Oxygen response to changes in the North Equatorial Undercurrent

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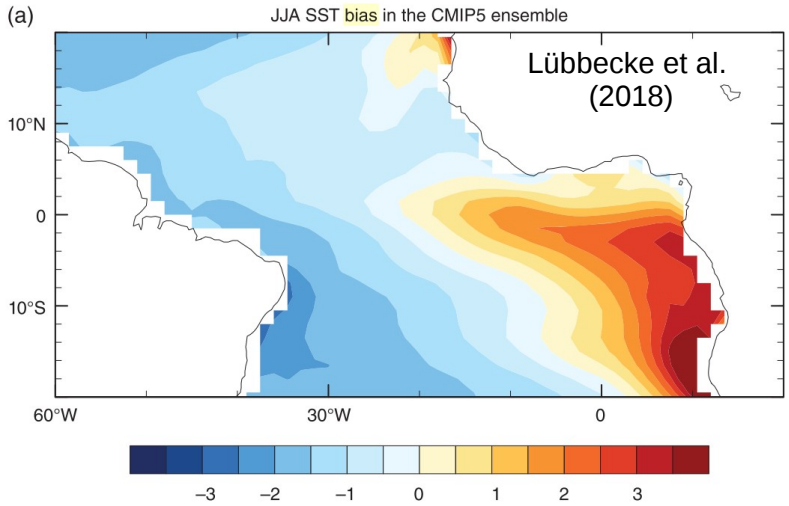
Model biases in the tropical Atlantic - Examples

Sea surface temperature bias (K) in CMIP5 ensemble



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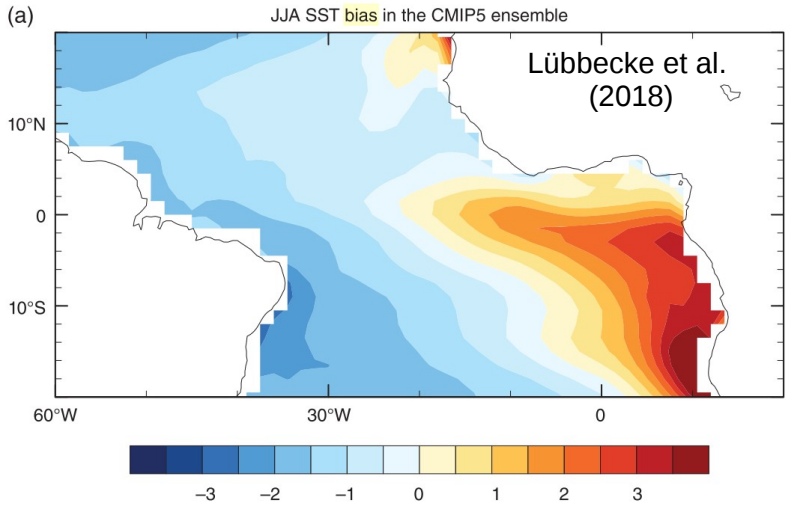
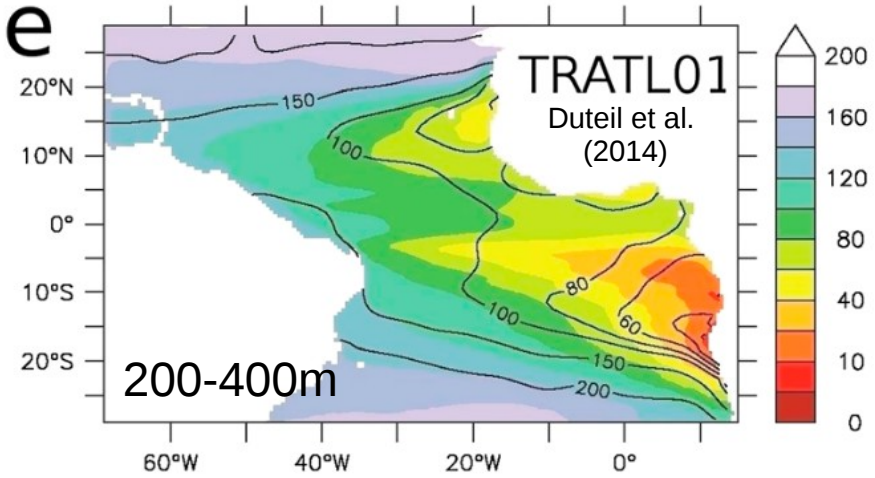
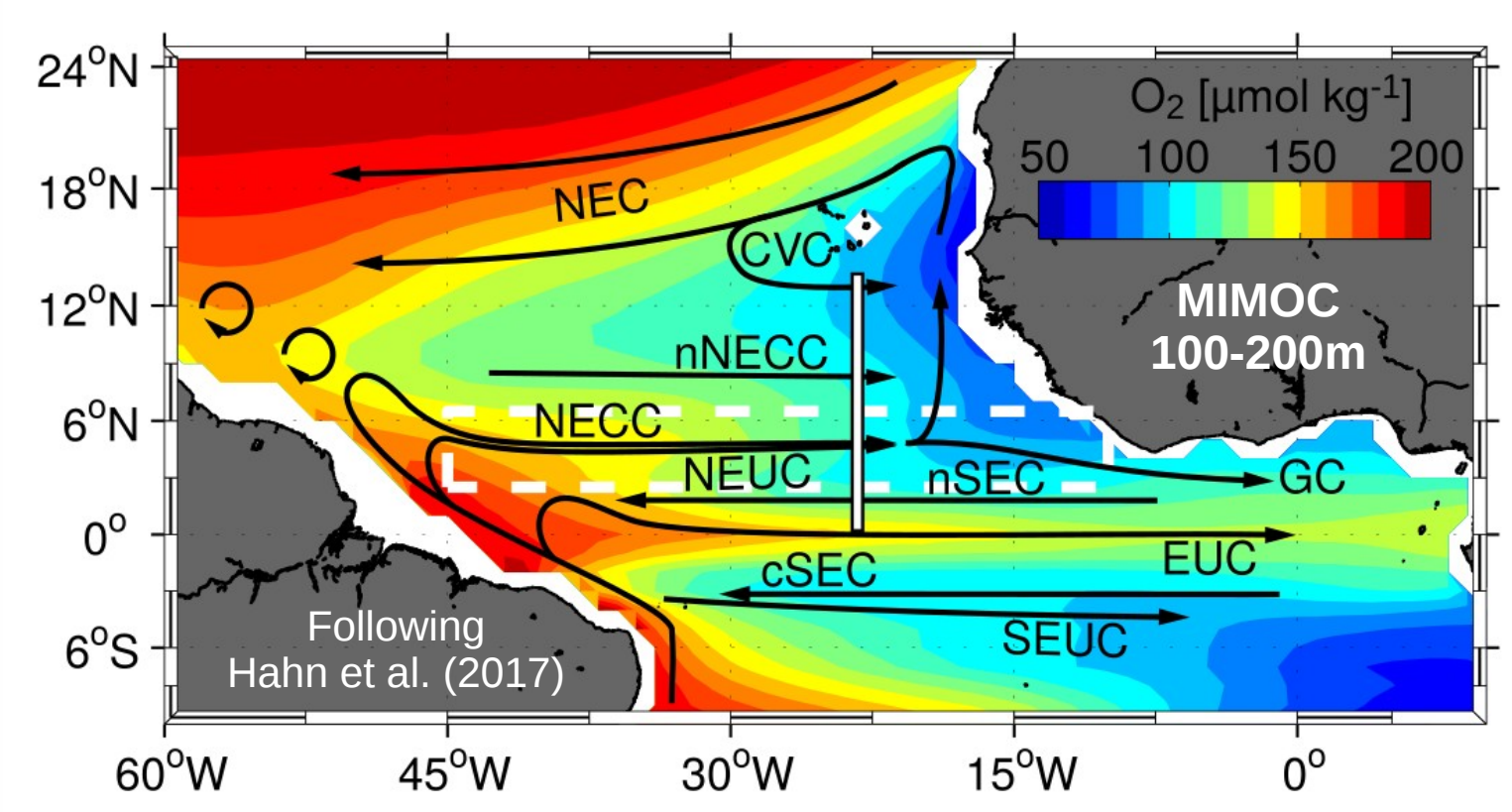


Oxygen concentration (µmol/l) in a OGCM



contours: observations (WAO) shading: model simulation

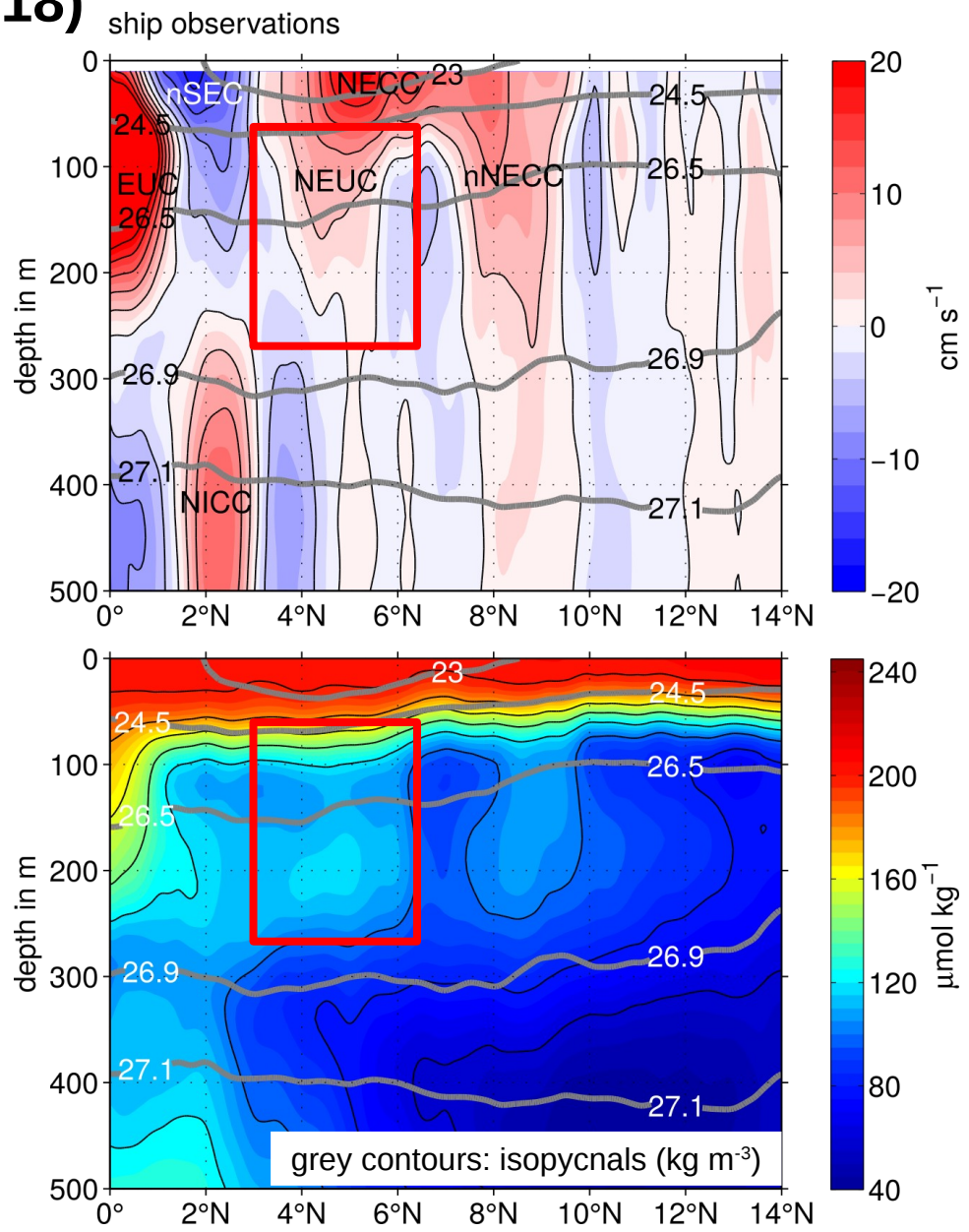
Oxygen and wind-driven circulation in the tropical Atlantic



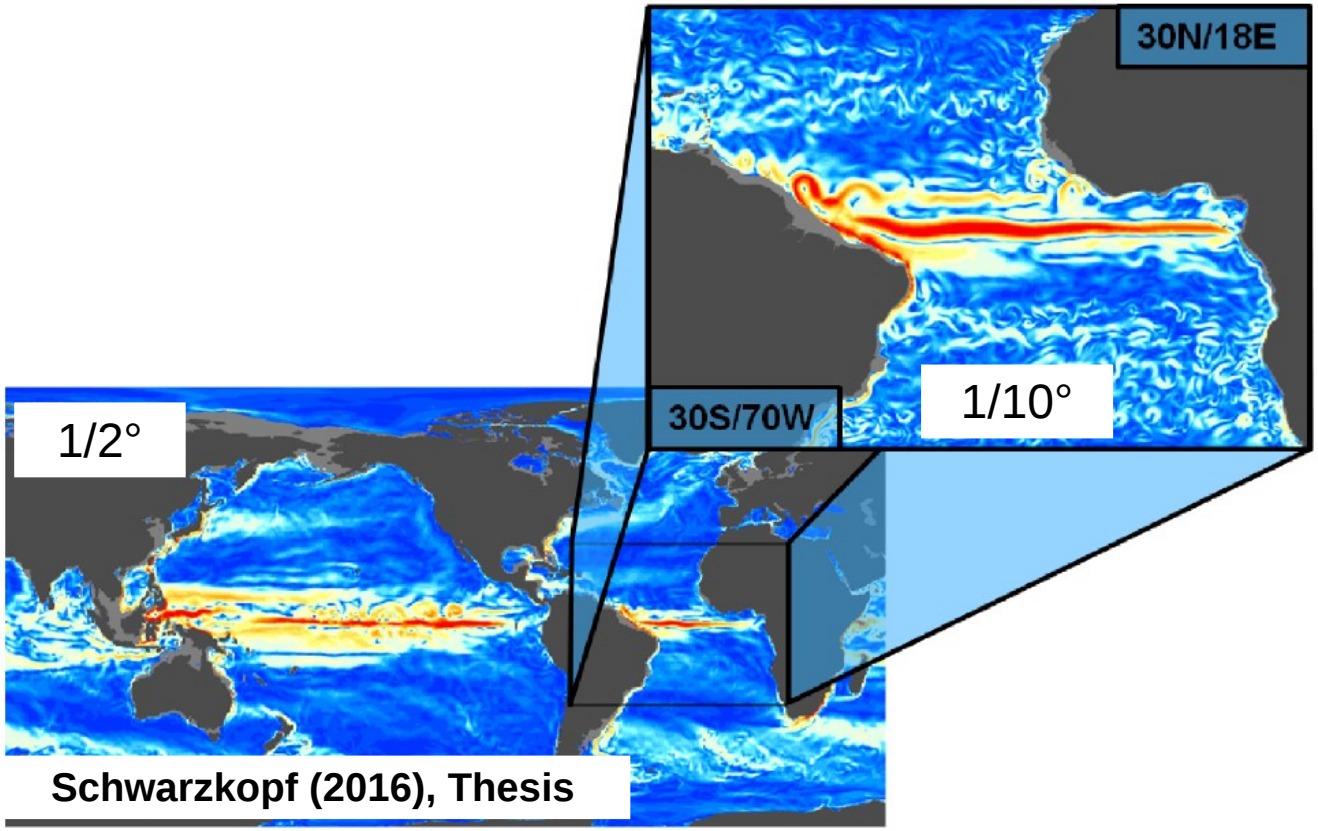
Eastward currents are transporting oxygen-rich water from the western boundary towards oxygen-poor regions in the East.

Ship sections along 23° W (2002-2018)

- Important oxygen supply by NEUC and nNECC (Stramma et al., 2008)
- Changes in oxygen associated with changes in NEUC and nNECC (Brandt et al., 2010)



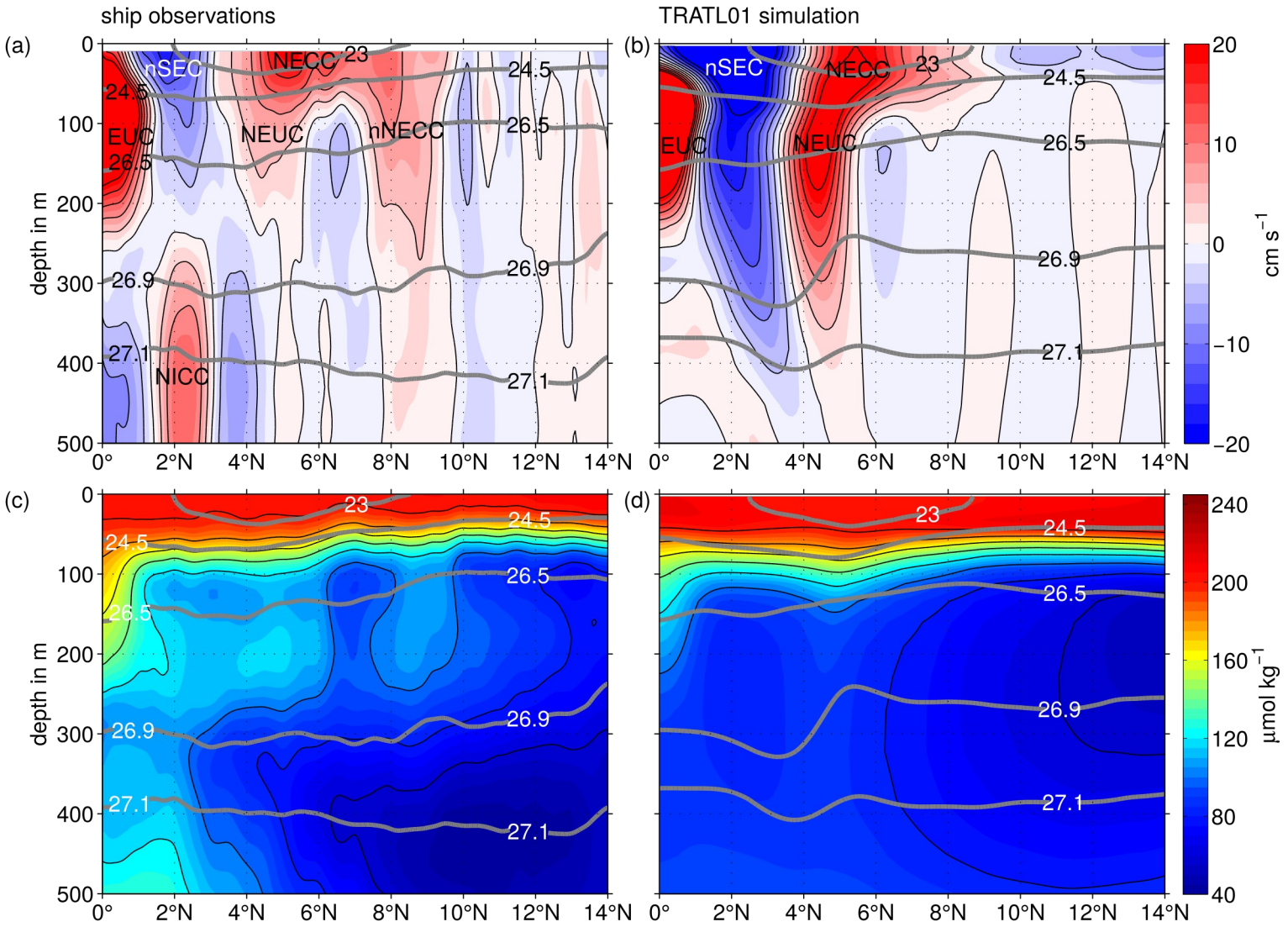
Model simulations (TRATL01)



- 1/10° nest covering the tropical Atlantic (TRATL01) is embedded into a global 1/2° ocean general circulation model (NEMO-ORCA05)
- CORE v2 forcing for the period 1948-2007
- Coupled with biogeochemical model (Duteil et al., 2014)

Mean state in TRATL01

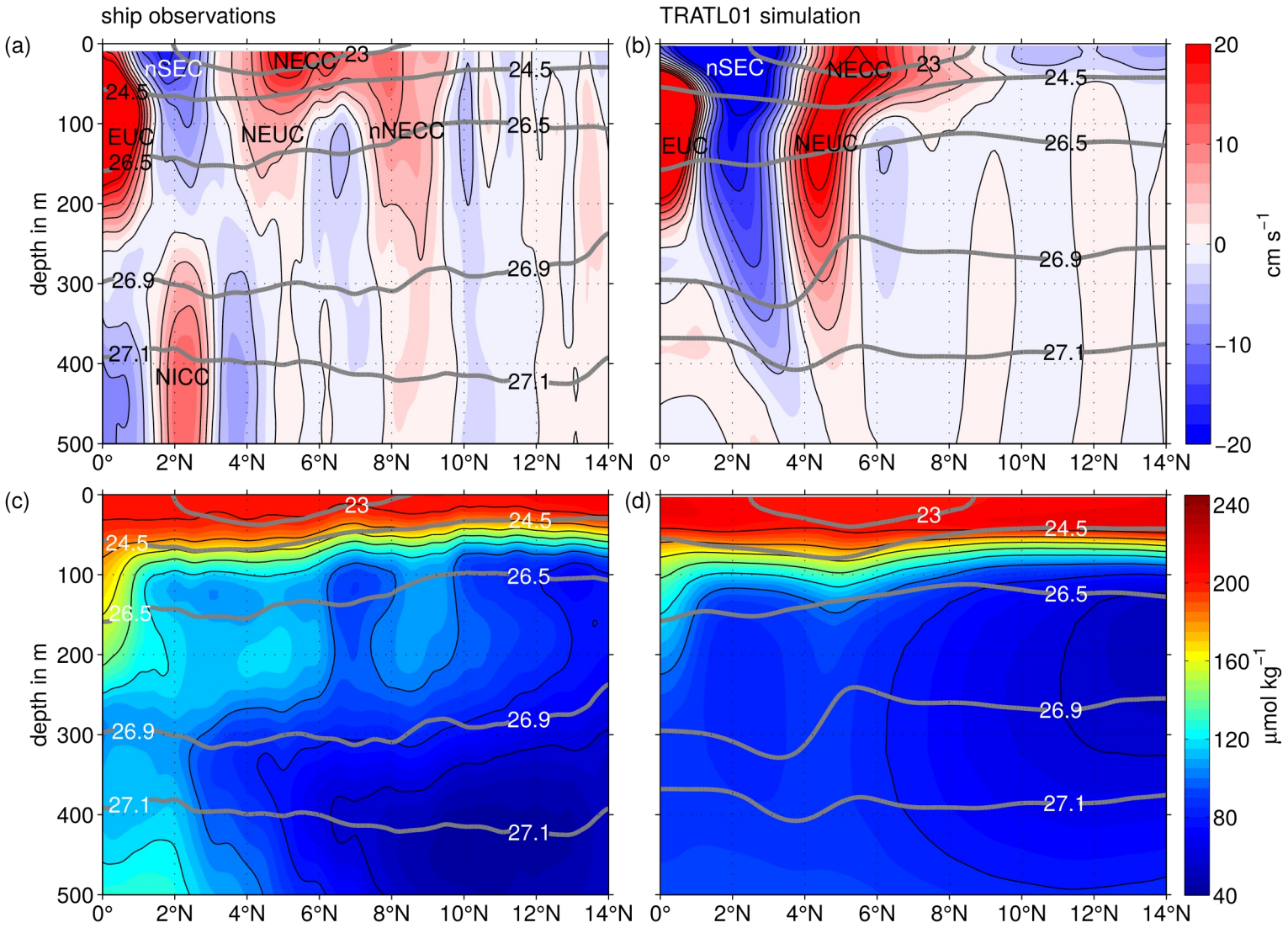
Observations versus TRATL01 – section along 23° W



Model compared to observations:

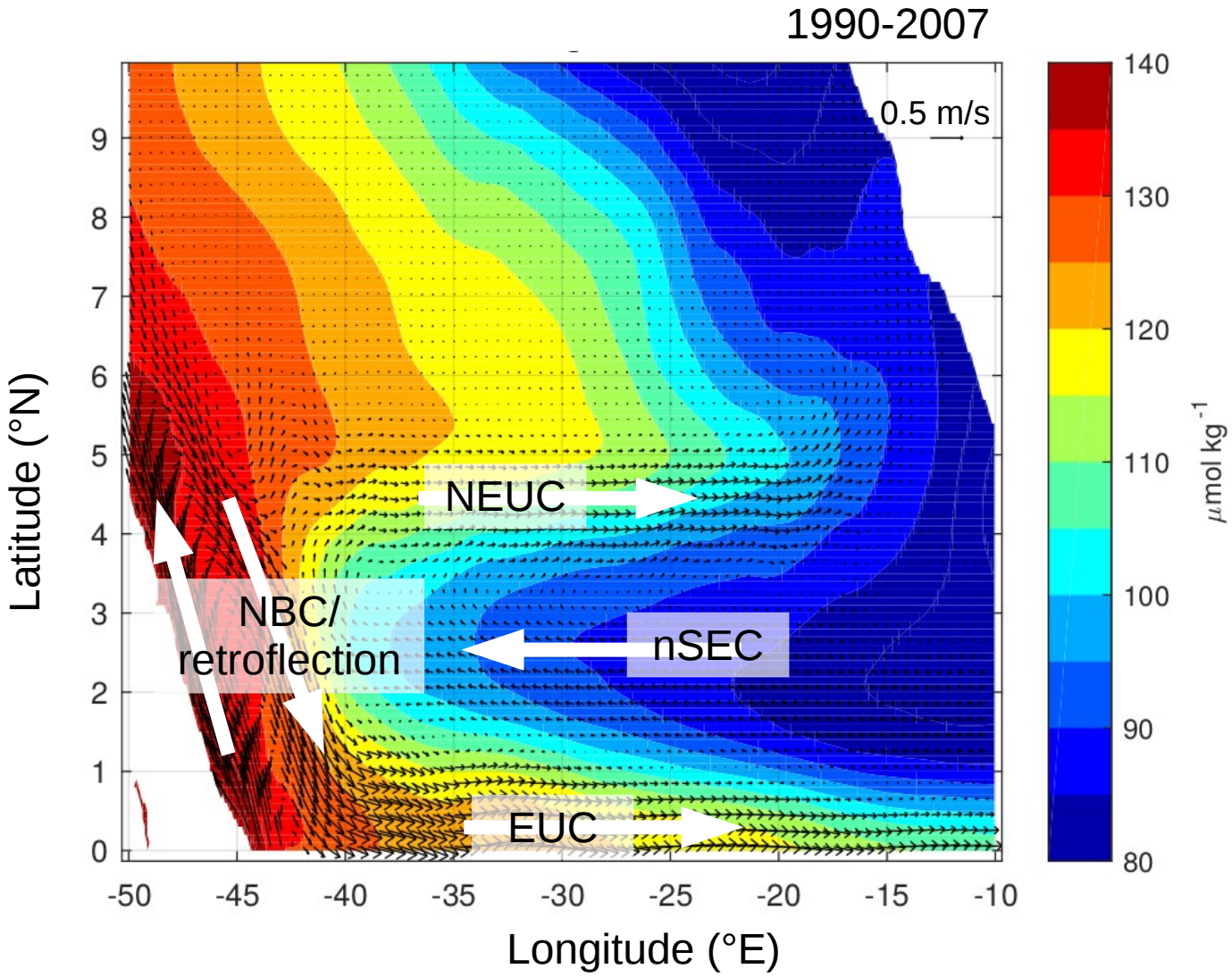
- In general off-equatorial zonal current bands weaker
- NEUC, nSEC stronger and deeper
- In general lower oxgen concentration beneath mixed layer
- OMZ core shallower and more northward

Observations versus TRATL01 – section along 23° W



- **What contributes to the model bias?**
- **What can we learn from it?**

TRATL01 oxygen and horizontal velocity along the 26.5 kgm^{-3} - isopycnal



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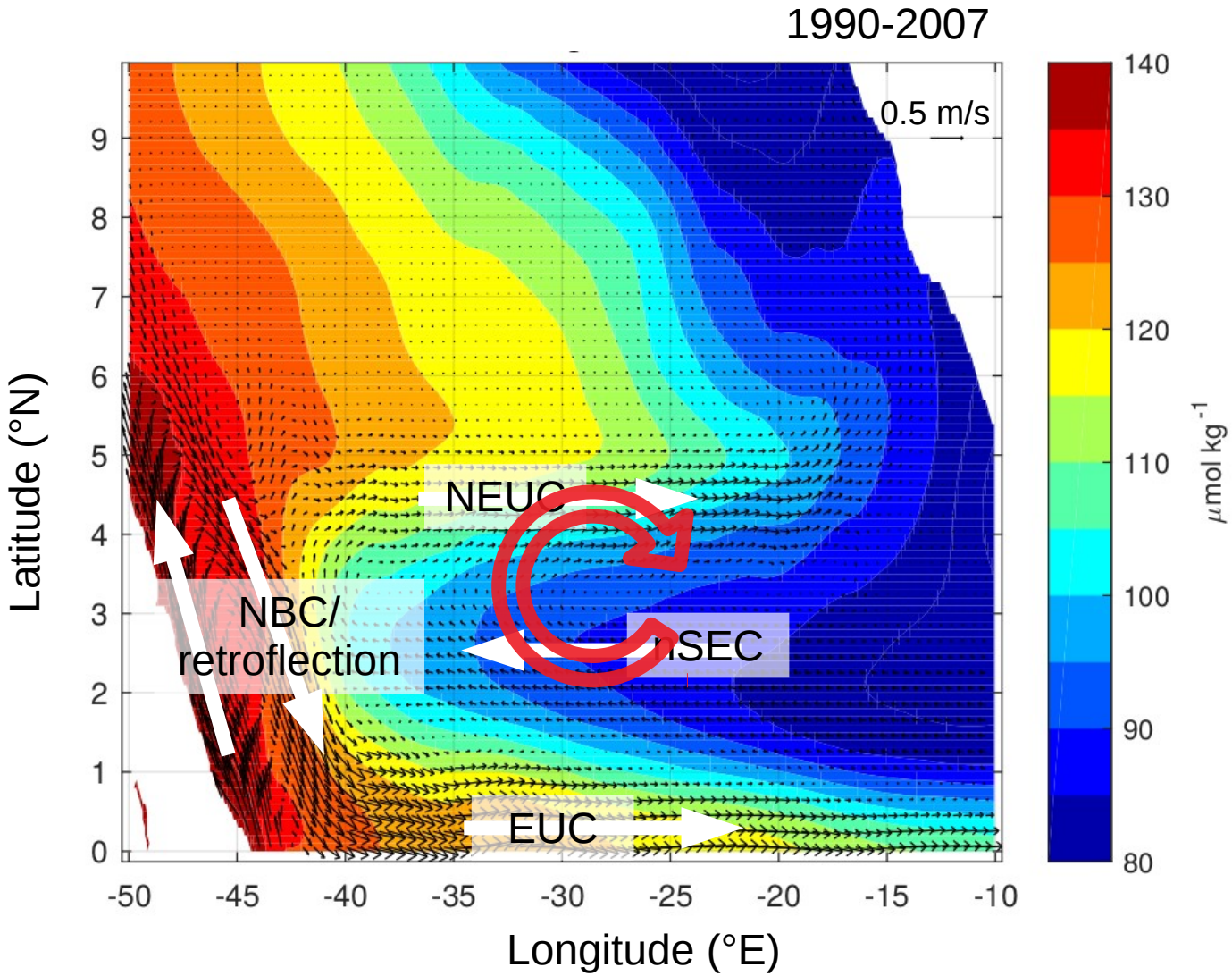
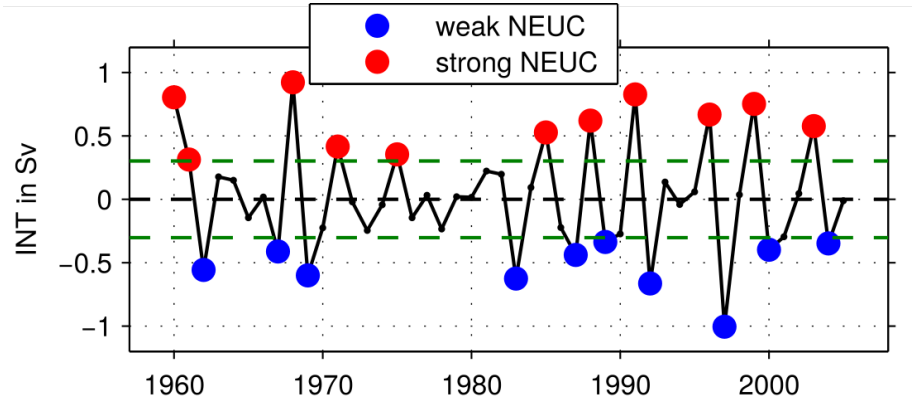


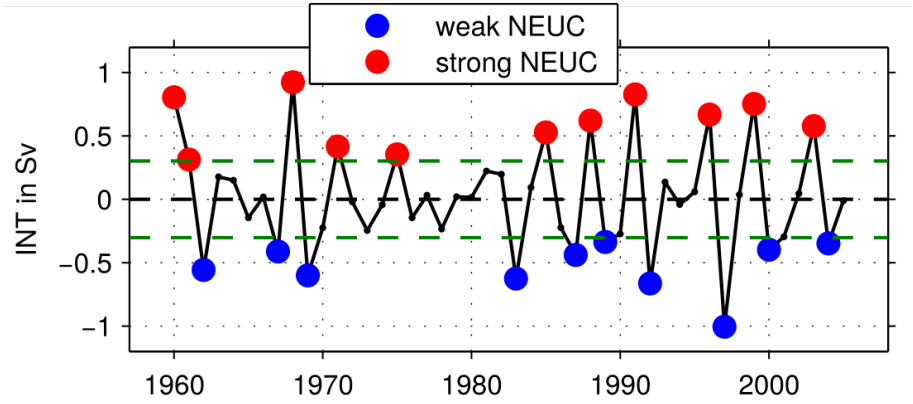
- Overestimation of recirculation between nSEC and NEUC in TRATL01 might explain lower oxygen concentraion in the NEUC altough it is stronger

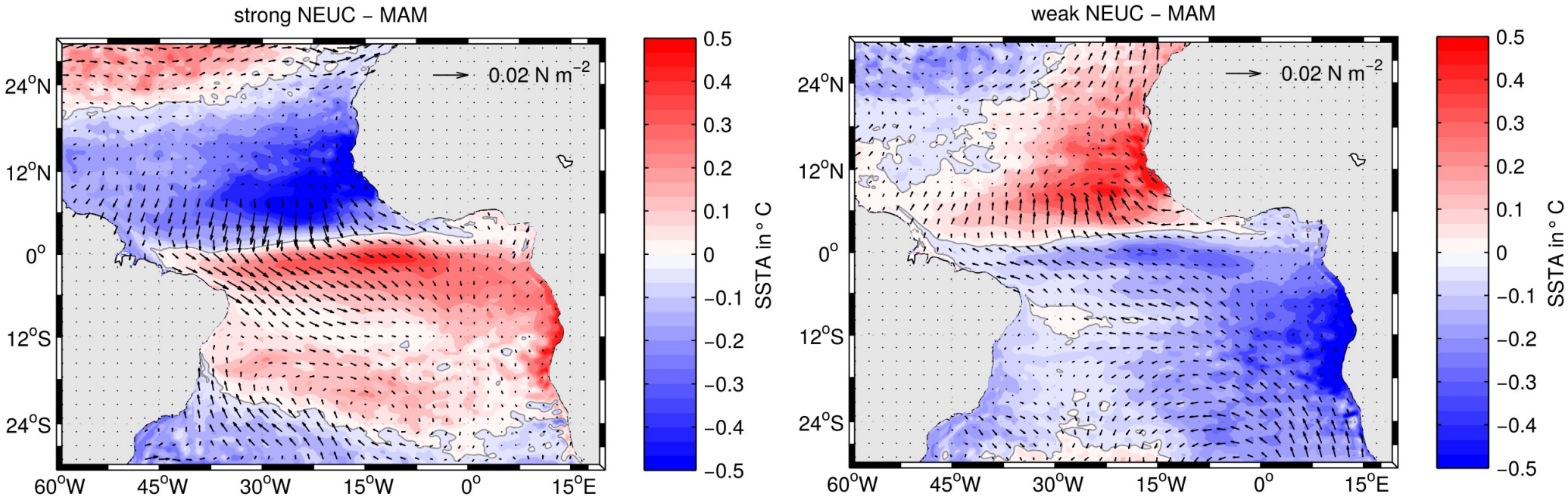
Interannual variability of NEUC in TRATL01

1-5-years band-pass filtered NEUC transport anomaly (TRATL01)



Interannual NEUC variability in TRATL01 linked to Atlantic Meridional Mode





- Anomalous SST and wind stress composites (March to May averages)

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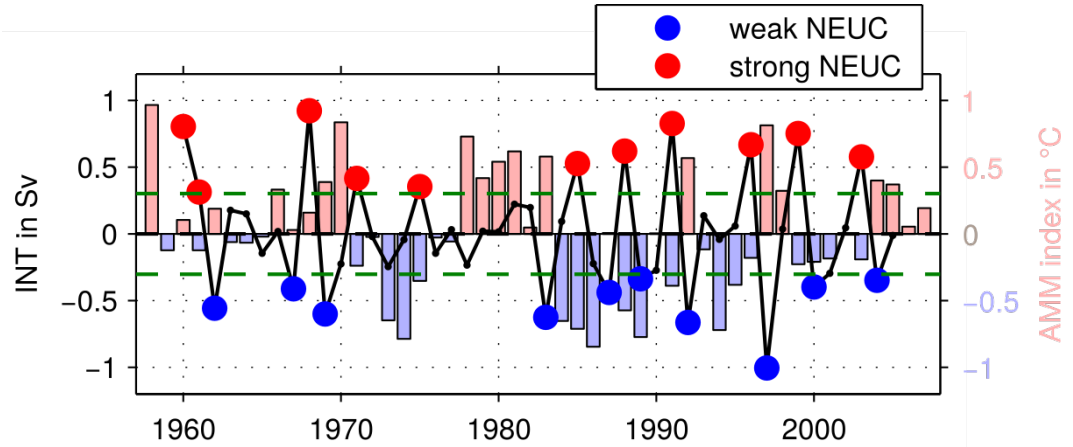

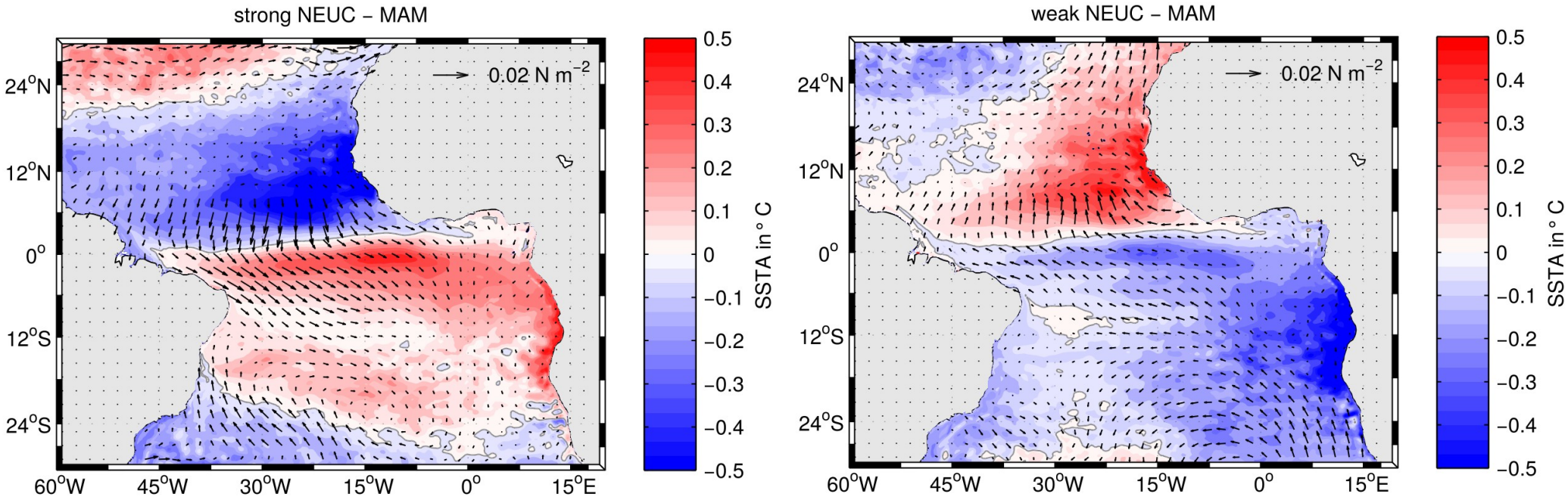

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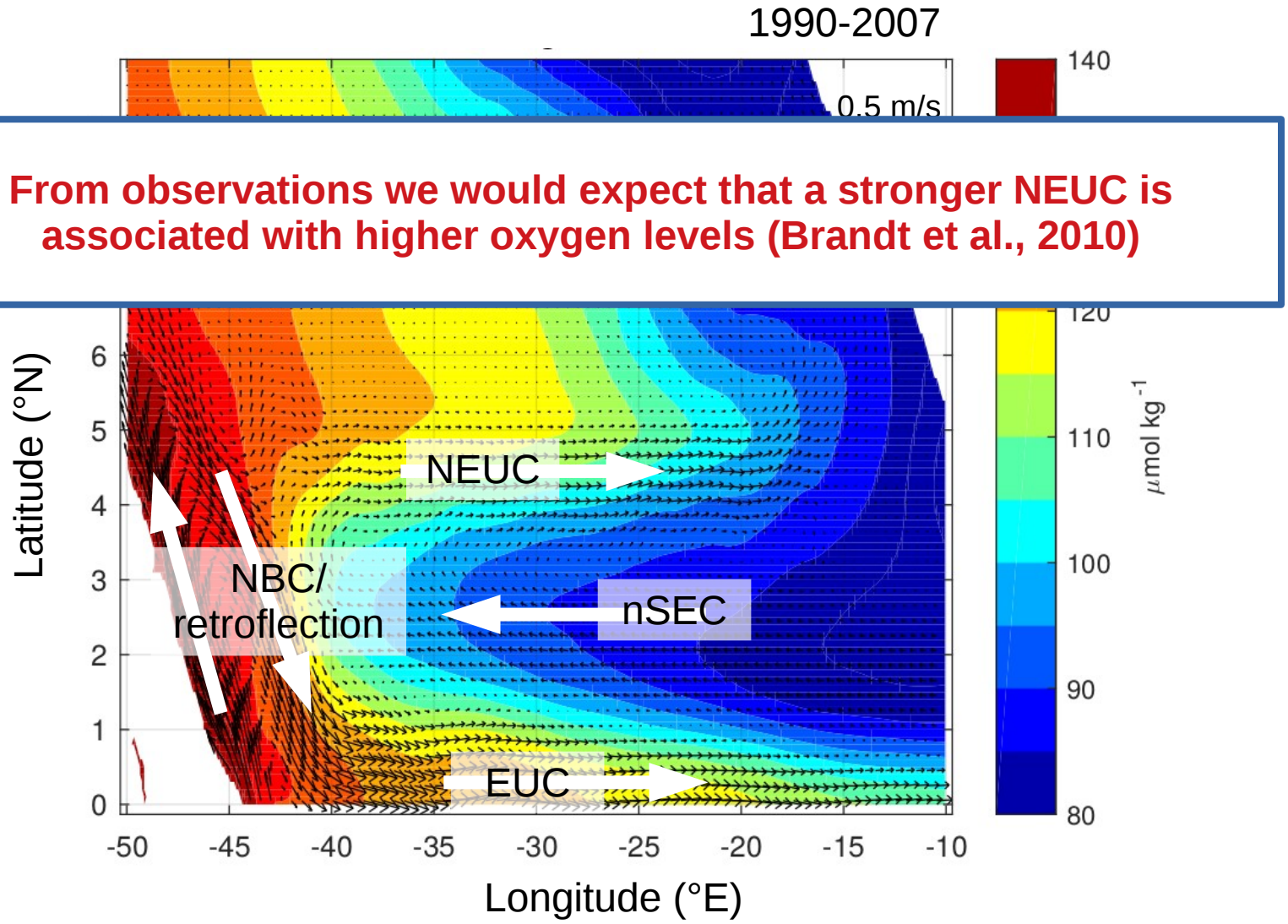
NEUC and oxygen

TRATL01 oxygen and horizontal velocity along the 26.5 kgm^{-3} - isopycnal



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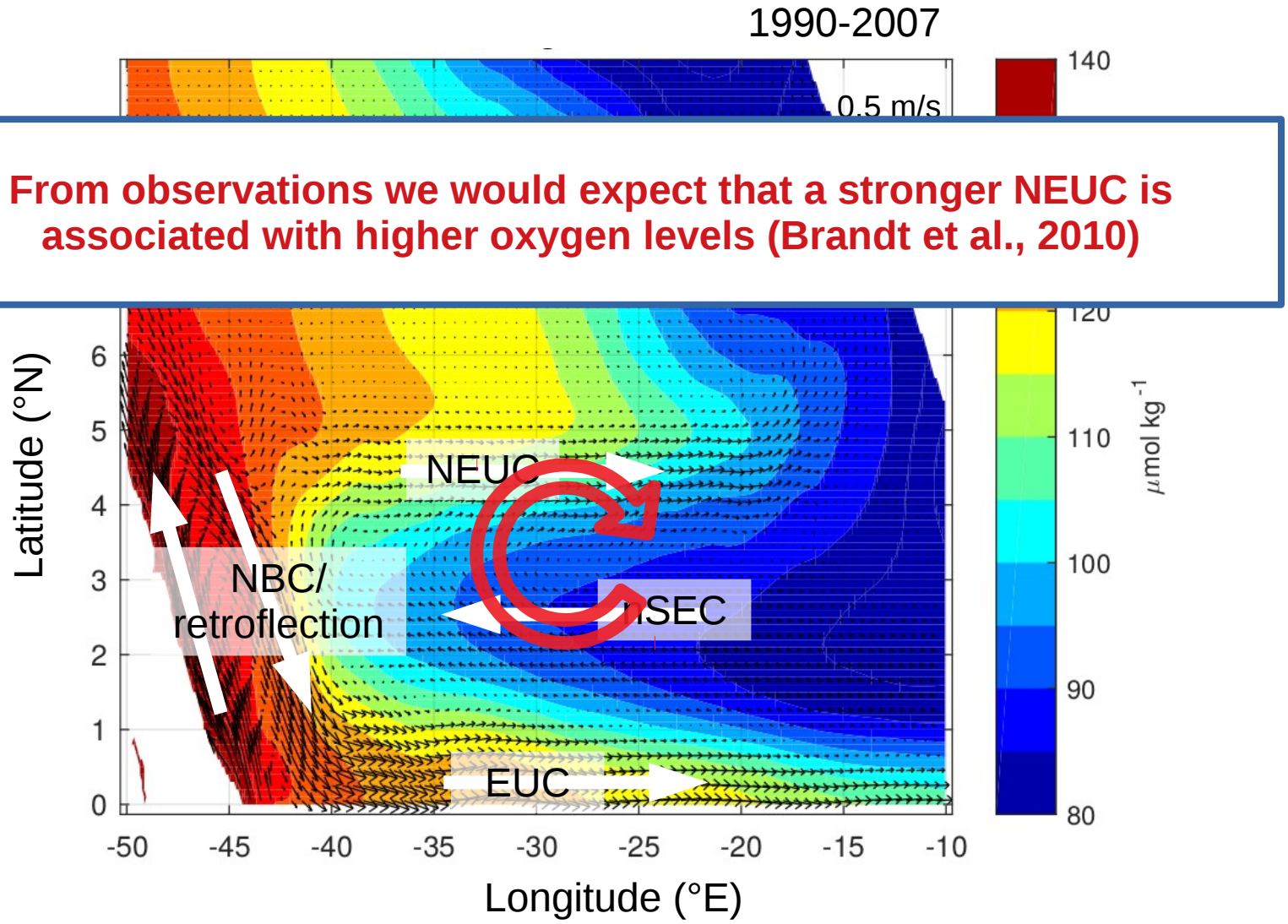

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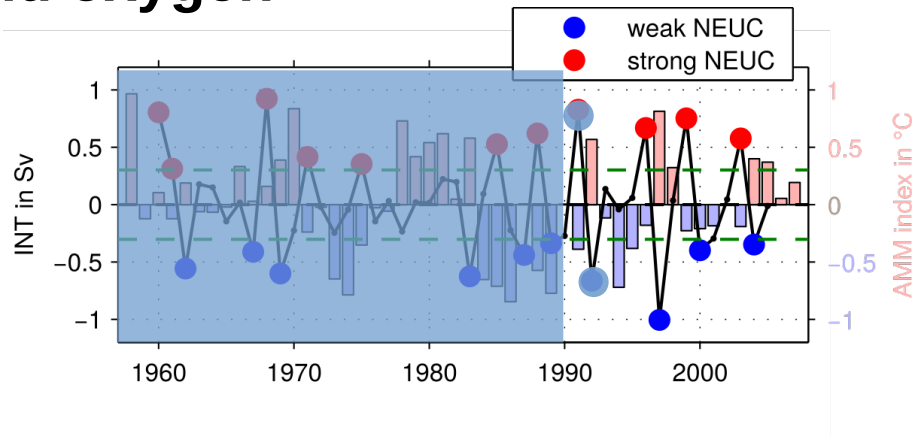

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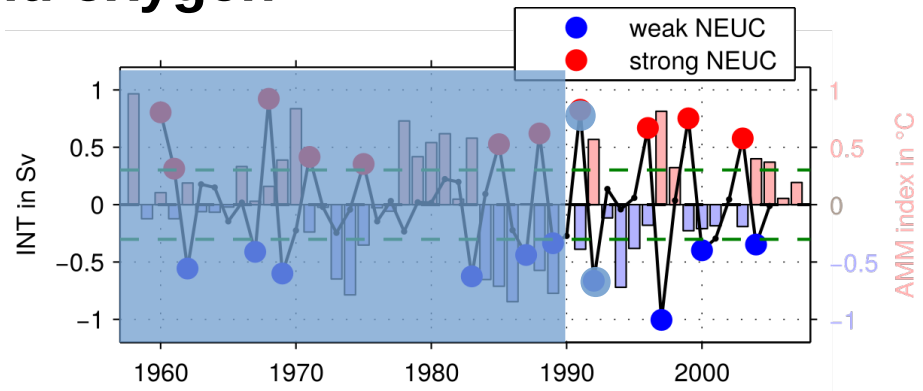

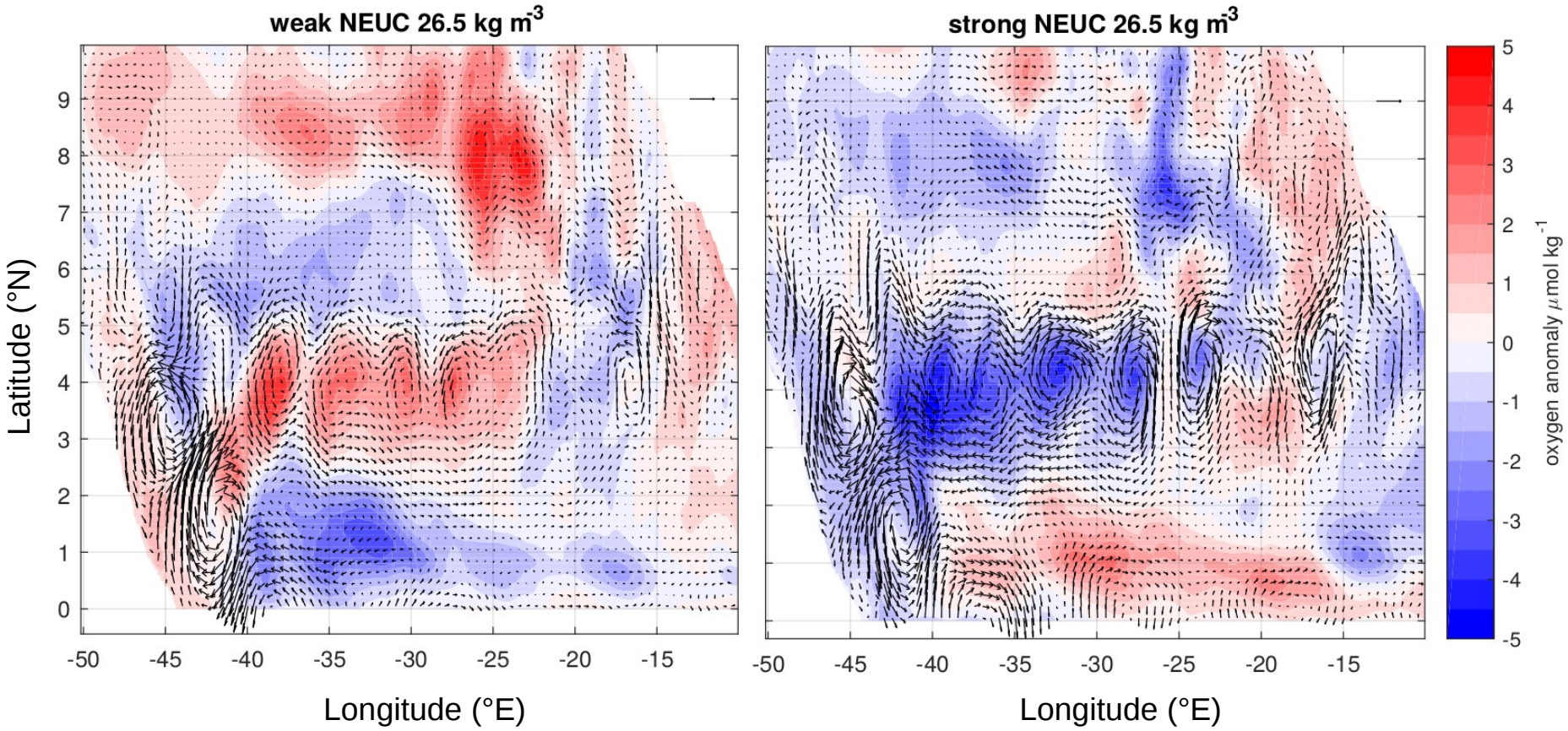

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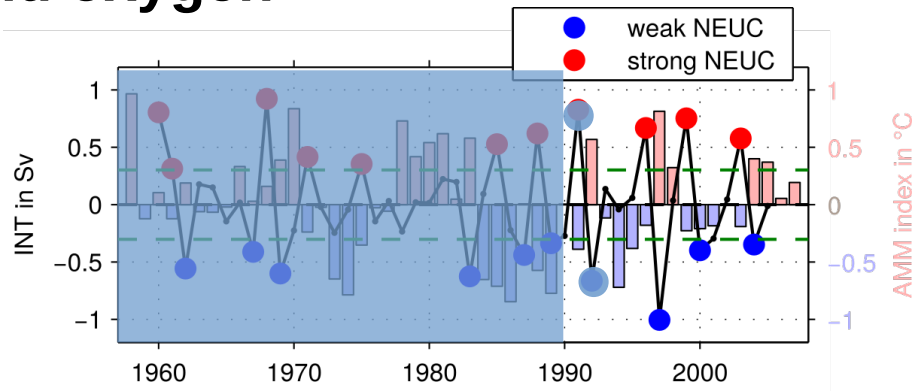

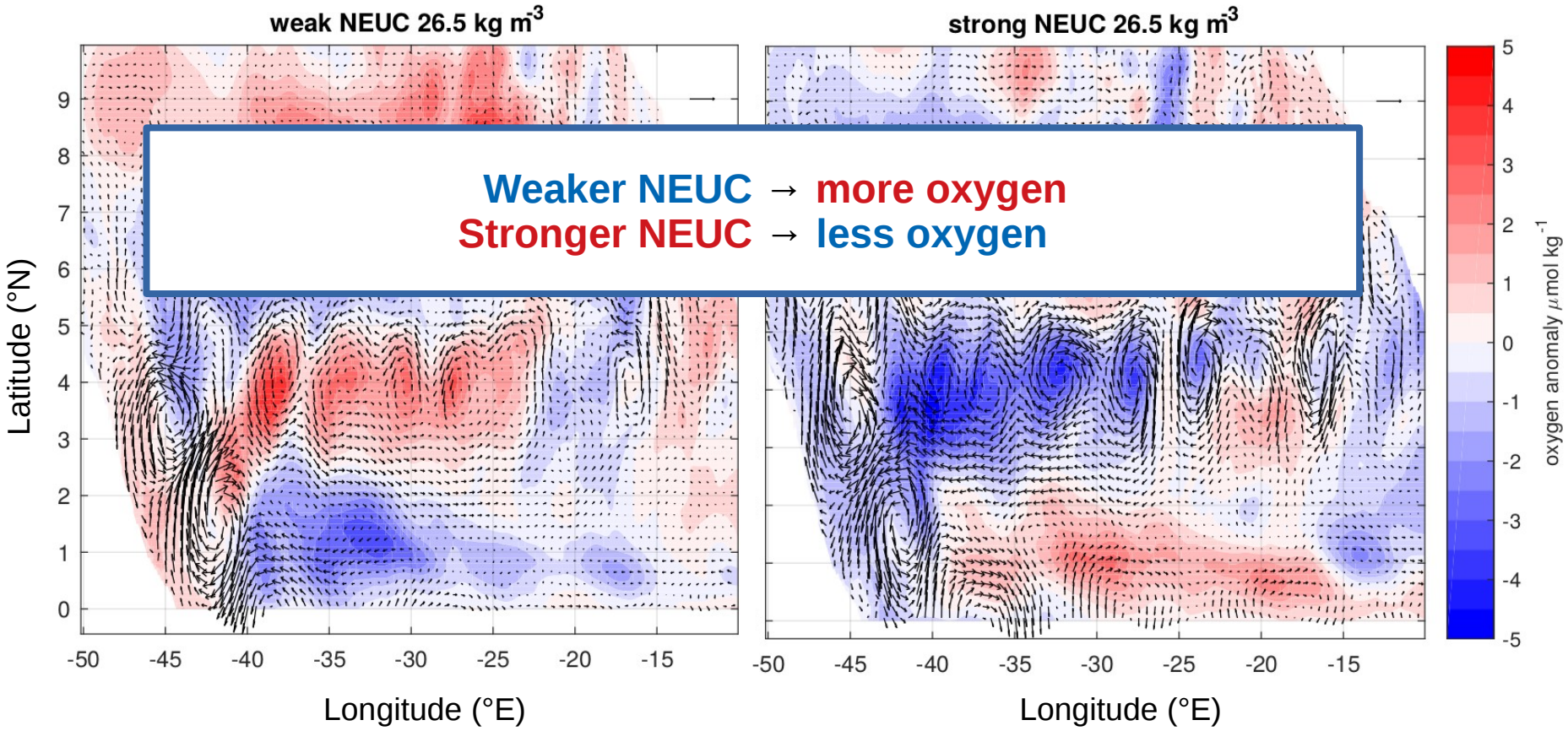

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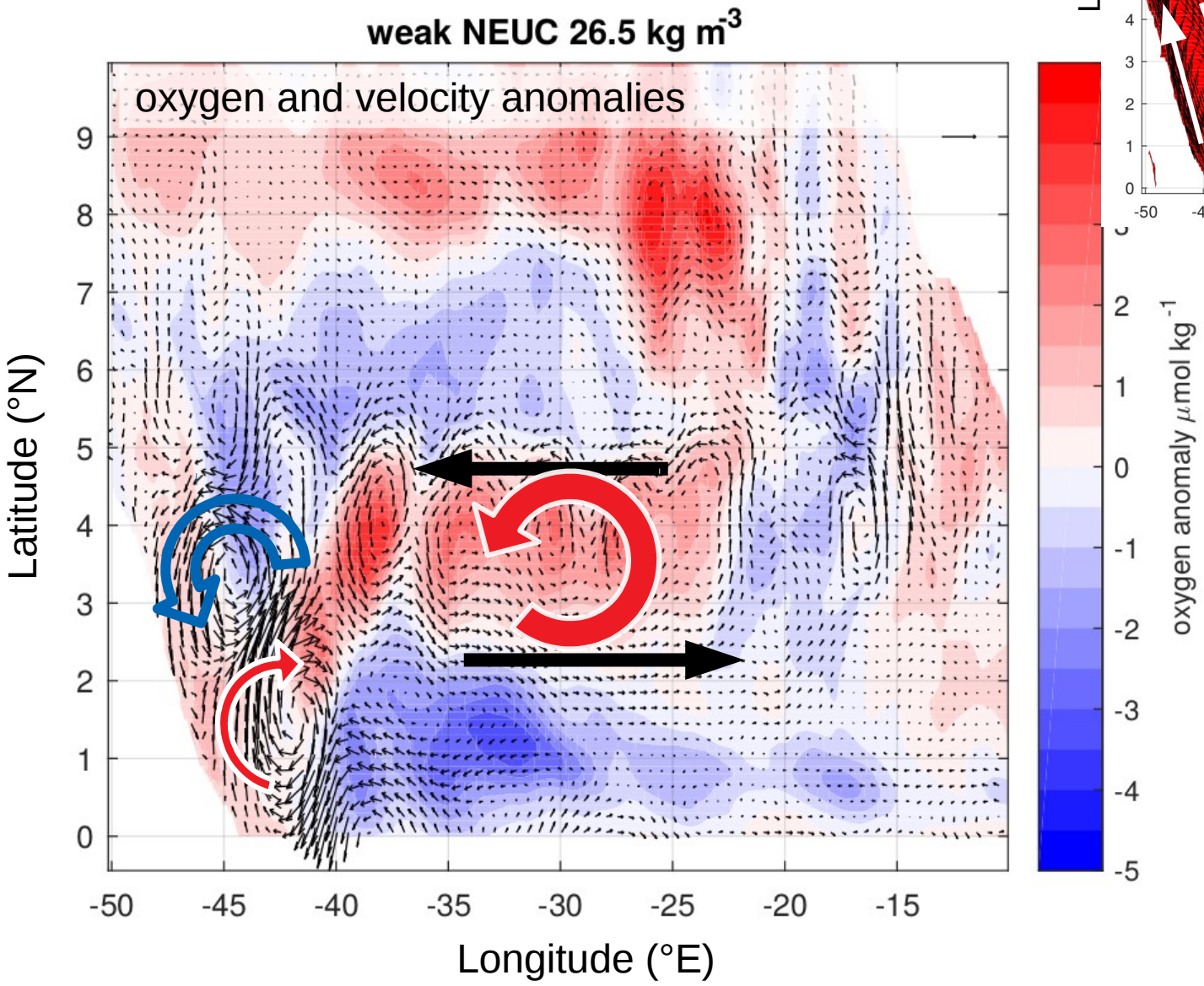
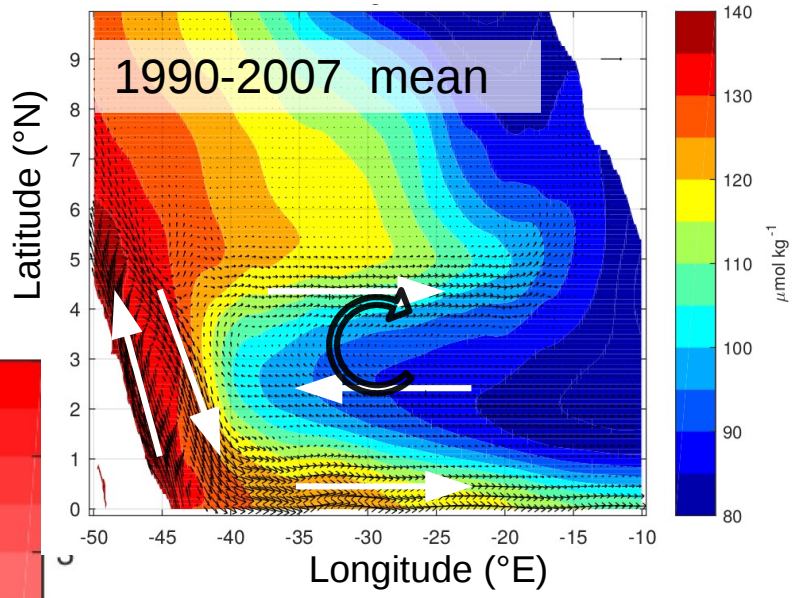
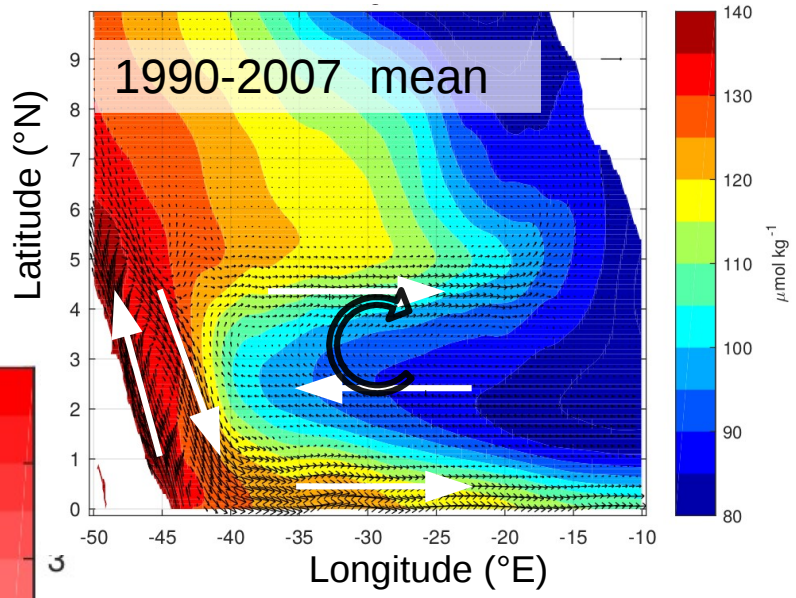


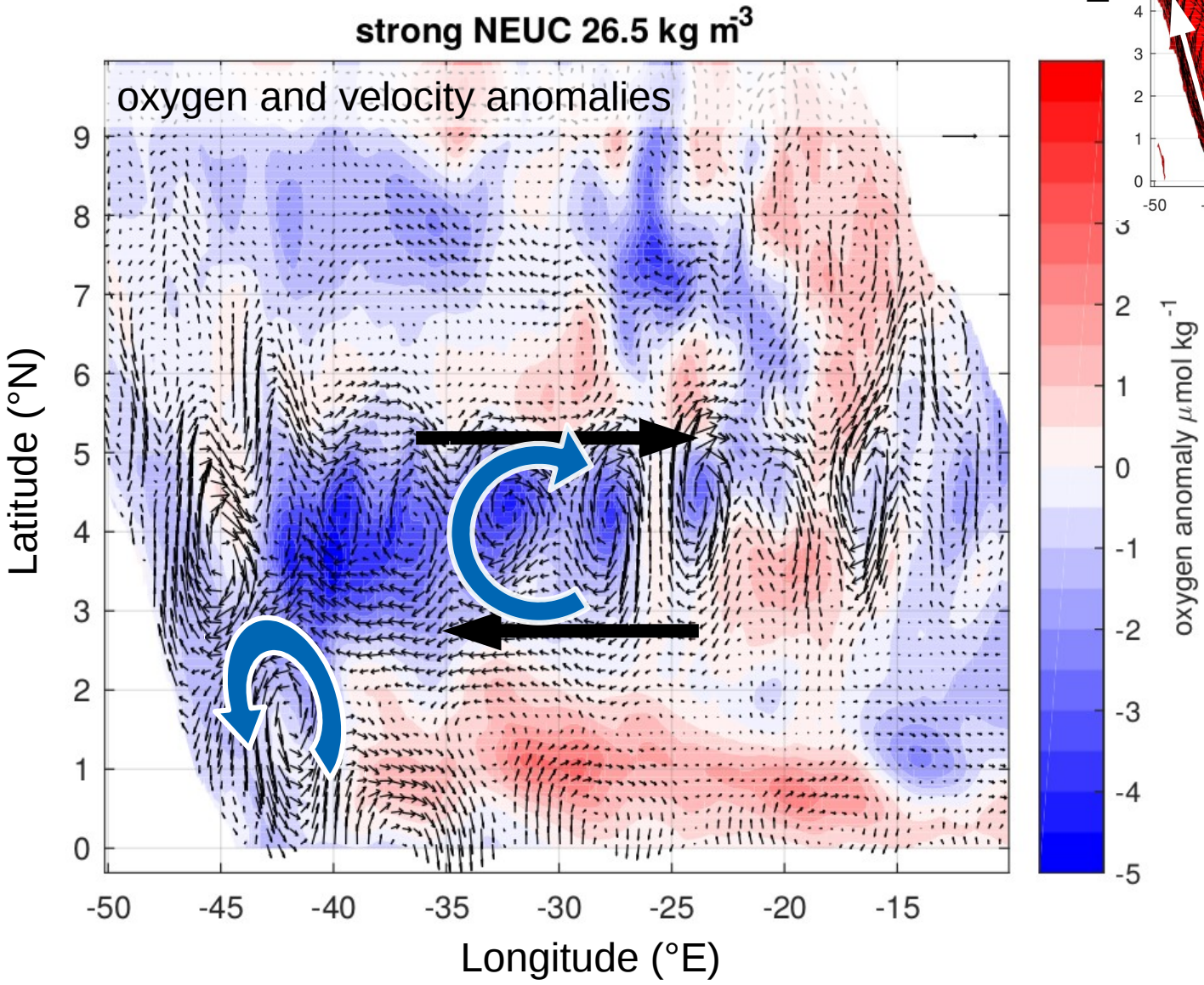


Positive oxygen anomaly:

- Weaker recirculation between NEUC and nSEC
- Stronger ventilation by NBC

NEUC variability and oxygen





Negative oxygen anomaly:

- Stronger recirculation between NEUC and nSEC
- weaker ventilation by NBC

Possible responses of oxygen to changes in the NEUC

- **Stronger NEUC** associated with **enhanced supply from NBC**
  → **more oxygen** (Brandt et al., 2010)

- **Stronger NEUC** due to **recirculations with nSEC** (e.g. TIWs)
  → **less oxygen**

- Oxygen anomalies at the western boundary may also impact oxygen concentrations within the NEUC

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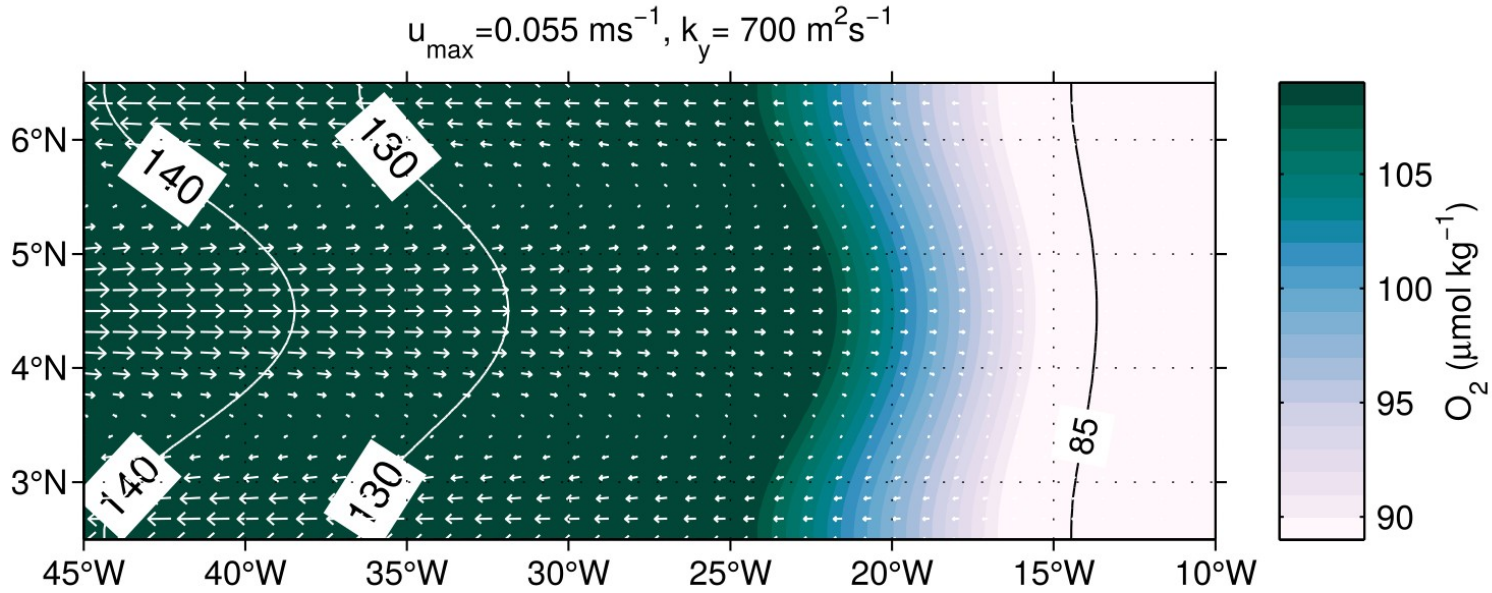
→ Conceptual model

Conceptual model

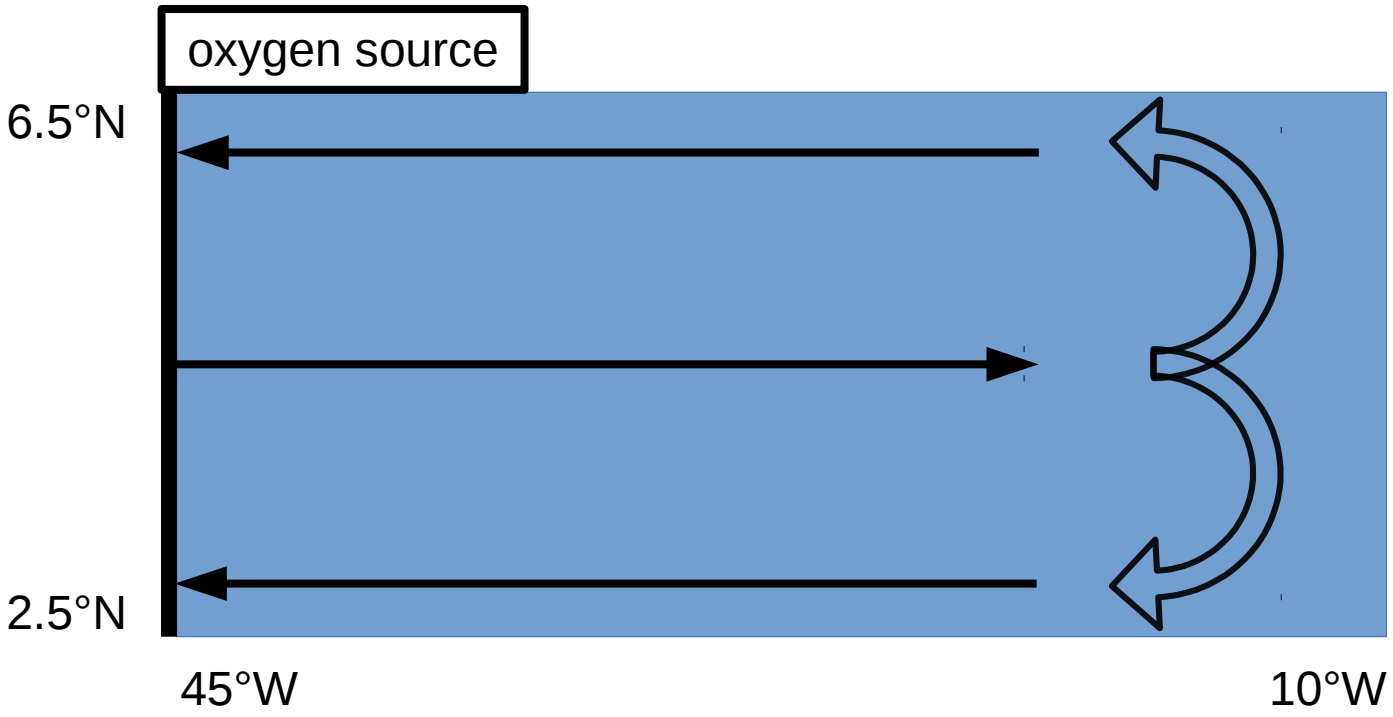
Simple advection-diffusion model following Brandt et al. (2010)



$$\frac{\partial C}{\partial t} = -aOUR - u\frac{\partial C}{\partial x} - v\frac{\partial C}{\partial y} + k_x\frac{\partial^2 C}{\partial x^2} + k_y\frac{\partial^2 C}{\partial y^2} + k_y F_{corr}\frac{\partial^2 C_{bg}}{\partial y^2} + k_z F_{corr}\frac{\partial^2 C_{bg}}{\partial z^2}$$

- $-aOUR$: Consumption (Karstensen et al., 2008)
- $-u\frac{\partial C}{\partial x} - v\frac{\partial C}{\partial y}$: horizontal advection
- $+k_x\frac{\partial^2 C}{\partial x^2} + k_y\frac{\partial^2 C}{\partial y^2}$: horizontal eddy diffusivity
- $+k_y F_{corr}\frac{\partial^2 C_{bg}}{\partial y^2}$: meridional eddy diffusivity (background oxygen)
- $+k_z F_{corr}\frac{\partial^2 C_{bg}}{\partial z^2}$: vertical eddy diffusivity (background oxygen)

Conceptual model – different simulations



SIM mean flow: **eastward current and its return flows**
SIM recirculation: recirculation between NEUC and nSEC

VAR mean flow: time variable flow field (SIM mean flow)
VAR recirculation: time variable recirculation (SIM recirculation)
VAR oxygen source: time variable oxygen source at western boundary (SIM mean flow)

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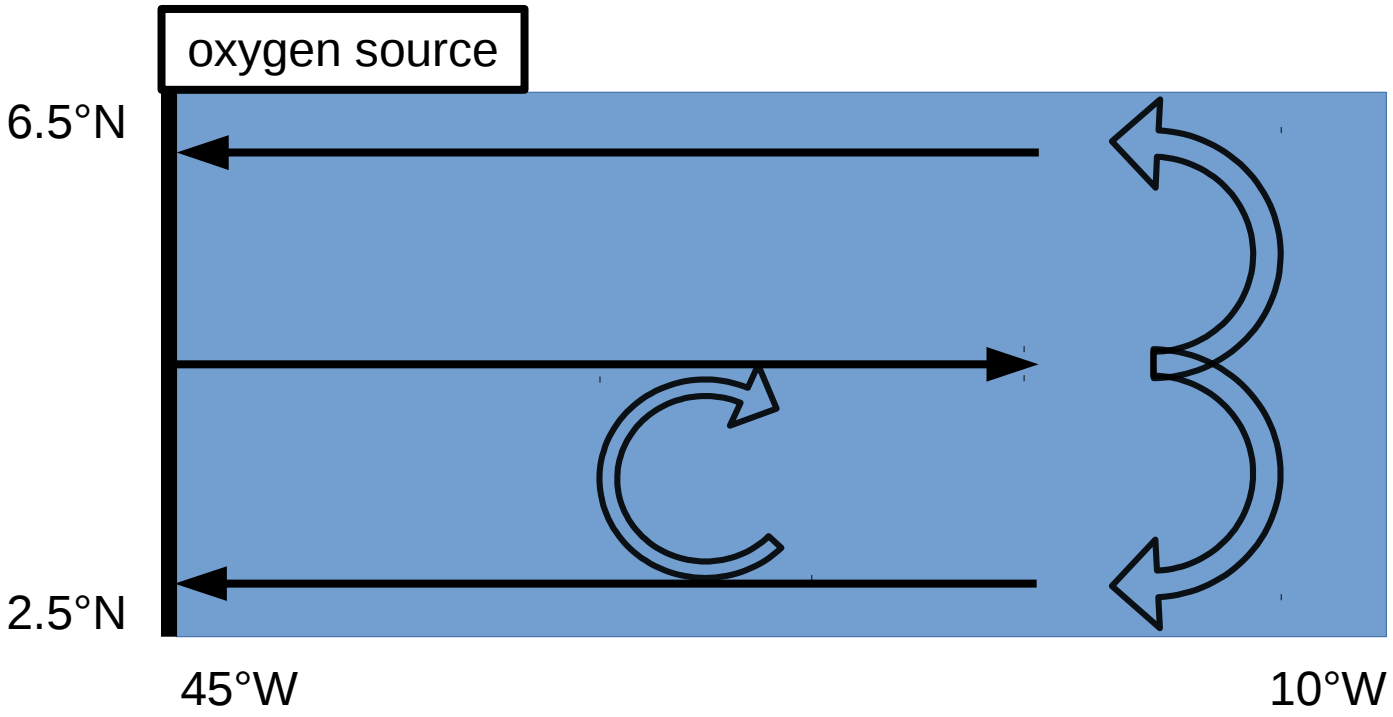

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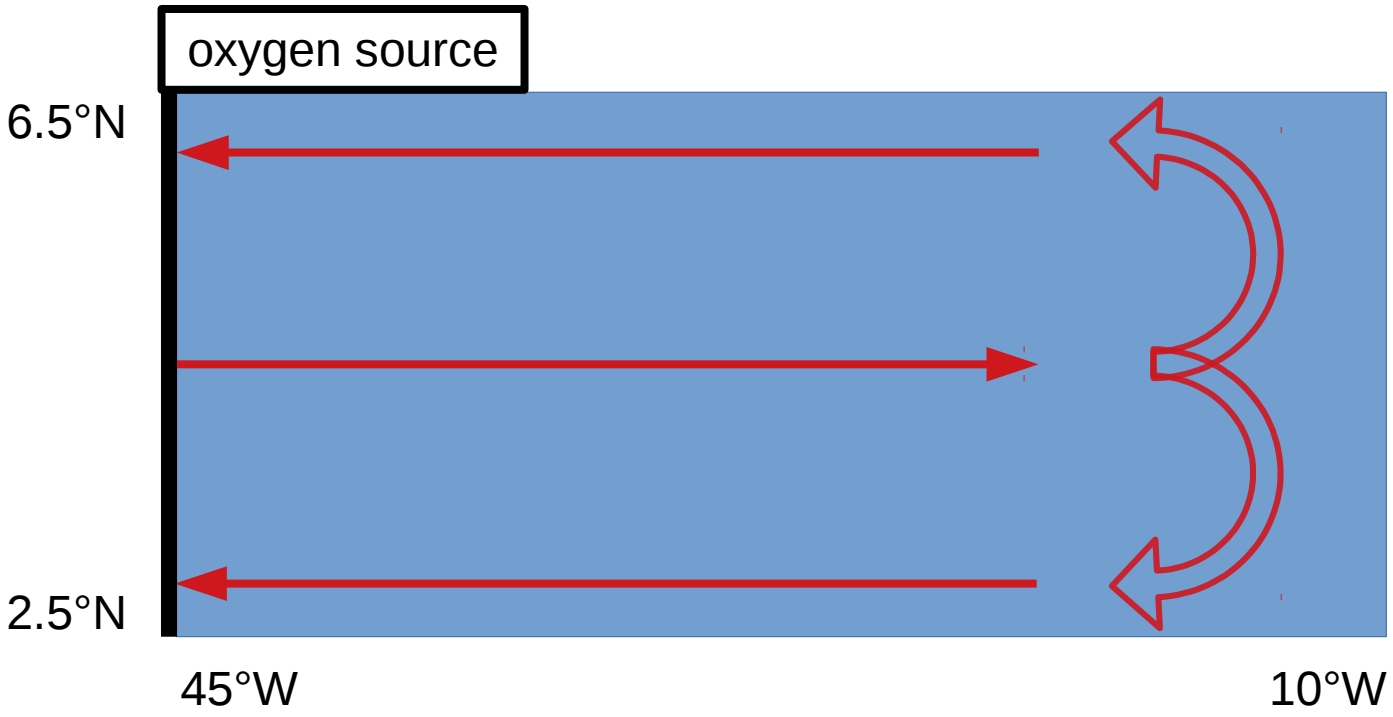

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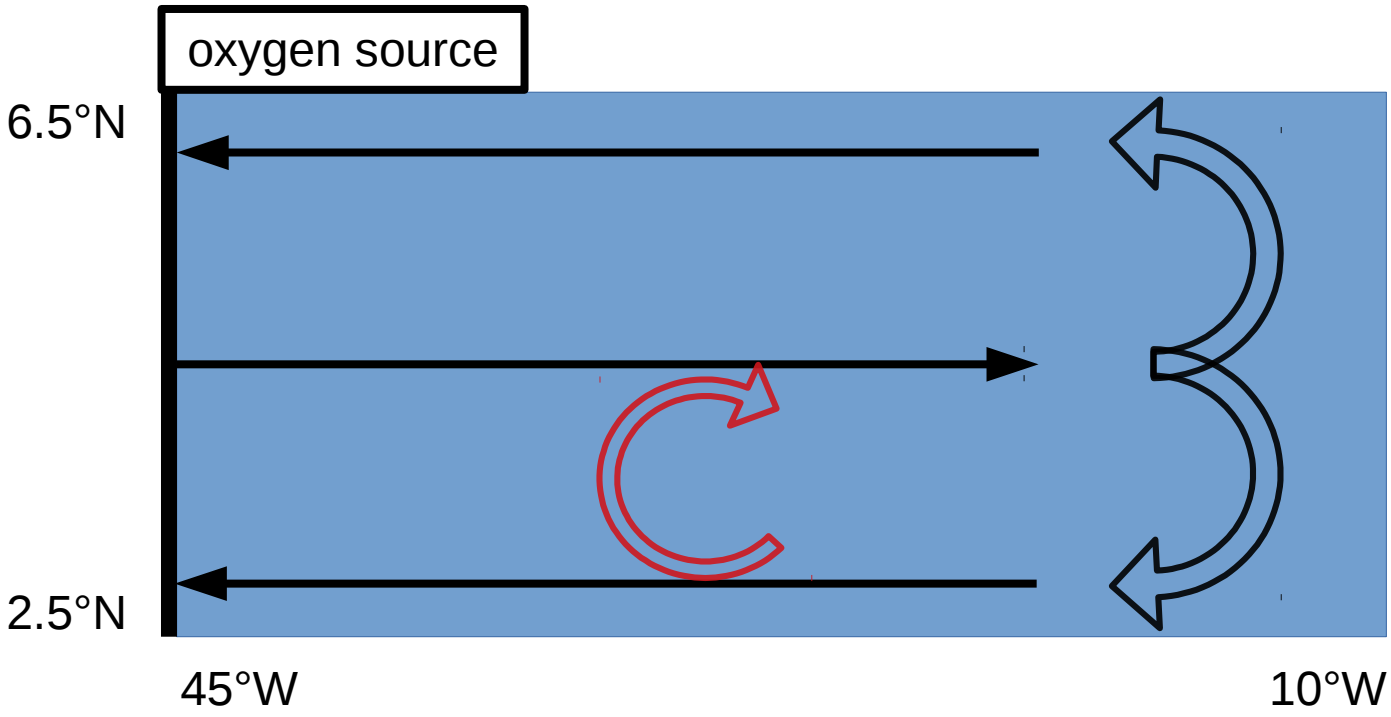

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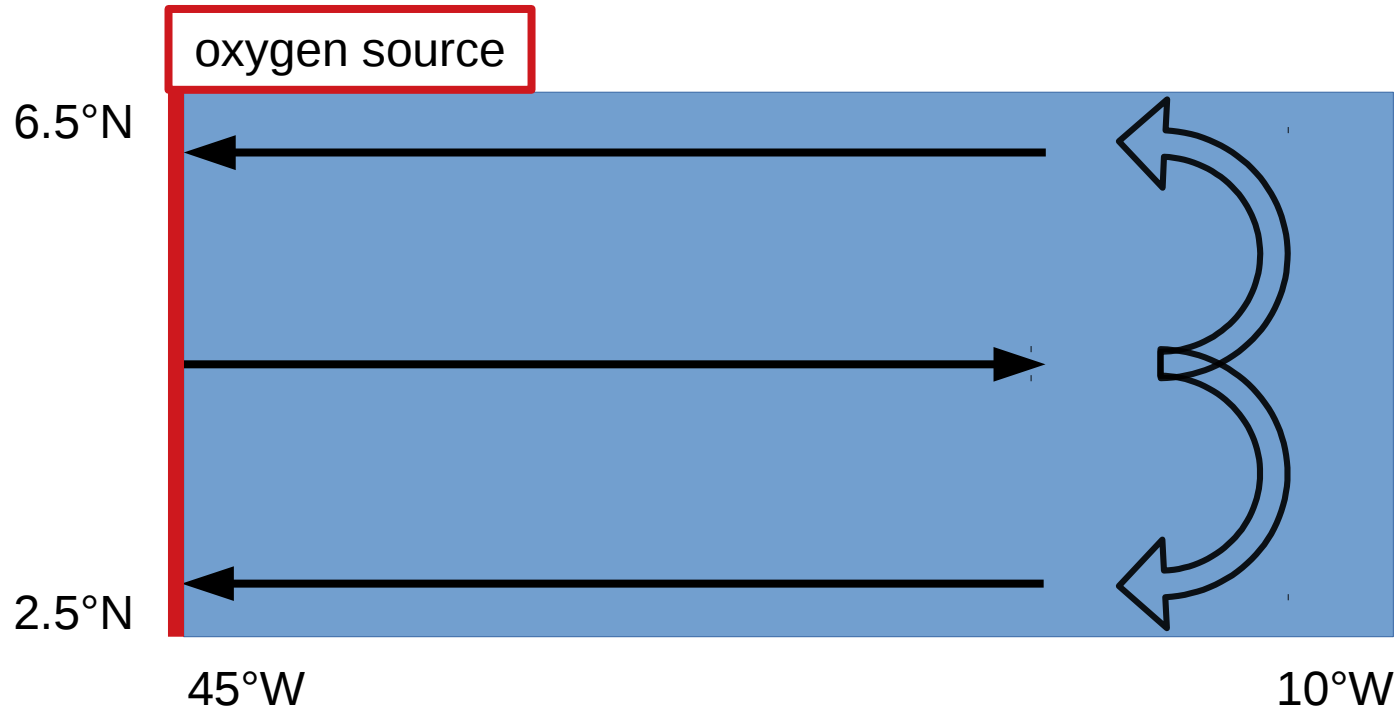

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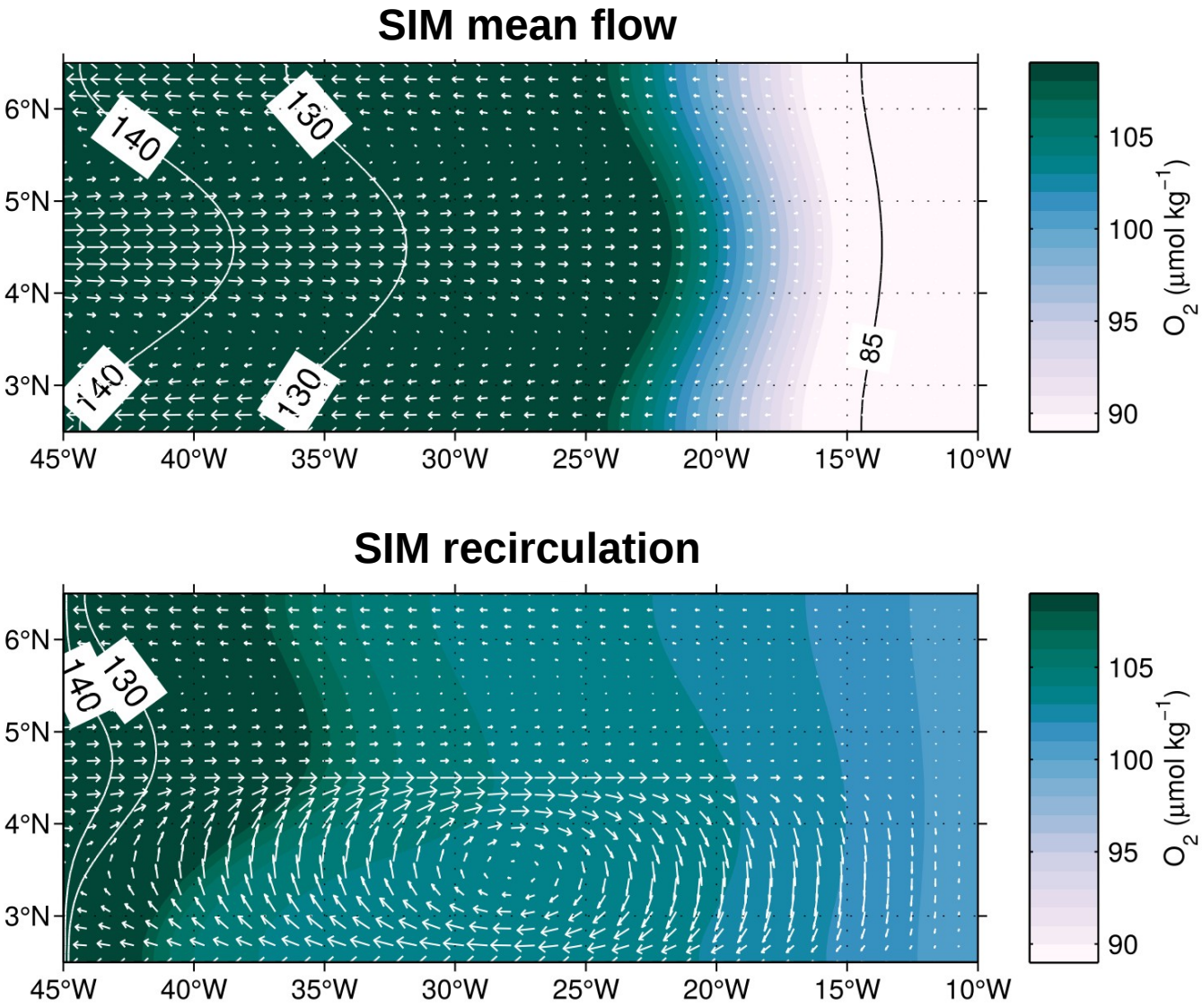
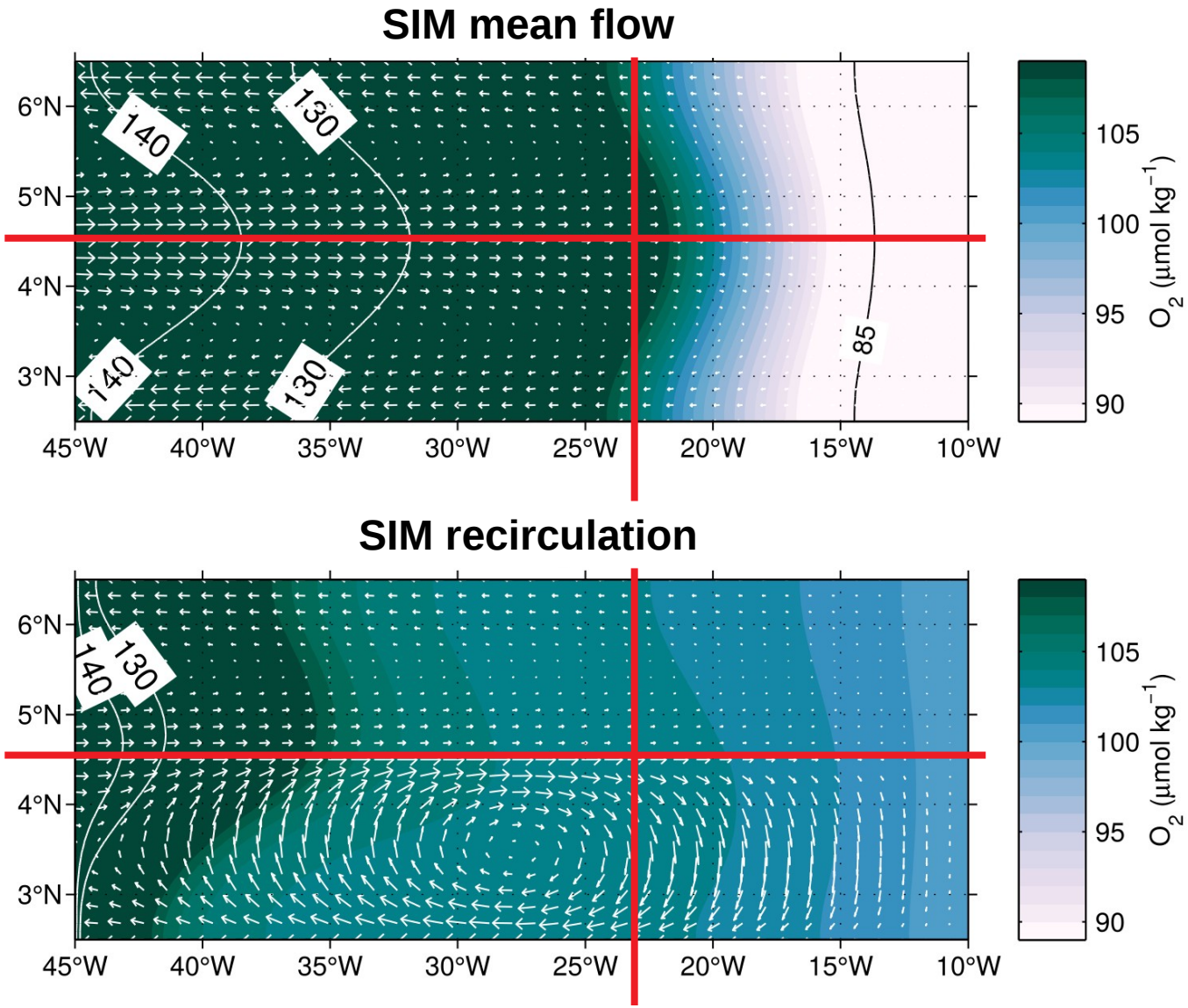
Conceptual model – steady state



SIM recirculation compared to SIM mean flow:

- homogeneous oxygen field in central and eastern basin
- less oxygen west of 20°W
- more oxygen east of 20°W

Conceptual model – steady state



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SIM mean flow

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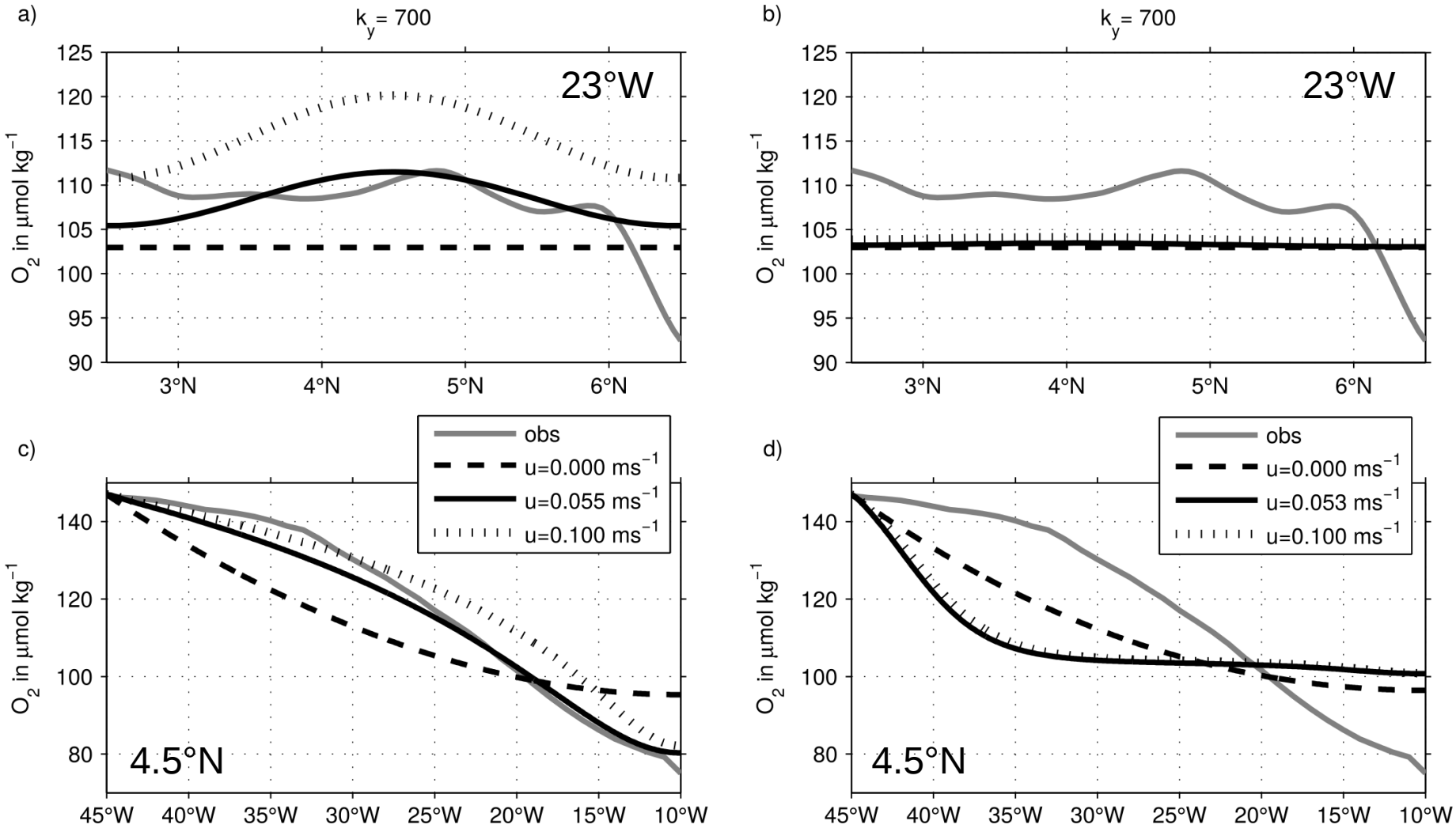

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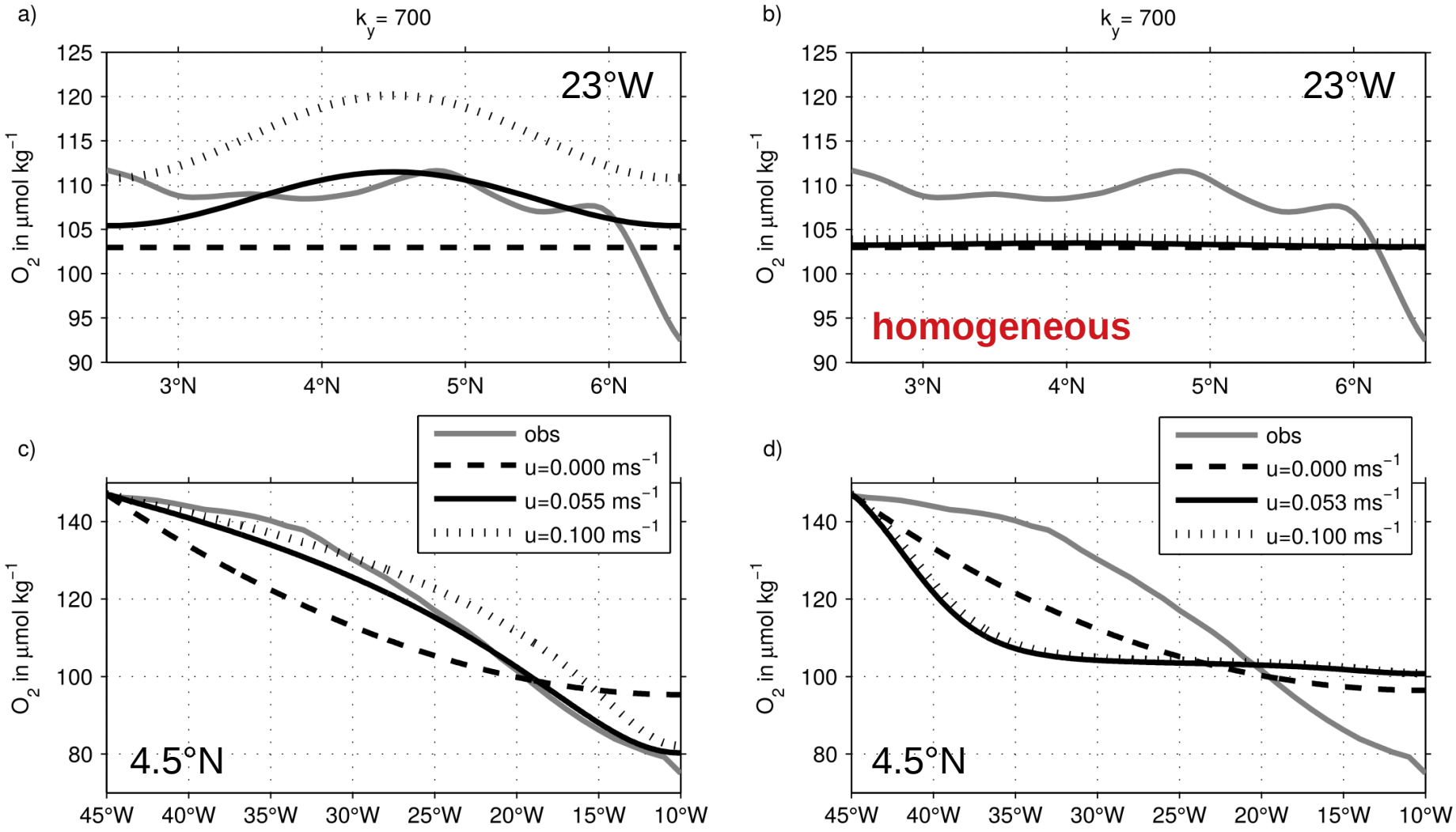

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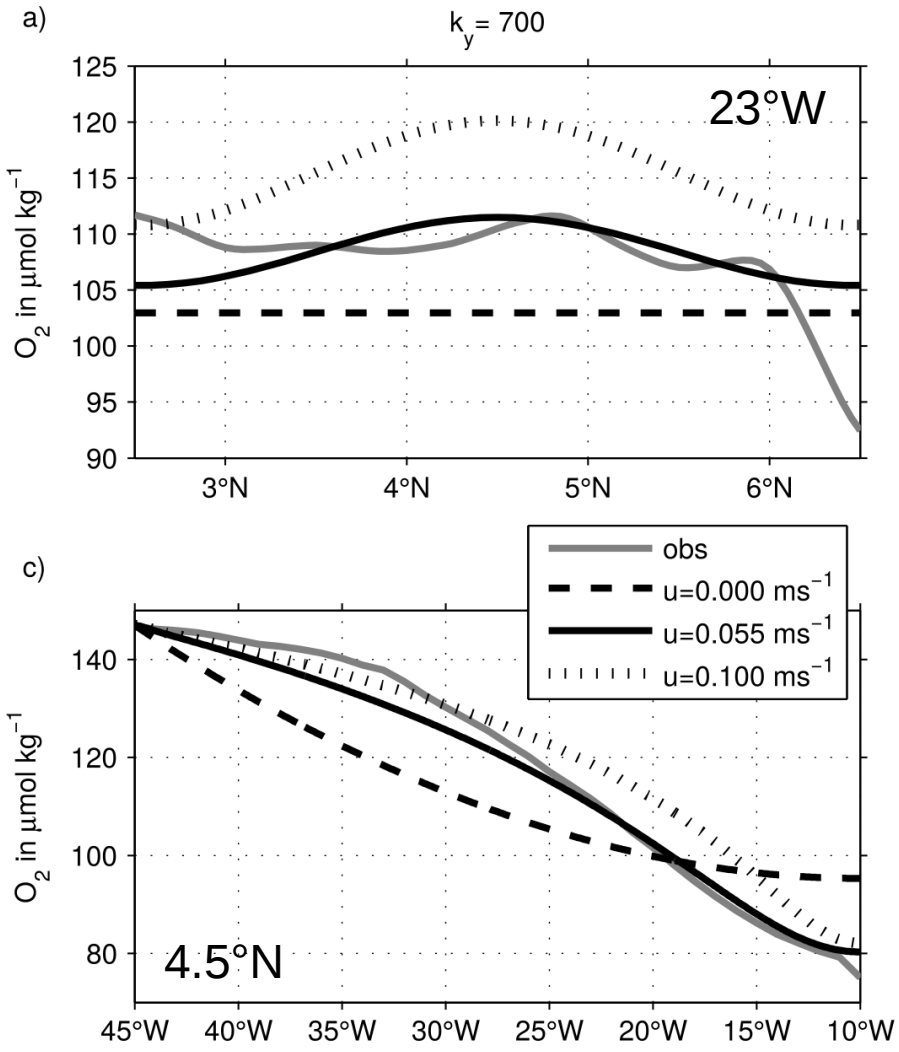

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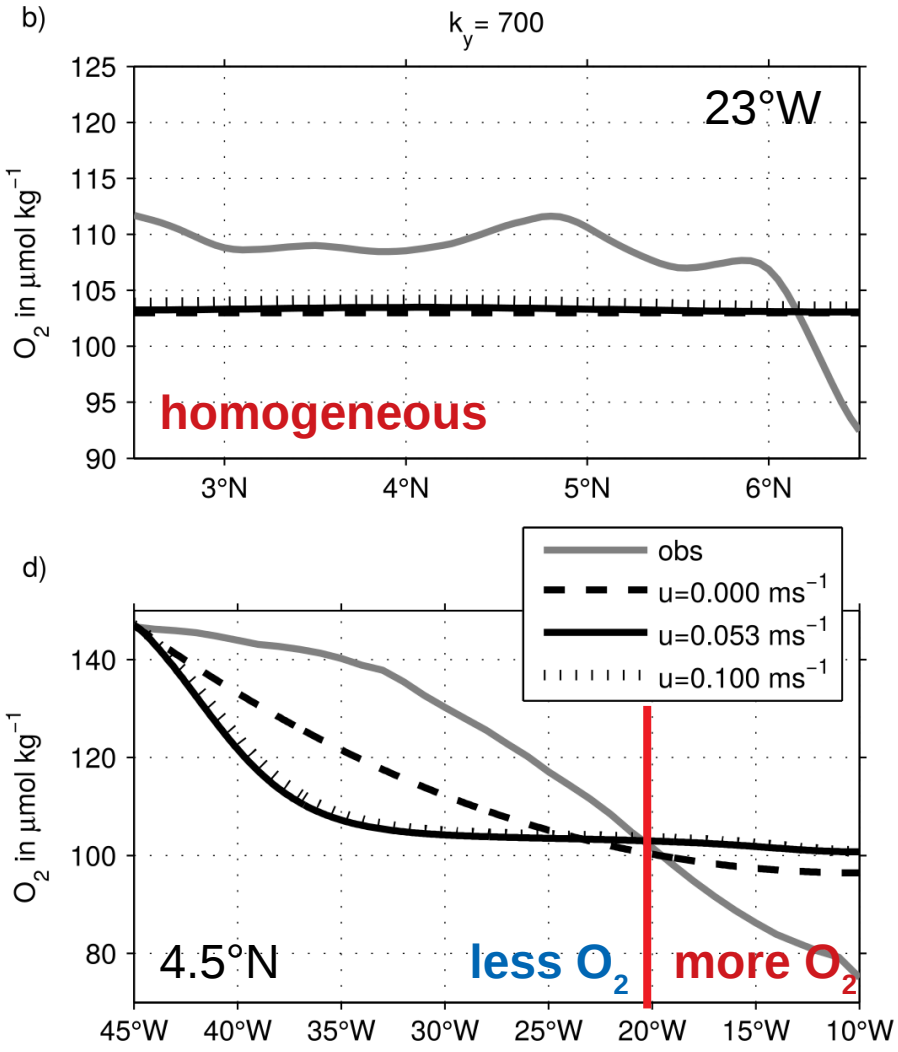
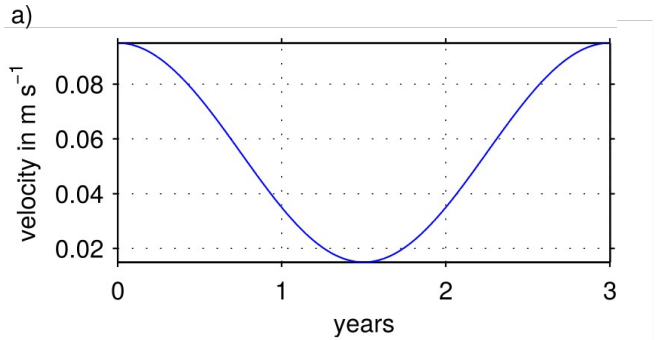
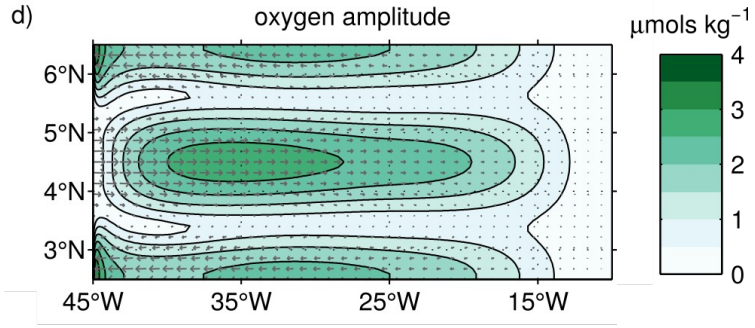
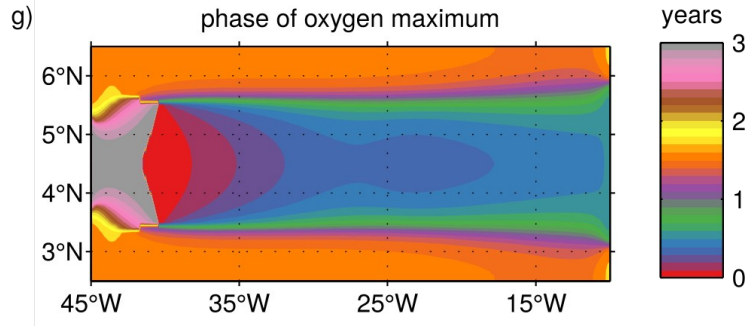


Conceptual model – temporal variability

VAR mean flow







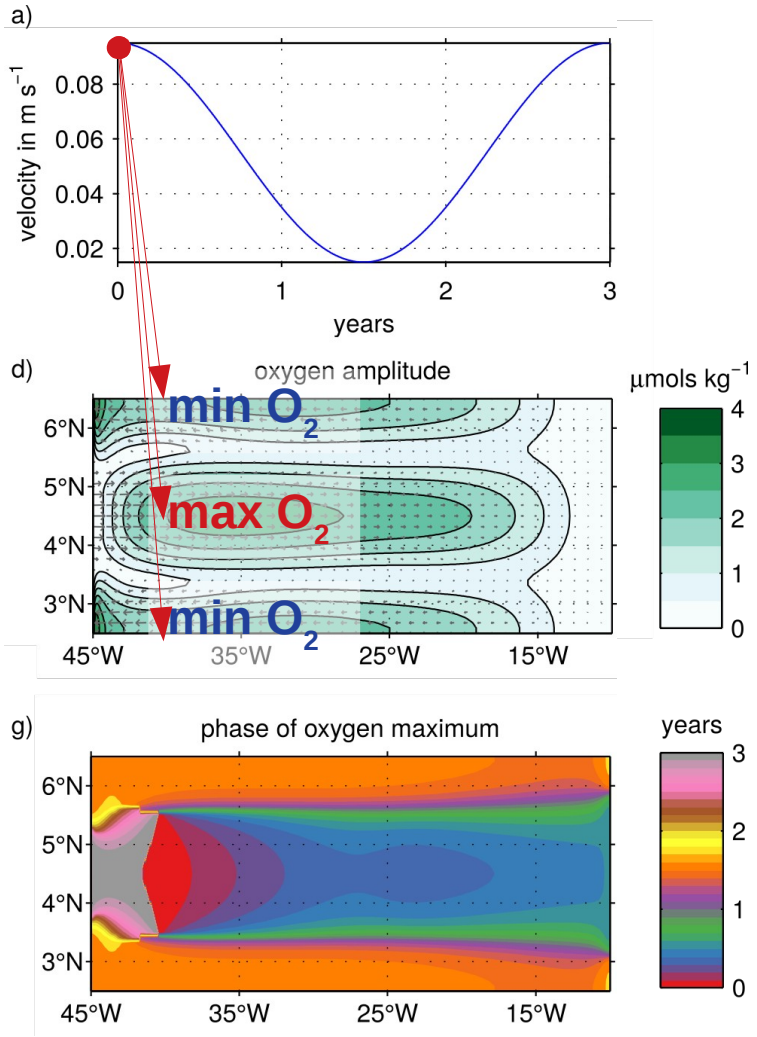
→ Amplitude of forcing term (sinusoid, 3 years period)

→ Amplitude of oxygen variability

→ Phase of maximum oxygen (time lag between maximum of forcing term and maximum of oxygen)

Conceptual model – temporal variability

VAR mean flow



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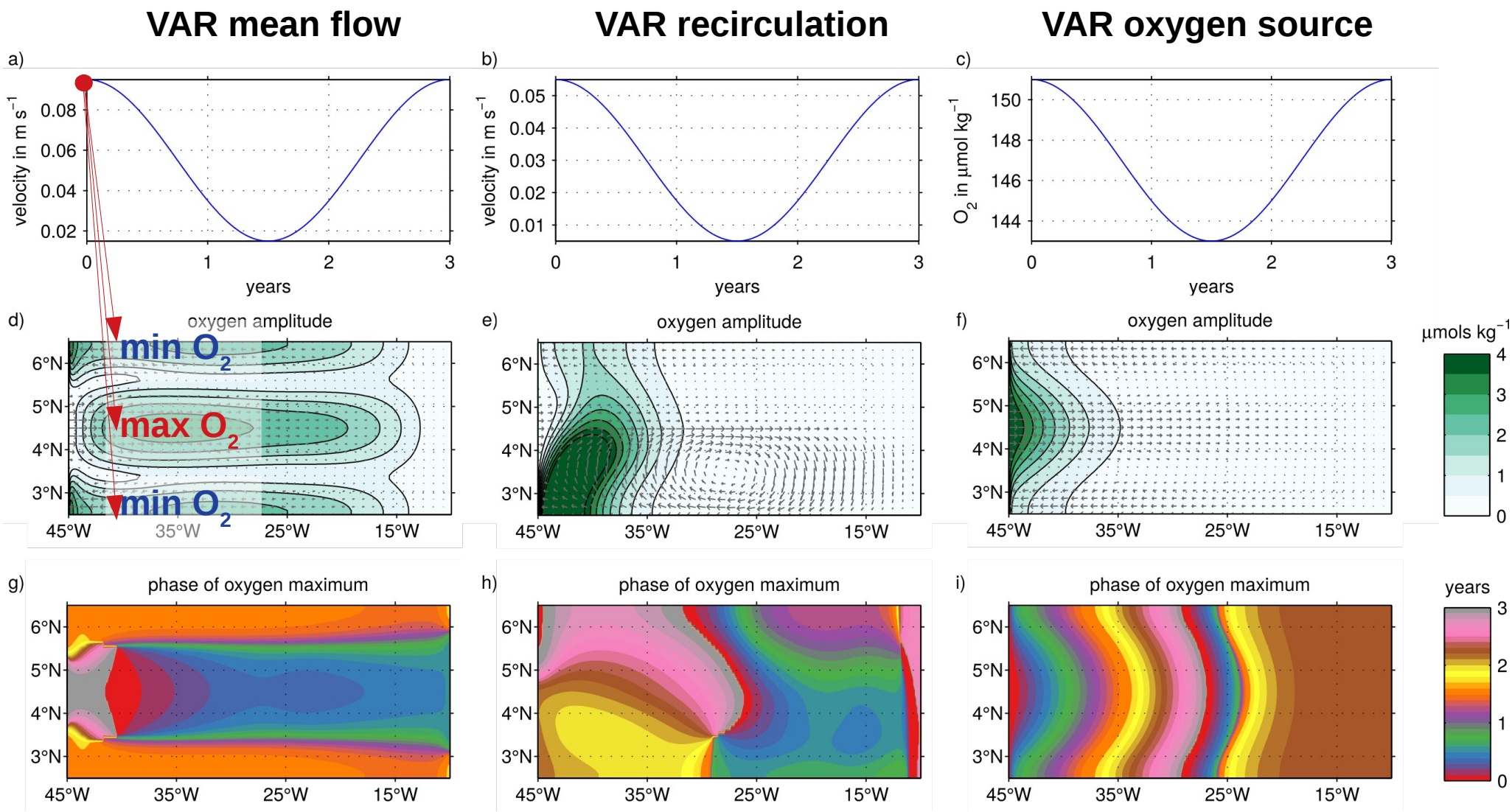

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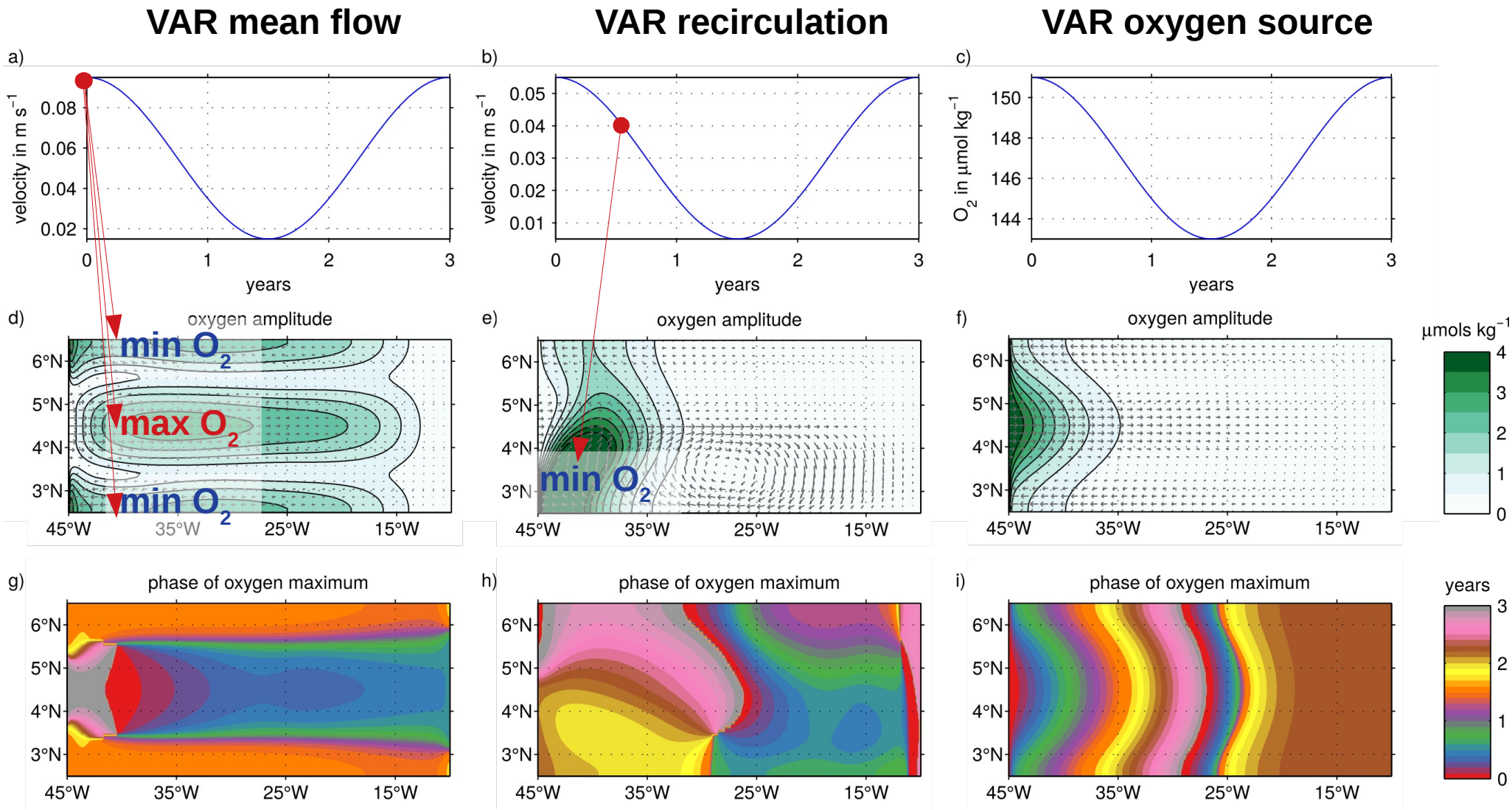

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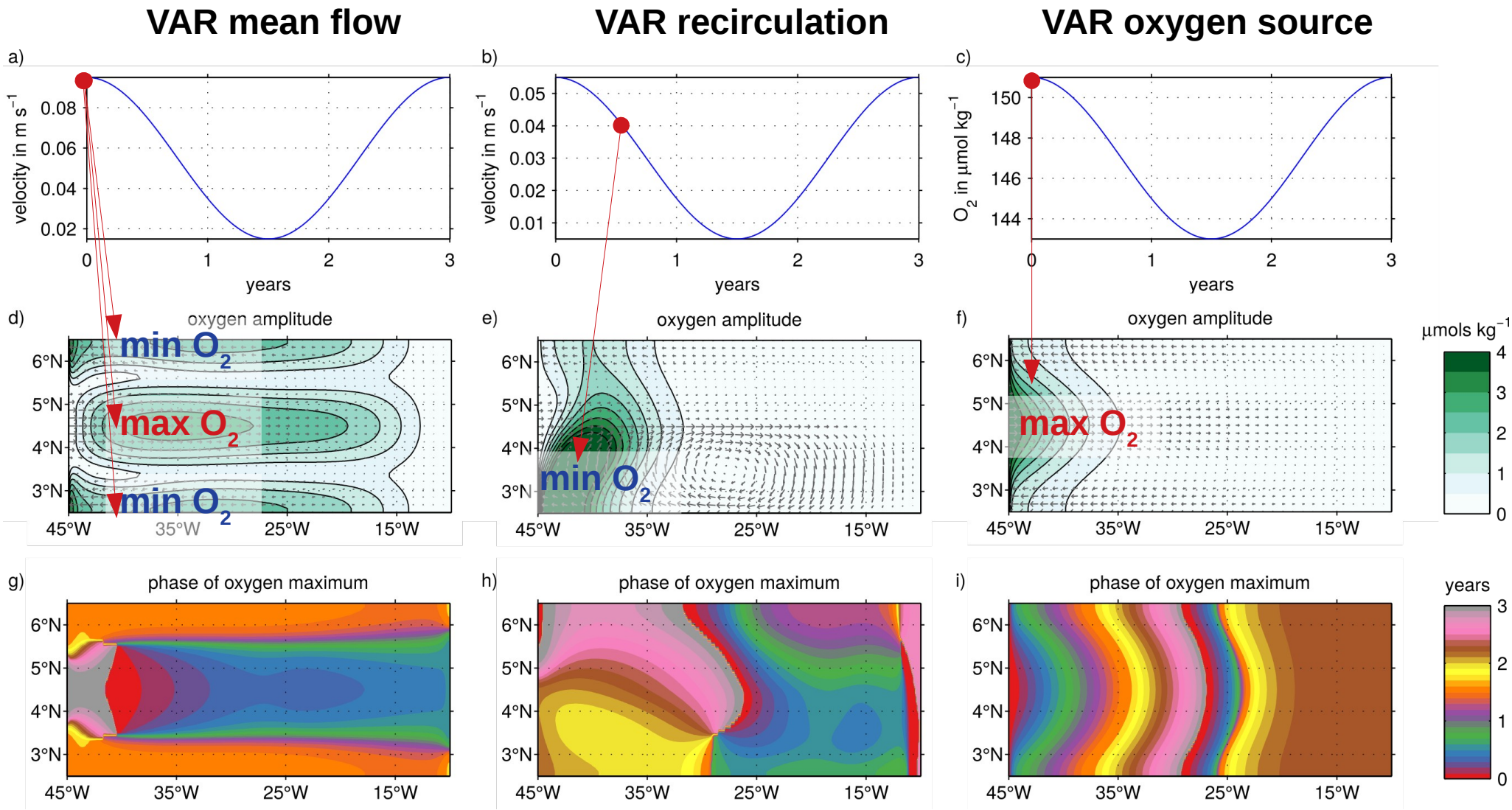

Conclusion

- **Processes that lead to model bias in mean state can also impact variability**
- **It is important to understand these processes**

Conceptual model:

- **Recirculation between NEUC and nSEC results in less oxygen within the currents**
- **Oxygen response to changes in NEUC**
  - Stronger NEUC associated with enhanced supply from NBC → more oxygen along the NEUC (VAR mean flow)
  - Stronger NEUC due to recirculations with nSEC (e.g. TIWs) → less oxygen in western basin (VAR recirculation)
- **Oxygen changes at western boundary have minor impact (VAR oxygen source)**