Reshuffling of Nitrate (NO3) in the Southern Ocean

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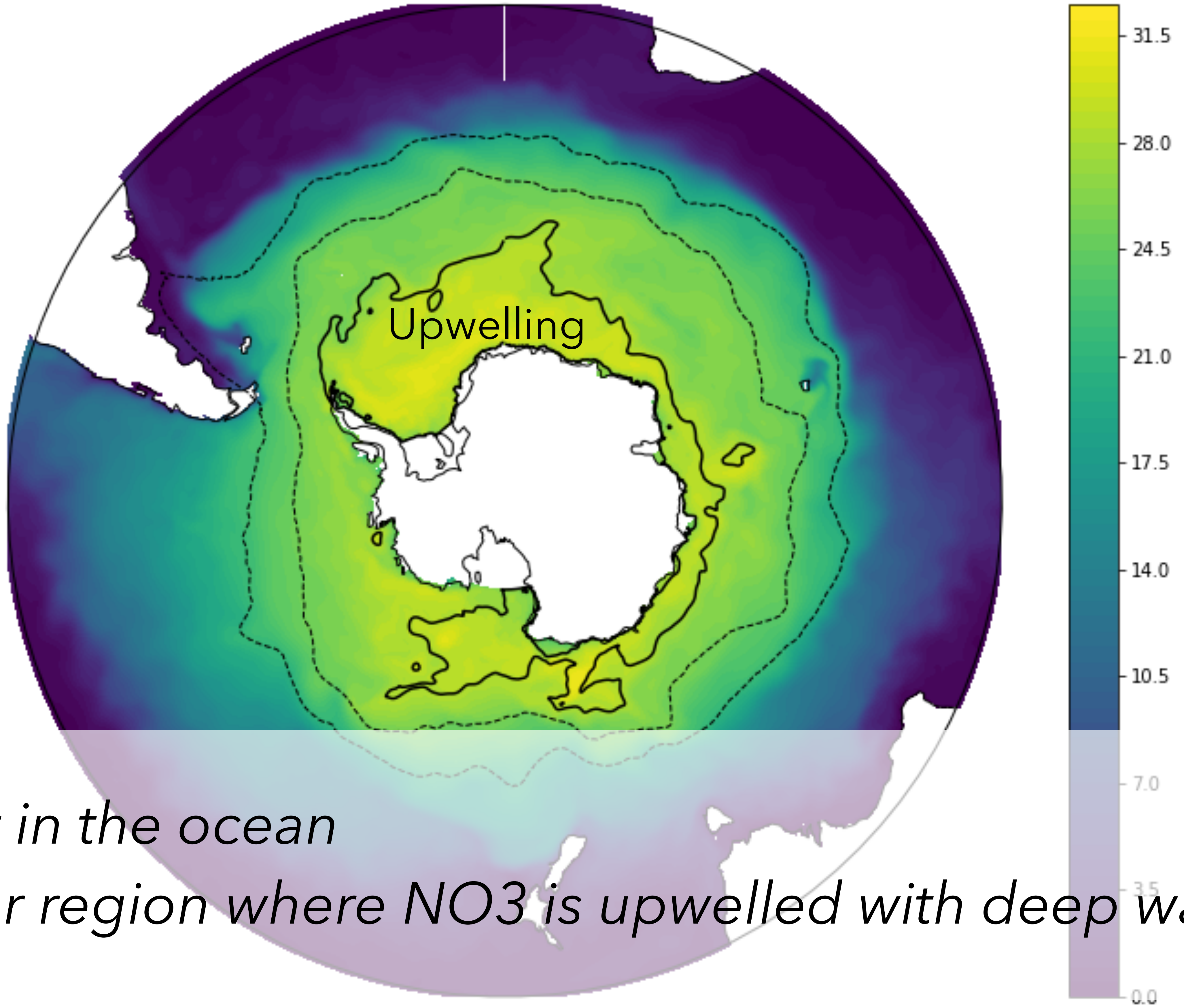
Sharing Geoscience Online, May 2020

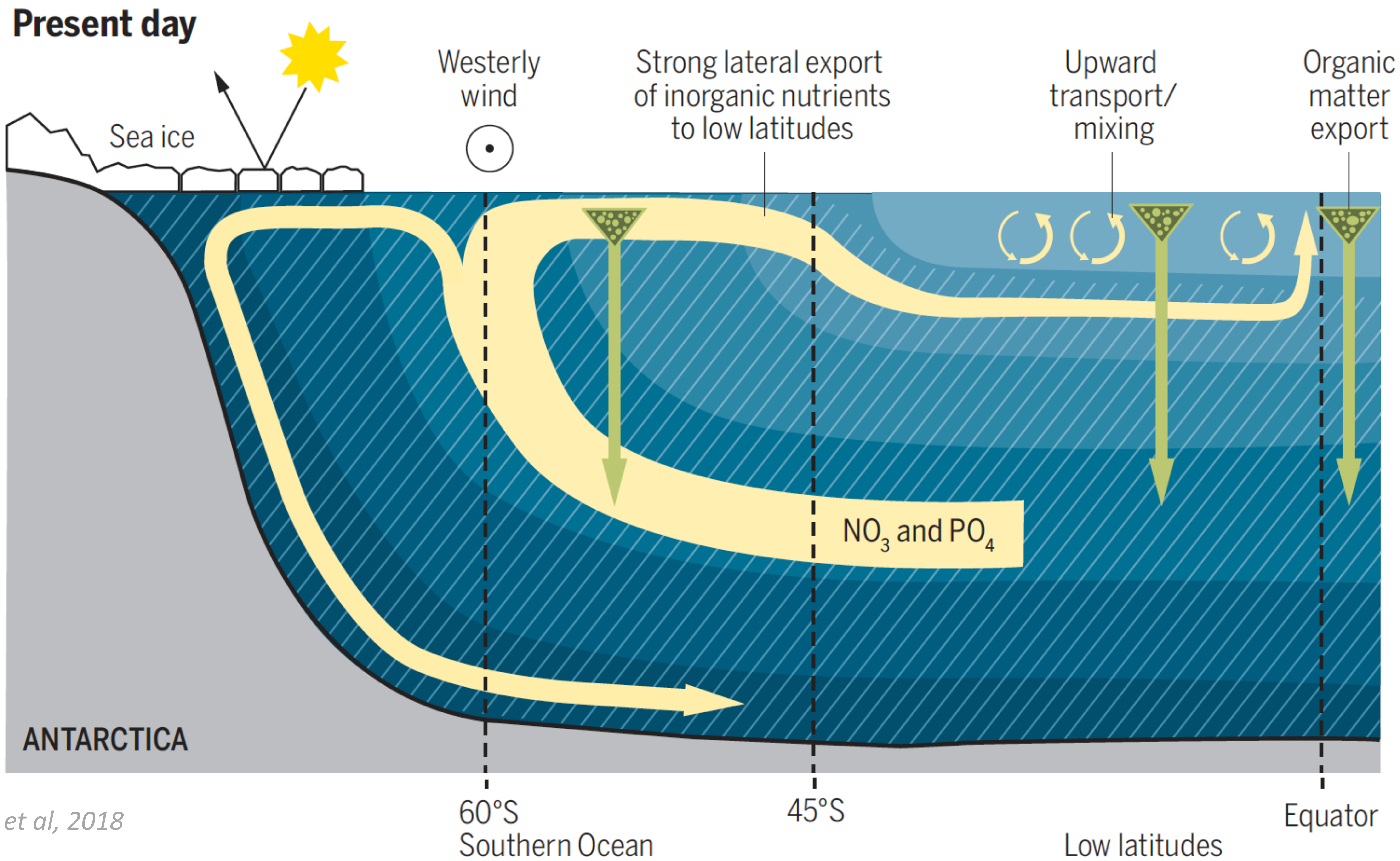


Climatological surface nitrate (NO3) [mmol/m³] and contours of outcropping densities

- *NO3 is a major limiting nutrient in the ocean*
- *The Southern Ocean is the major region where NO3 is upwelled with deep waters*

… MOTIVATION: WHY SHOULD I CARE ABOUT HOW NO3 IS RESHUFFLED IN THE SOUTHERN OCEAN?

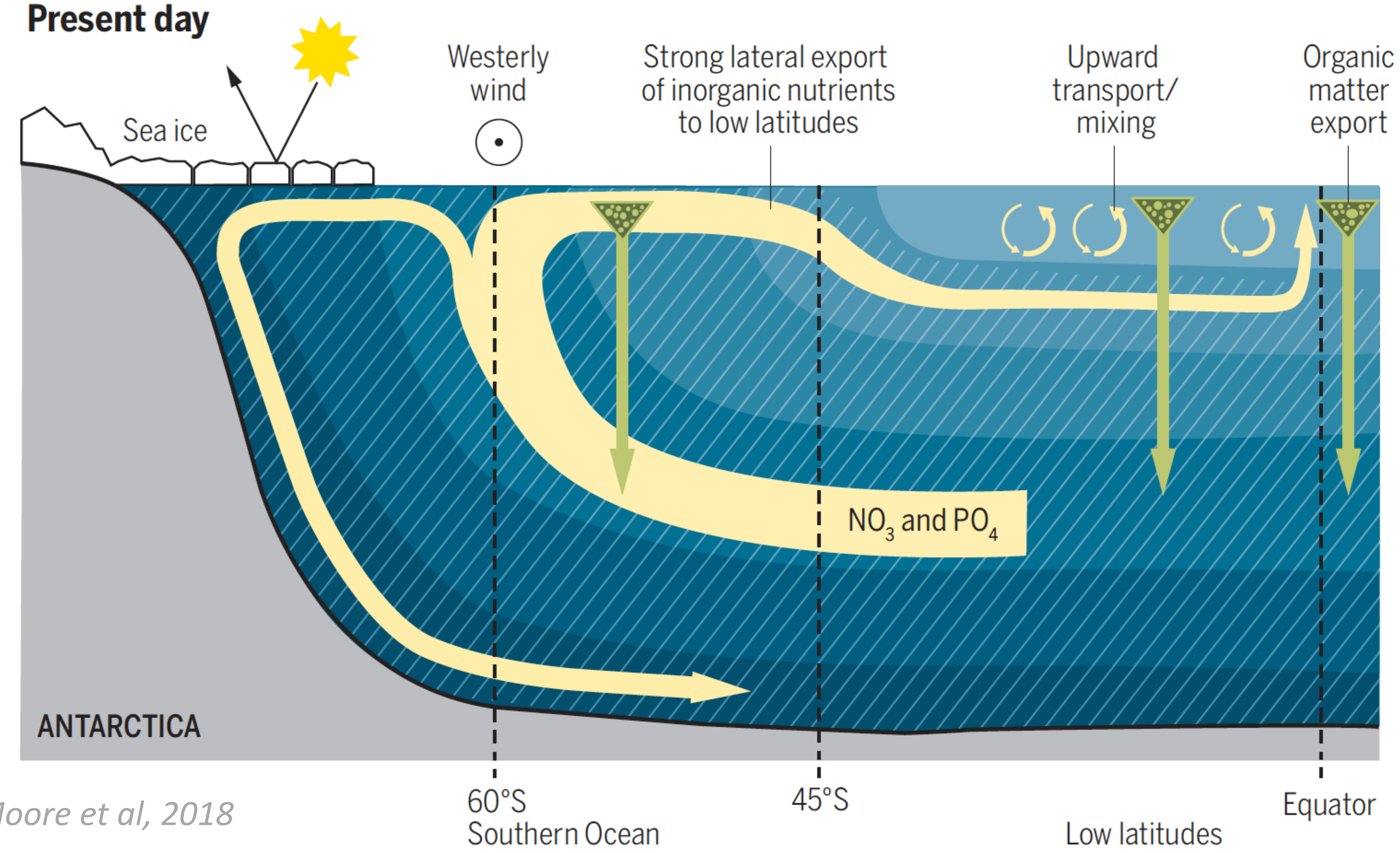
- *E.g., Sarmiento et al, 2004, Moore et al, 2018:*
  *Southern Ocean fuels lower latitude primary productivity -> **fisheries***
- *E.g., Gruber & Galloway, 2008:*
  *The nitrogen cycle is coupled with the carbon-cycle -> **climate***



Laufkoetter and Gruber, 2018, discussing Moore et al, 2018

(1) Quantify nitrate (NO3) reshuffling across Southern Ocean water masses

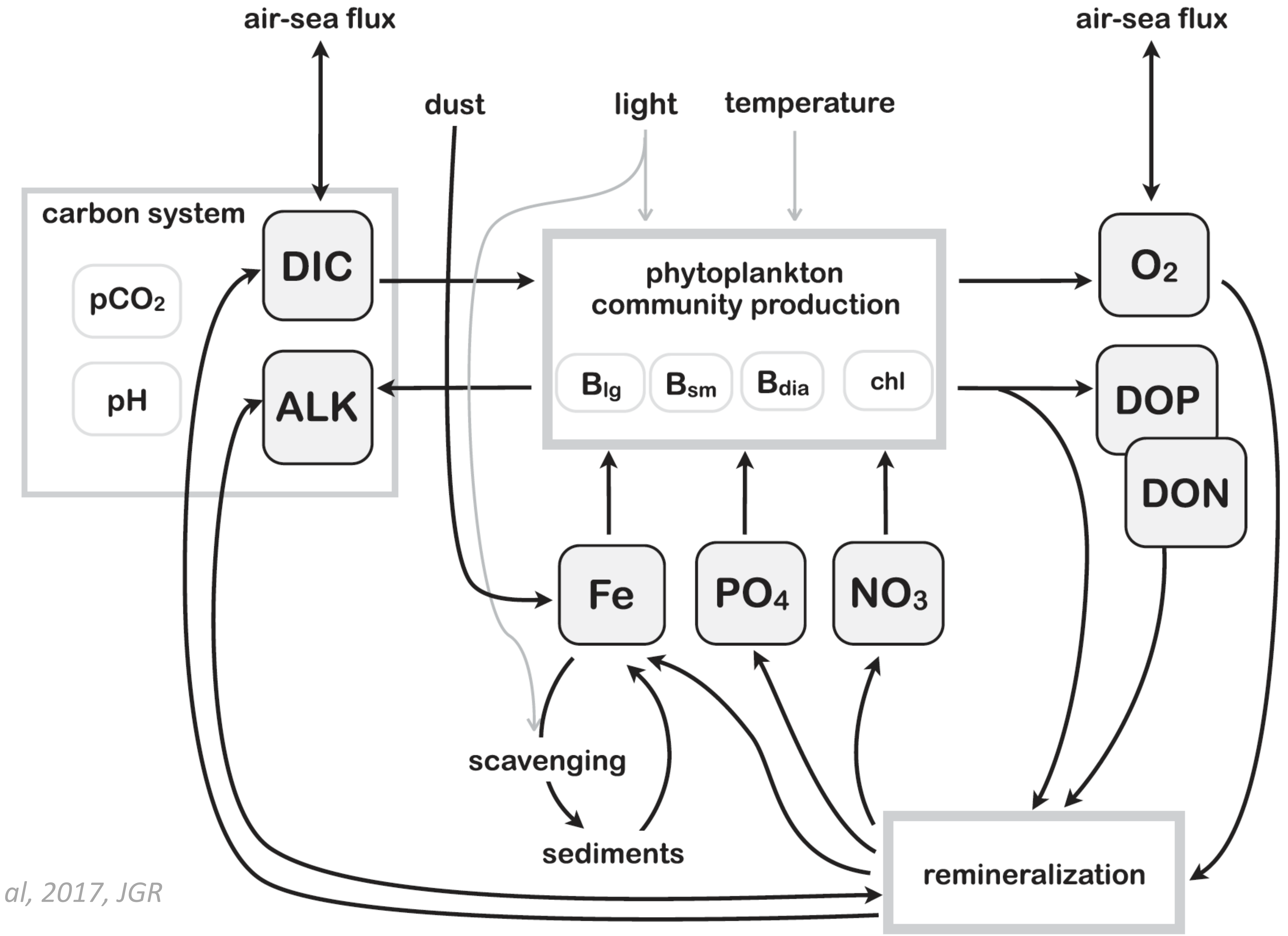
(2) Assess bottleneck processes



Laufkoetter and Gruber, 2018, discussing Moore et al, 2018

B-SOSE (Biogeochemical Southern Ocean State Estimate) *Mazloff et al, 2010, JPO; Rosso et al, 2017, Verdy et al, 2017, JGR*

- *Ocean circulation model based on MITgcm*
  biogeochemical (BGC) model: BLING with added N-cycle complexity
- *Assimilates observations (including BGC Argo floats), dynamically consistent, budgets close*
- *Spatial resolution: 1/3°, 52 levels*
- *5-day averages from 2008 to 2017*

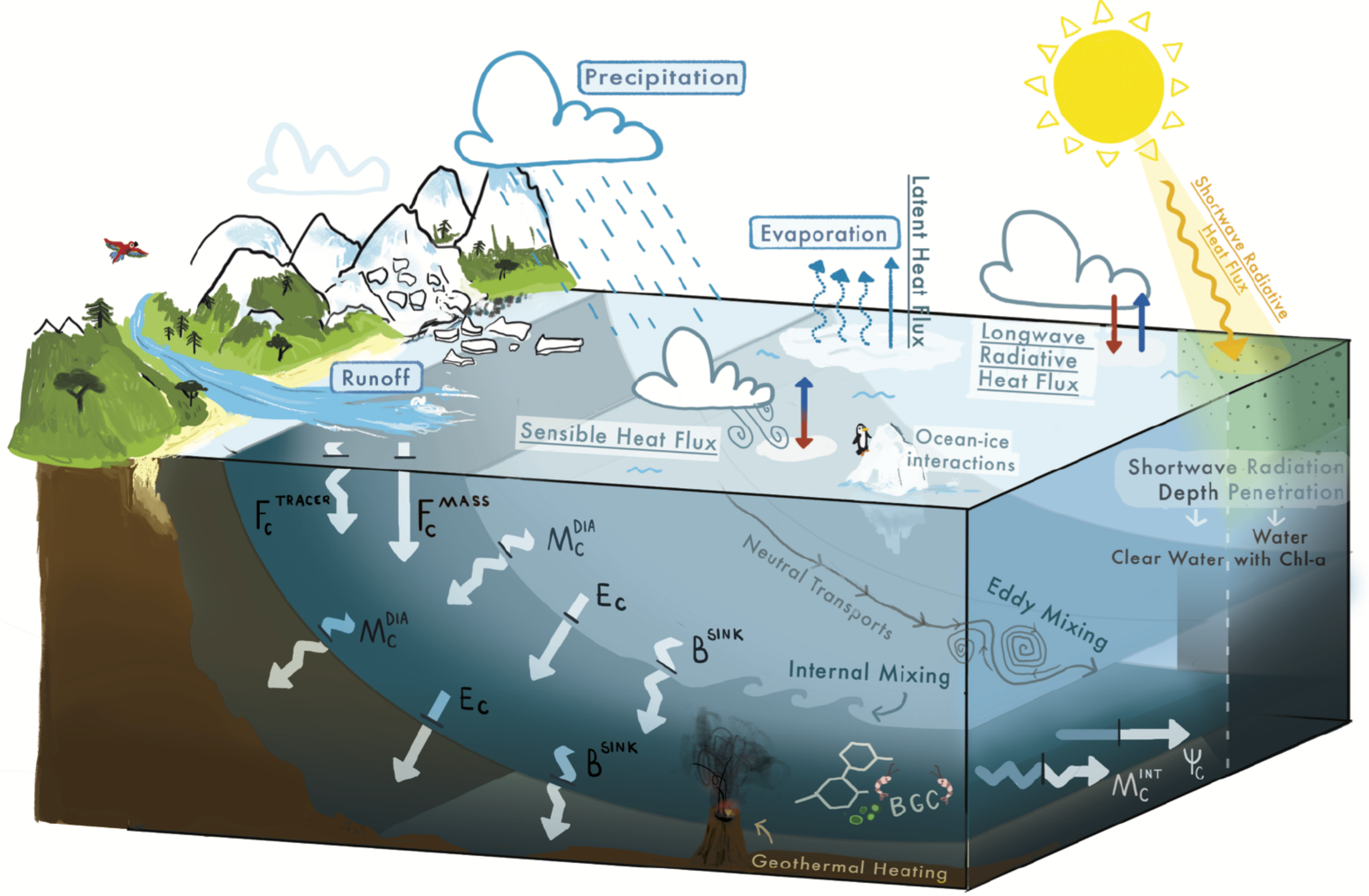


Schematic of BLING from Verdy et al, 2017, JGR

Combination of

- *What drives the nitrate (NO3) water mass inventories and their changes? ->* ***Based on NO3 budget***
  NO3 is driven by advection (overturning), mixing and biological uptake and remineralization Rosso et al, 2017, JGR
- *What drives NO3 fluxes associated with the overturning? ->* ***Based on water mass transformation analysis***

Iudicone et al, 2008, JPO; Iudicone et al, 2011, Biogeosci.; Walin, 1981, Tellus; Marshall et al, 1999



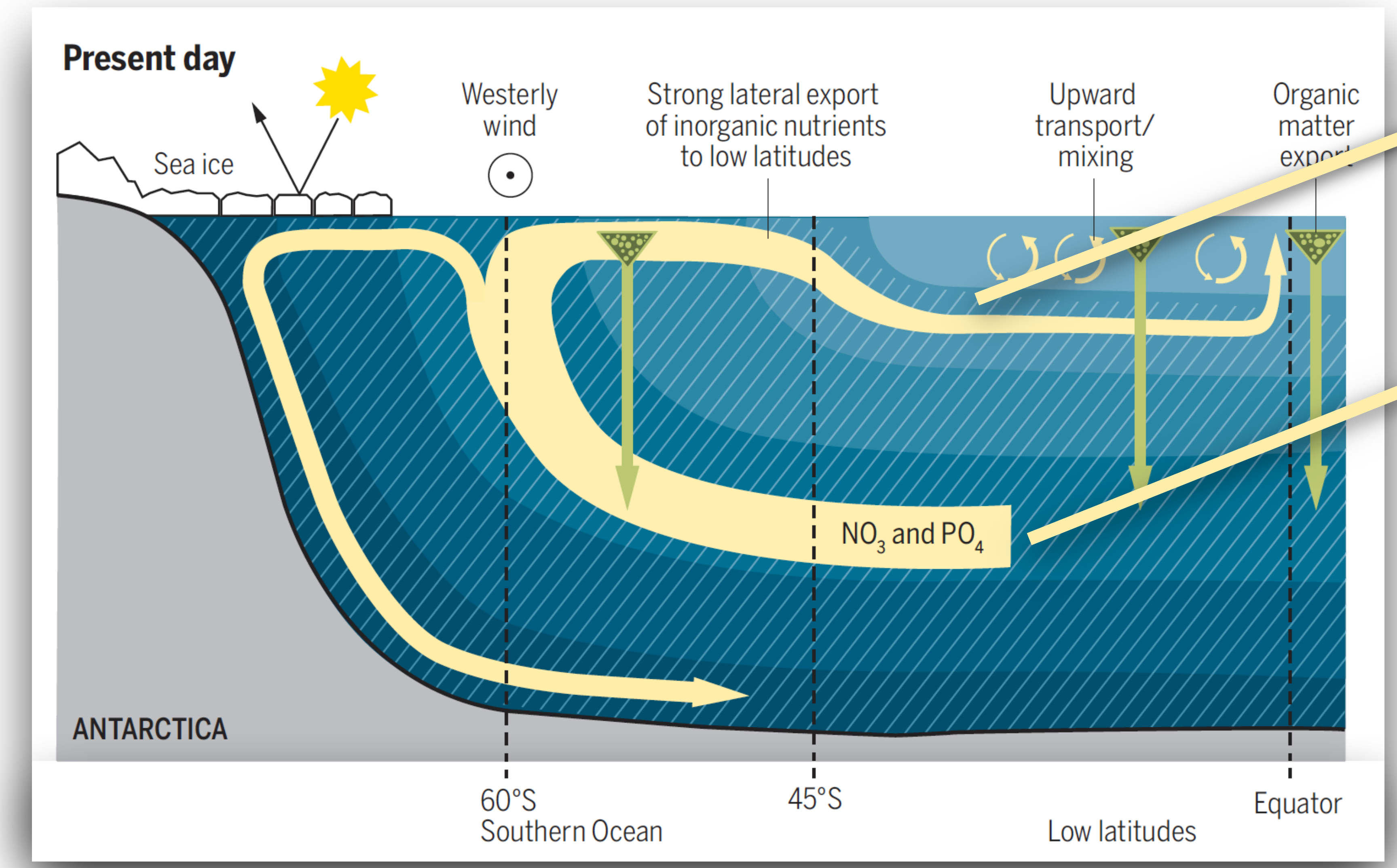
For the mathematical derivation of the combination of water mass transformation analysis with tracers (NO3) see, e.g., the review by Groeskamp et al, 2019, Ann. Rev. of Mar. Sci. (see also Figure to the right)

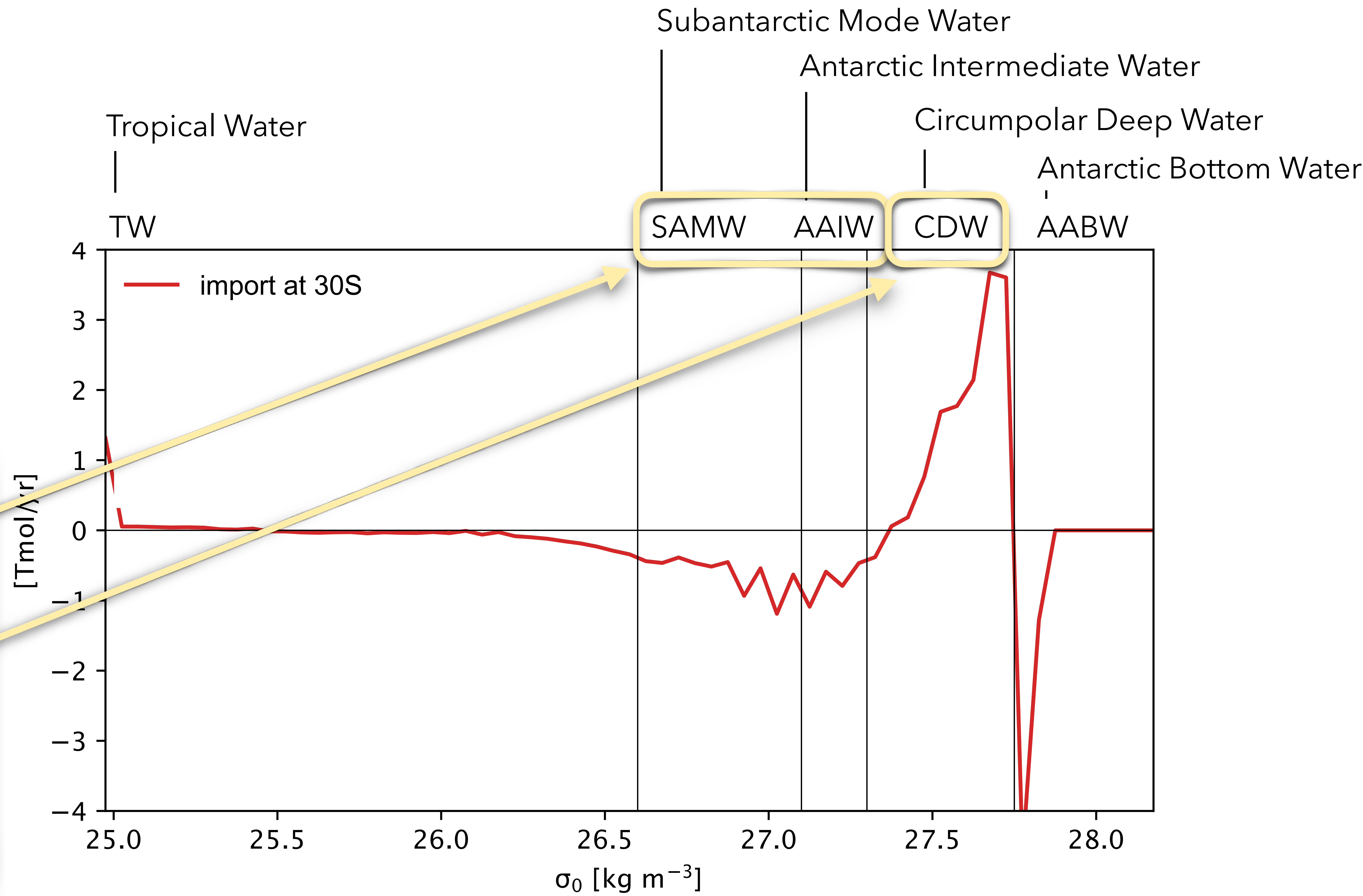
… RESULTS: NO3 import at 30S

Example quantification: ***Import in CDW*** *and negative import, i.e.,* ***export in SAMW/AAIW***

- *CDW imports 14 Tmol/yr*
- *SAMW + AAIW export 9 Tmol N/yr, sufficient to support the carbon sequestration flux below 2000m (0.66 Gt C/yr, i.e., ~8 Tmol N/yr)*

Henson et al, 2012, GBC

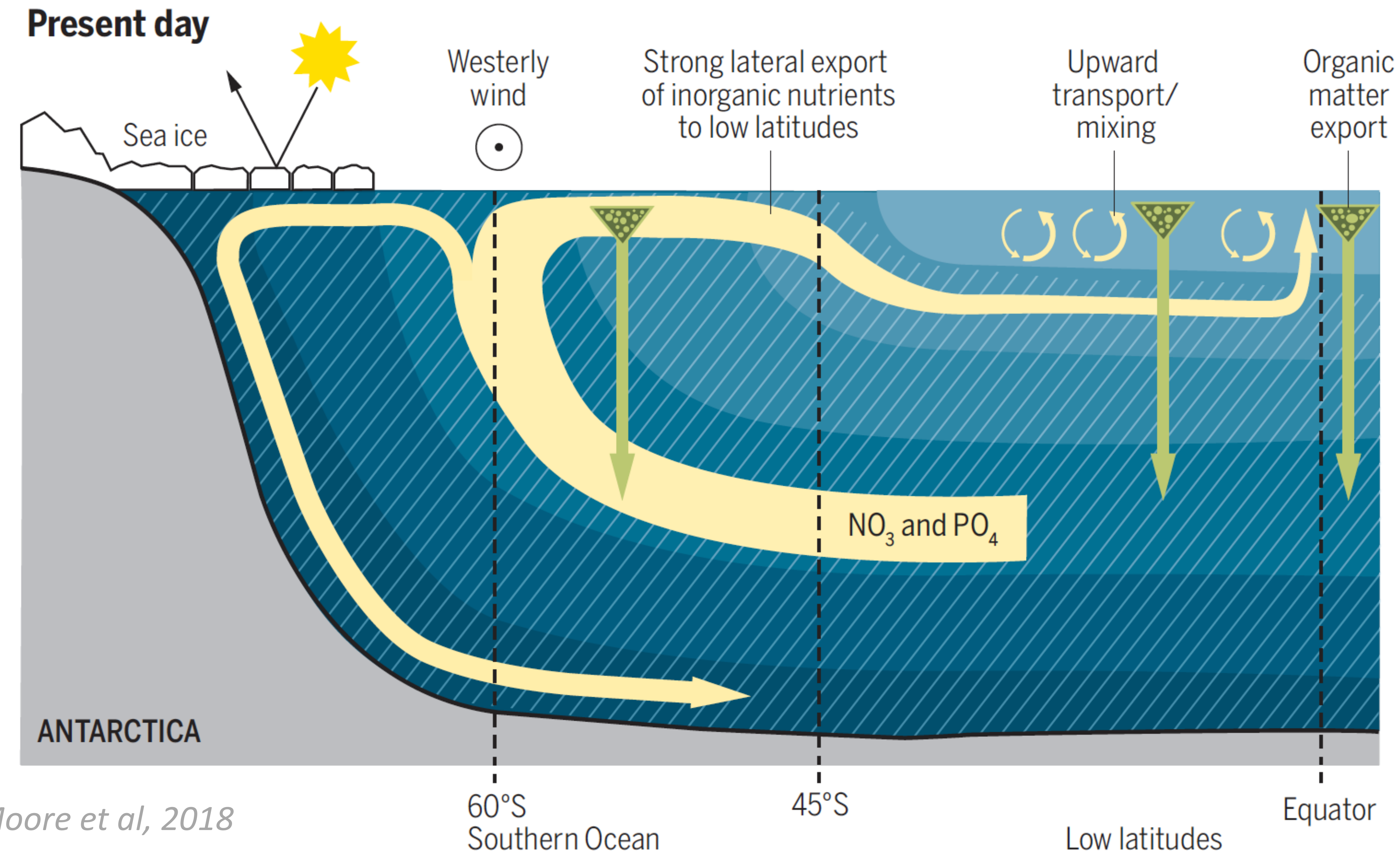




(1) Quantify nitrate (NO3) reshuffling across Southern Ocean water masses

Example quantification: 9 Tmol N/yr exported in SAMW (2/3) + AAIW (1/3)

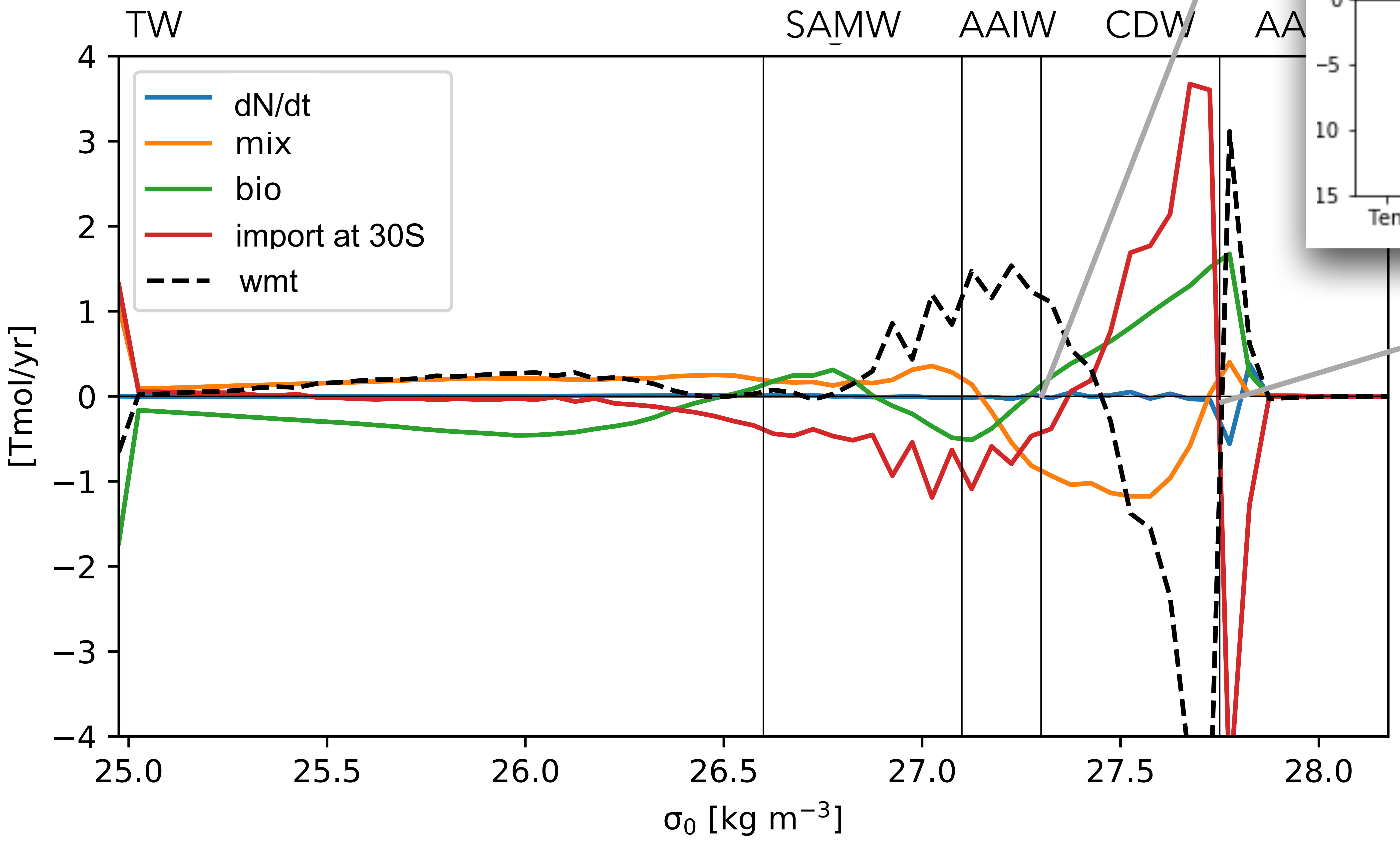
(2) Assess bottleneck processes

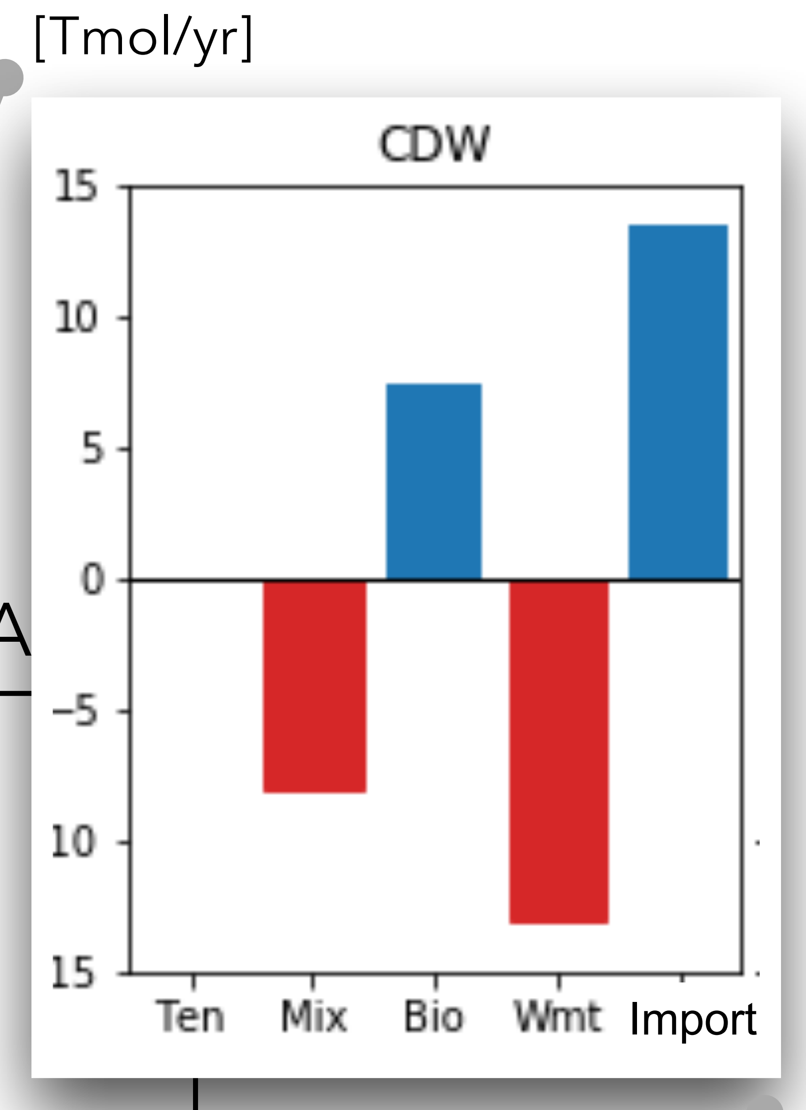


Laufkoetter and Gruber, 2018, discussing Moore et al, 2018

CDW

- ***60% import** of NO3 & **30% remineralization (Bio)** support loss to AAIW/SAMW/AABW via mixing (Mix) and diapycnal volume transport, i.e., water mass transformation (Wmt)*





... RESULTS: bottleneck processes

CDW

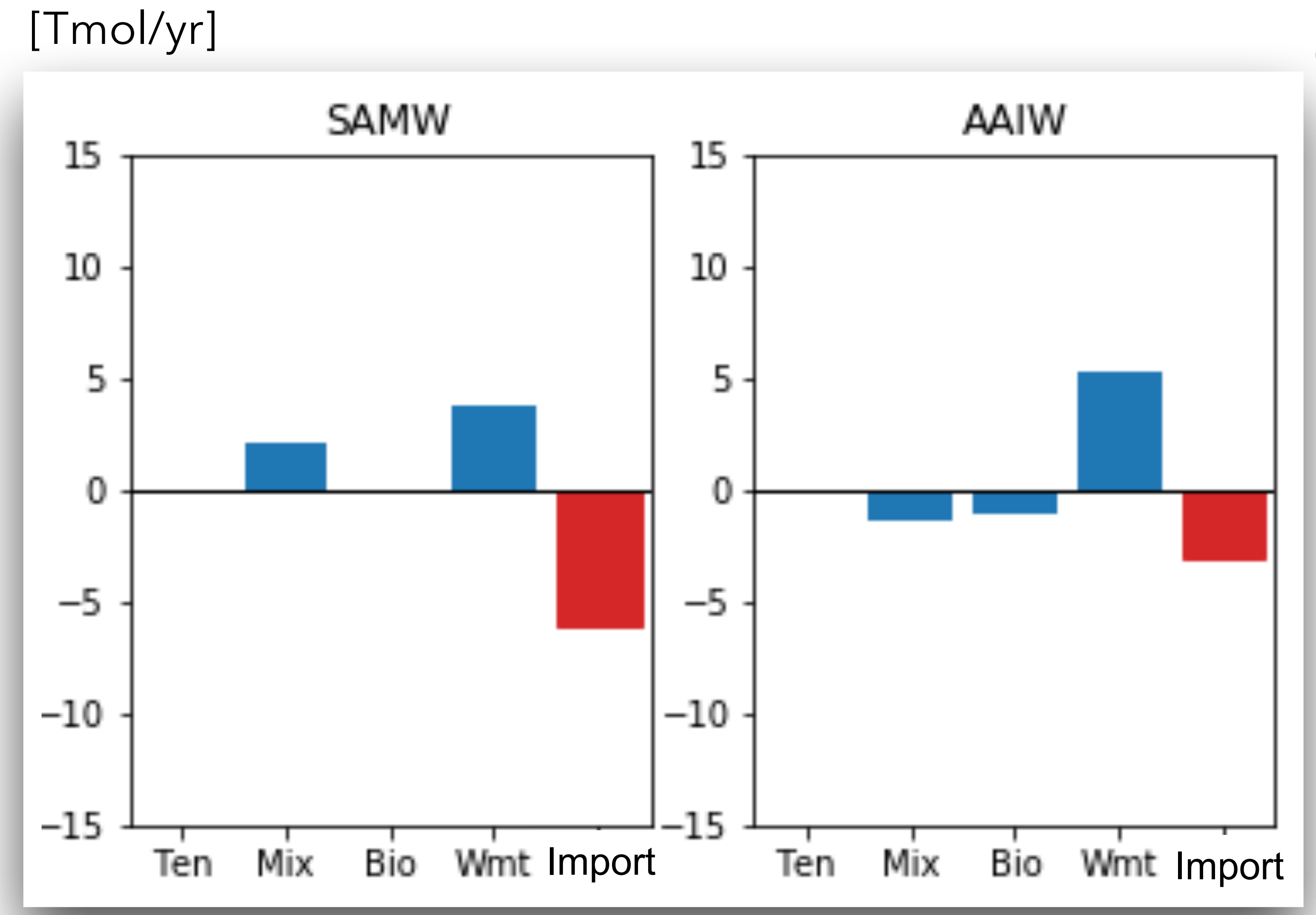
- ***60% import** of NO3 & **30% remineralization (Bio)** support loss to AAIW/SAMW/AABW via mixing (Mix) and diapycnal volume transport, i.e., water mass transformation (Wmt)*

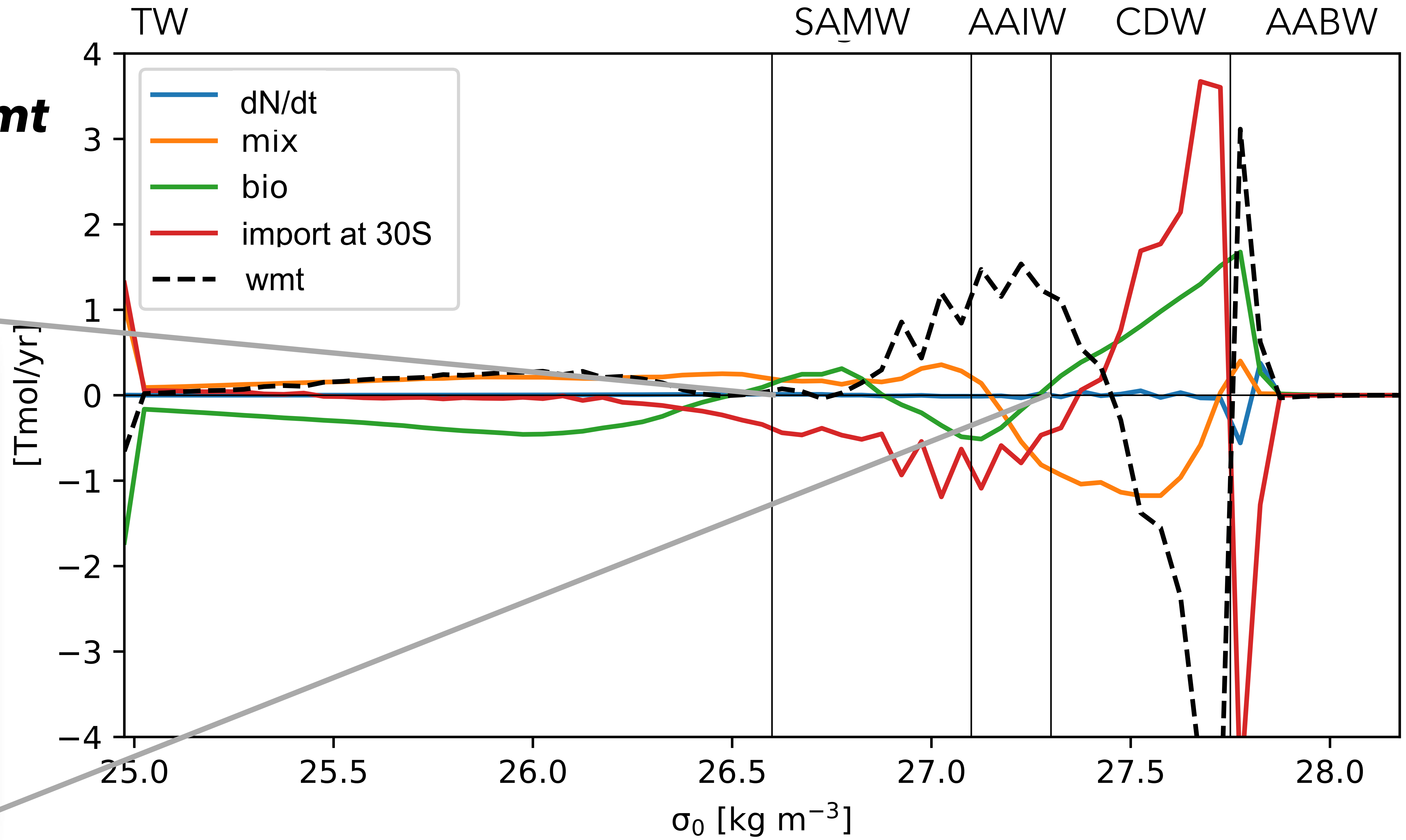
SAMW

- *Export of NO3 supported by **35% Mix** & **65% Wmt***
  (driven by surface fluxes)

AAIW

- *Export of NO3 supported by **Wmt***
  (driven by density mixing)





... OBJECTIVES

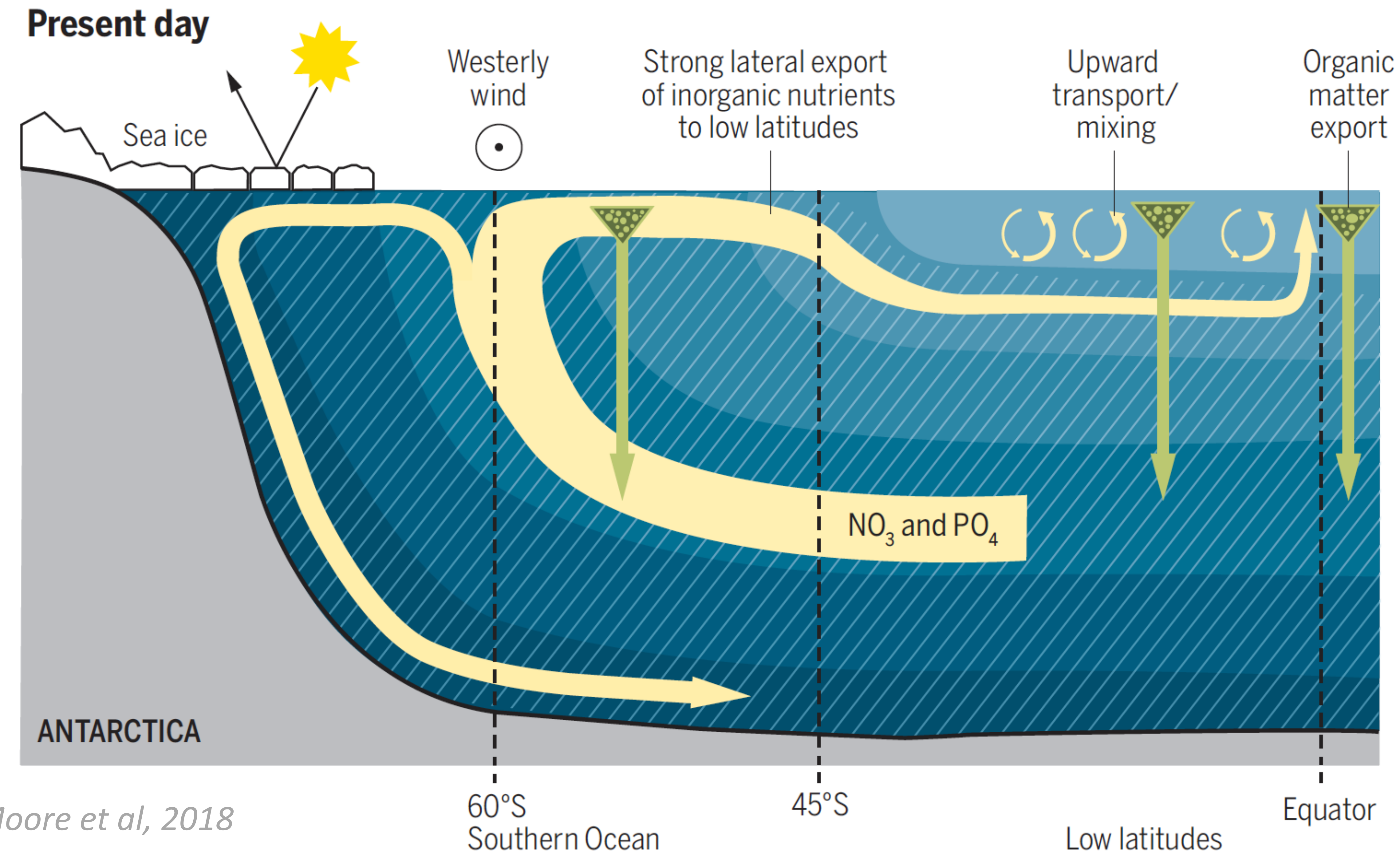
(1) Quantify nitrate (NO3) reshuffling across Southern Ocean water masses

Example quantification: 9 Tmol N/yr exported in SAMW (2/3) + AAIW (1/3)

(2) Assess bottleneck processes

Example assessment: Support of SAMW and AAIW export:

Next to water mass transformation, i.e., overturning (driven mainly by air-sea fluxes), roughly 1/4 tracer mixing



Laufkoetter and Gruber, 2018, discussing Moore et al, 2018

… NEXT STEPS

- *Update of data to higher resolution iteration of B-SOSE (1/6°)*
- *Assessment of spatio-temporal variability, including mixed layer versus interior ocean processes*

Example: Variability of net biological fluxes (Bio) with latitude and mixed layer vs interior ocean