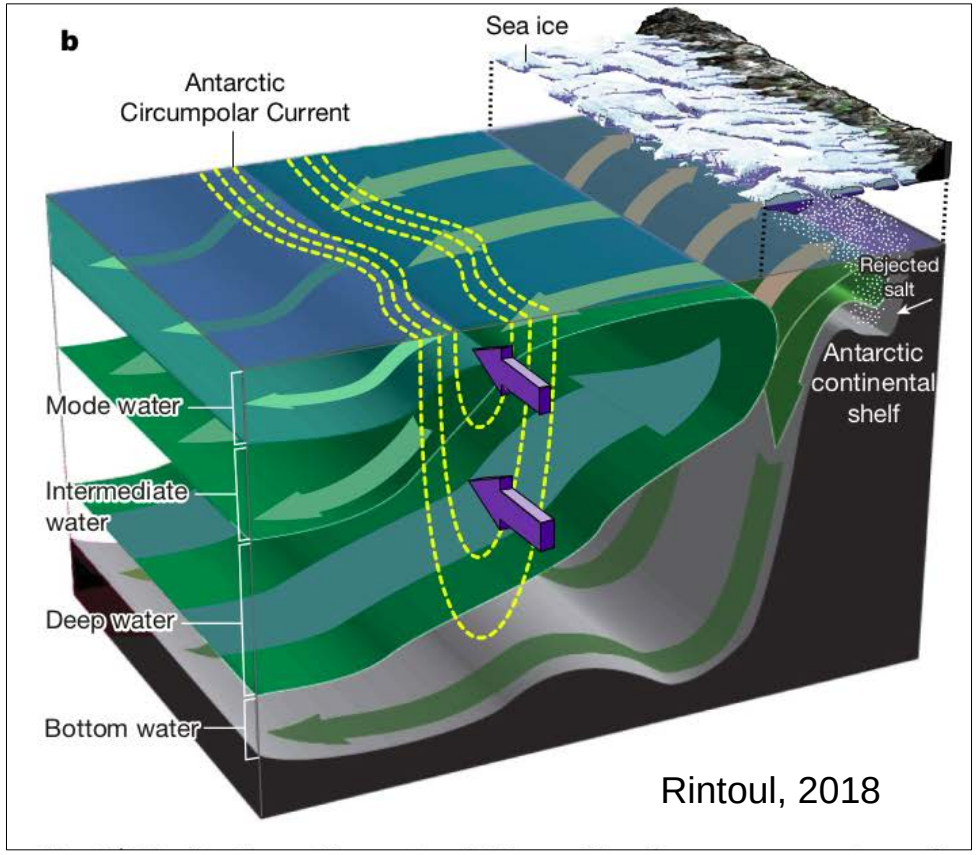
Water masses variability in the Southern Hemisphere oceans over the last decade

Esther Portela, Nicolas Kolodziejczyk, Virginie Thierry, Christophe Maes

1. Introduction and background: Study region

Southern Ocean and Antarctic Circumpolar Current (ACC)



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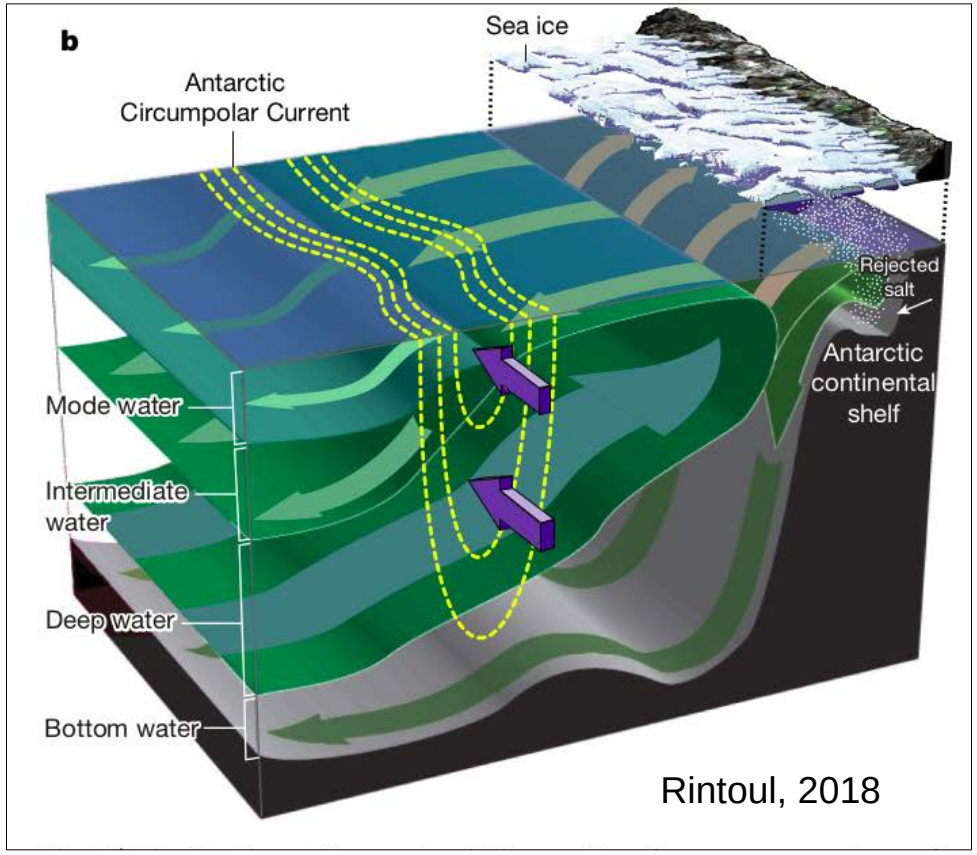
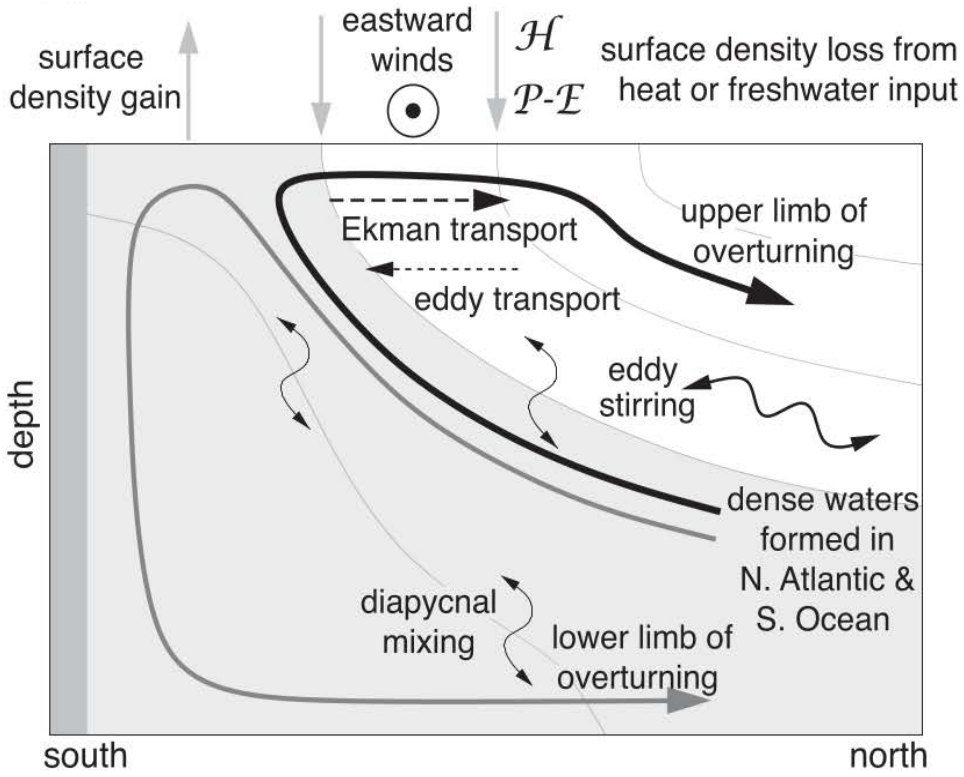


Rintoul, 2018

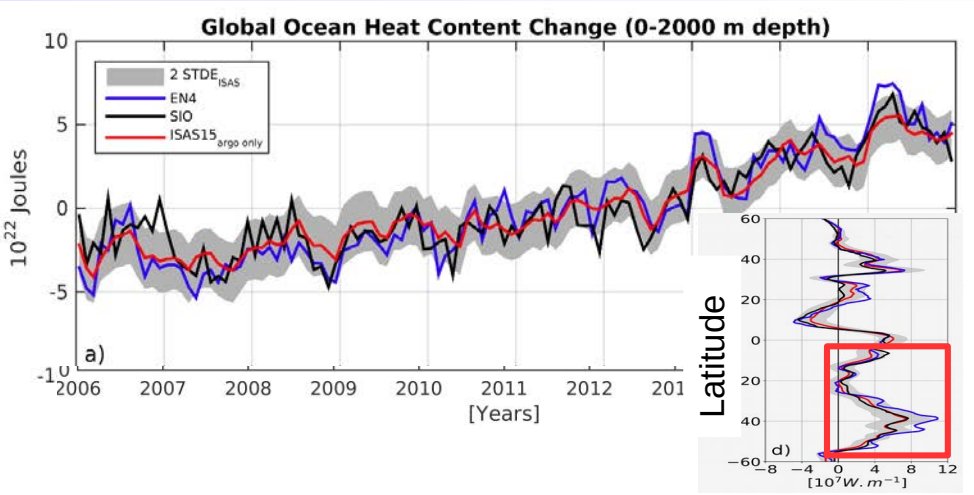
From Badin et al., (2013)



ACC = wind driven current + eddy field

1. Introduction and background

Global Warming

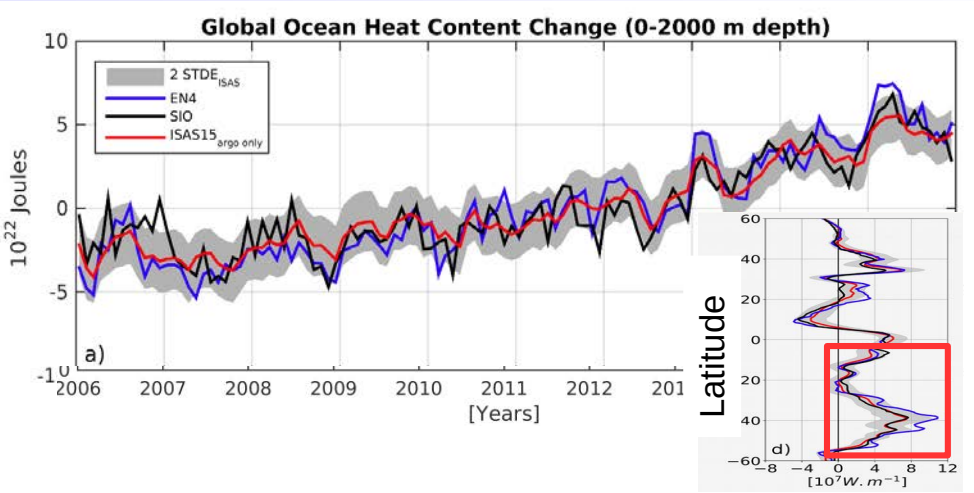


1. Introduction and background

Las decade trends in OHC and thickness

SAMW : Hot spots of heat gain and loss

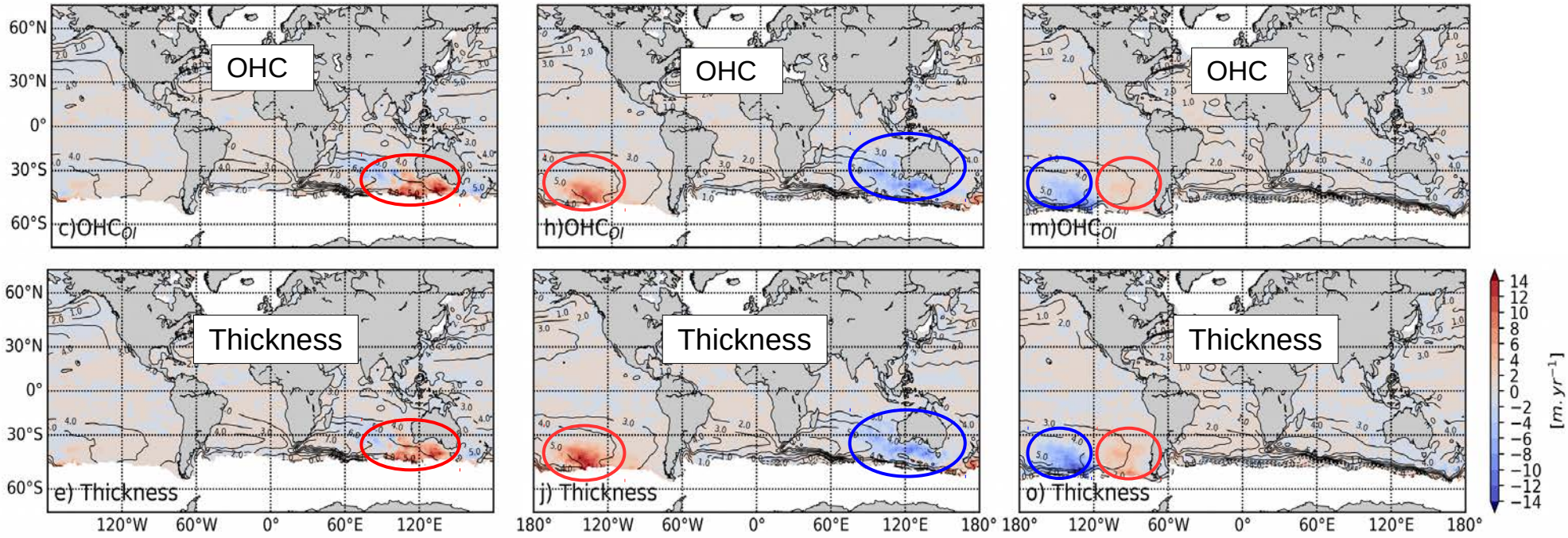
(Kolodziejczyk et al., 2019)



σ = 26.7 – 26.8

σ = 26.8 – 26.9

σ = 26.9 – 27



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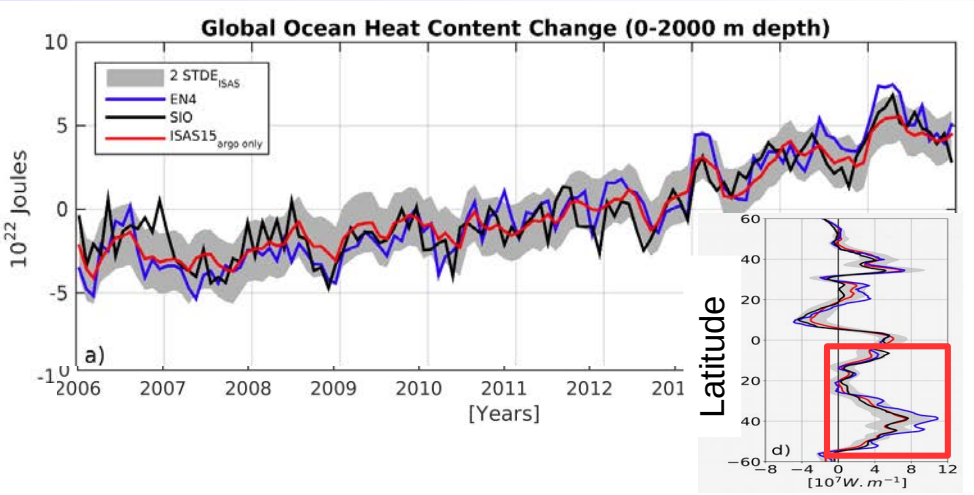

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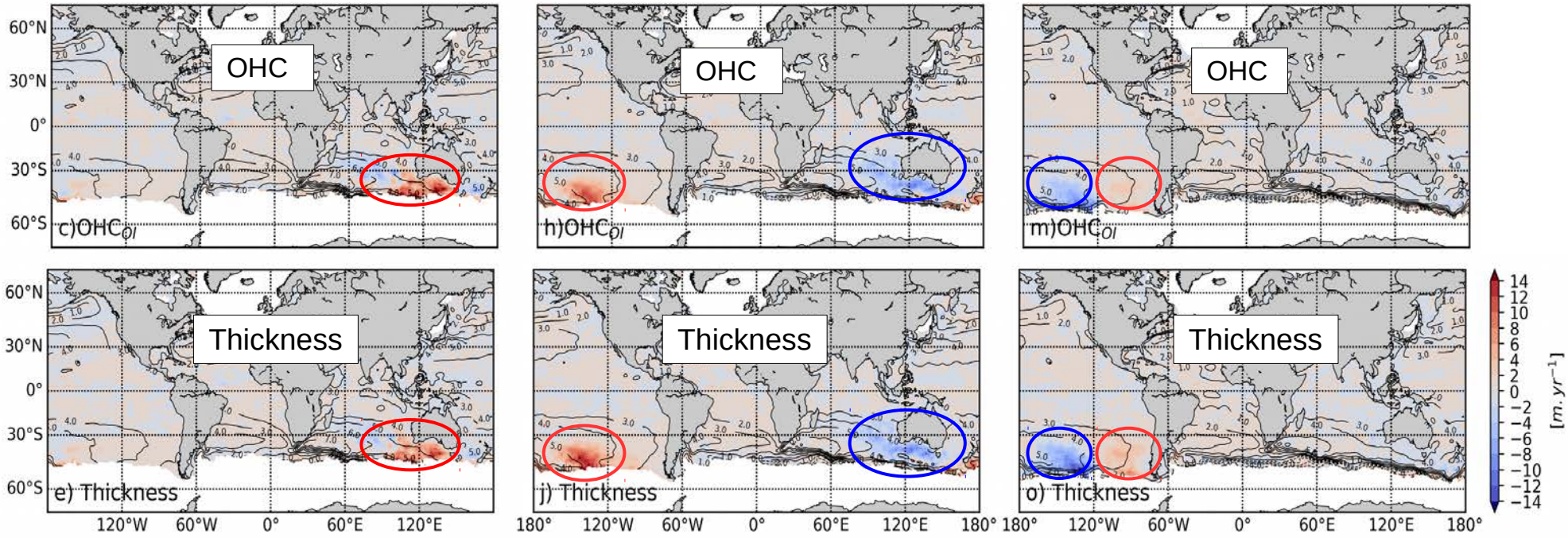

In the interannual to decadal timescale

Which mechanisms are driving the variability at the hot-spots of the volume change?

2. Methods

Volume Budget of interior waters

$$\underbrace{VolumeTrend}_{\frac{dV}{dt}} = \underbrace{Subduction}_{S} + \underbrace{Transformation}_{U_{(\sigma,\tau)}} + \underbrace{Exchange\ flux}_{\Psi}$$

Argo Data

Density – spiciness (σ-τ) coordinates

Spiciness (τ): Thermohaline change along isopycnals

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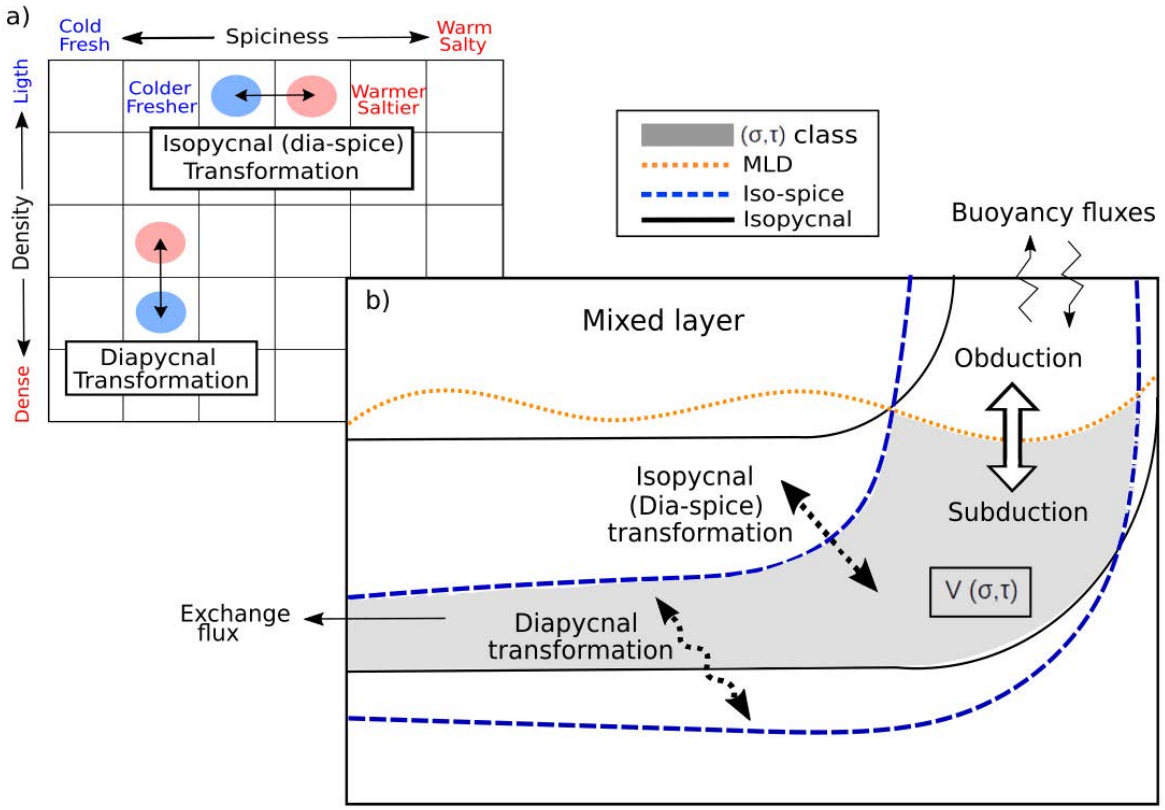

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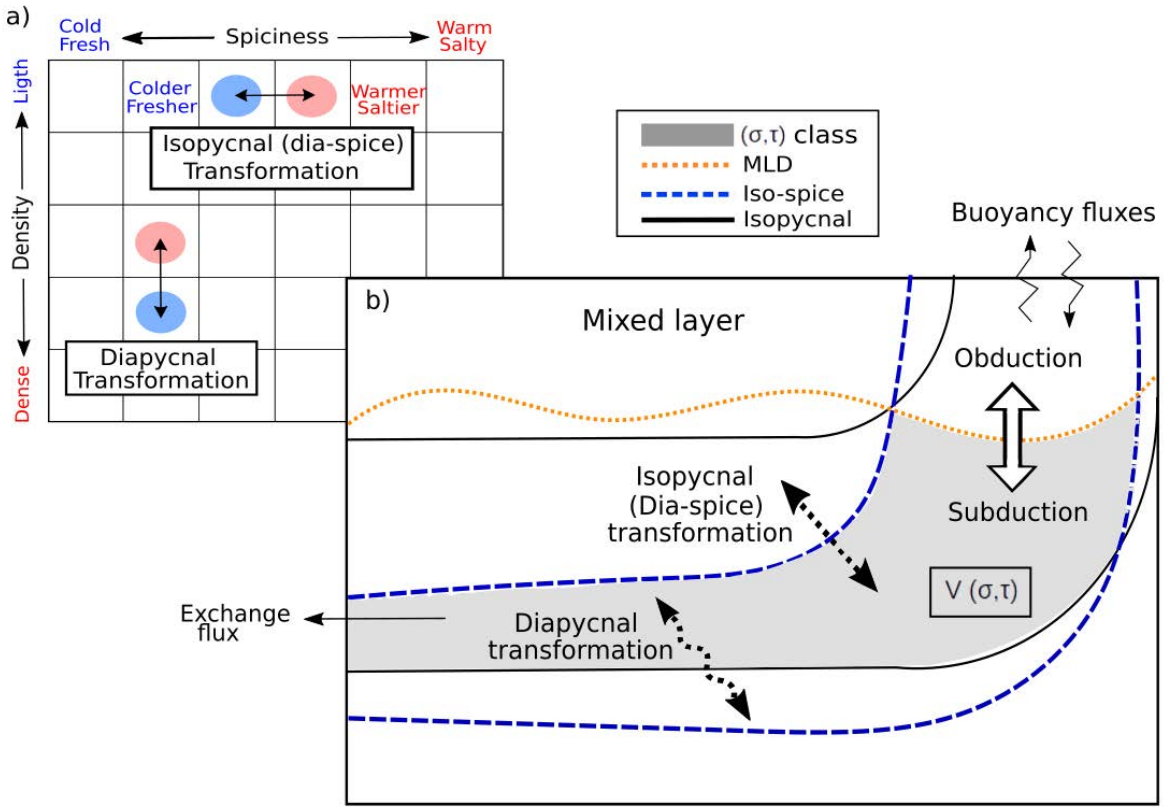


Subduction :

$$\underbrace{S(x,y)}_{Subduction} = \underbrace{U_H \cdot \nabla_h H}_{lateral\ induction} + \underbrace{w_H}_{vertical\ v} + \underbrace{\nabla_h (U_H^*)}_{eddy\ induced}$$

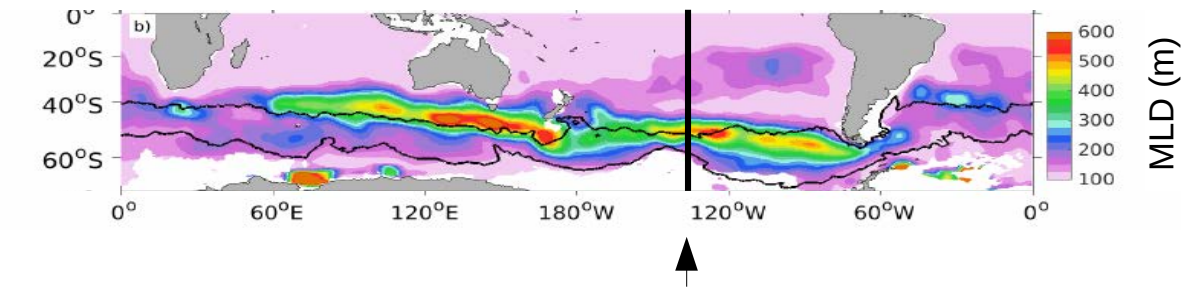
Transformation
(Following Evans et al., 2014):

$$\frac{dV}{dt} - S = Ax$$

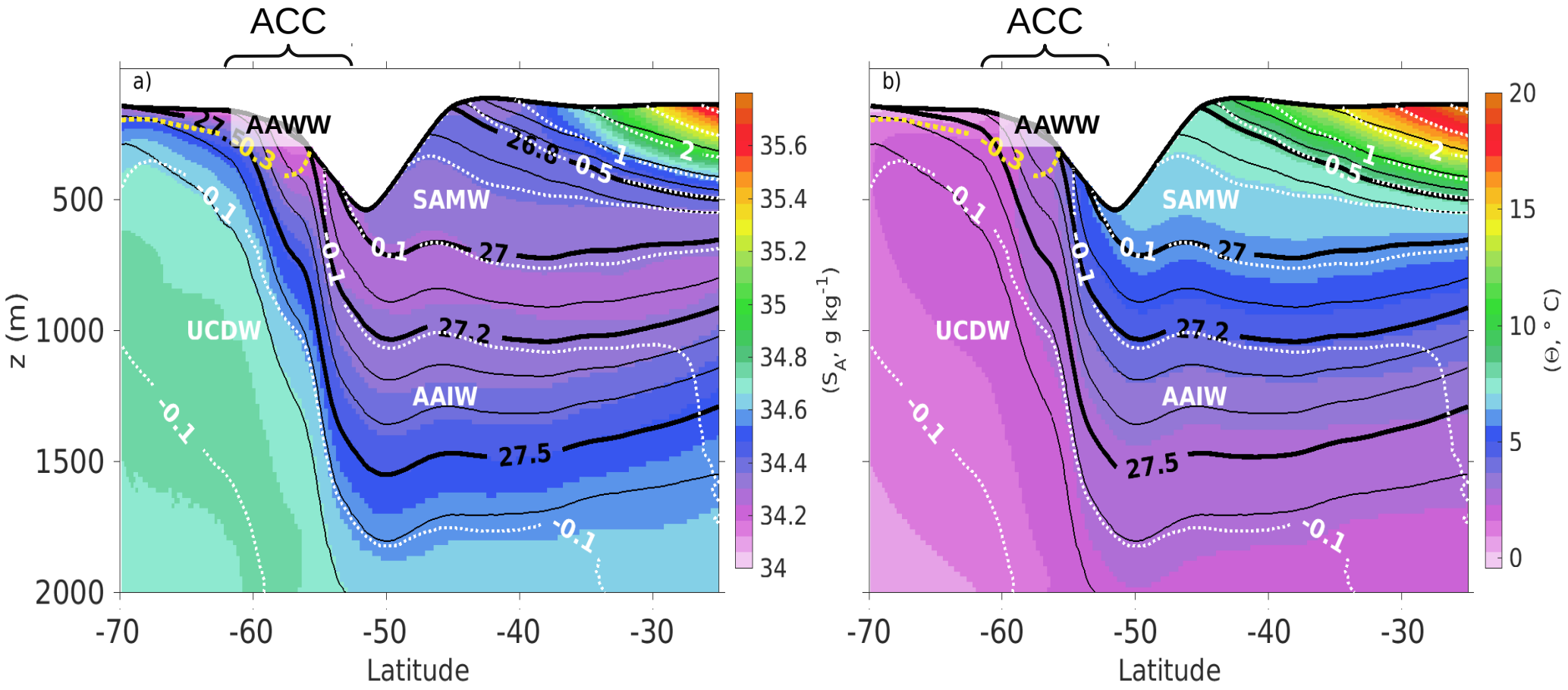
A: matrix of coefficients of the linear equations
x: vector of dia-surface transformations

3. Water-masses in the Southern Ocean

Main waters masses in the Southern Ocean :



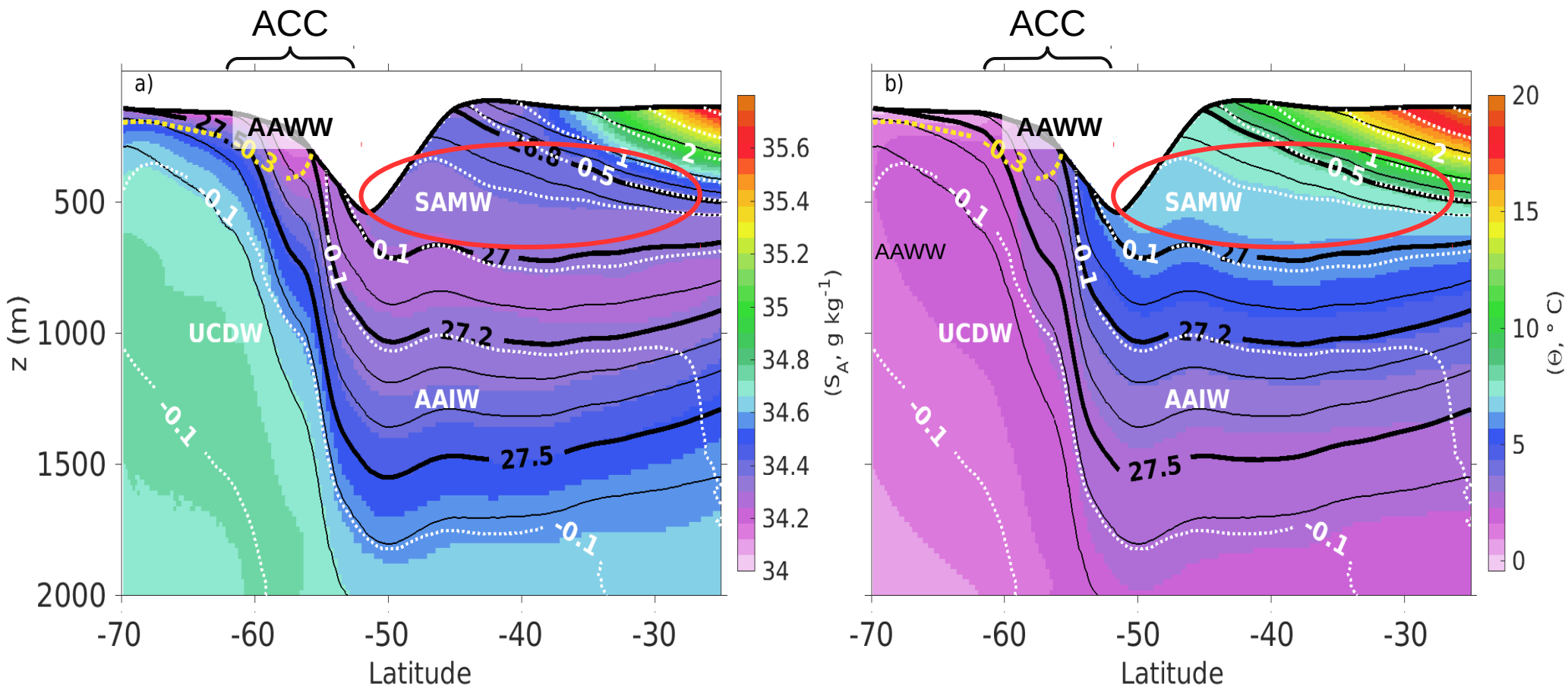
Vertical profile at 130ºW in the South Pacific



3. Water-masses in the Southern Ocean

Main waters masses in the Southern Ocean :

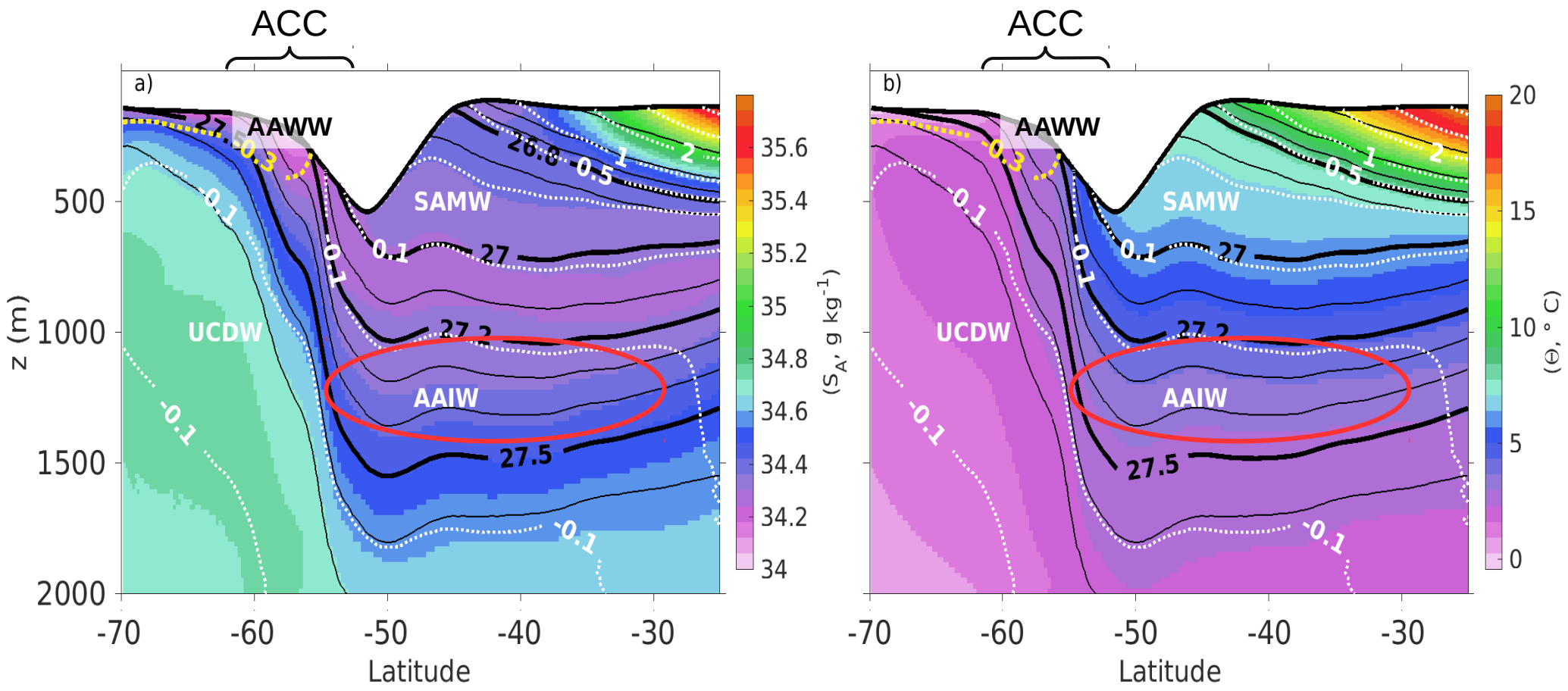
- SubAntarctic Mode Water (SAMW)



3. Water-masses in the Southern Ocean

Main waters masses in the Southern Ocean :

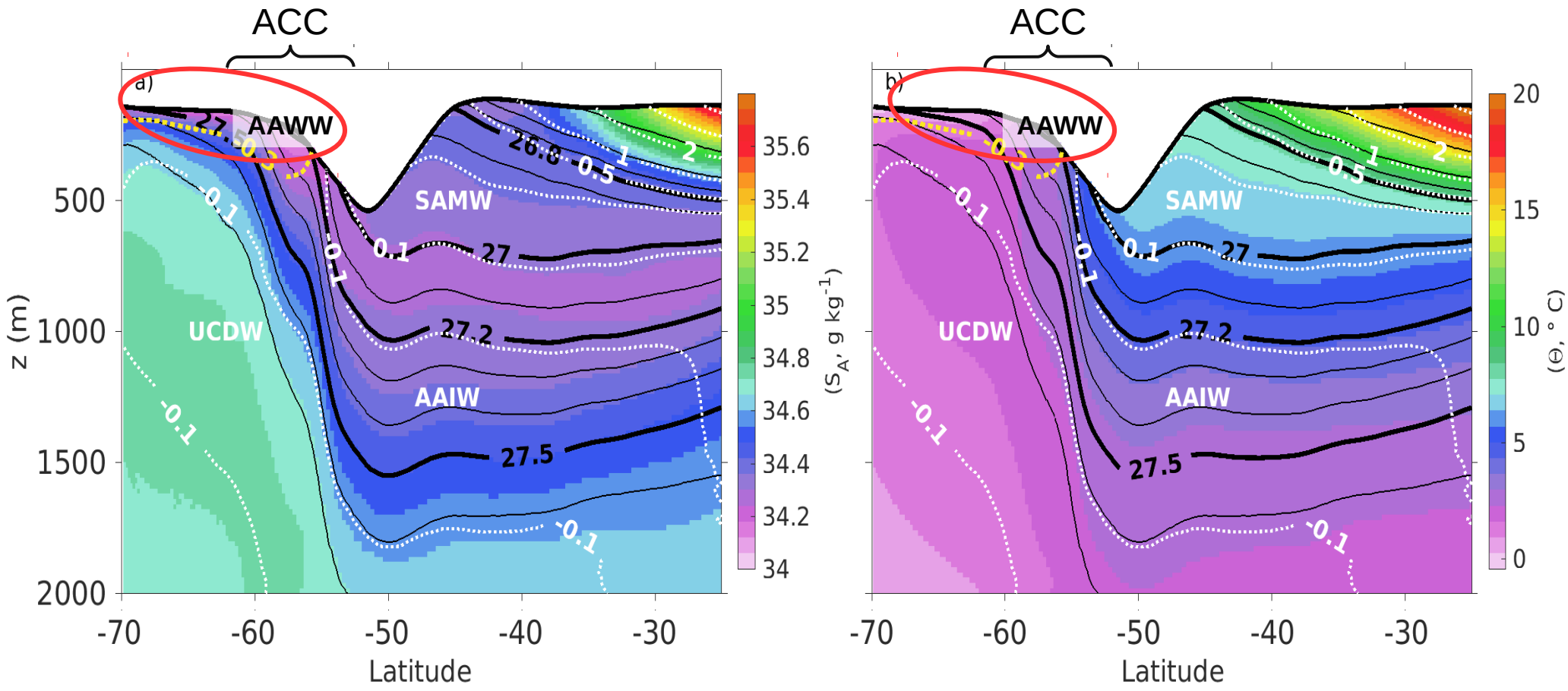
- SubAntarctic Mode Water (SAMW)
- Antarctic Intermediate Water (AAIW)



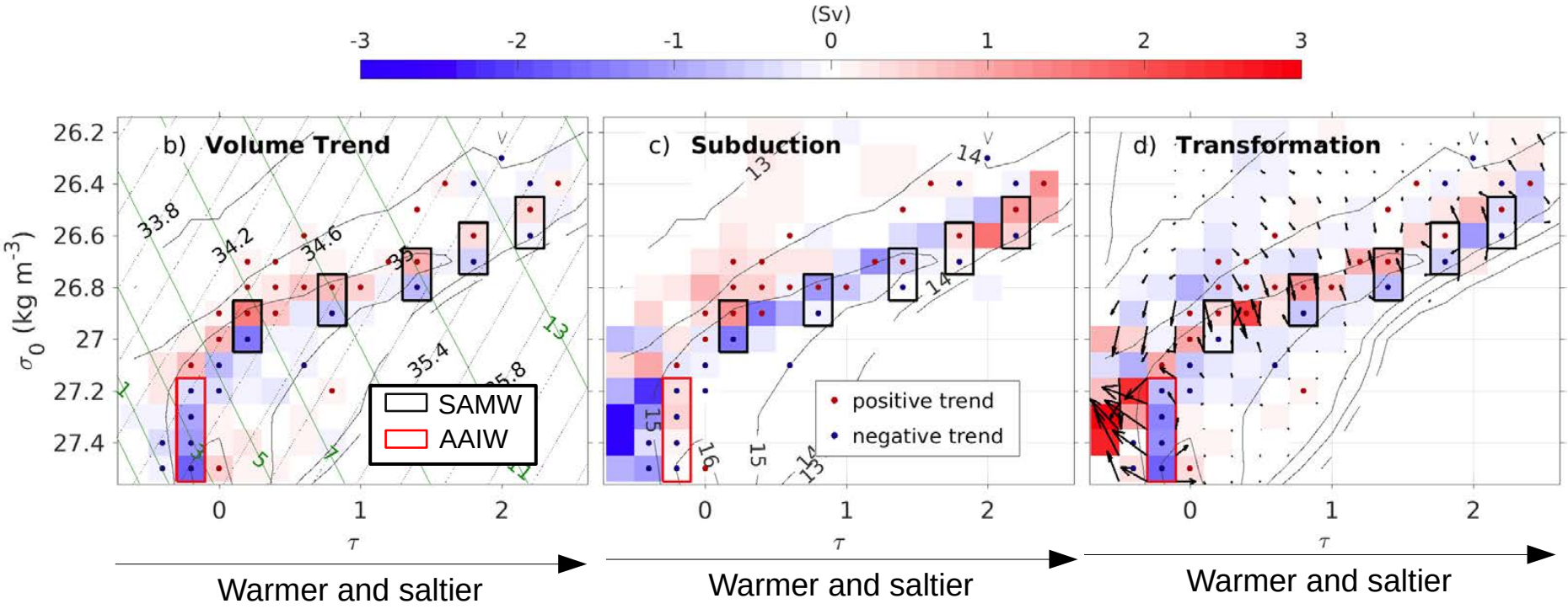
3. Water-masses in the Southern Ocean

Main waters masses in the Southern Ocean :

- SubAntarctic Mode Water (SAMW)
- Antarctic Intermediate Water (AAIW)
- Antarctic Winter Water (AAWW)

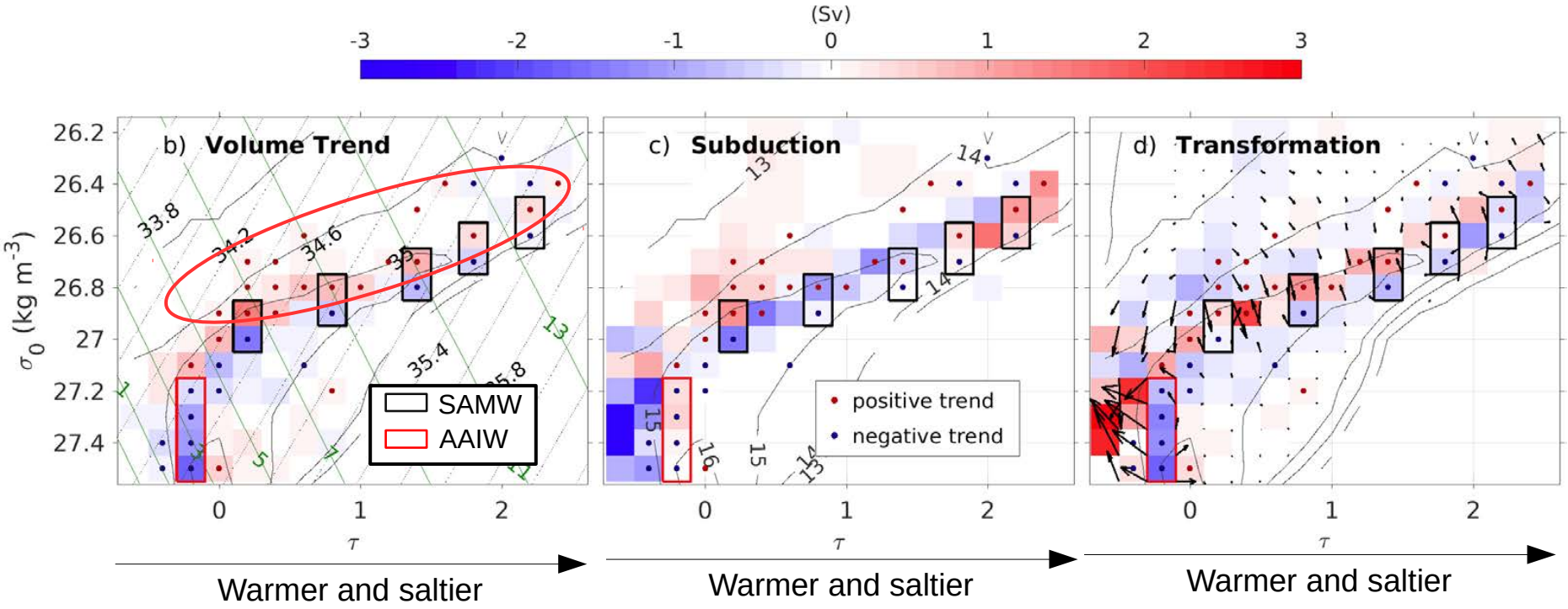


Volume Budget



Volume Budget

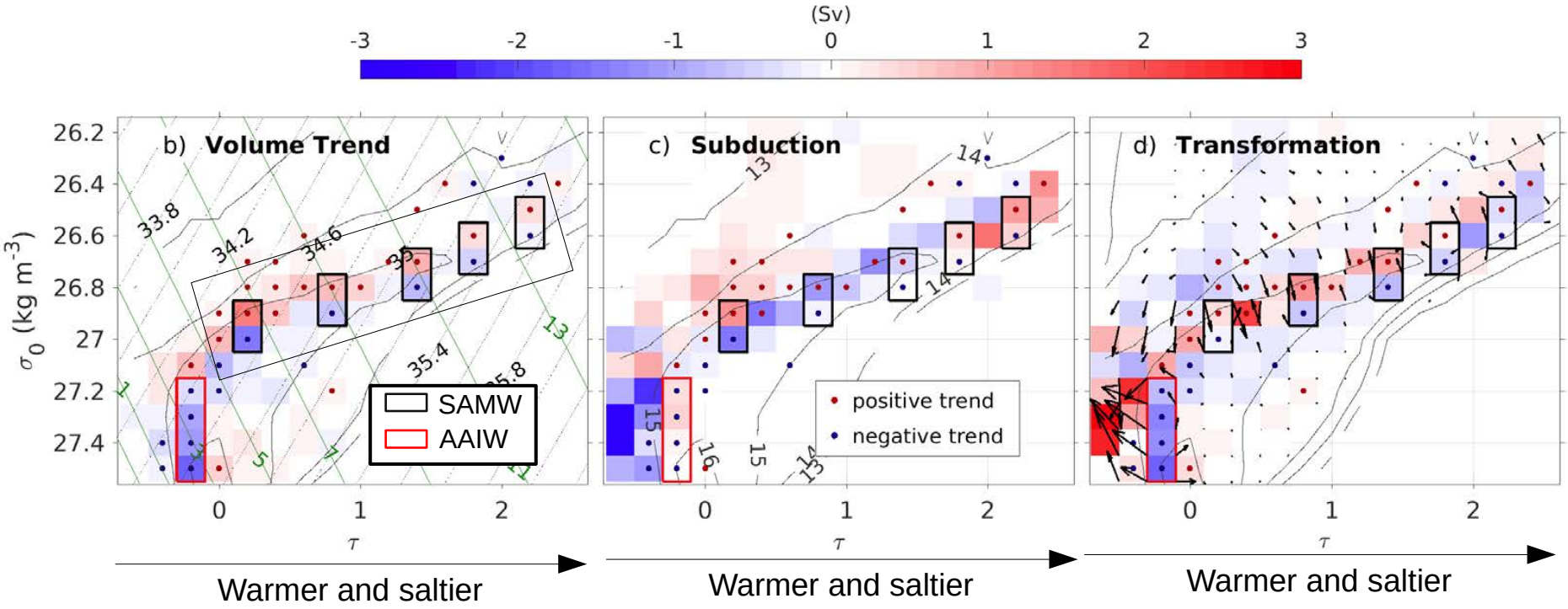
Lightening of the upper waters



Volume Budget

Lightening of the upper waters

SAMW
- Upper σ-layers: Volume gain
- Lower σ-layers: Volume loss

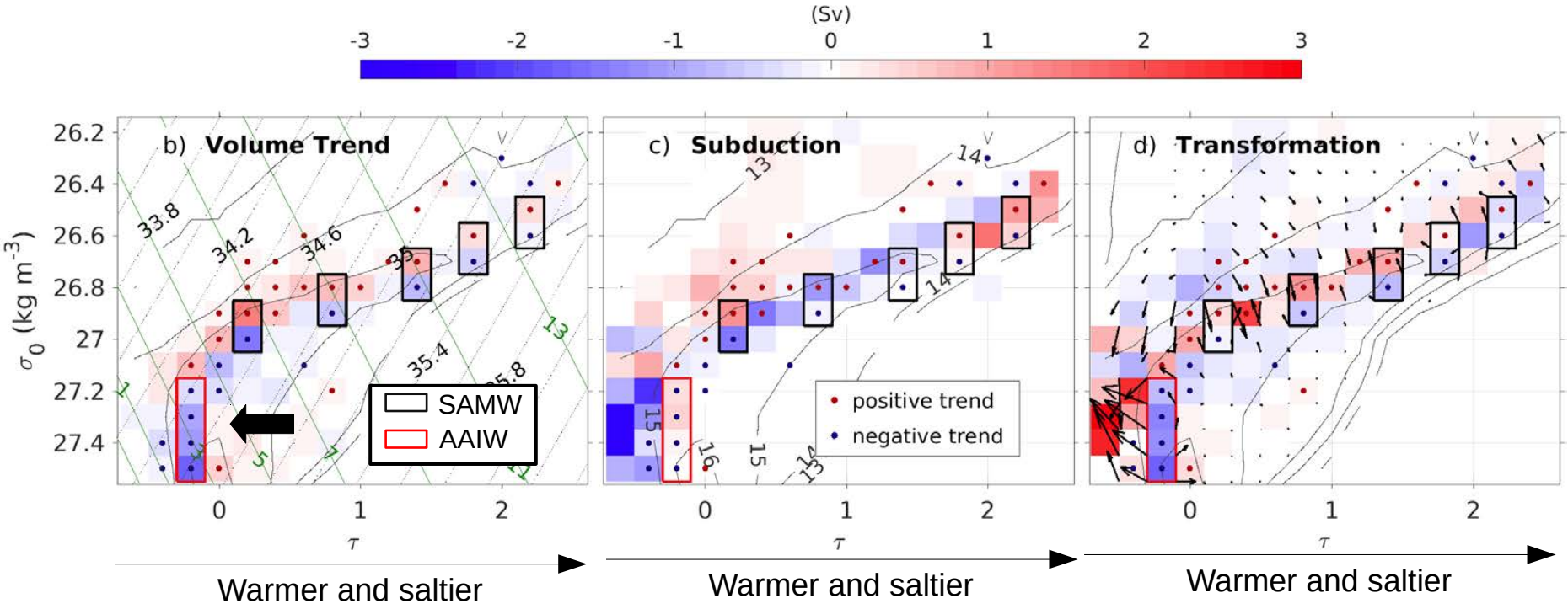


Volume Budget

Lightening of the upper waters

SAMW
- Upper σ-layers: Volume gain
- Lower σ-layers: Volume loss

Intermedate Waters
- AAIW: Volume loss
- AAWW: No volume change



Volume Budget

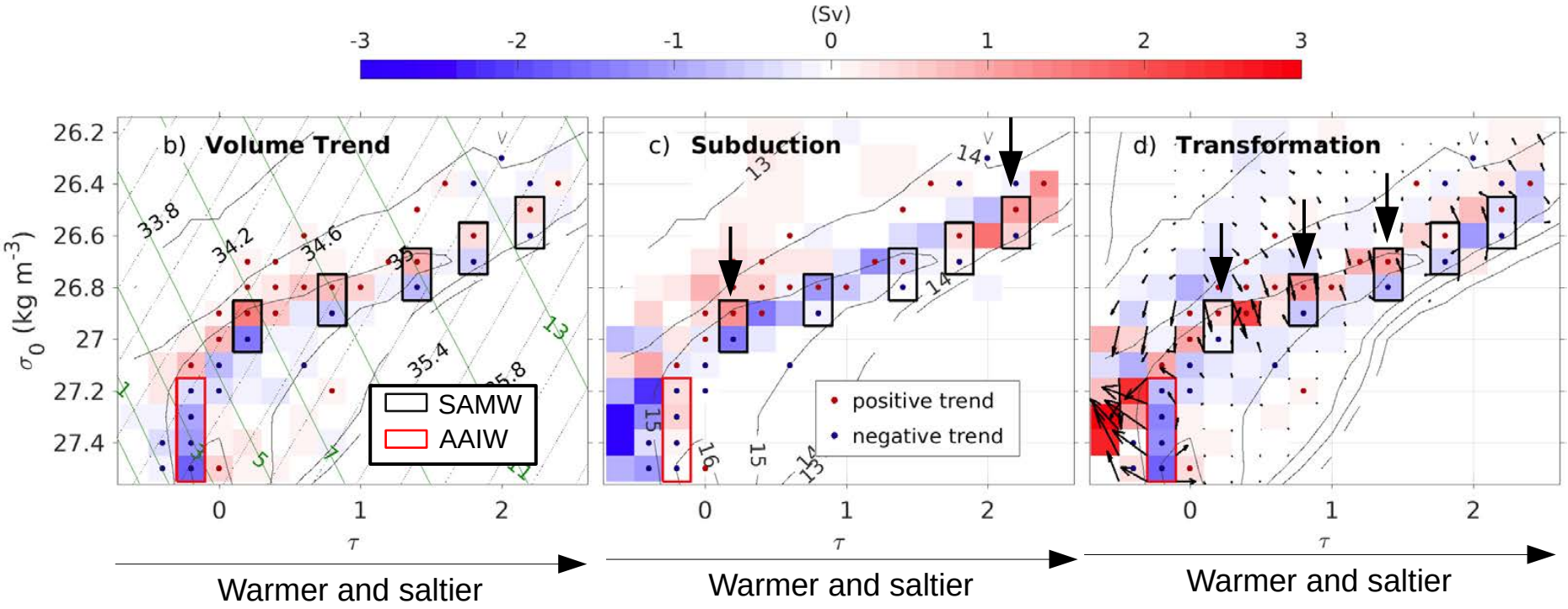
Lightening of the upper waters

SAMW

- Upper σ-layers: Volume gain → Subduction (σ-τ integrated)
- Lower σ-layers: Volume loss → Negative transformation

Intermedate Waters

- AAIW: Volume loss
- AAWW: No volume change

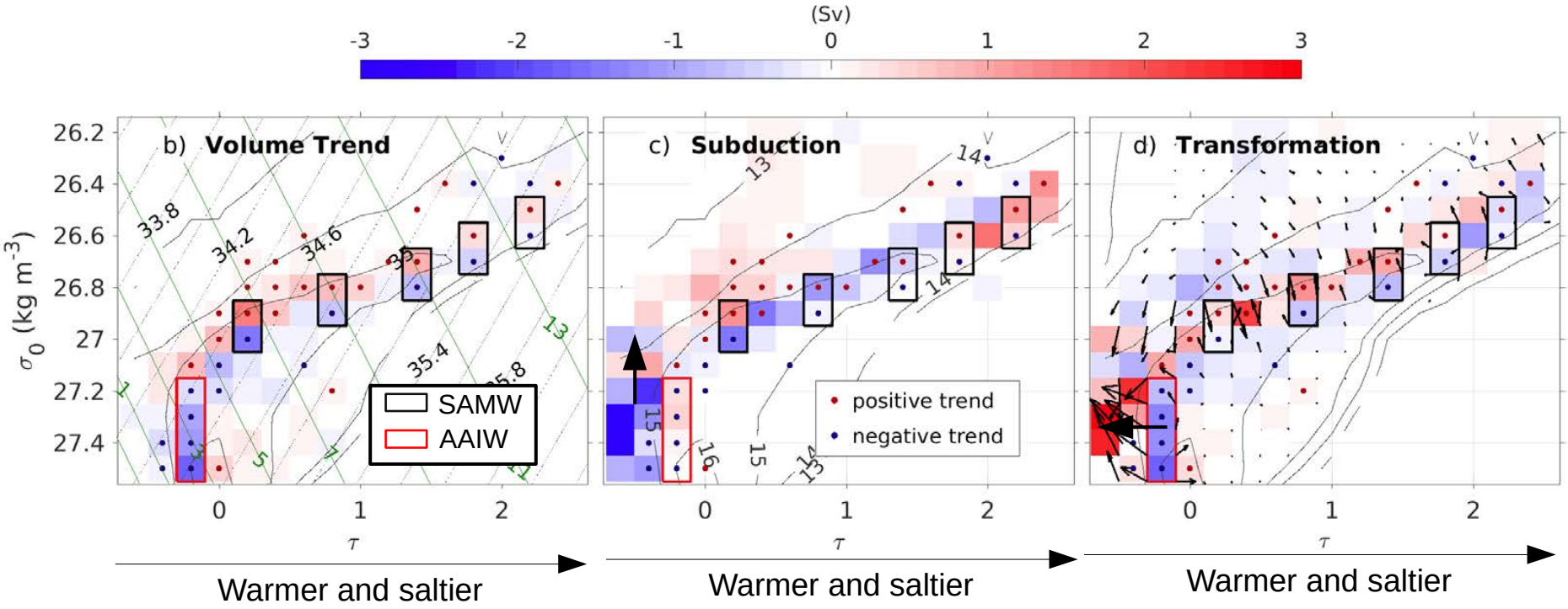


Volume Budget

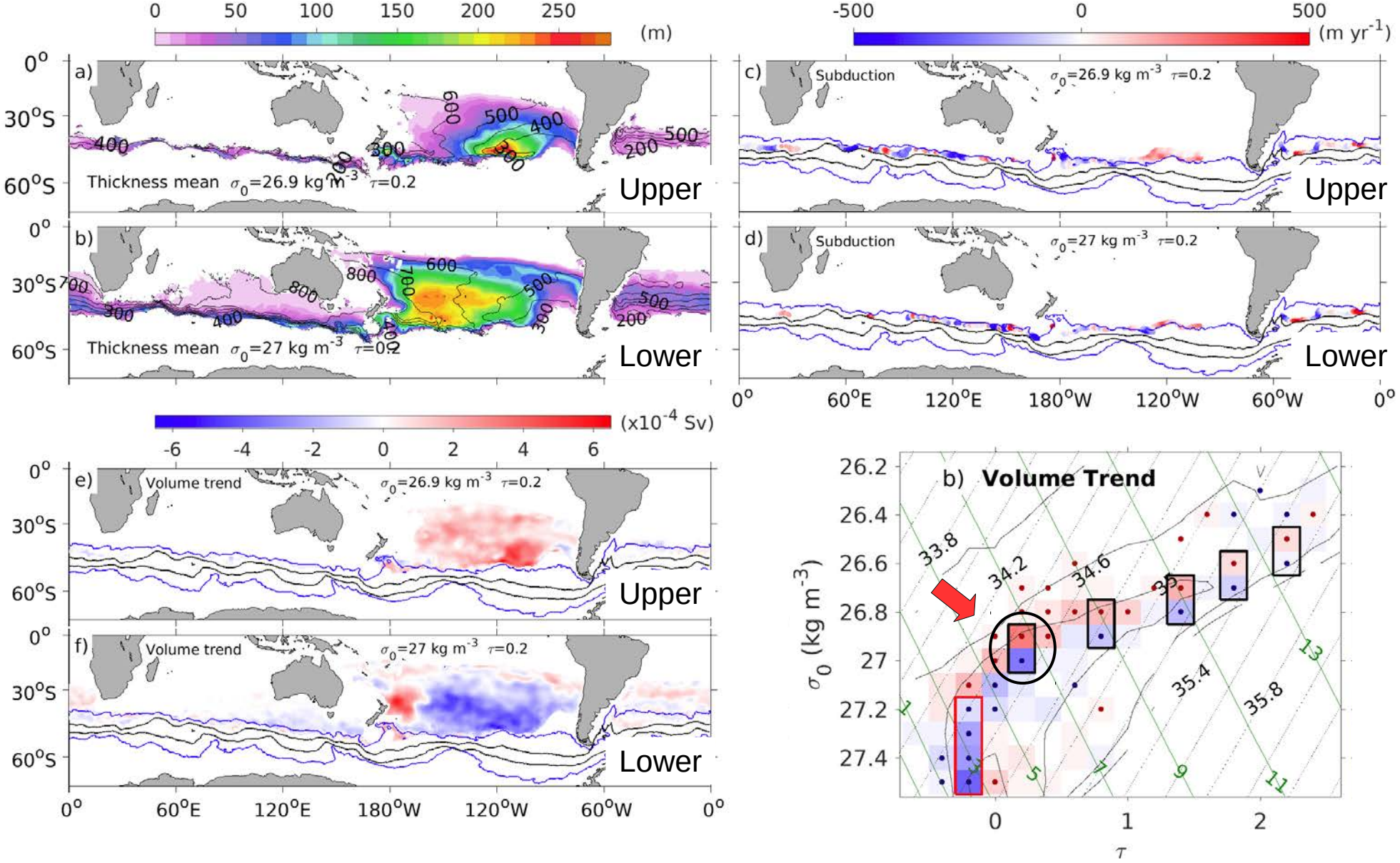
Lightening of the upper waters

SAMW
- Upper σ-layers: Volume gain → Subduction (σ-τ integrated)
- Lower σ-layers: Volume loss → Negative transformation

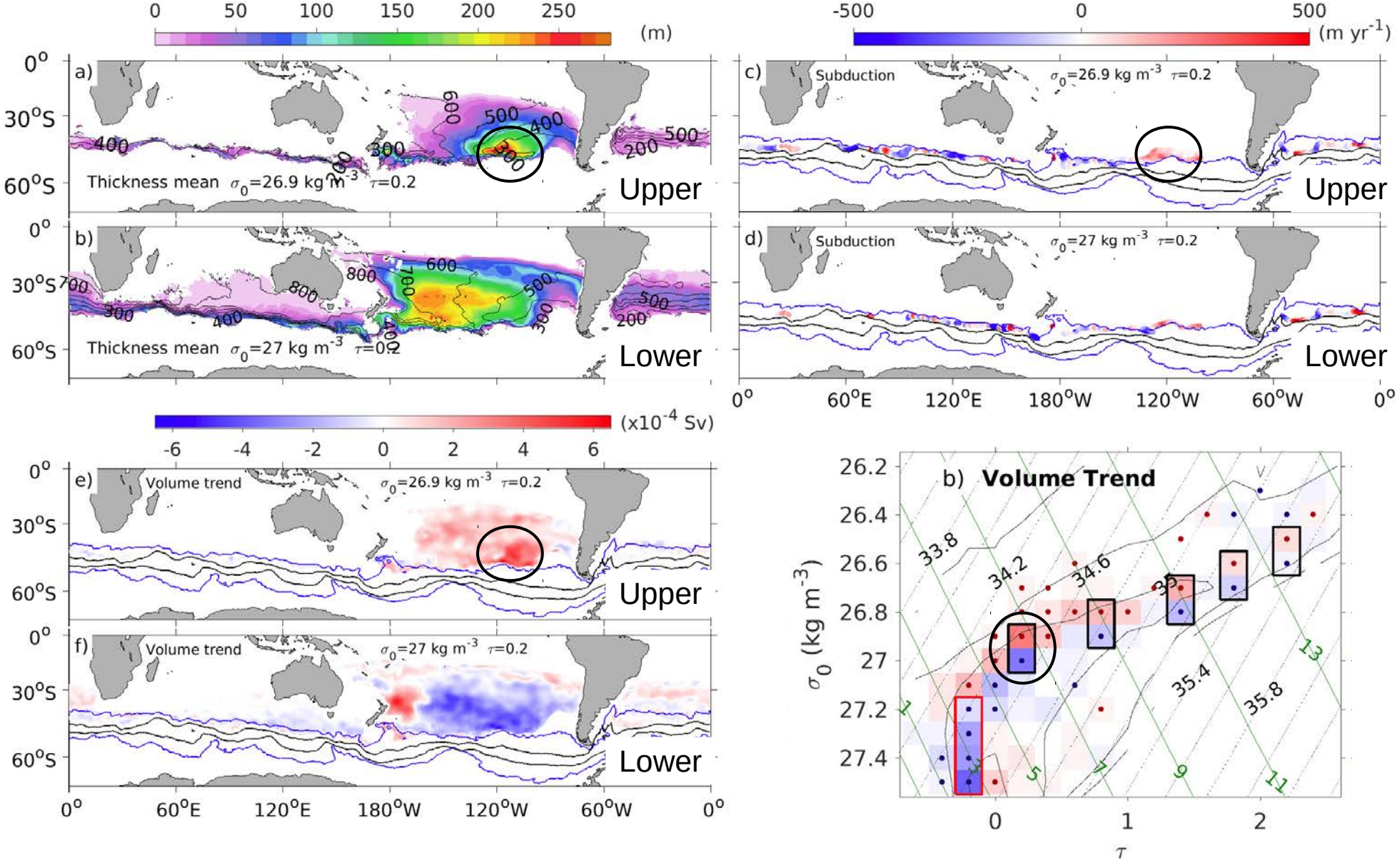
Intermedate Waters
- AAIW: Volume loss → Weak subduction, negative transformation
- AAWW: No volume change → Strong obduction, positive transformation



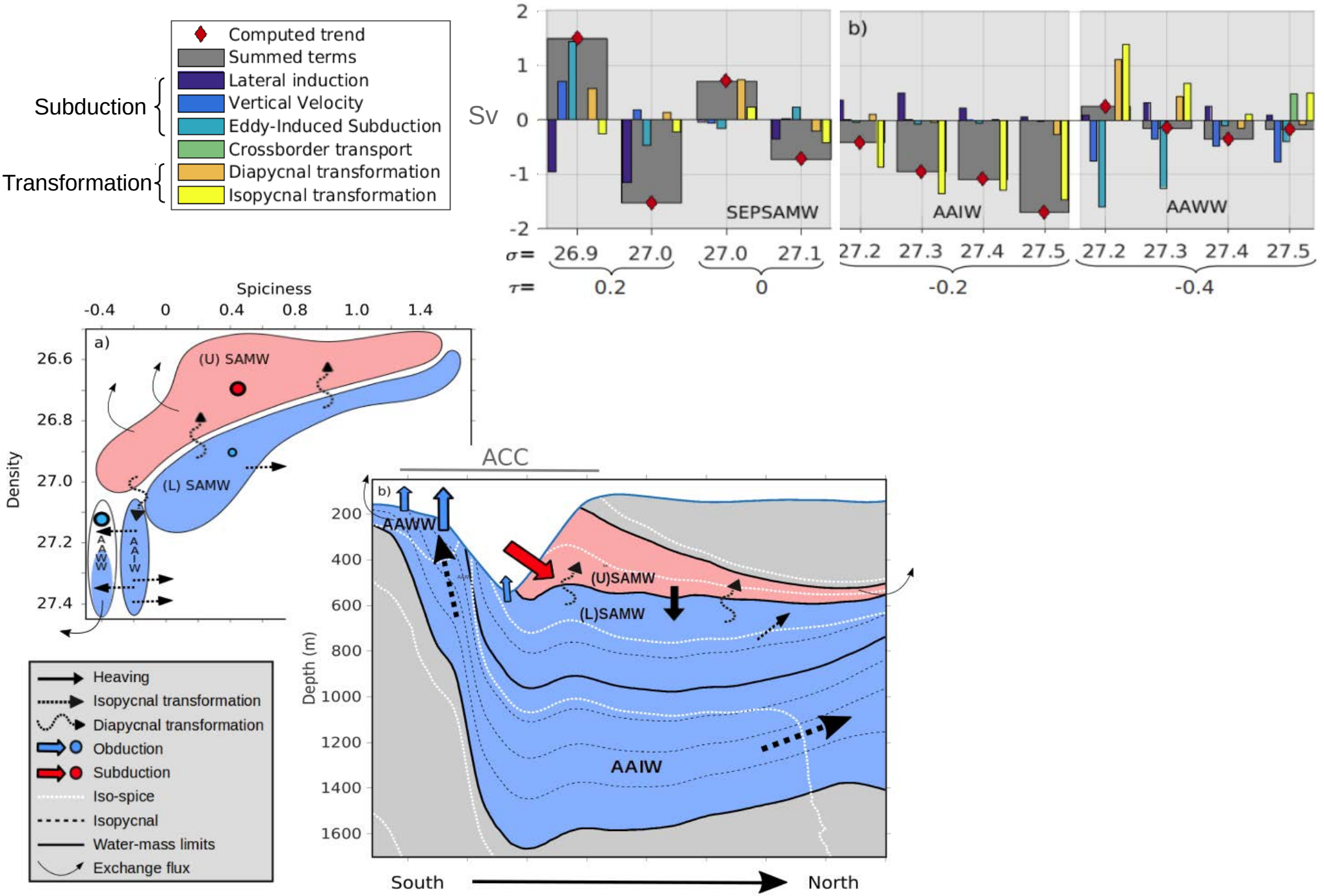
Example: Southeastern Pacific (SEP)SAMW



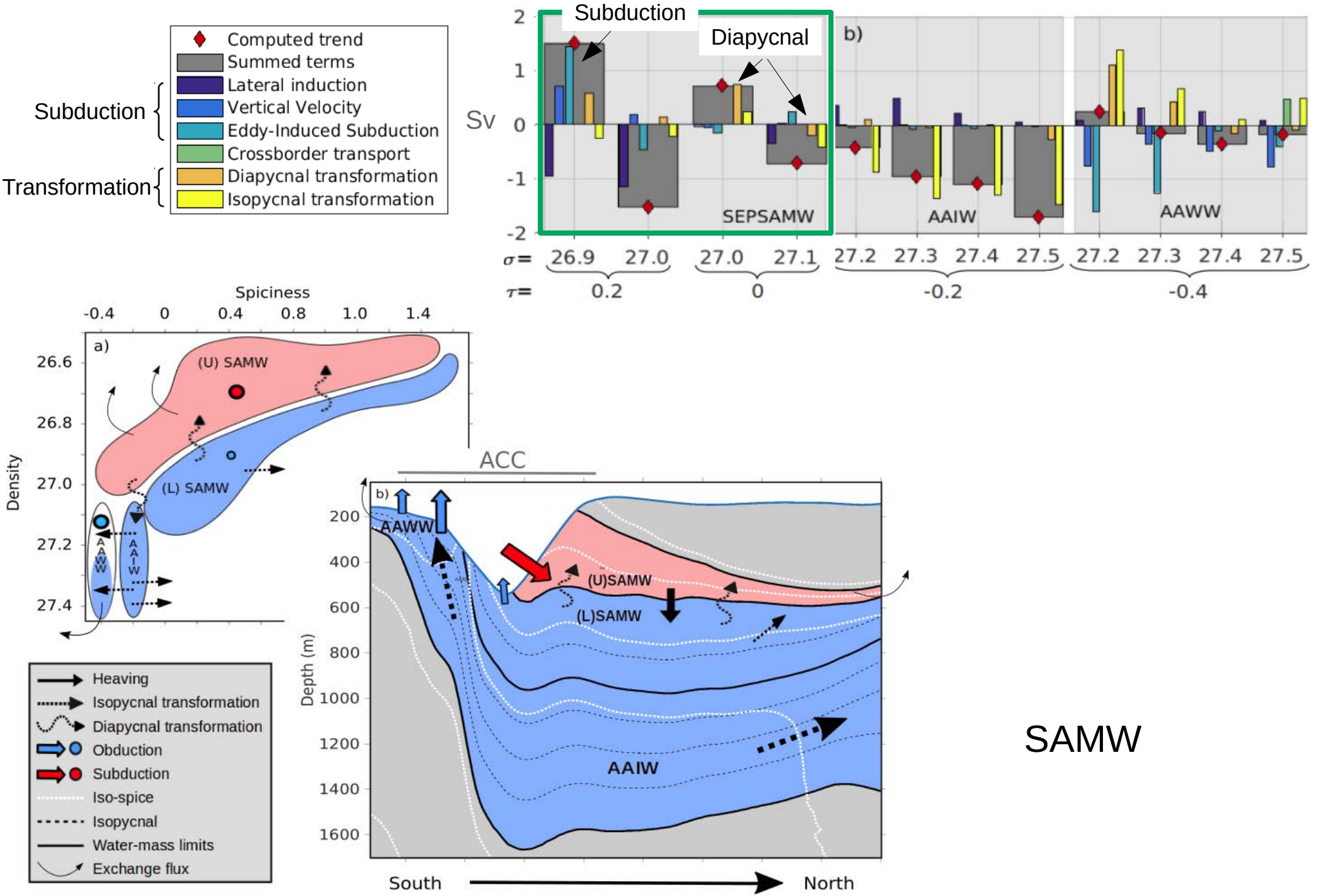
Example: Southeastern Pacific (SEP)SAMW



5. Summary


Computed trend
Summed terms
Lateral induction
Vertical Velocity
Eddy-Induced Subduction
Crossborder transport
Diapycnal transformation
Isopycnal transformation
Subduction
Transformation
Sv
SEPSAMW
AAIW
AAWW
b)
σ=
τ=
26.9 27.0 27.0 27.1 27.2 27.3 27.4 27.5 27.2 27.3 27.4 27.5
0.2 0 -0.2 -0.4
Spiciness
Density
a)
(U) SAMW
(L) SAMW
AAWW
AAIW
ACC
Depth (m)
(U)SAMW
(L)SAMW
AAIW
South
North
Heaving
Isopycnal transformation
Diapycnal transformation
Obduction
Subduction
Iso-spice
Isopycnal
Water-mass limits
Exchange flux

5. Summary



SAMW

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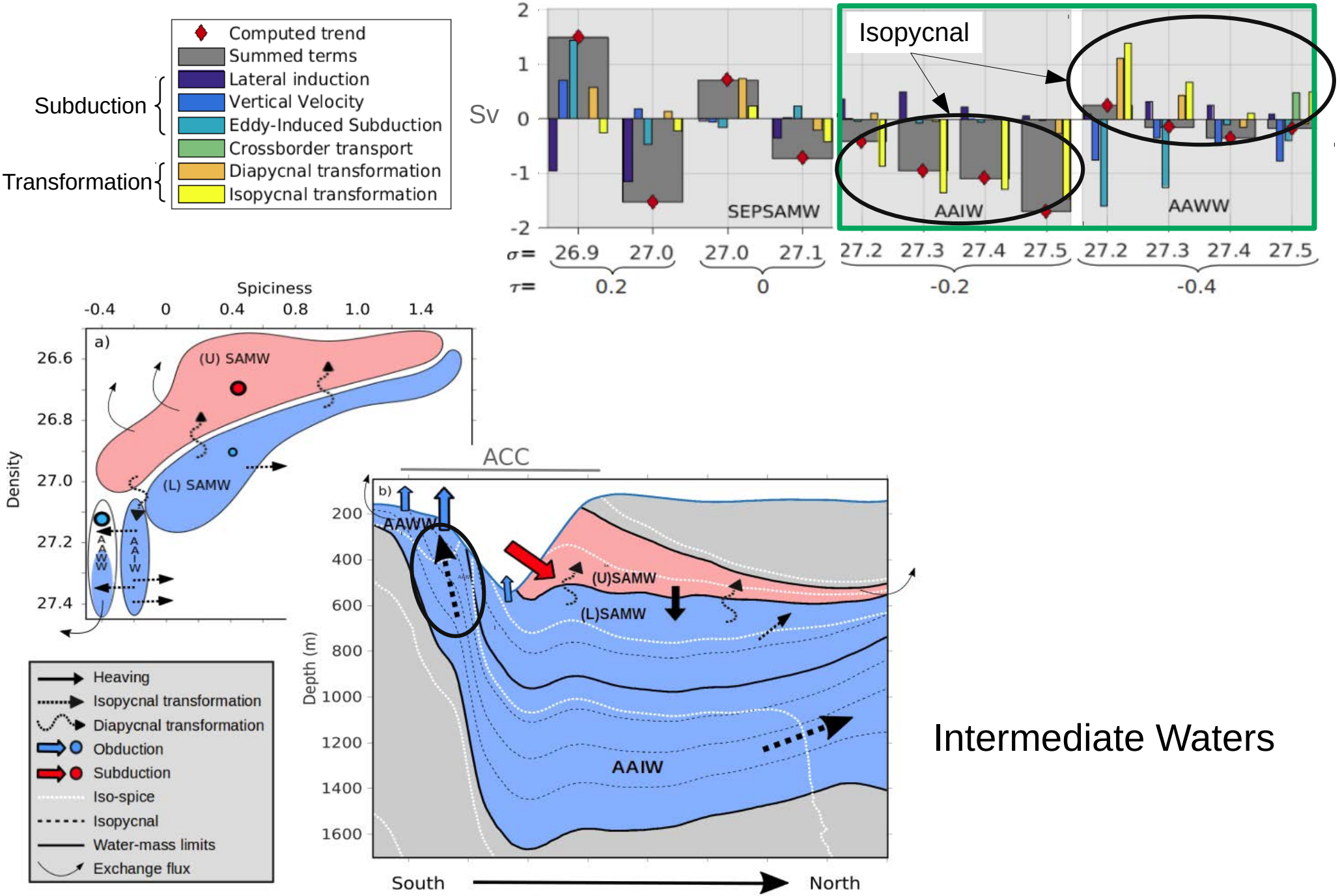
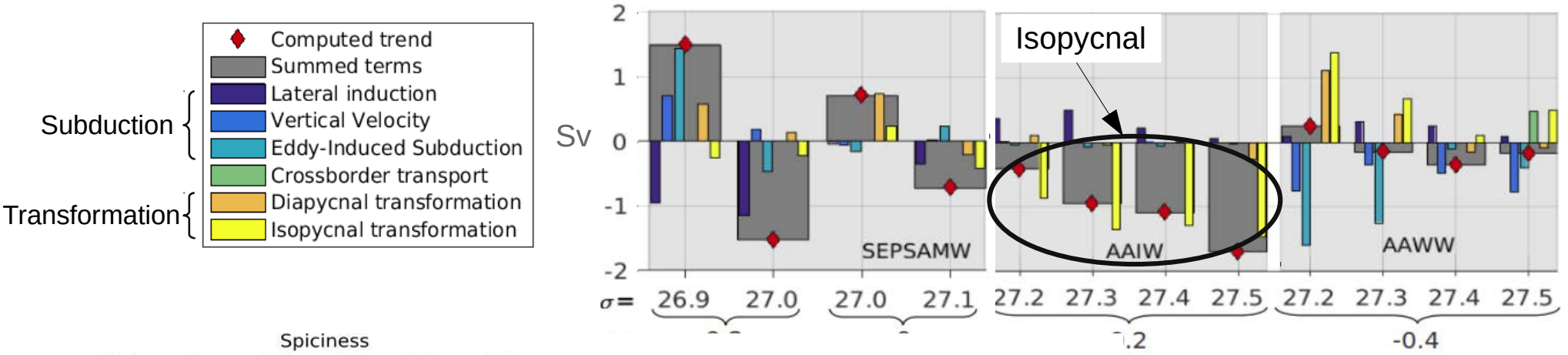
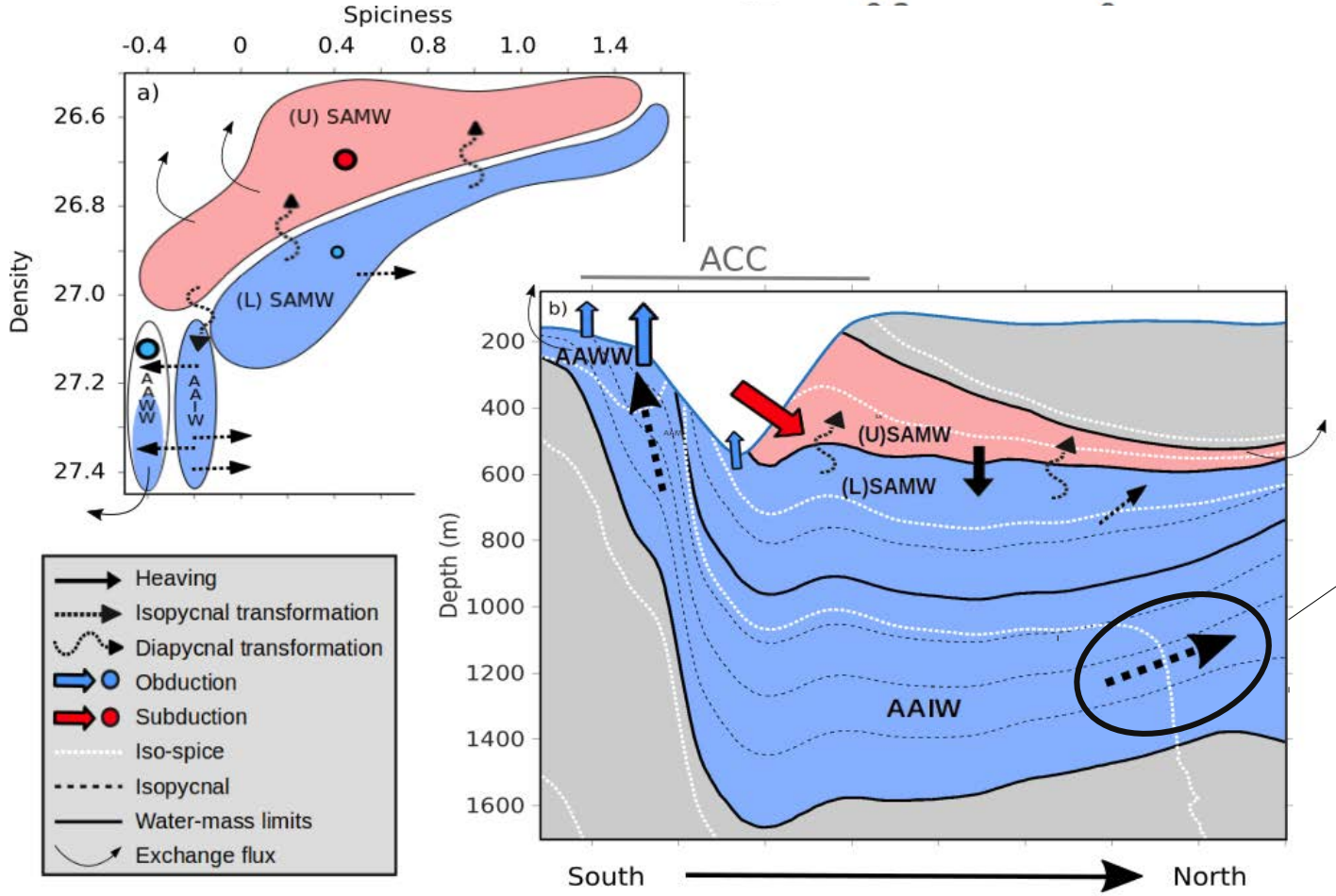


Intermediate Waters

5. Summary





isopycnal transformation from AAIW to spicier IW

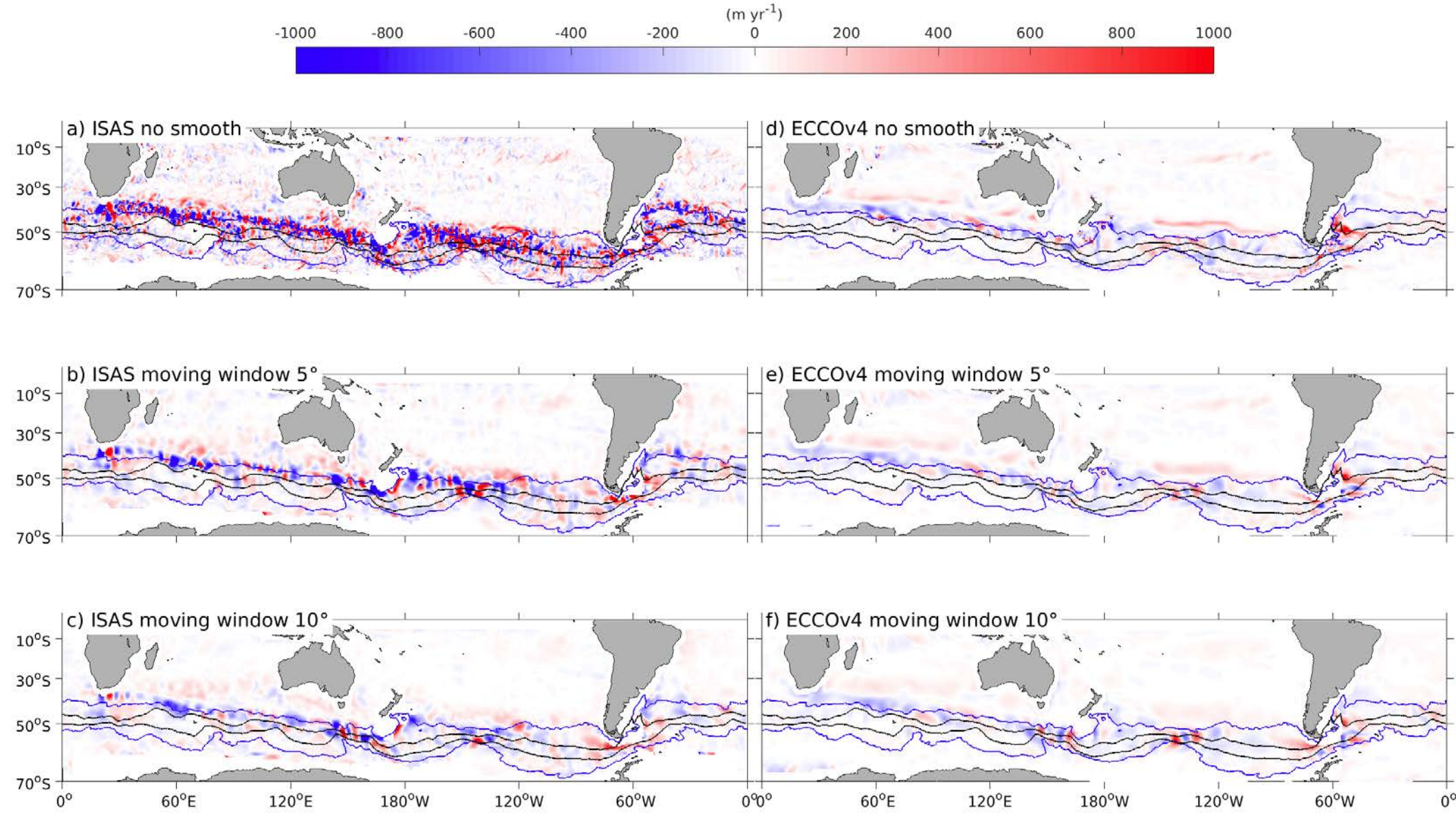
	Water mass	Volume trend	Driving mechanisms
SAMW	Upper SAMW	Positive	Subduction Diapycnal transformation
	Lower SAMW	Negative	Diapycnal transformation Isopycnal transformation
Intermediate Waters	AAIW	Negative	Isopycnal transformation
	AAWW	~0	Isopycnal transformation Obduction
	Tropical IW	~0	Isopycnal transformation

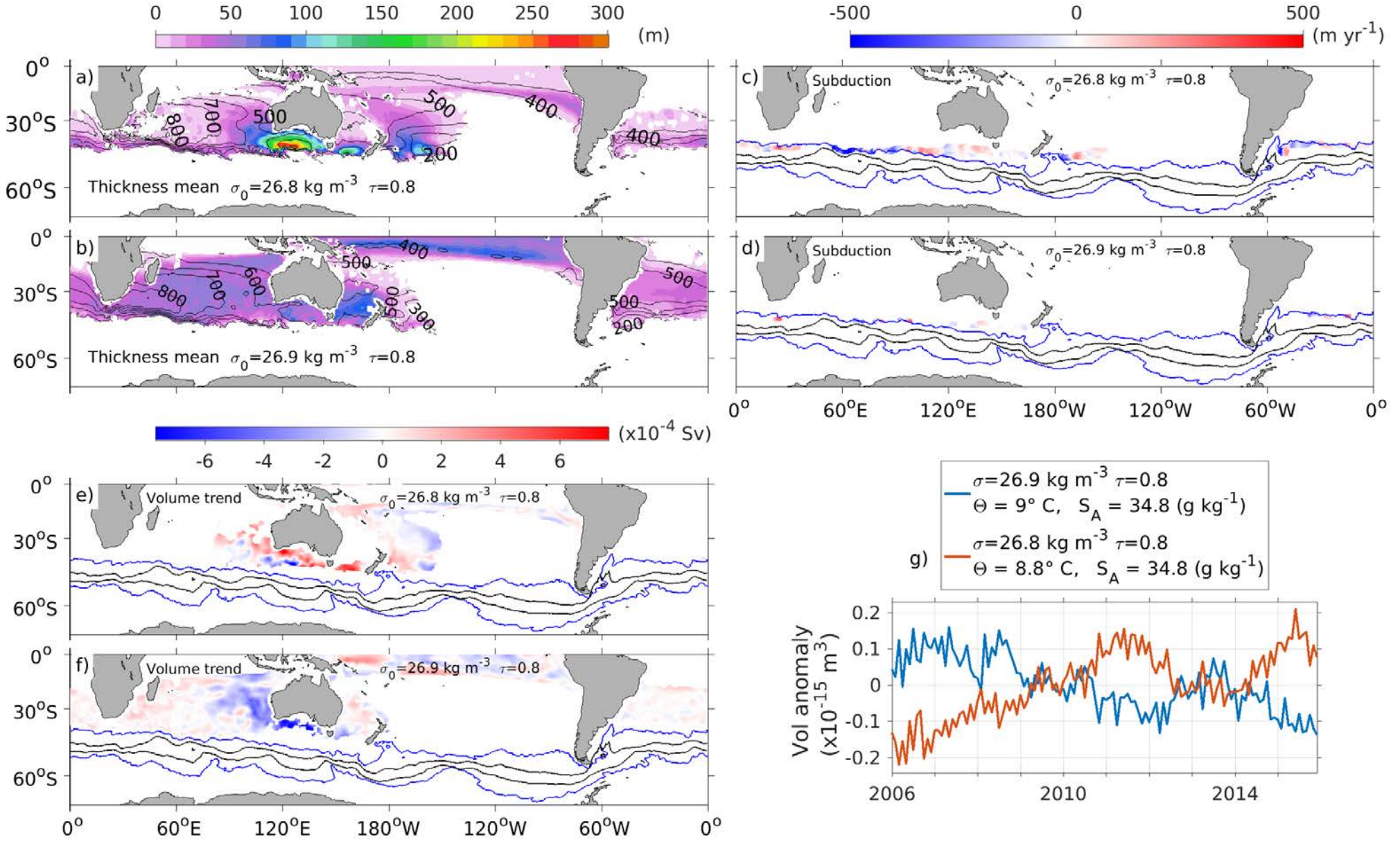
...Thank you

Questions ?

...Thank you

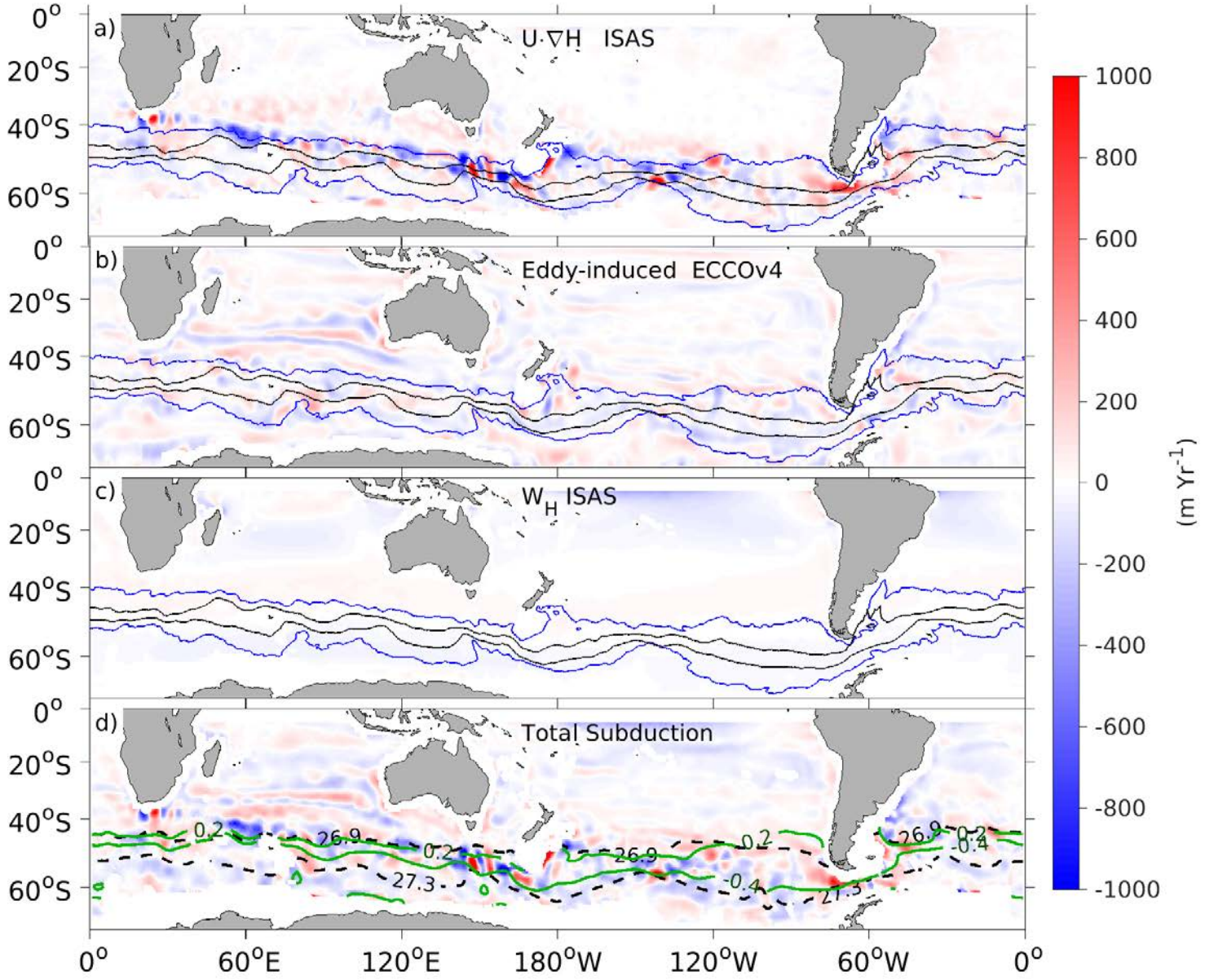
ISAS vs ecco

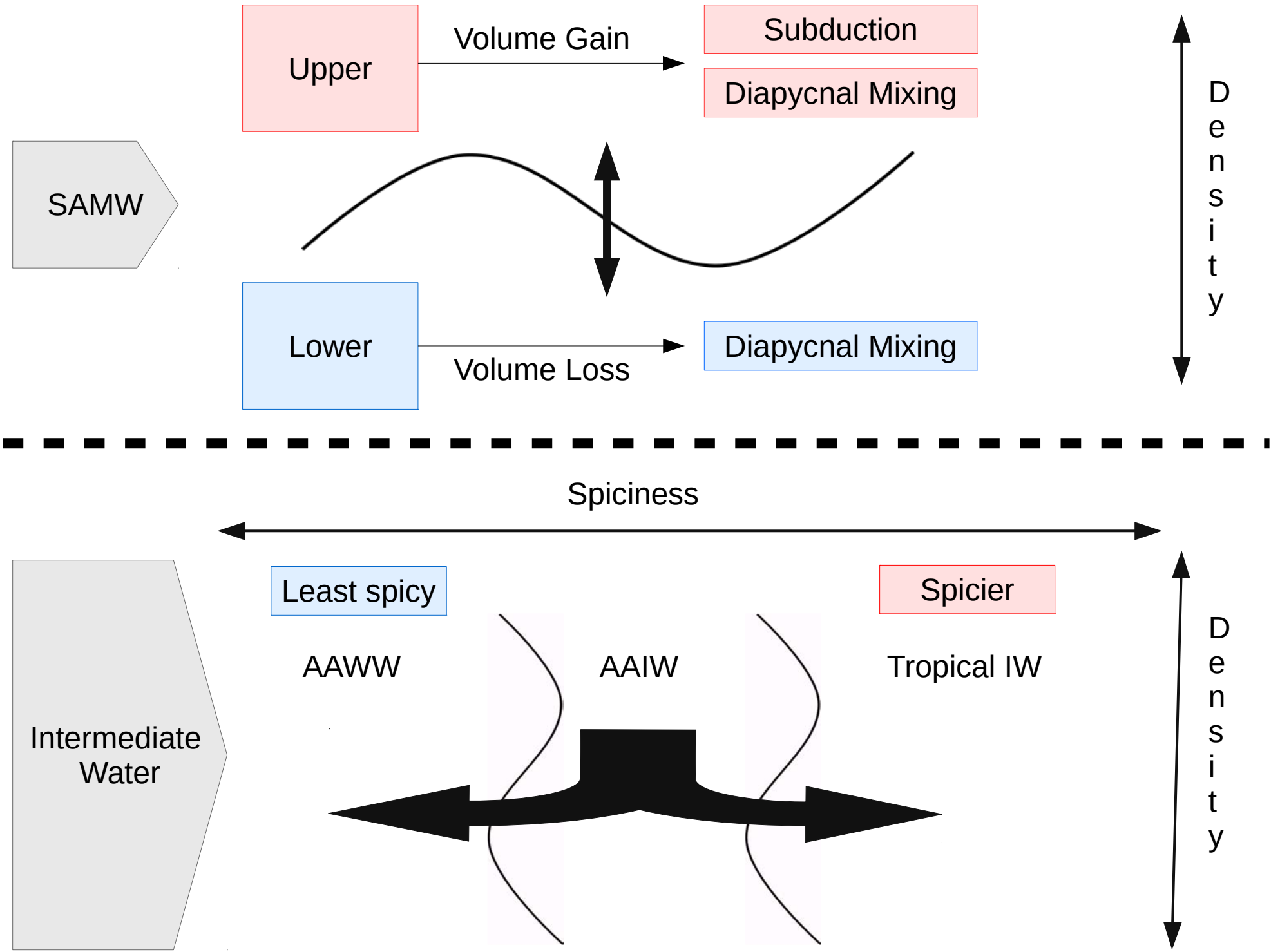

(m yr-1)
-1000
-800
-600
-400
-200
0
200
400
600
800
1000
a) ISAS no smooth
d) ECCOv4 no smooth
b) ISAS moving window 5°
e) ECCOv4 moving window 5°
c) ISAS moving window 10°
f) ECCOv4 moving window 10°
10°S
30°S
50°S
70°S
0°
60°E
120°E
180°W
120°W
60°W


0 50 100 150 200 250 300 (m)
-500 0 500 (m yr^{-1})
a)
Thickness mean σ_0=26.8 kg m^{-3} τ=0.8
b)
Thickness mean σ_0=26.9 kg m^{-3} τ=0.8
c) Subduction σ_0=26.8 kg m^{-3} τ=0.8
d) Subduction σ_0=26.9 kg m^{-3} τ=0.8
(x10^{-4} Sv)
-6 -4 -2 0 2 4 6
e) Volume trend σ_0=26.8 kg m^{-3} τ=0.8
f) Volume trend σ_0=26.9 kg m^{-3} τ=0.8
0° 30°S 60°S
0° 60°E 120°E 180°W 120°W 60°W 0°
g)
σ=26.9 kg m^{-3} τ=0.8
Θ = 9° C, S$_A$ = 34.8 (g kg^{-1})
σ=26.8 kg m^{-3} τ=0.8
Θ = 8.8° C, S$_A$ = 34.8 (g kg^{-1})
Vol anomaly (x10^{-15} m^3)
0.2 0.1 0 -0.1 -0.2
2006 2010 2014

Subduction decomposition

$$\underbrace{U_H \cdot \nabla_h H}_{\textit{lateral induction}} + \underbrace{\nabla_h \left(U_H^* \right)}_{\textit{eddy induced}} + \underbrace{w_H}_{\textit{vertical v}} = \underbrace{S(x,y)}_{\textit{Subduction}}$$




Upper
Volume Gain
Subduction
Diapycnal Mixing
SAMW
Lower
Volume Loss
Diapycnal Mixing
Density
Spiciness
Intermediate Water
Least spicy
Spicier
AAWW
AAIW
Tropical IW
Density