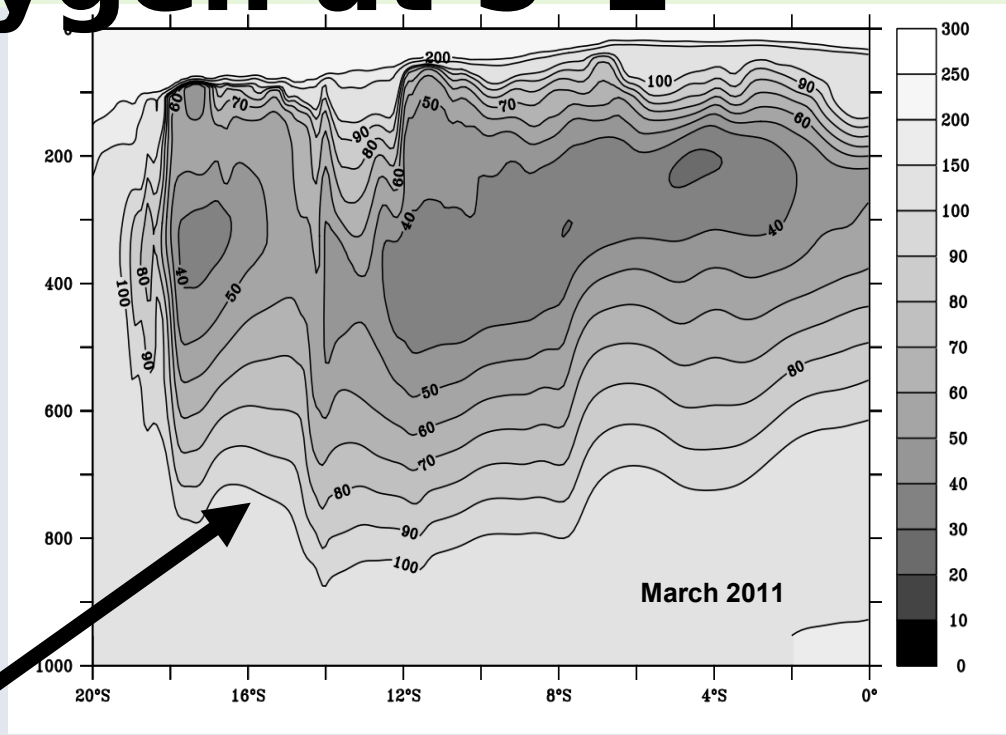
Avoid hypoxia

Optimum / maximum temperature (Werner et al.)

Follow food gradients

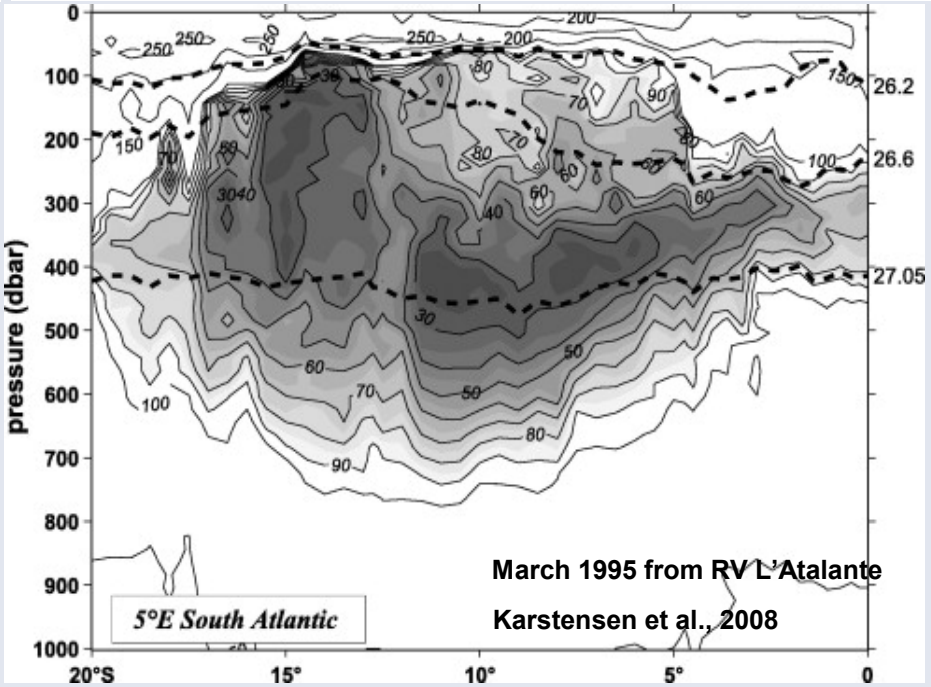
Results: oxygen at 5°E



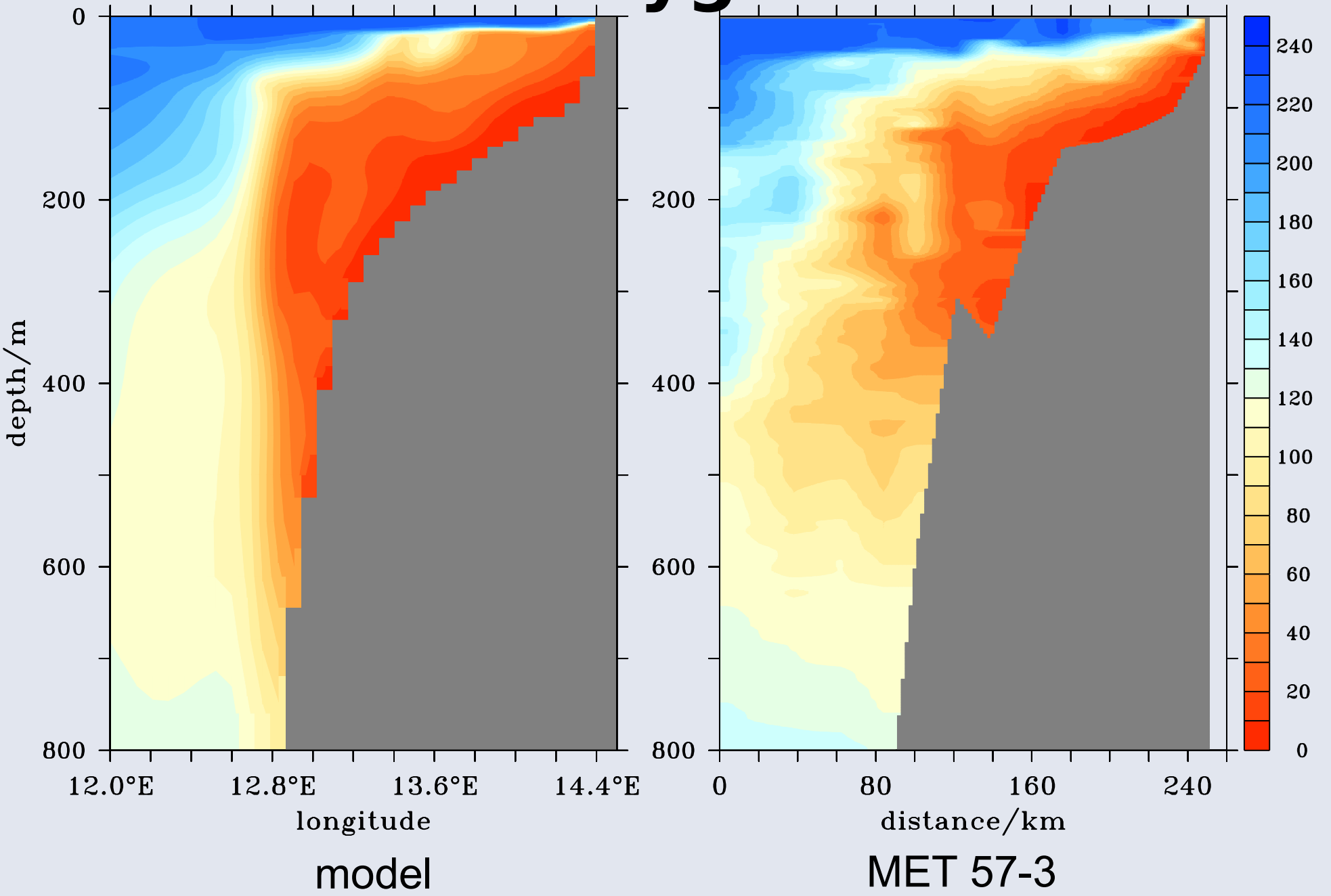


Initial state

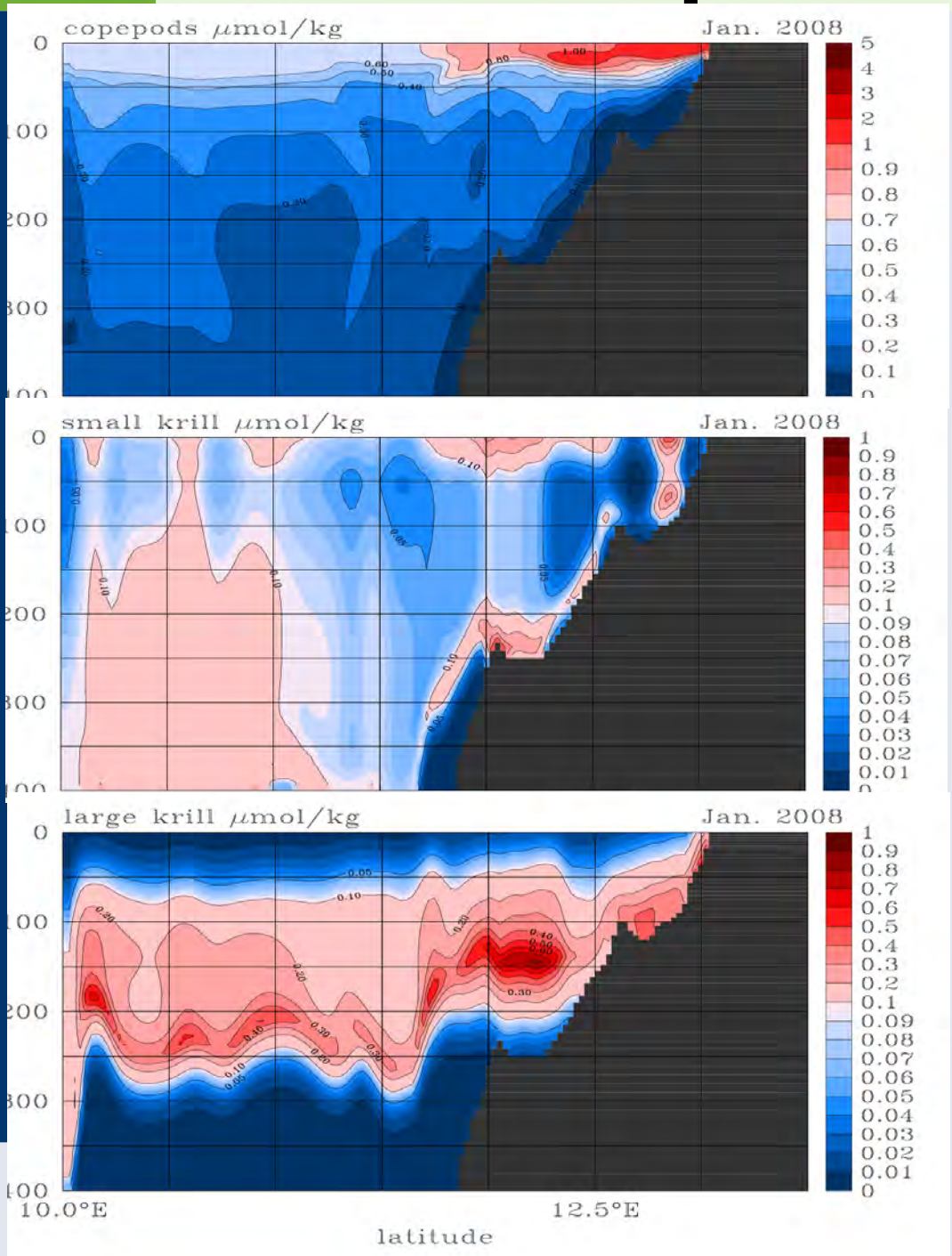
After 11 years



Results: oxygen at 23°S



Results: zooplankton distribution

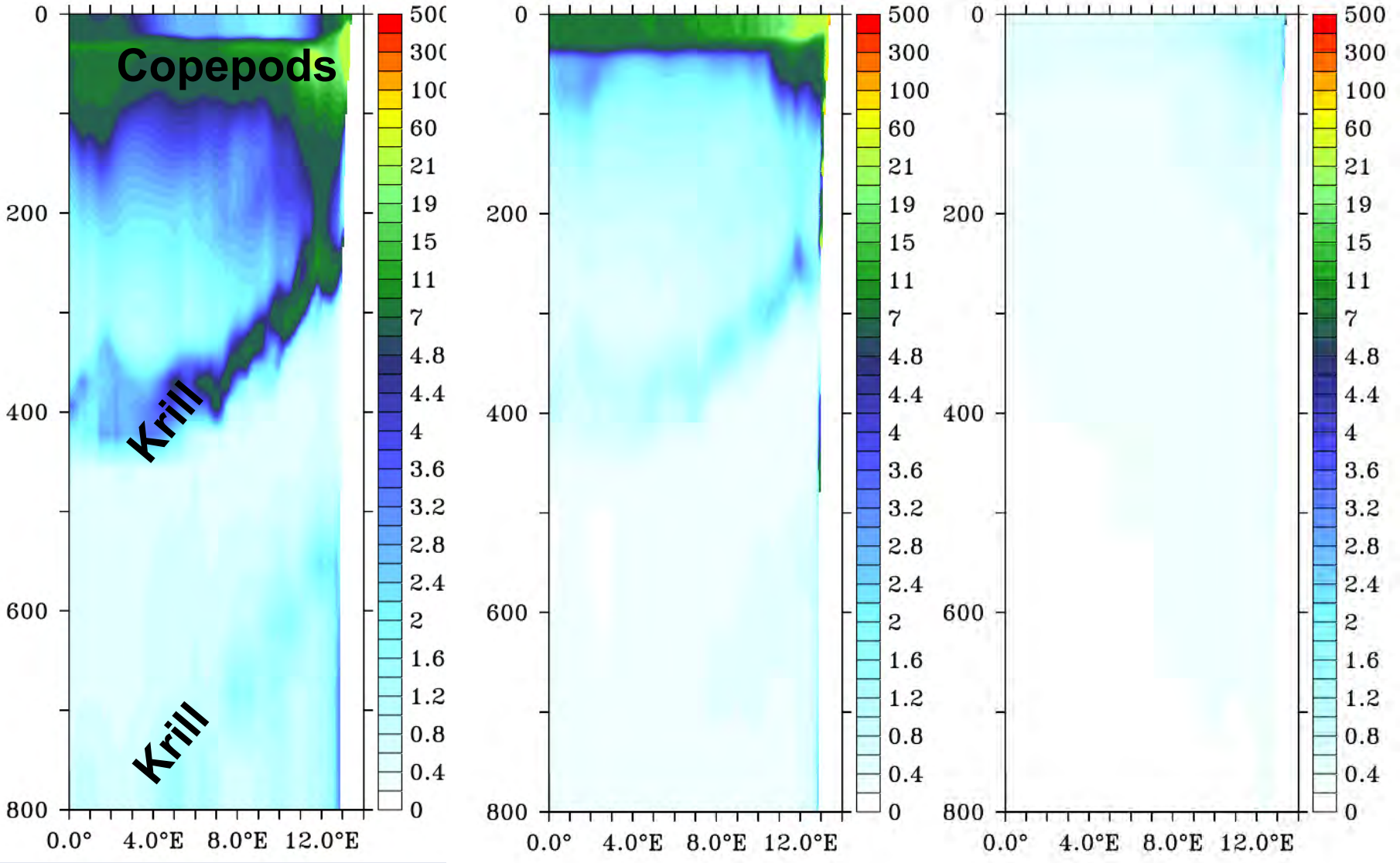


No migration
Grow, where the food is

Biomodal distribution
from diel migration

Avoid light
Stay near optimum temperature
Avoid hypoxia
Follow food gradients

Oxygen consumption



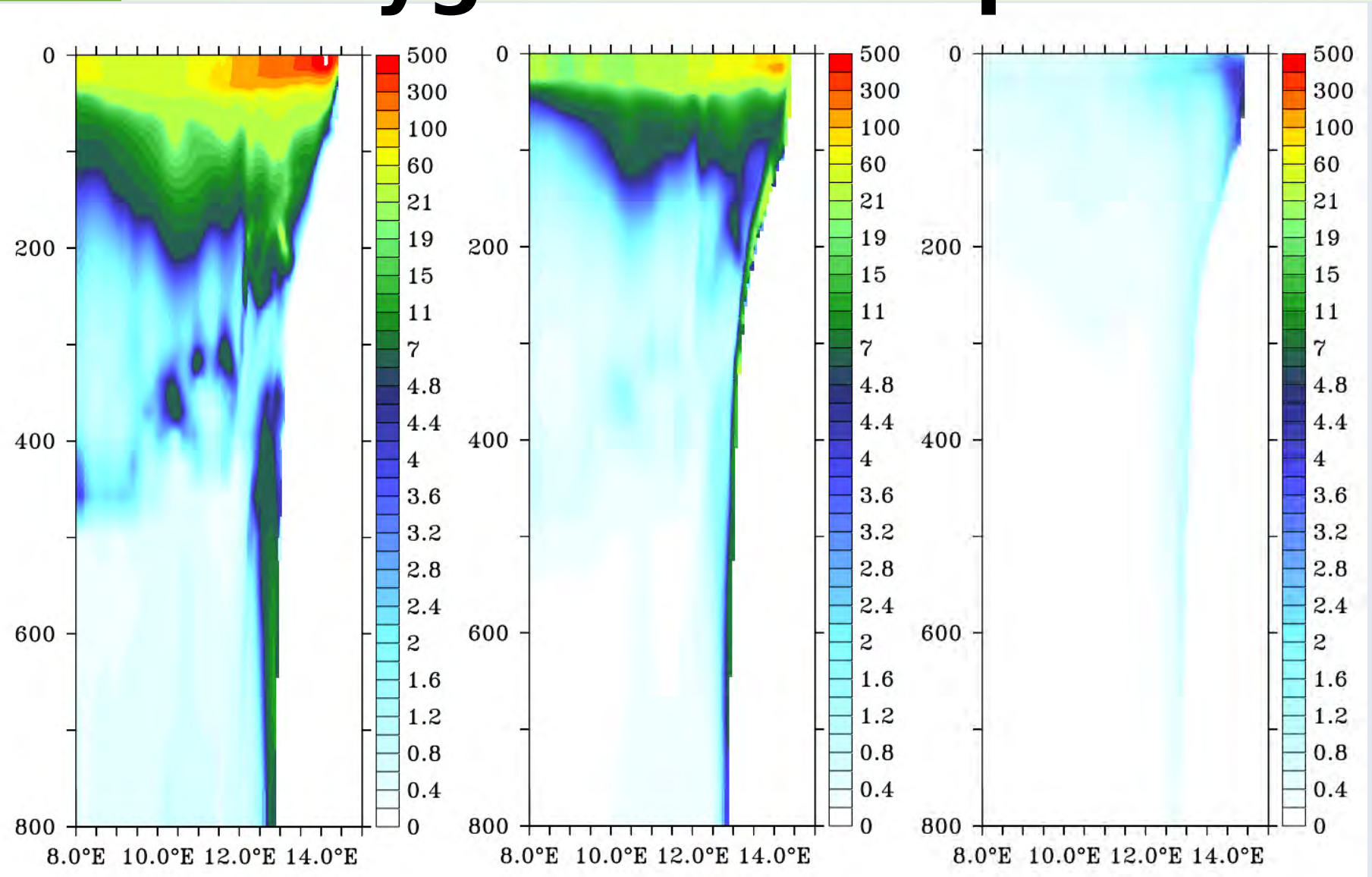
Zooplankton respiration [µmol/kg/y]

Nitrification [µmol/kg/y]

Detritus mineralisation [µmol/kg/y]

Oxygen consumption

23°S

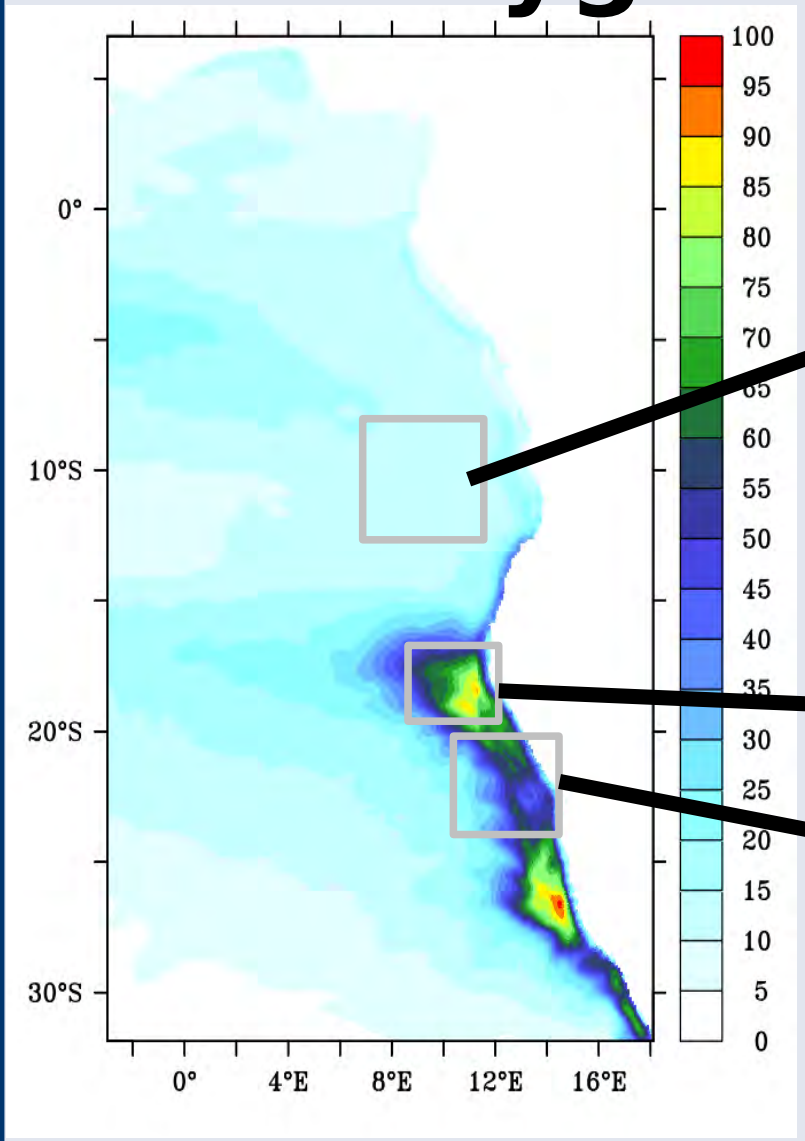


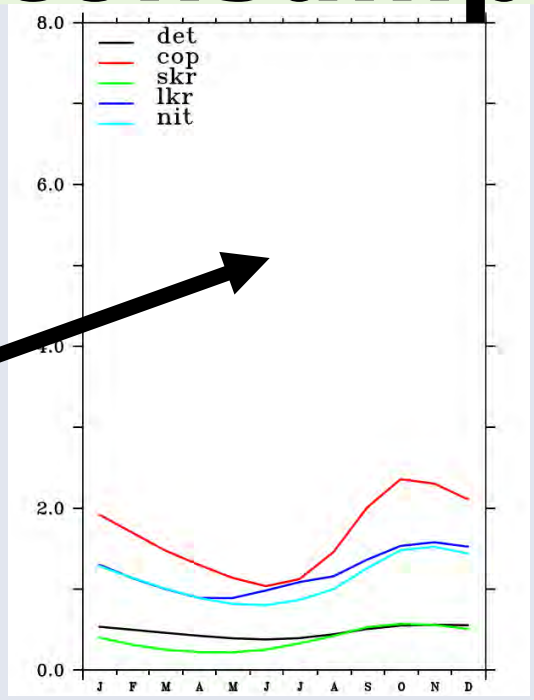
Zooplankton respiration [µmol/kg/y]

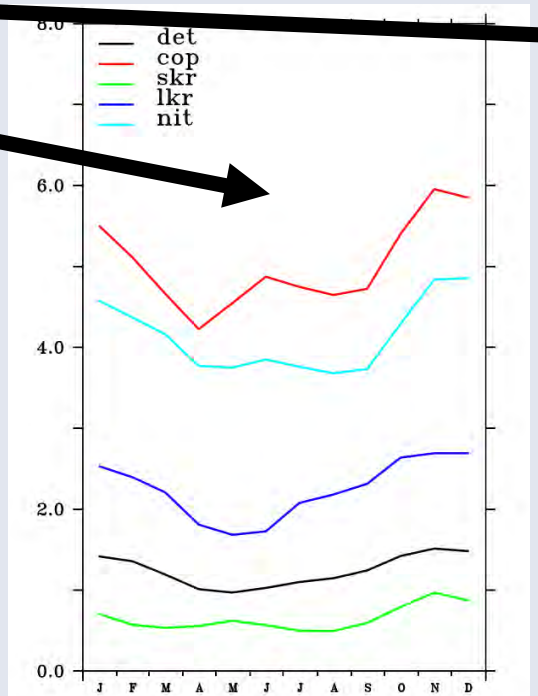
Nitrification [µmol/kg/y]

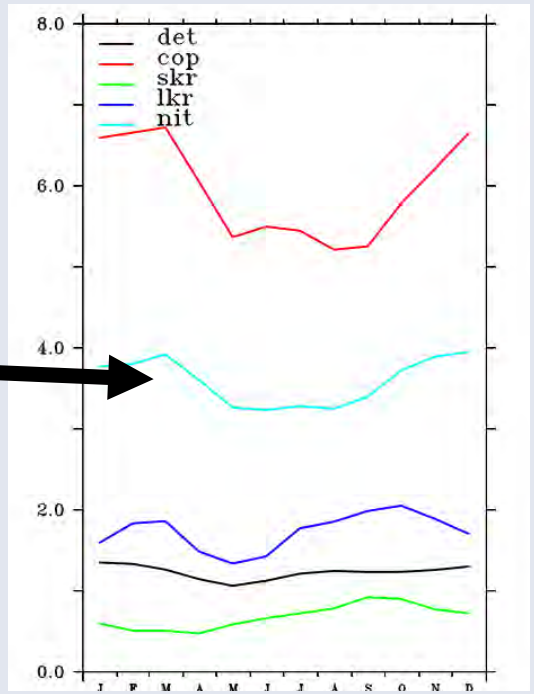
Detritus mineralisation [µmol/kg/y]

Oxygen consumption



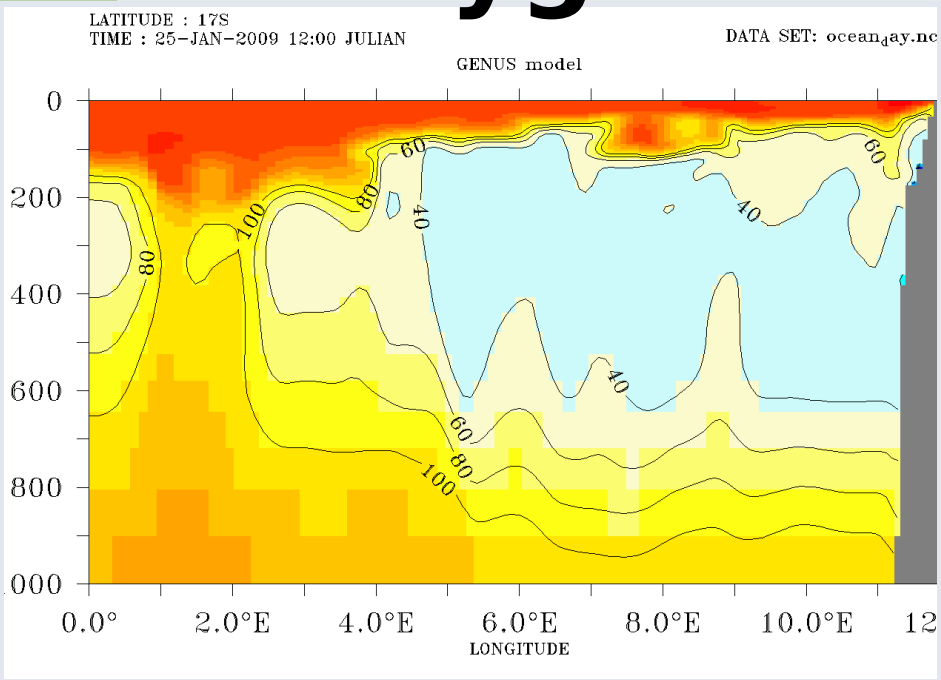


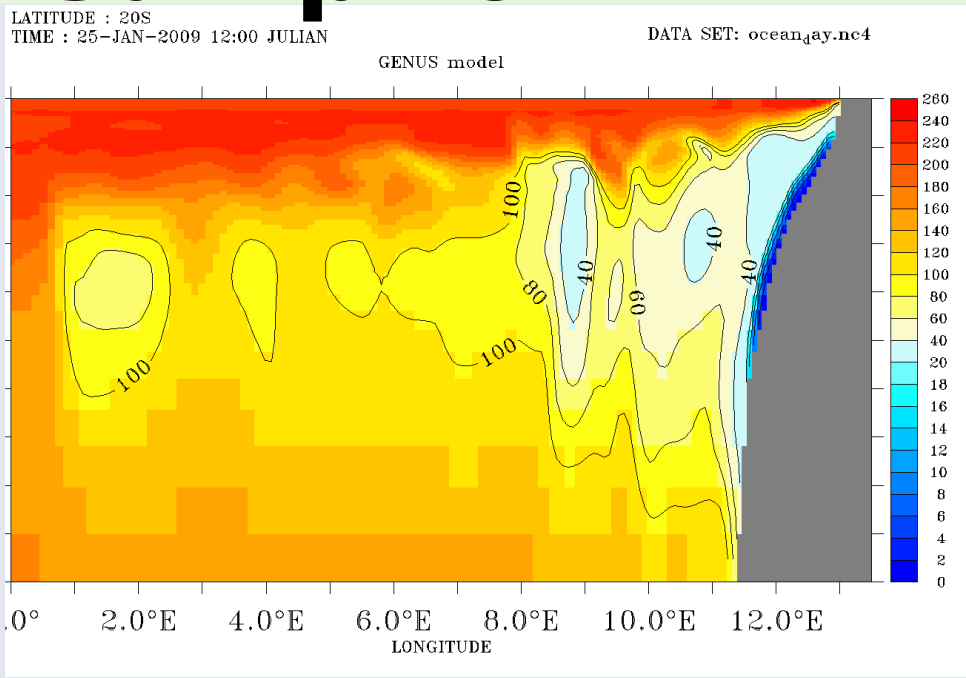


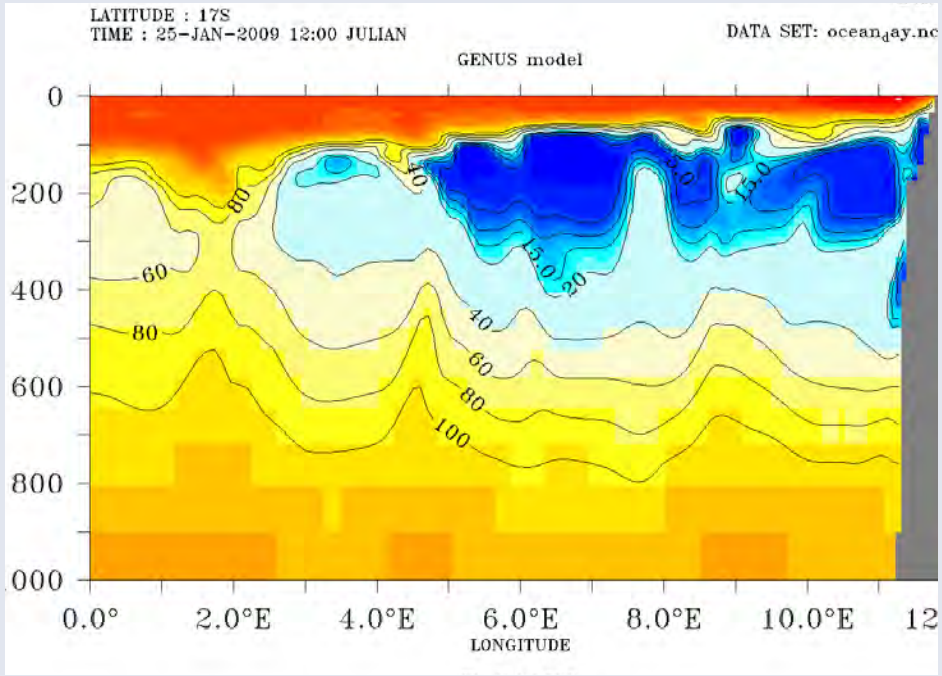


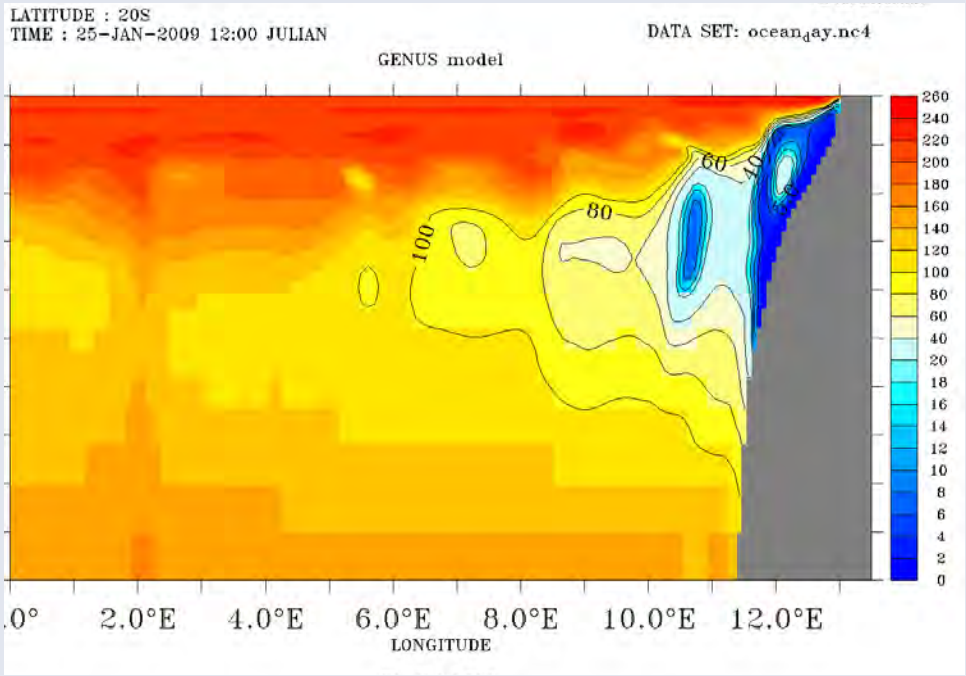
Vertically integrated oxygen consumption 100 m – 600 m (mmol m^{-2} d^{-1})

Oxygen consumption

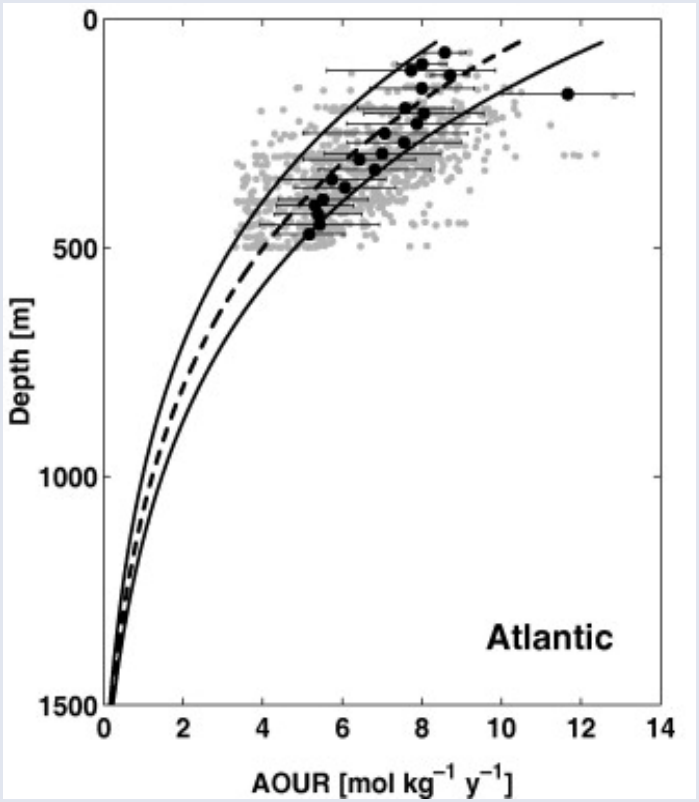


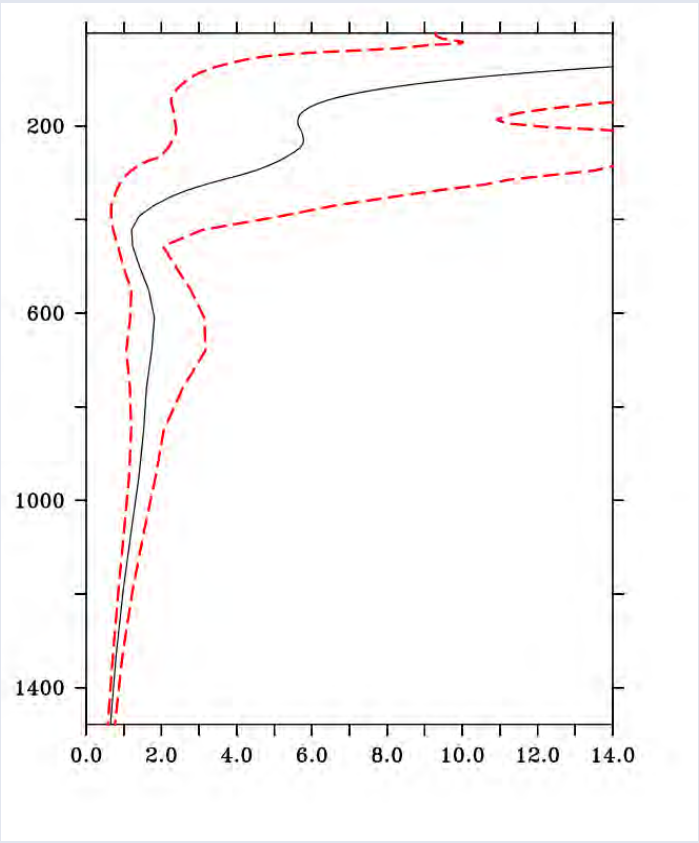






Results: AOUR





Karstensen et al., 2008

Time scales

1. physical time scales

$$\text{Residence time} = \frac{\text{Inventory}}{\text{Surface flux}}$$

Angola gyre : > 30 y (Tomczak, 1996)
Northern Benguela : 150 d (Eggert (next), Mohrholz et al. (2008)

2. biological time scales:

$$\text{Respiratory time} = \frac{\text{Oxygen concentration}}{\text{AOUR}}$$

Angola gyre : 1 ... 10 y (Kartstensen et al. (2008)
Northern Benguela : 1 ... 10 y

Discussion

Is the implemented food web significant?

Is the resulting biomass realistic?

Is the implemented behaviour realistic?

Is the assigned respiratory power of the various functional groups realistic?

Conclusions

**In the Benguela system ventilation by the PUC (physics) dominates. Organismic oxygen consumption modifies the oxygen status only.
(Exception: Sulphidic events from low physical fluxes.)**

In the Angola Gyre physical time scales are largerer than respiratory oxygen consumption time scales.

In the model, results organisms responding to oxygen conditions reveal as the main players.

Reduced zooplankton metabolic activity at low oxygen conditions and avoidance of the oxygen minimum zone stabilize the oxygen content there.

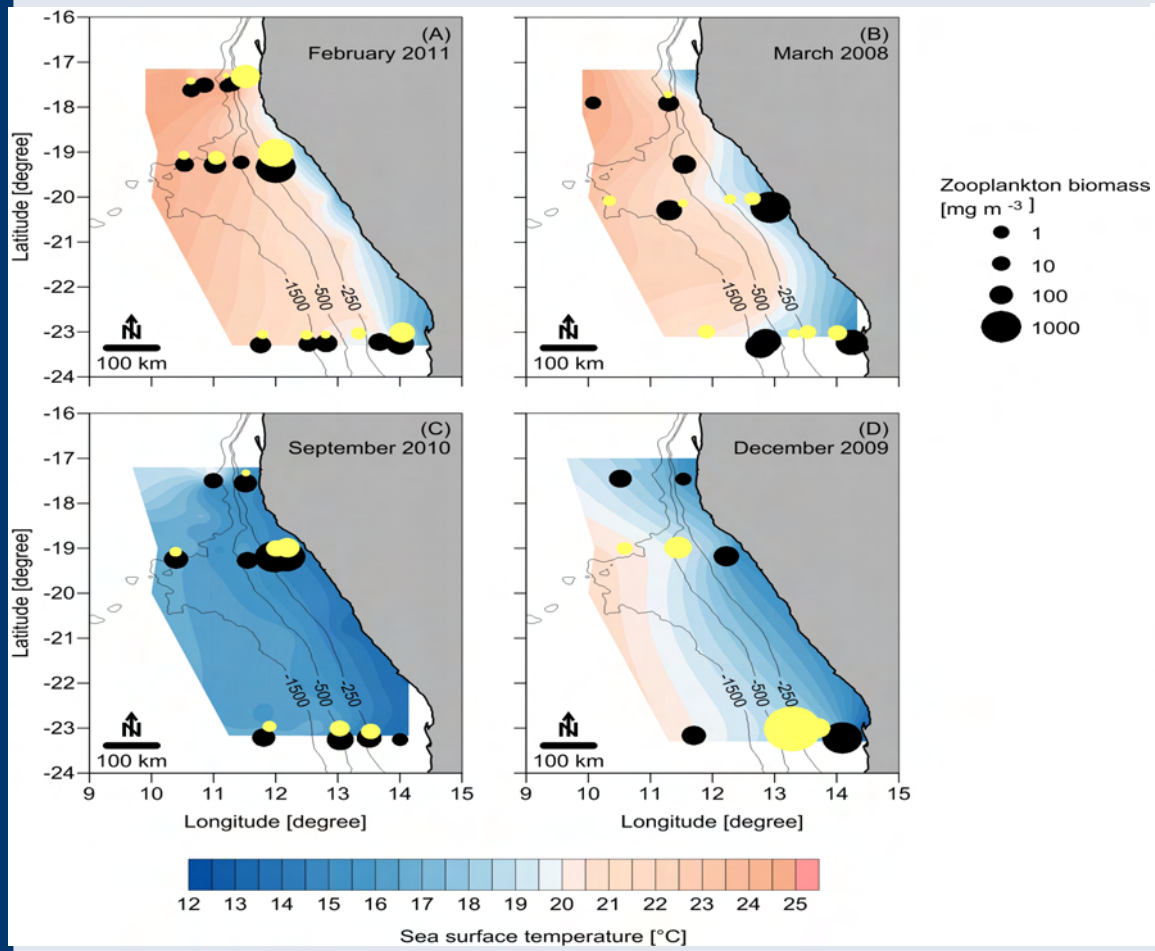
Zooplankton respiration thresholds and oxygen tolereance define a lower limit for the oxygen content in the Angola gyre.

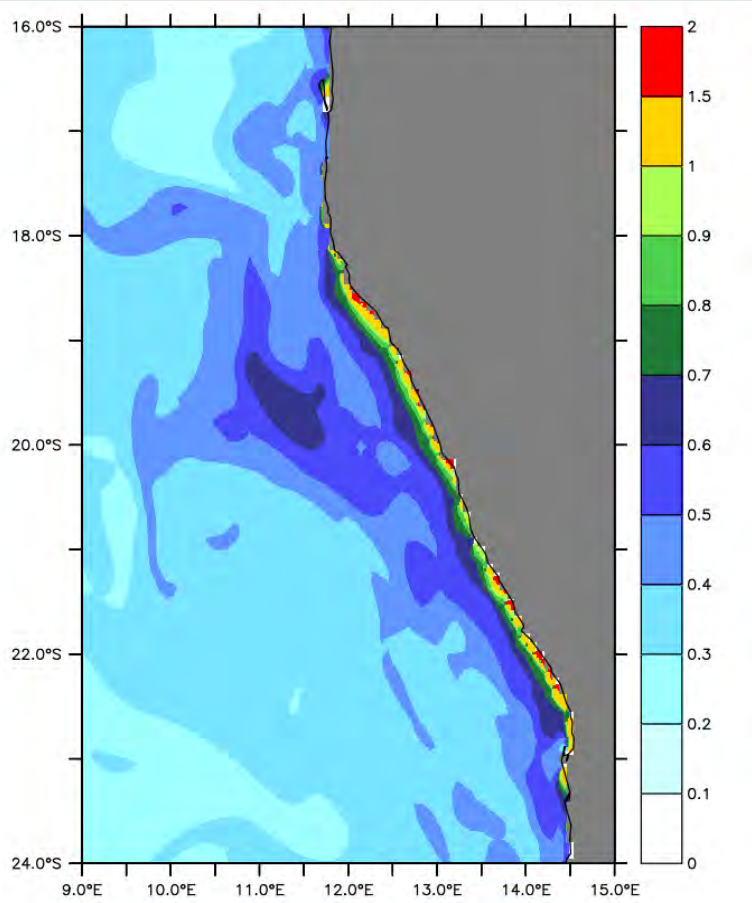
Conclusions

Zooplankton breakdown from extending OMZ????

Transition from extending OMZ → deepening OMZ?

Zooplankton biomass

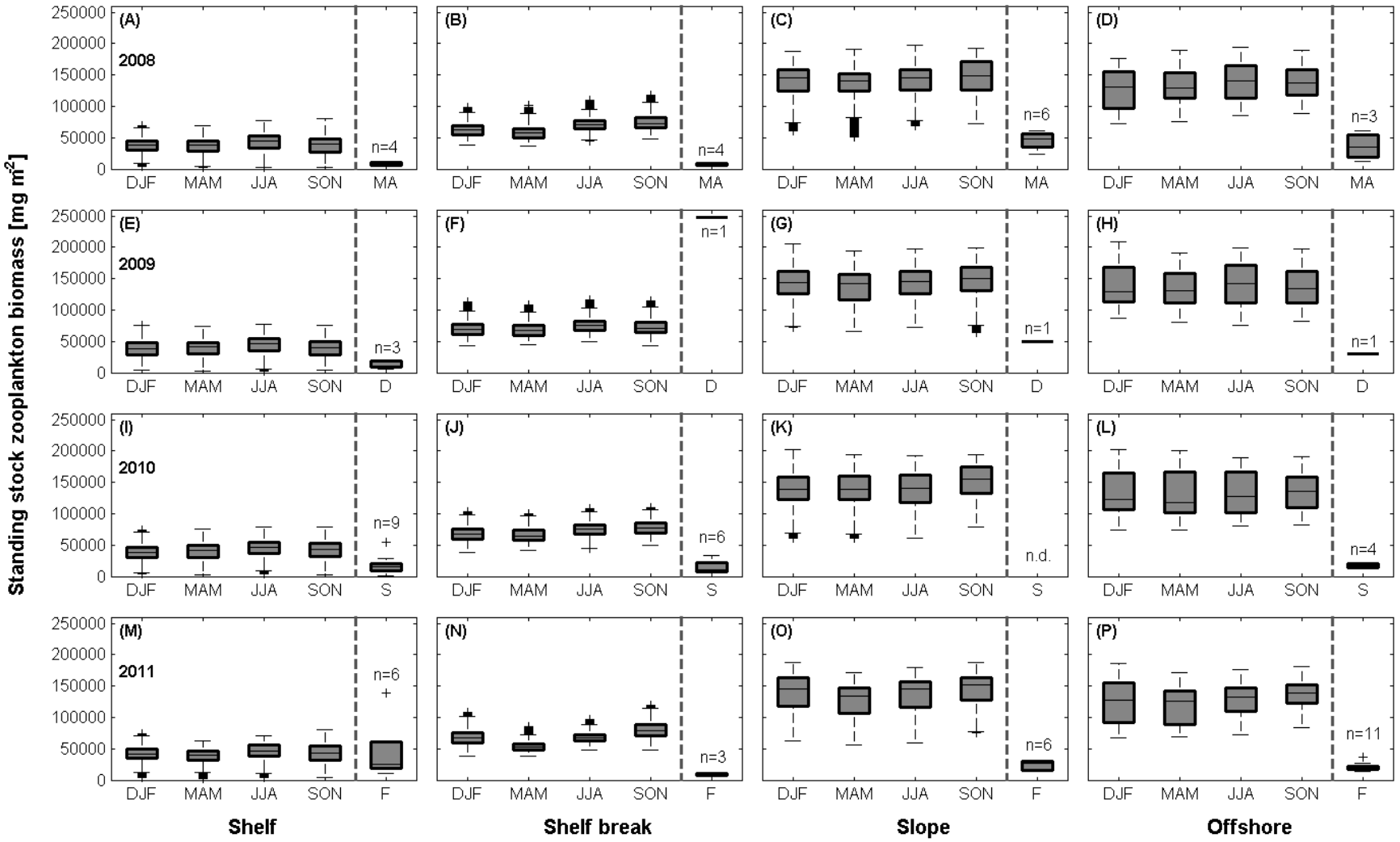




Martin et al. (2014)

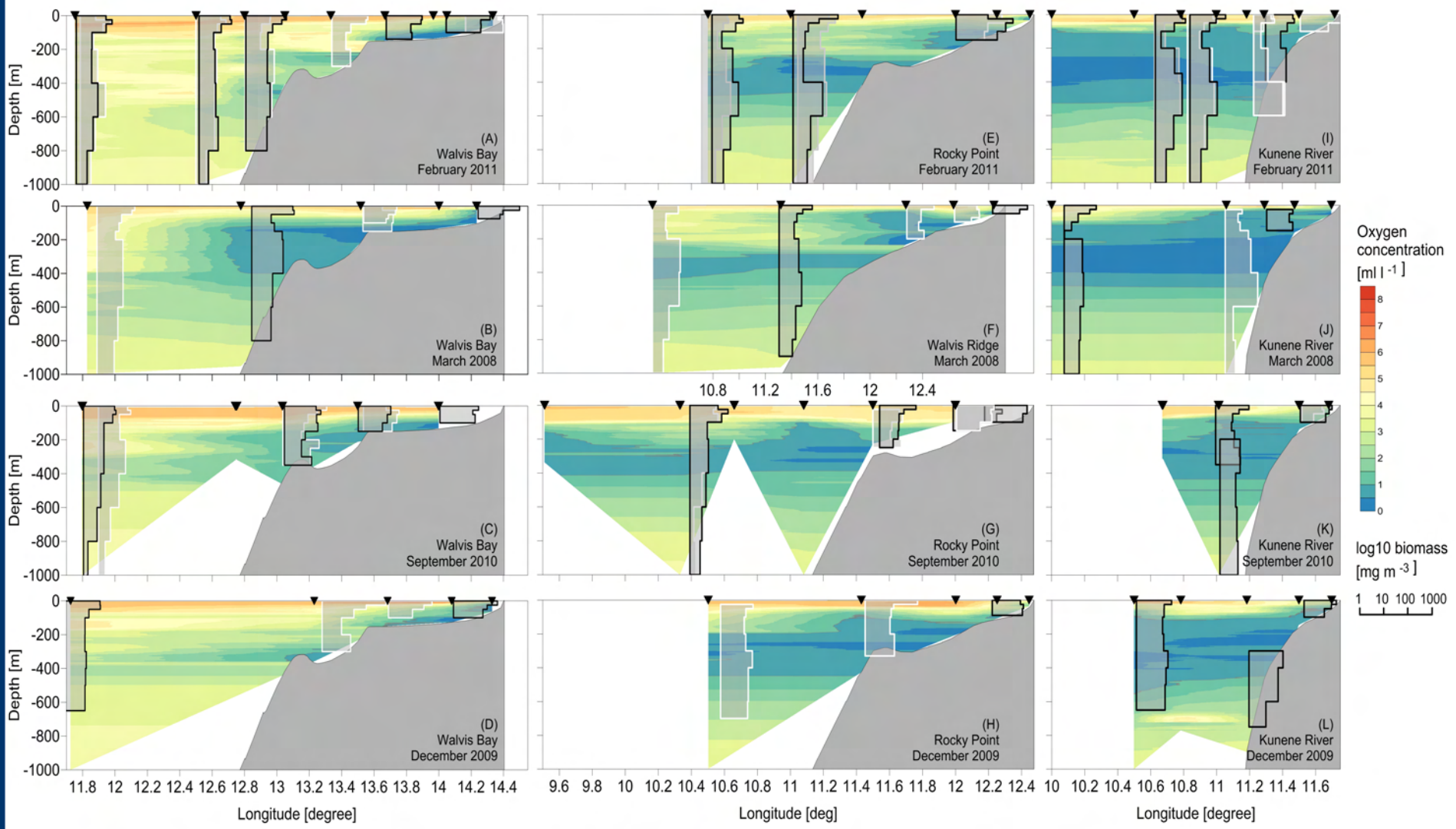
Model mesozooplankton

Zooplankton biomass



Eggert in Martin et al. (2014)

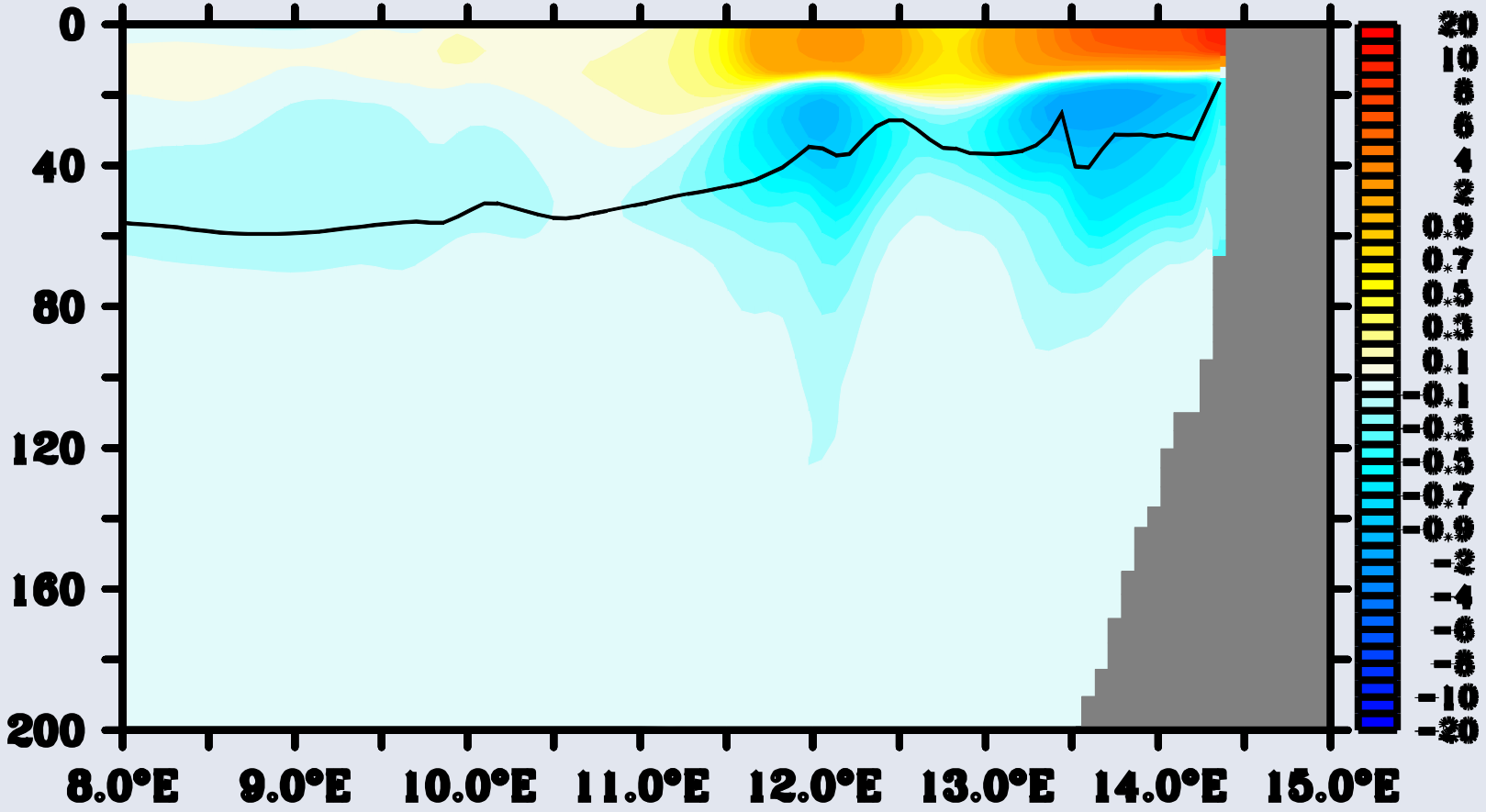
Zooplankton biomass



Martin et al. (2014)


Thank You!
Foto: T. Heene(2013)

Oxygen related Processes Consumption in the water column



Typical oxygen budget [µmol/kg/y], 23°S July 2004

Primary production, respiration, mineralisation, nitrification