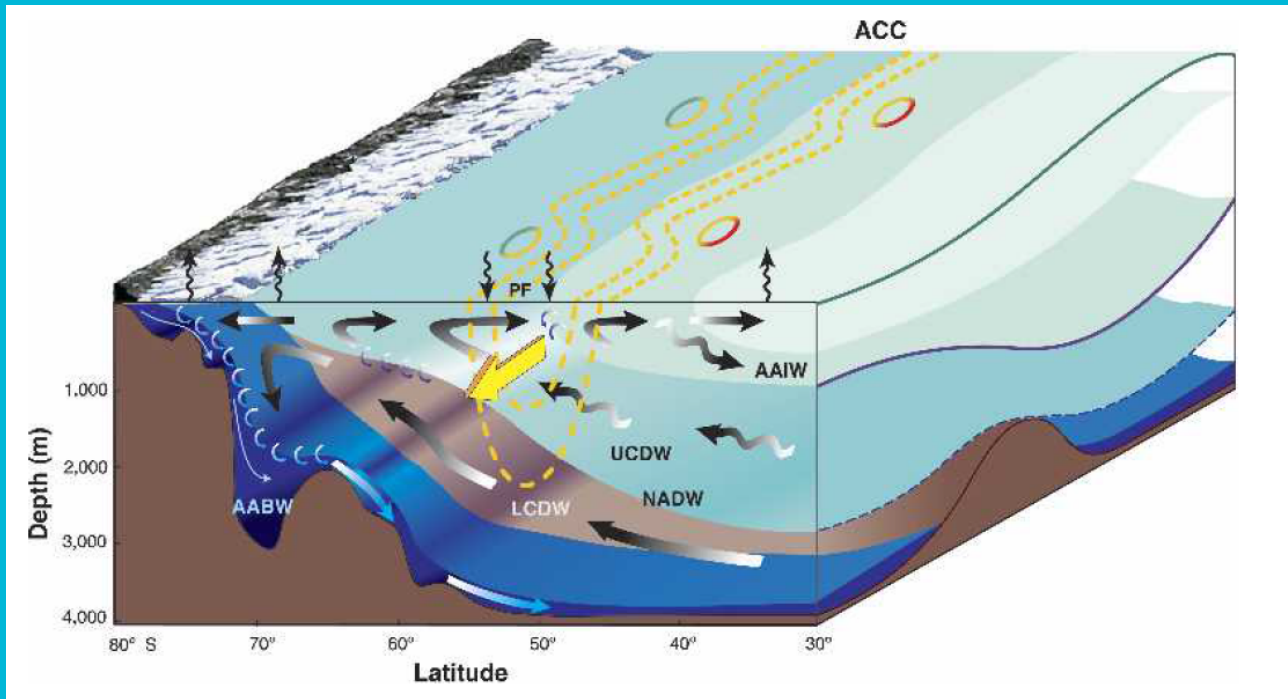


1° versus 1/10°

what are the implications for C_{ant} subduction in the Southern Ocean?



Southern Ocean
contributes to
30% of sink of
anthropogenic
carbon
dioxide

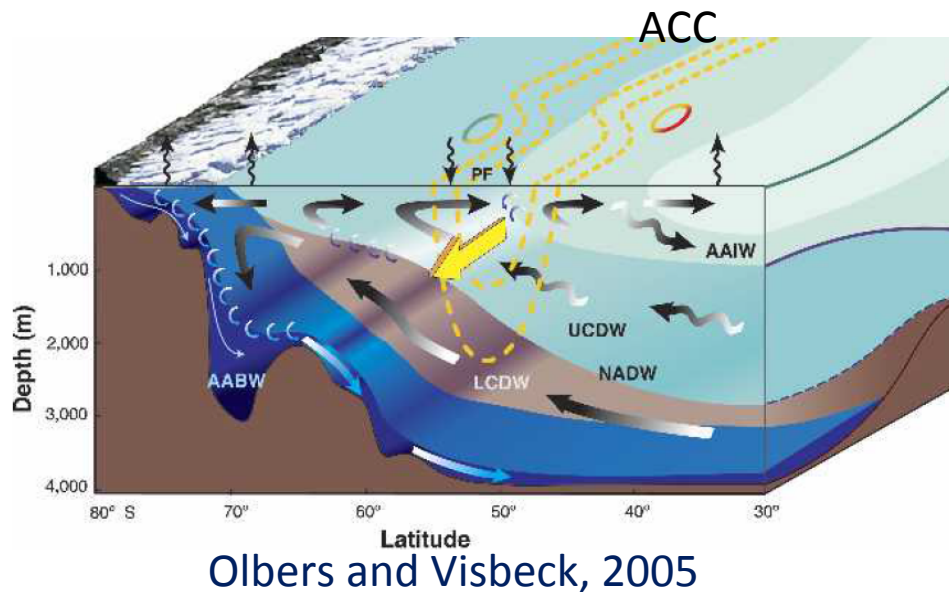
Olbers and Visbeck, 2005

OCEAN & ATMOSPHERE – OCEAN AND CLIMATE DYNAMIC PROGRAM
www.csiro.au

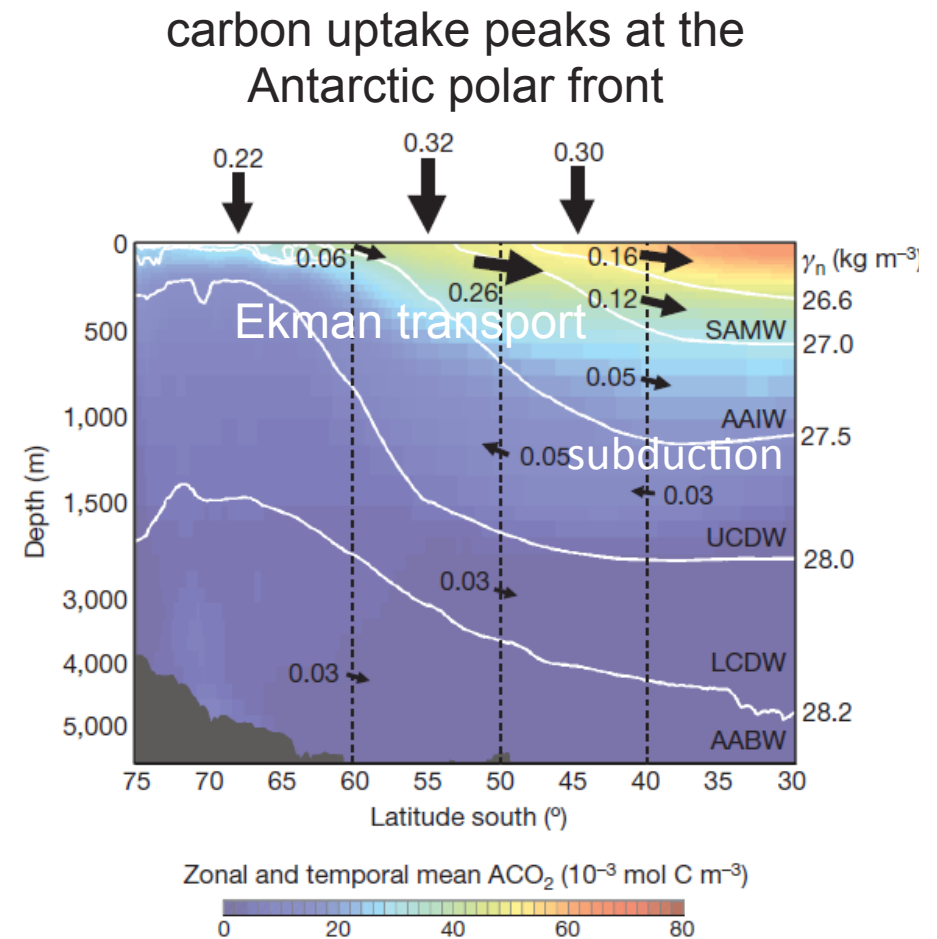
Clothilde Langlais, Andrew Lenton, Richard Matear, Steve Rintoul, Didier Monselesan, Benoit Legresy, Matt Chamberlain, Paula Condeperdo, Joan Llort, Sebastien Moreau, Andreas Klocker



What do we know about C_{ant} pathways? What are the gaps?



- Uptake at PF at 55°S
- Northward Ekman transport
- Subduction
- High inventory of Cant north of 55°S
- Regional hot spot of subduction



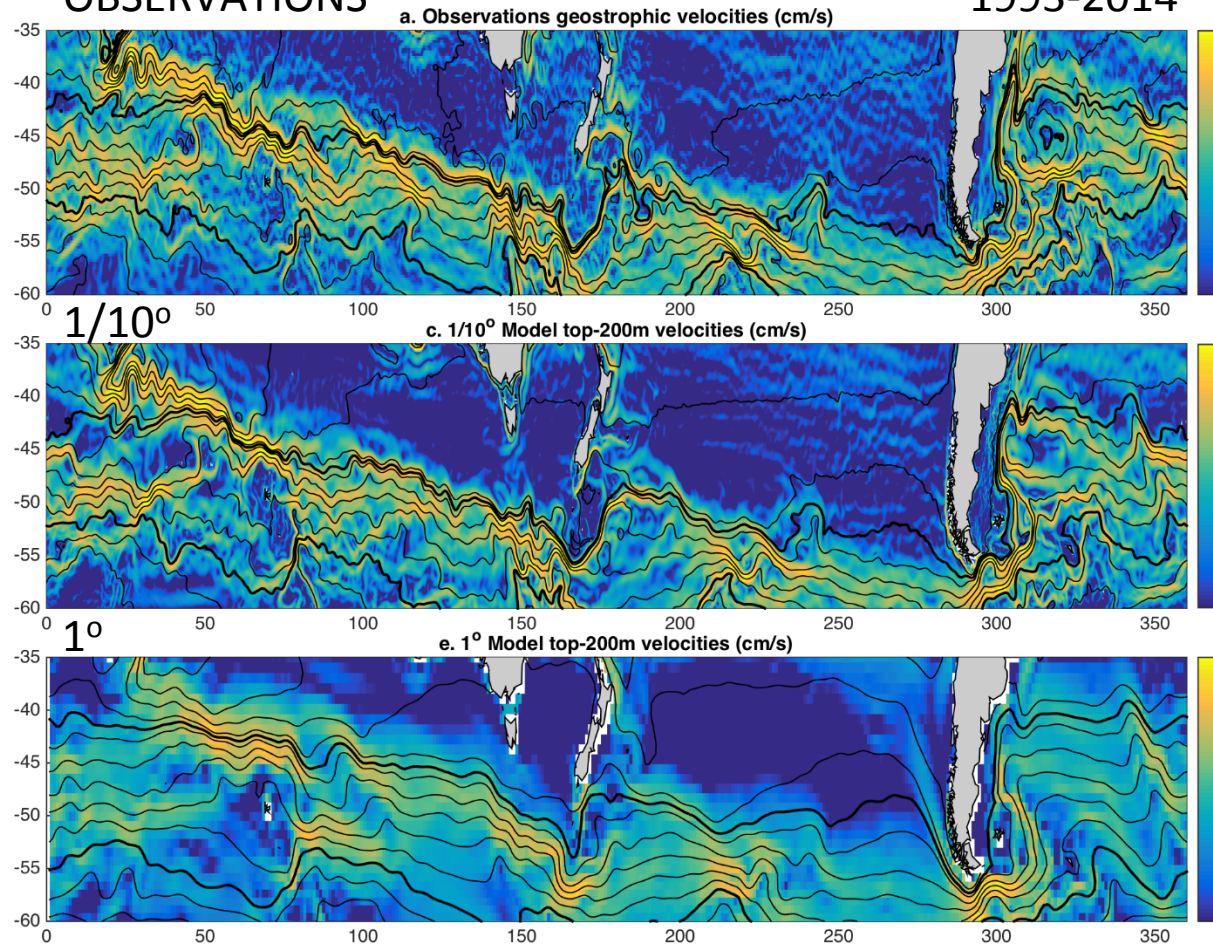
GAP : Physical mechanisms involved in Cant transfer through the mixed layer?

1/10° Ocean Forecasting Australia Model (OFAM3) Zhang et al., 2016

1° ACCESS-O Matear et al.

OBSERVATIONS

1993-2014



- MOM4 ocean model
- 50 z-level
- WOMBAT BGC model
- Ice model in 1°
- 20 yr Spin-up with 1979
- 1979-2014 historical run : JRA-55 surface forcing (bulk formulae)
- 2006-2101 projection run : JRA-55 x3 + CMIP5 trend (rcp8p5)
- 1979-2101 control run

Does resolution matter for local pathways of C_{ant} ? NO

2007-2012

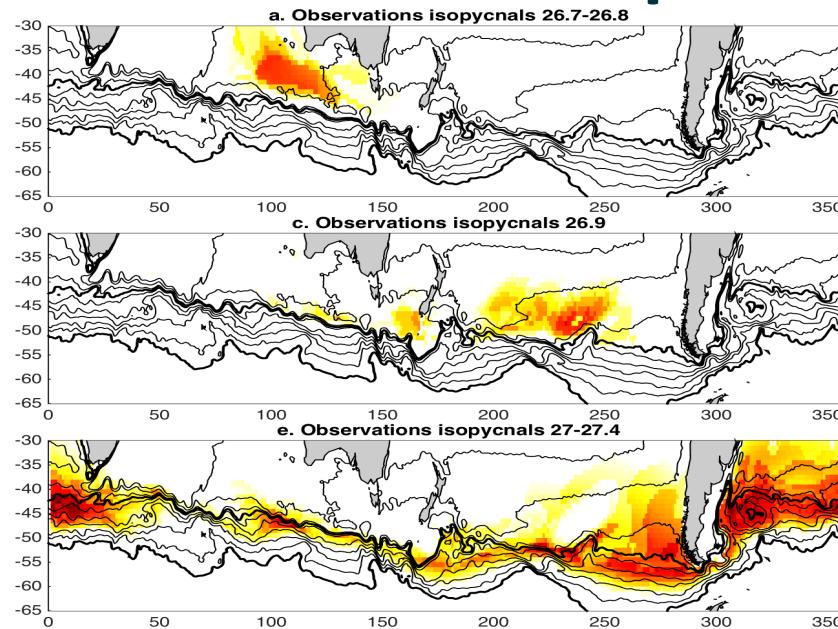
Light
SAMW

Dense
SAMW

AAIW

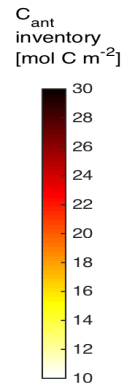
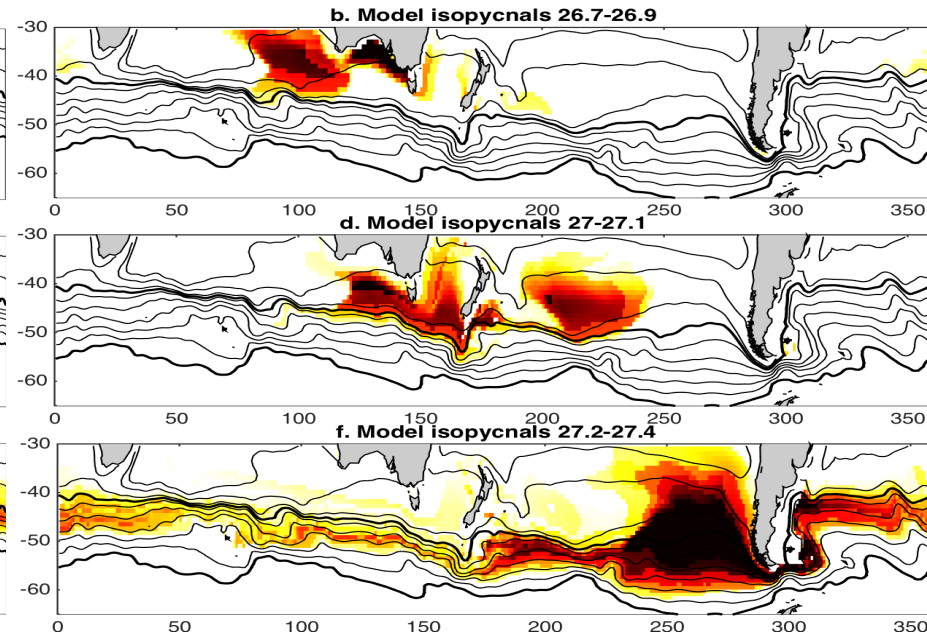
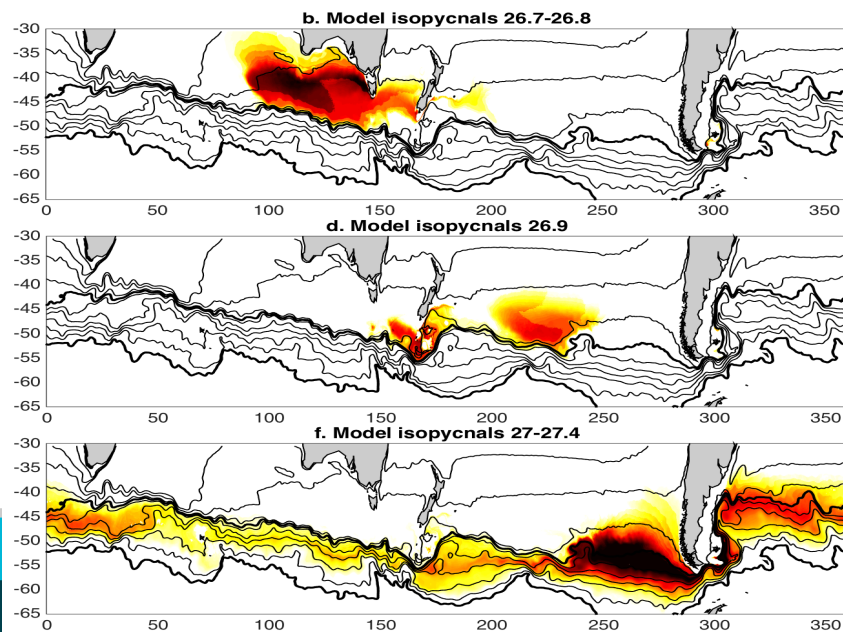
GLODAP OBS

Inventory of C_{ant} along
isopycnals



$1/10^\circ$

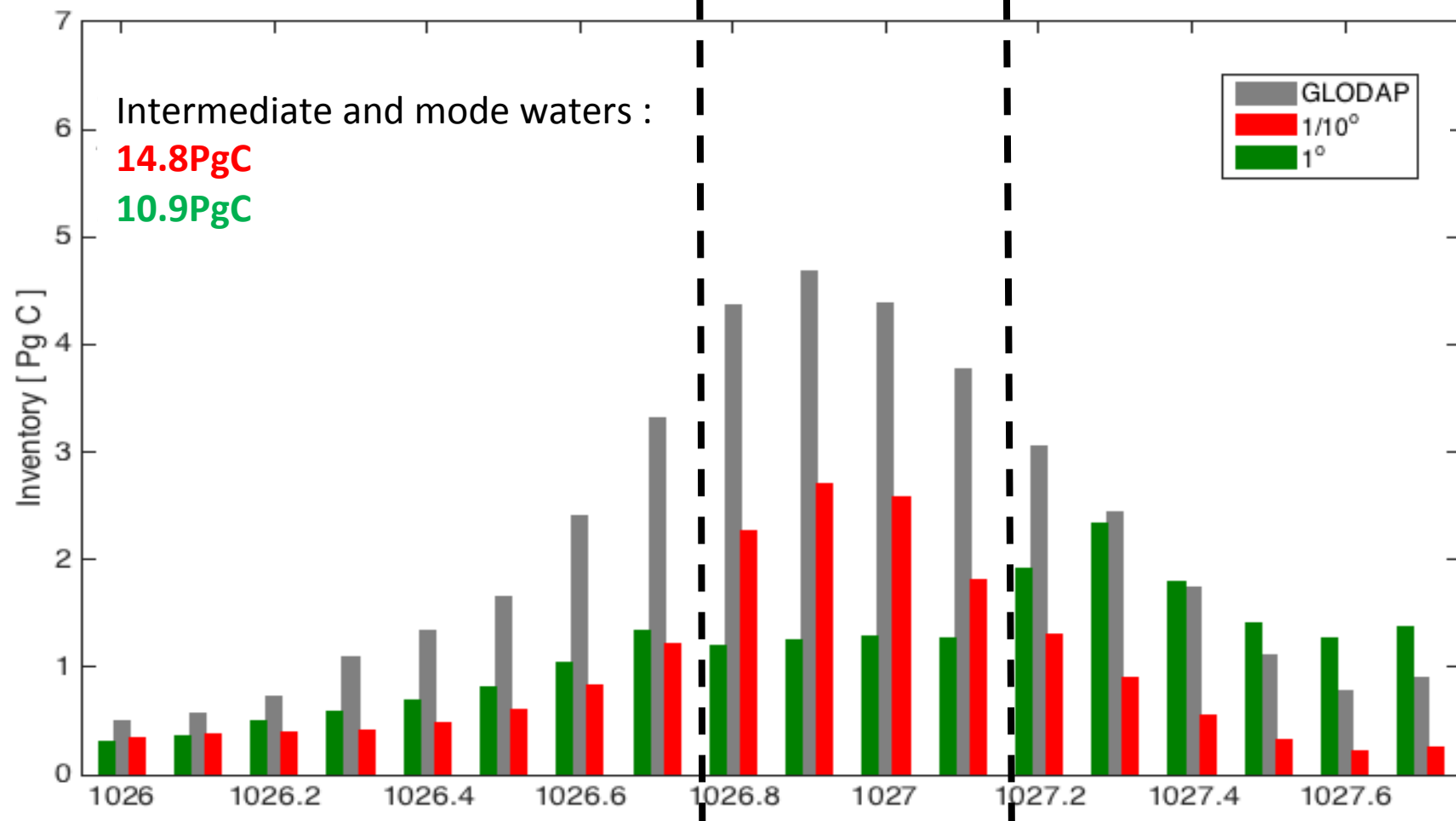
1°



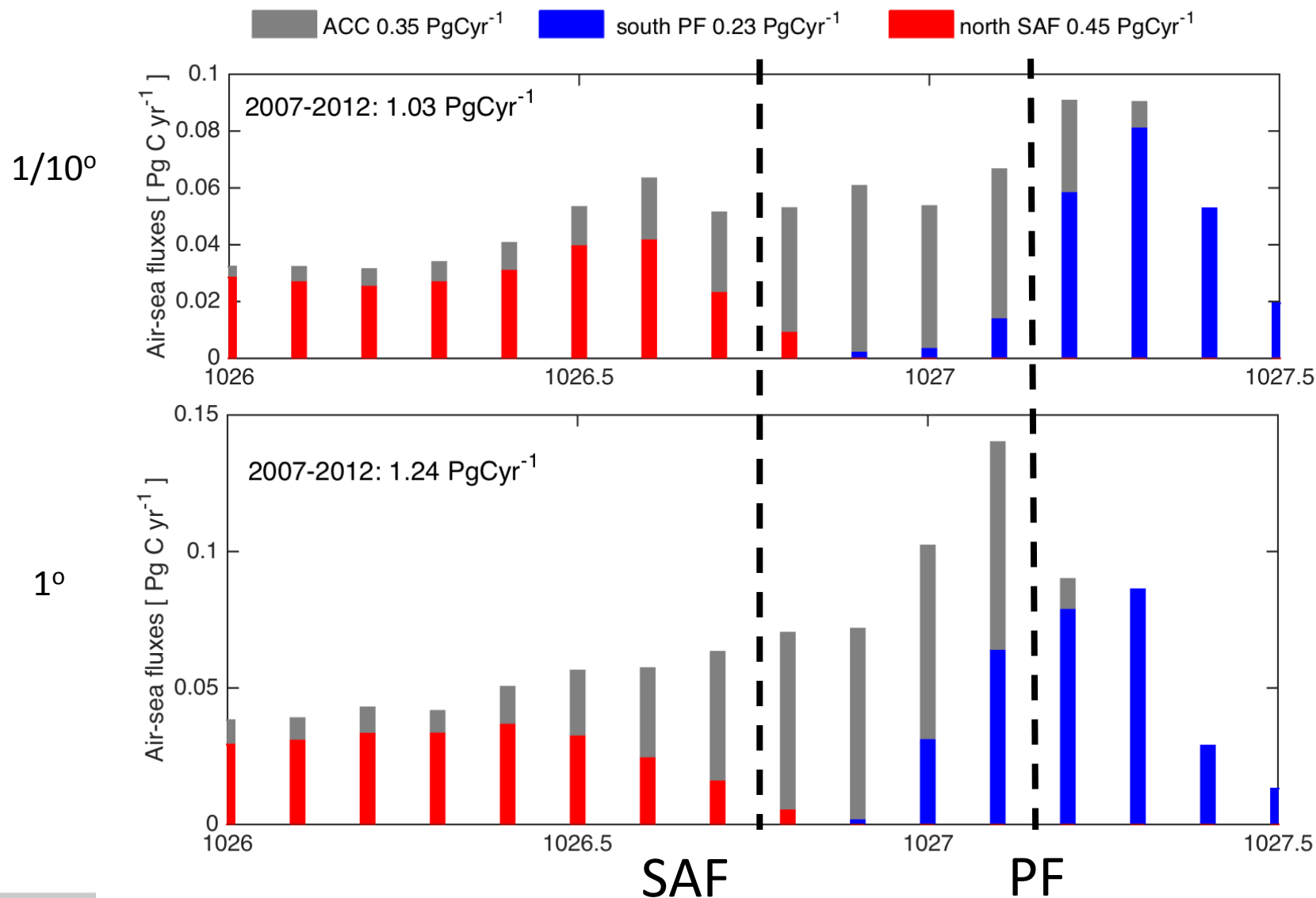
What about the amount of C_{ant} ? YES

Inventory below the mixed layer
from 30°S to PF

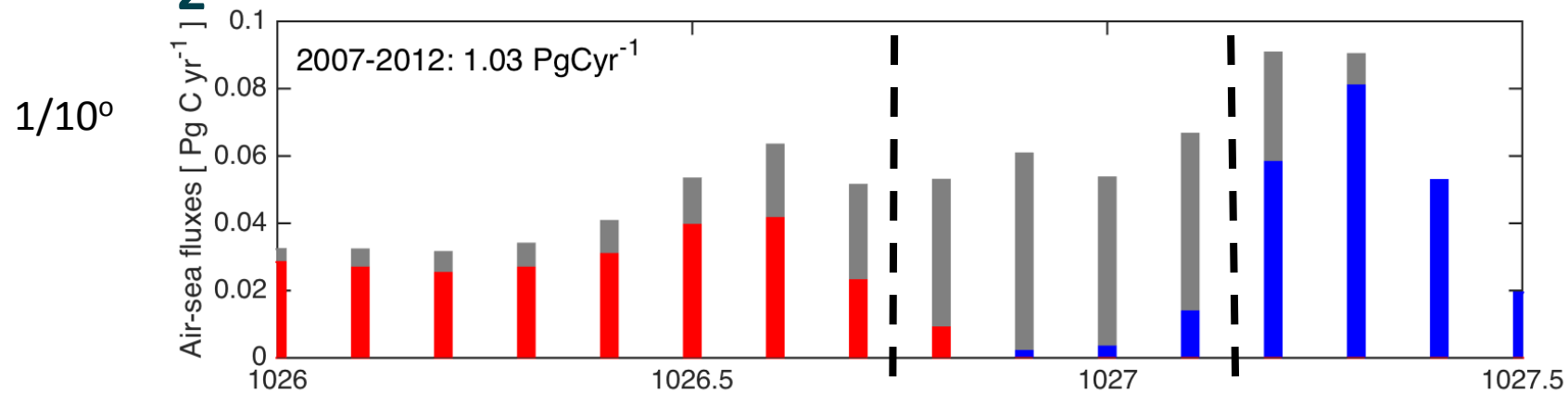
2007-2012



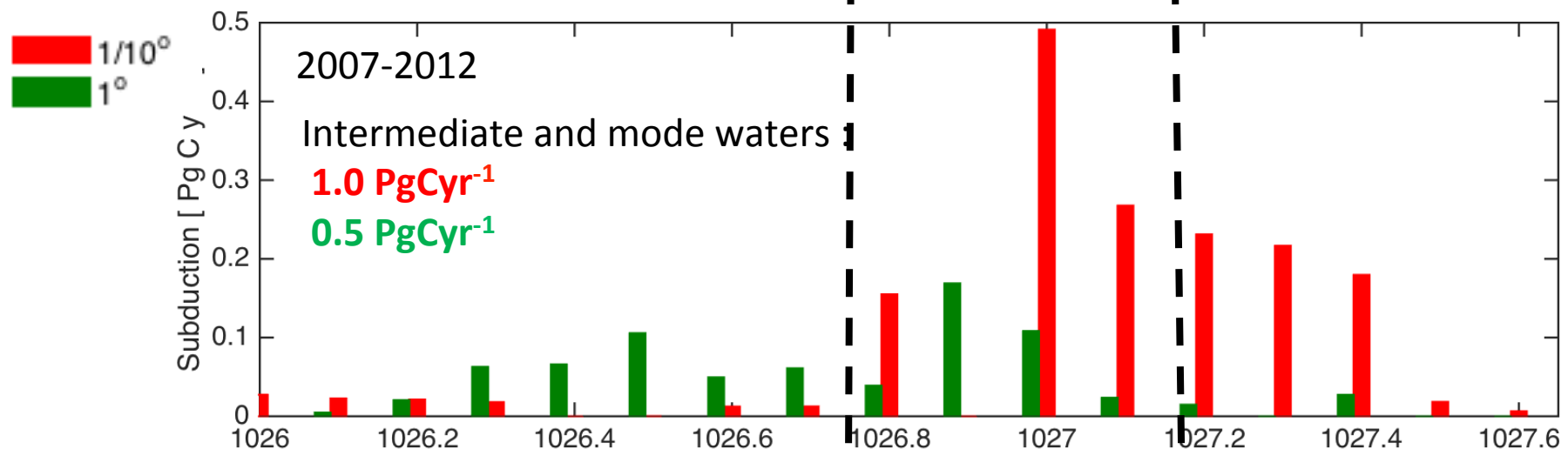
Different ACO₂ air-sea fluxes 2007-2012? NO



ACO₂ air-sea fluxes 2007-2012



Different C_{ant} transfer through winter mixed layer? YES



SAF

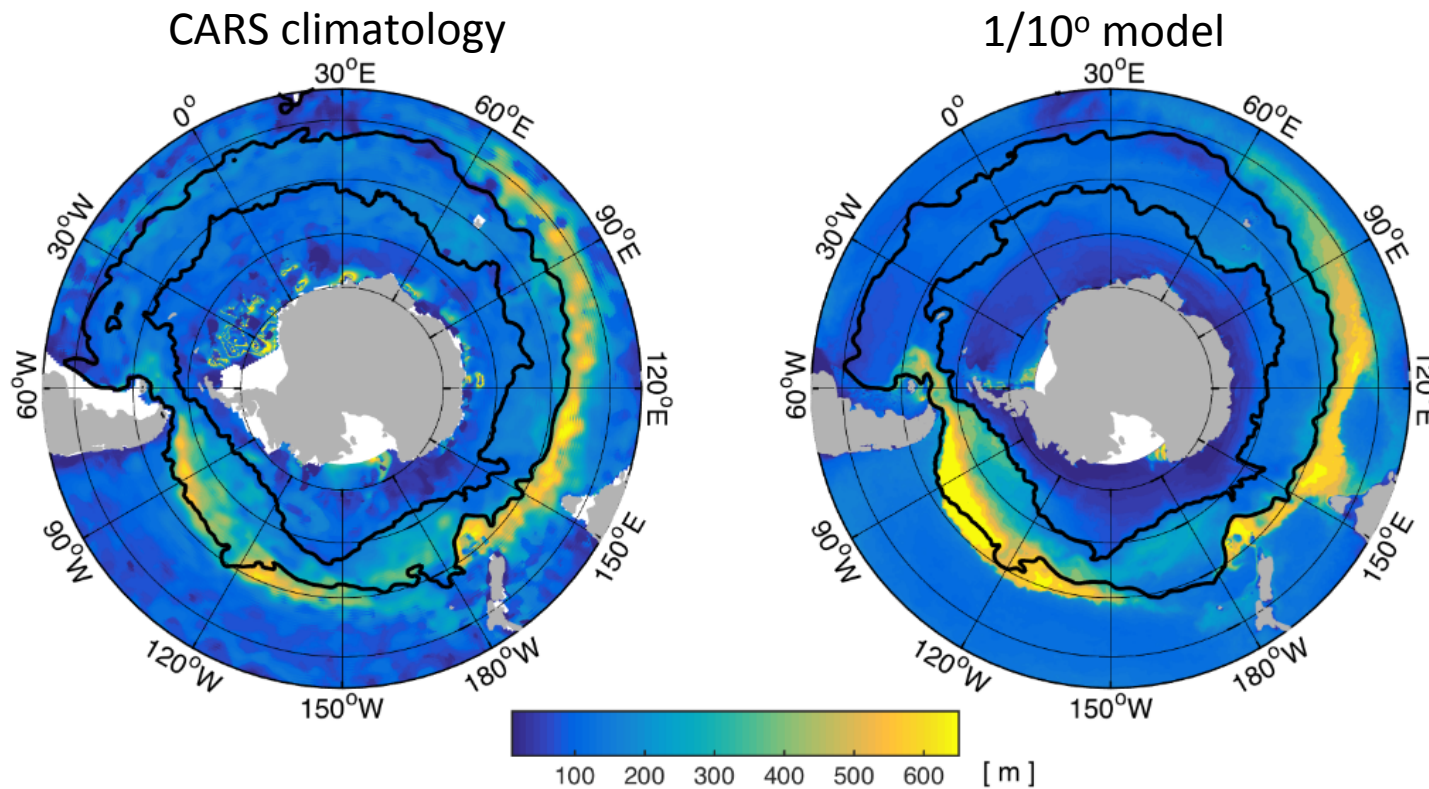
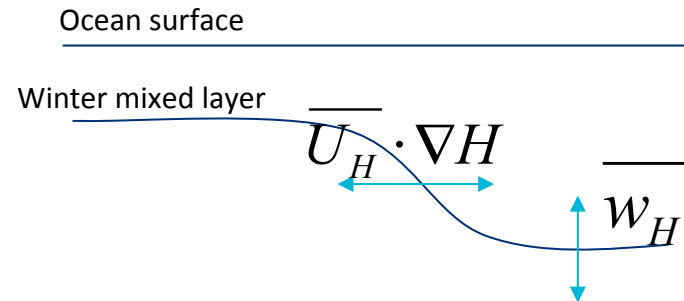
PF

Subduction = transfer through winter mixed layer

Marshall et al. (1993)

$$S = \overline{w_H} + \overline{U_H} \cdot \nabla H$$

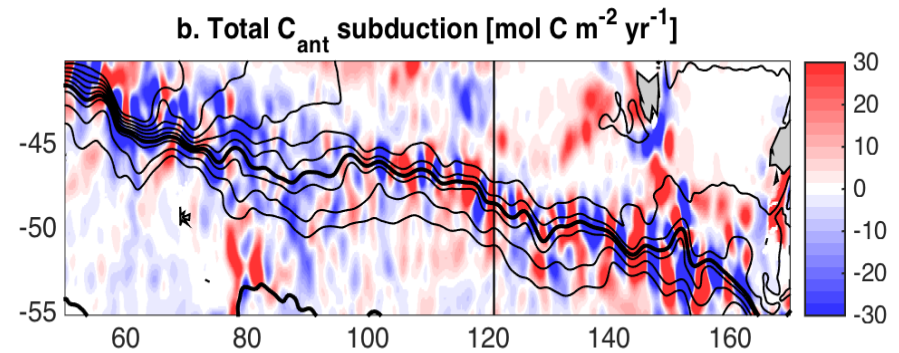
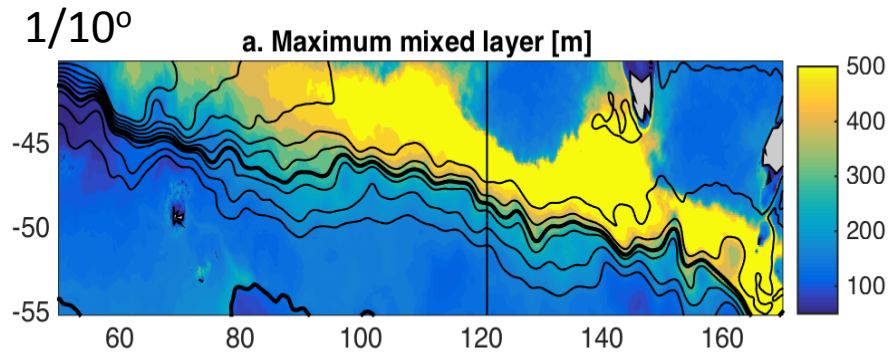
Vertical
advection + Horizontal
advection



Standing meanders

Stationary equivalent barotropic Rossby waves with wavelength of 200 to 500 km

$$L = \frac{2\pi}{\sqrt{\beta/\bar{u}}} \quad \text{Hughes, 1995, 2005}$$

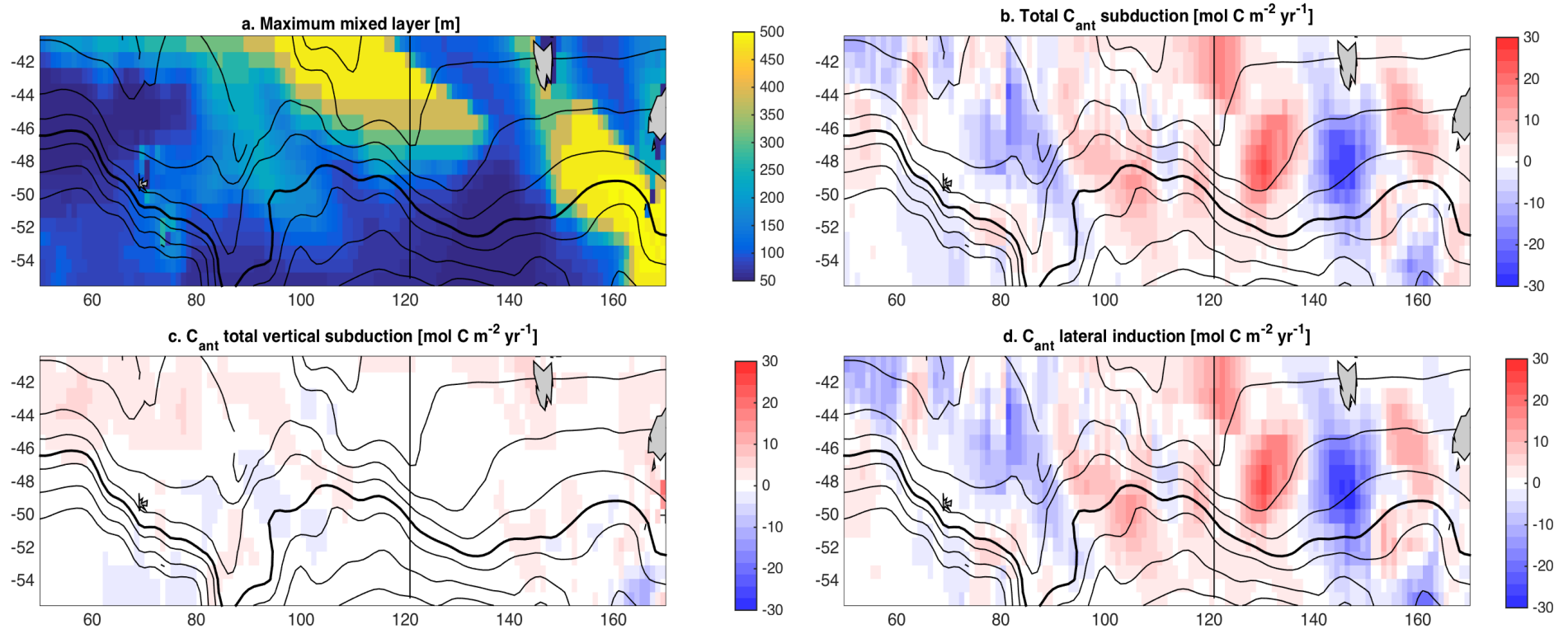


Intermediate and
subantarctic mode
water : 68%

No Standing meanders in 1° model

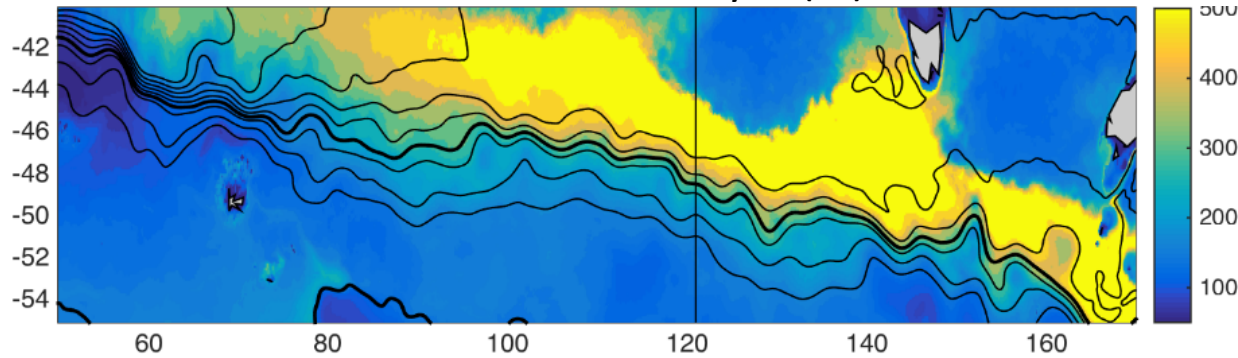
Main contribution from Lateral induction
Eastward end of deep pool of mixed layer

1°



Pathways summary

Winter mixed layer (m)



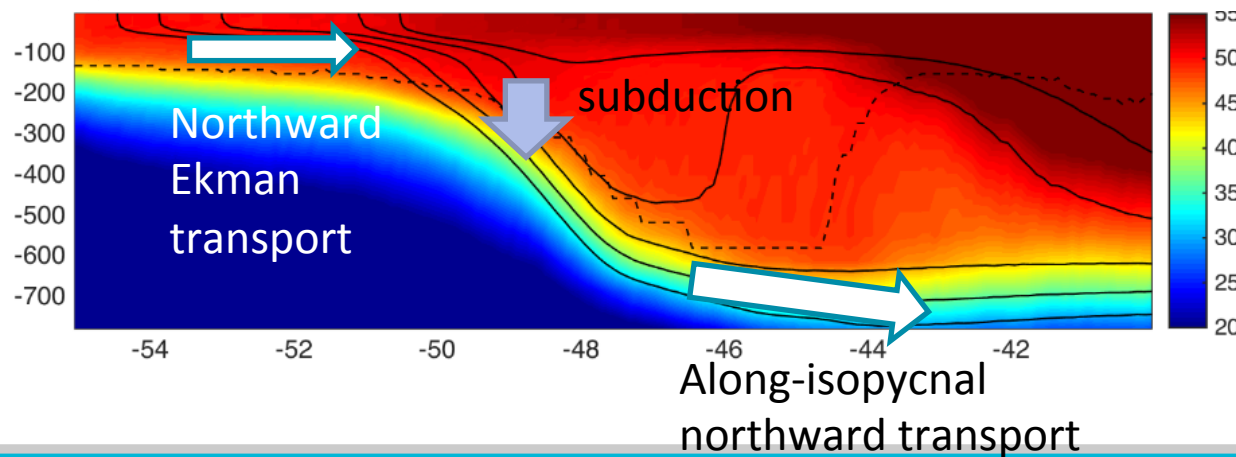
1° versus 1/10°?

Different Physical mechanism involved in subduction



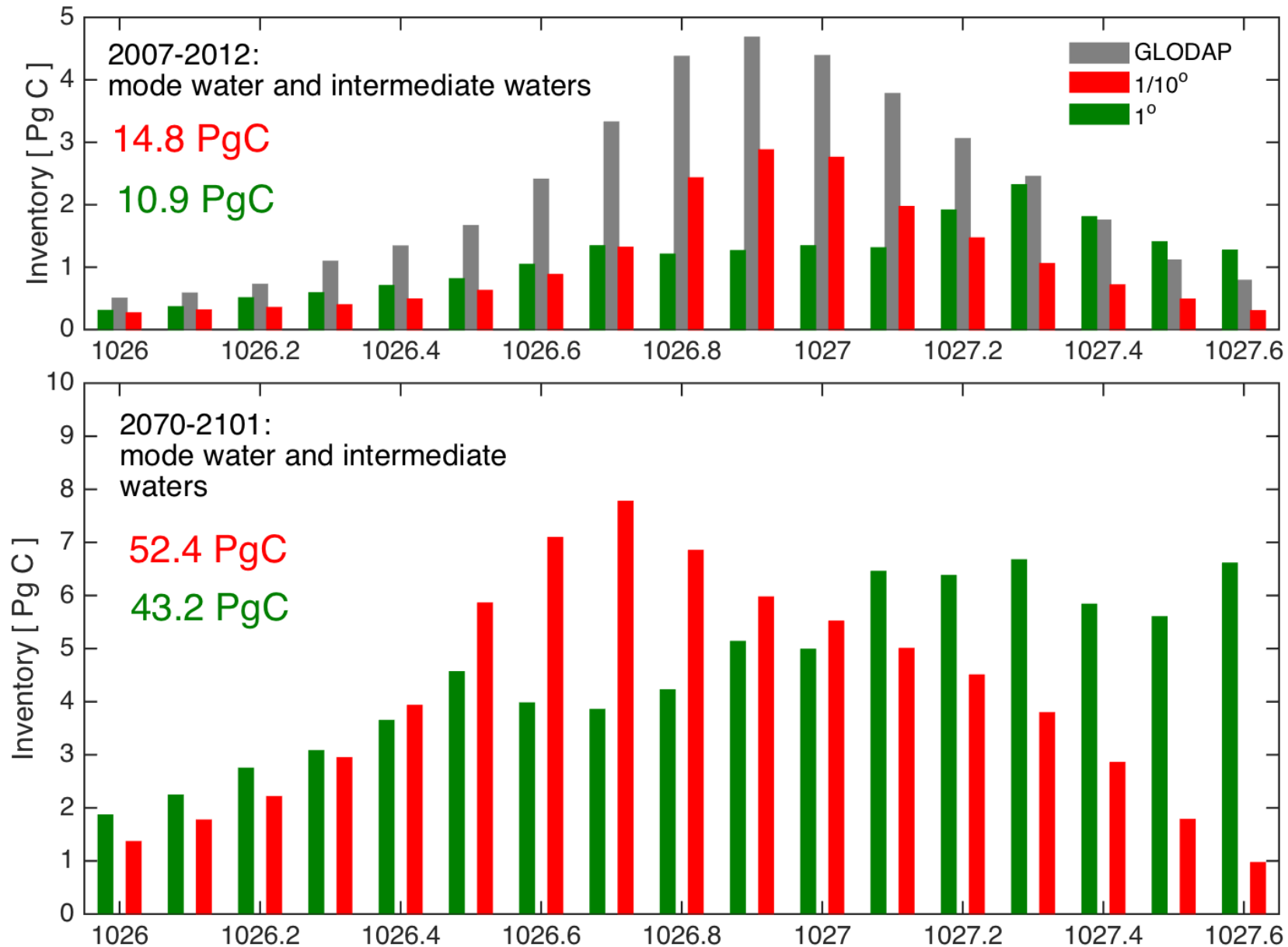
ACO₂ fluxes

C_{ant} at 121°E



Impact on C_{ant} amount in ocean interior

Inventory below the mixed layer 2070-2100



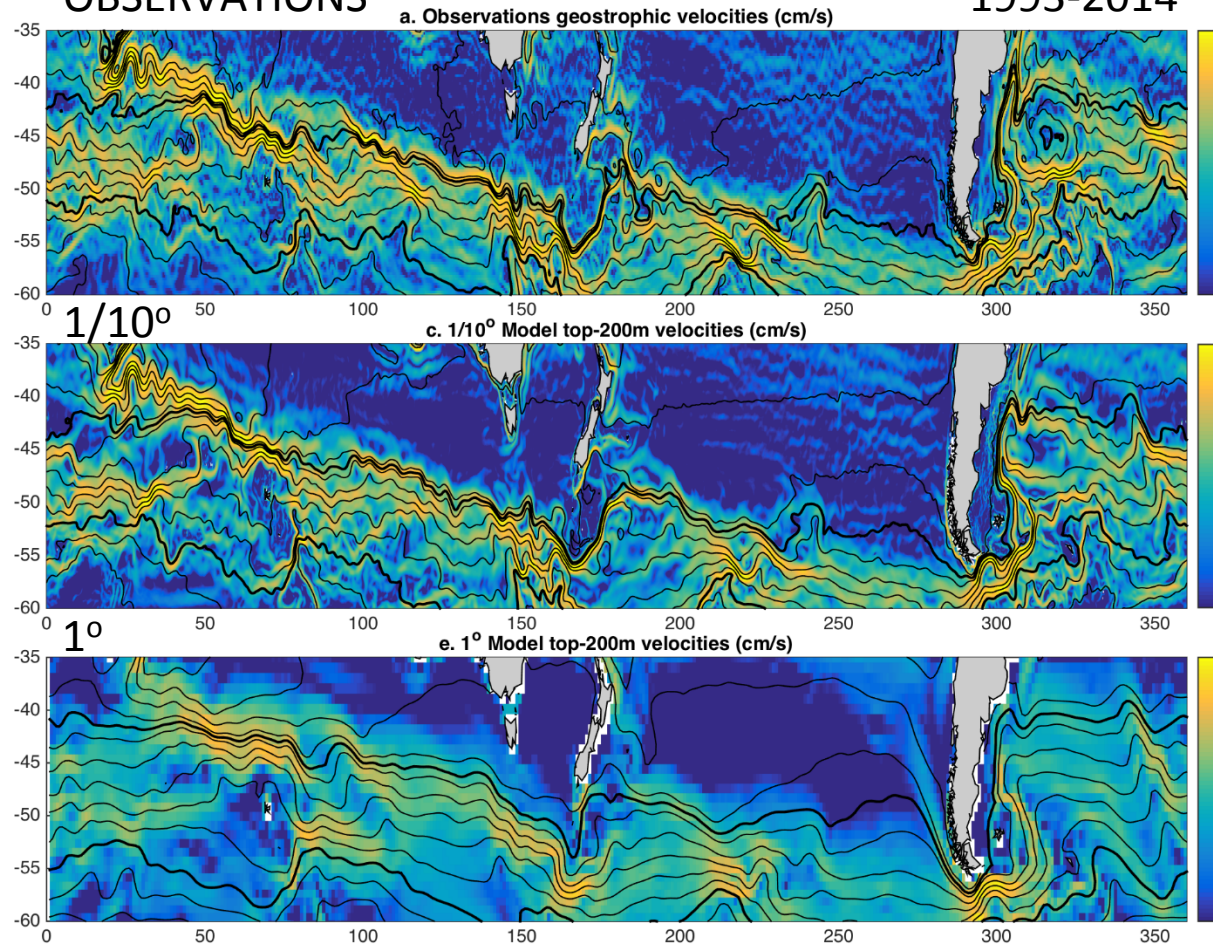
MODELLING SUMMARY – Link with COSIMA

1/10° Ocean Forecasting Australia Model (OFAM3) Zhang et al., 2016

1° ACCESS-O Matear et al.

OBSERVATIONS

1993-2014



- MOM4 ocean model
- 50 z-level
- WOMBAT BGC model
- Ice model in 1°
- **20 yr** Spin-up - 1979
- **1979-2014** historical run :
JRA-55 surface forcing
(bulk formulae)
- **2006-2101** projection run :
JRA-55x3 + CMIP5 trend (rcp8p5)
- **1979-2101** control run

COSIMA

- Ice model – YES!
- Spinup – Marshall
- 1°, 1/10°, 1/30°
- 100 levels – YES! - Matt
- C-grid – YES
- BGC model ?
- Bottom water ?
- Analysis tool ?

Thank you

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Presenter Title

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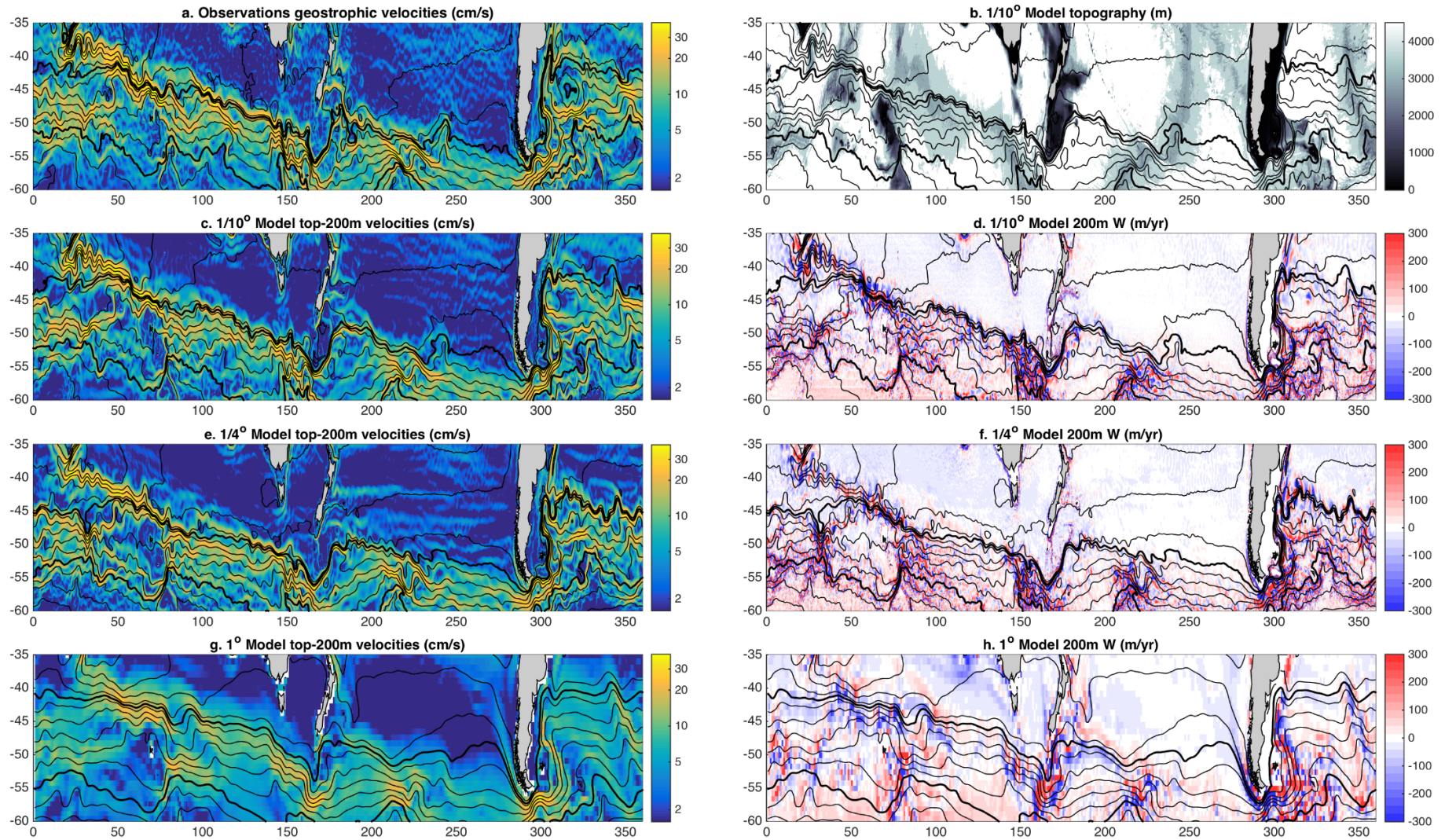


Fig. Supp 1 : **Stationary Rossby waves: location and impact of resolution** . a. AVISO 1993-2014 time-mean geostrophic velocities and SSH contours and b. $1/10^\circ$ model topography. Time-mean model horizontal velocities average over the top 200m and SSH contours (left), and time-mean model vertical velocities at 200m (right), for 3 different resolution: $1/10^\circ$ (c. and d.), $1/4^\circ$ (e. and f.) and 1° (g. and h.). Black contours show SSH contours with SAF and PF in bold.

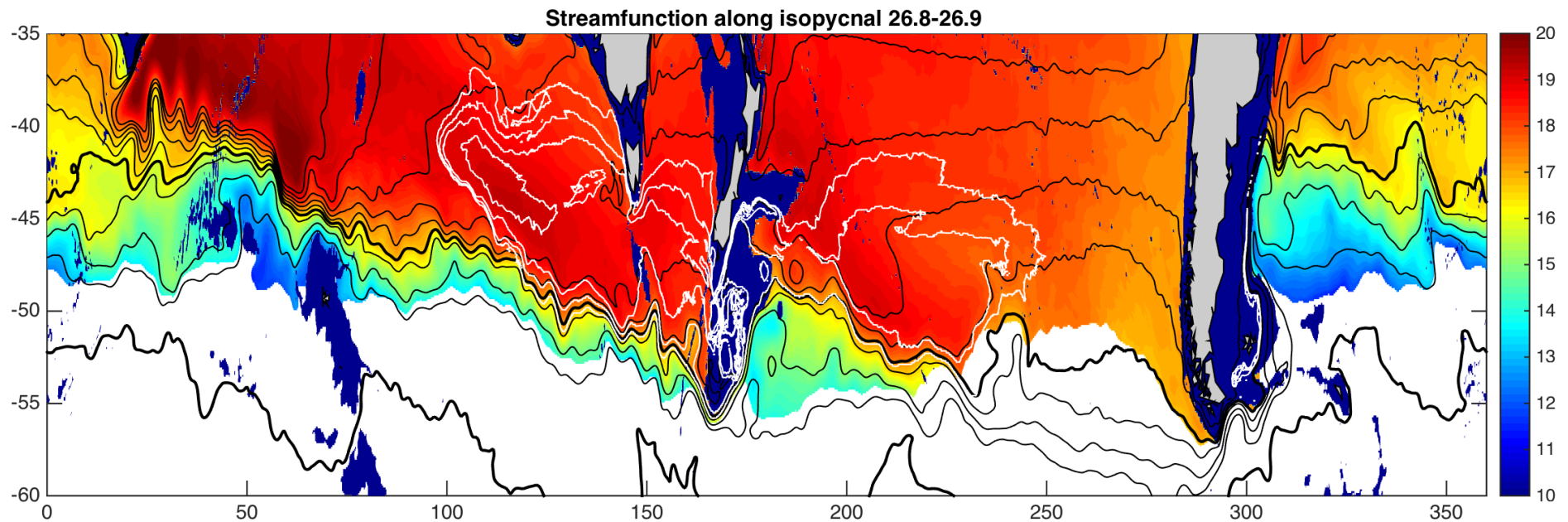
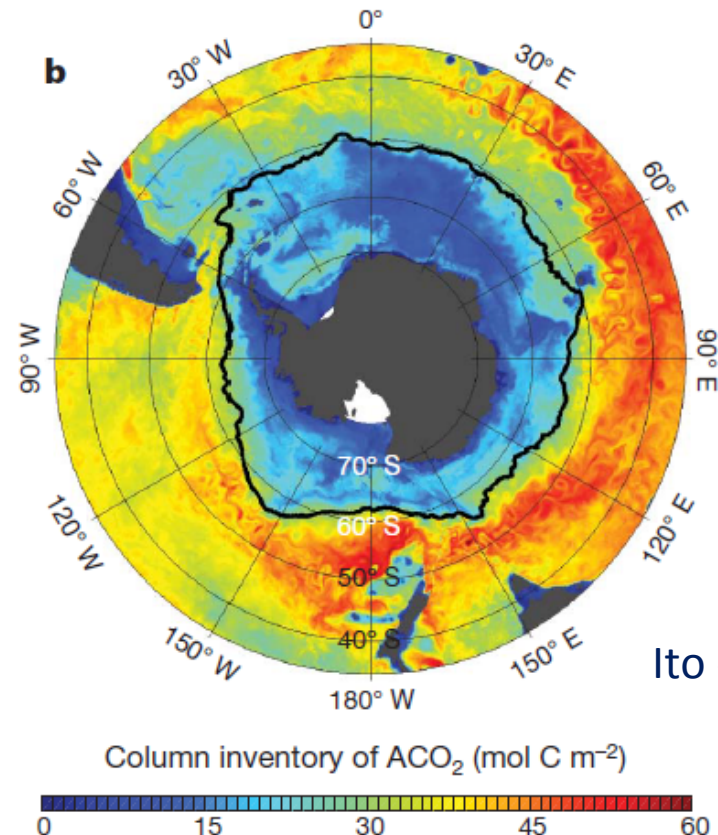
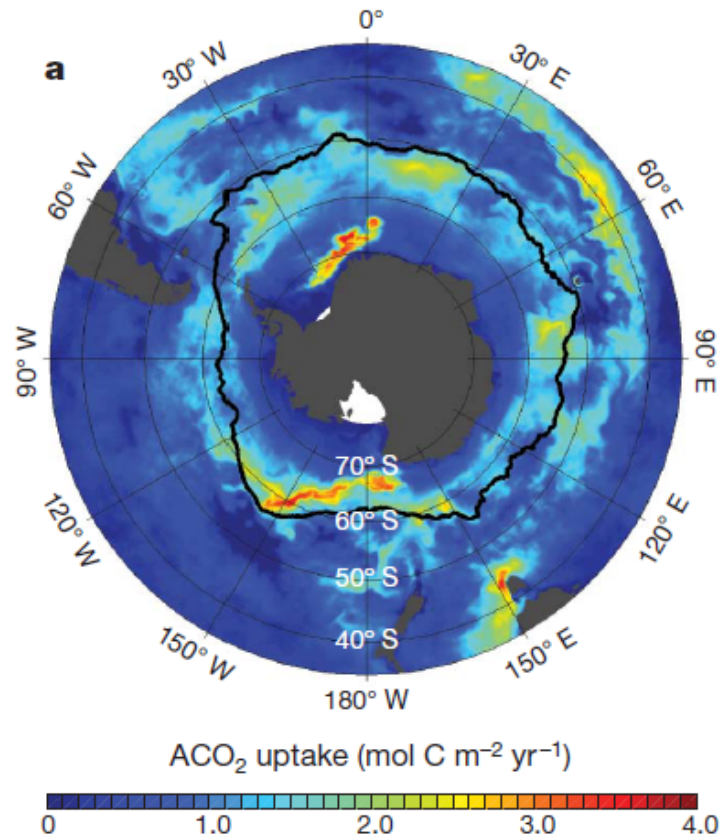


Fig. sup 7.: **Circulation and Cant inventory along isopycnals 26.8-26.9**: approximate isopycnal geostrophic streamfunction ($\text{m}^2.\text{s}^{-2}$) (colors) referenced to 2000m as defined by McDougall and Klocker (2010) and inventory of Cant along the selected isopycnals (White contours from 15 to 30 mol C m^{-2} every 5 mol C m^{-2}). Black lines are SSH contours with SAF and PF in bold. Blue patches show areas shallower than 2000m.

Anthropogenic Carbon (C_{ant}) in Southern Ocean

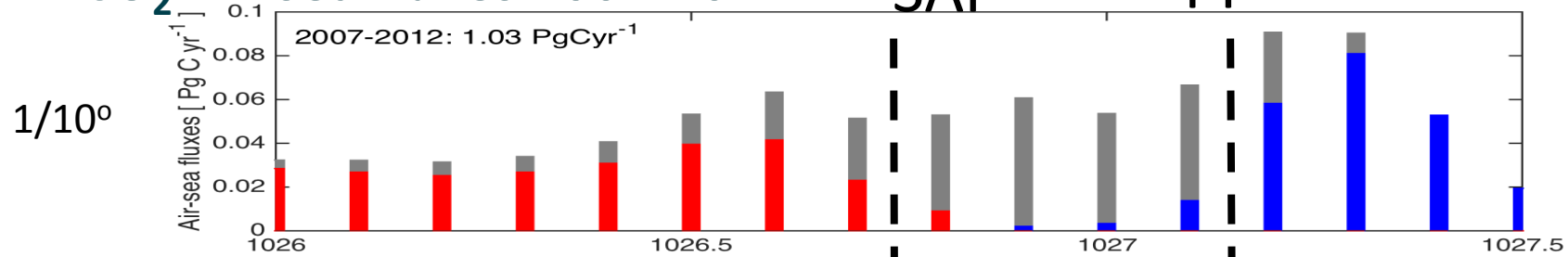
Southern Ocean contributes to 30% of sink of anthropogenic carbon dioxide

Inventory of 25 ± 5 Pg C in Southern Hemisphere

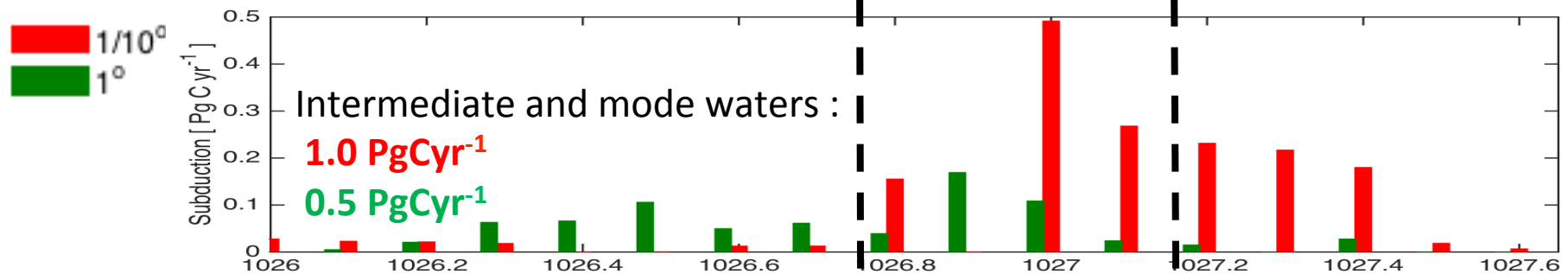


Ito et al. 2010

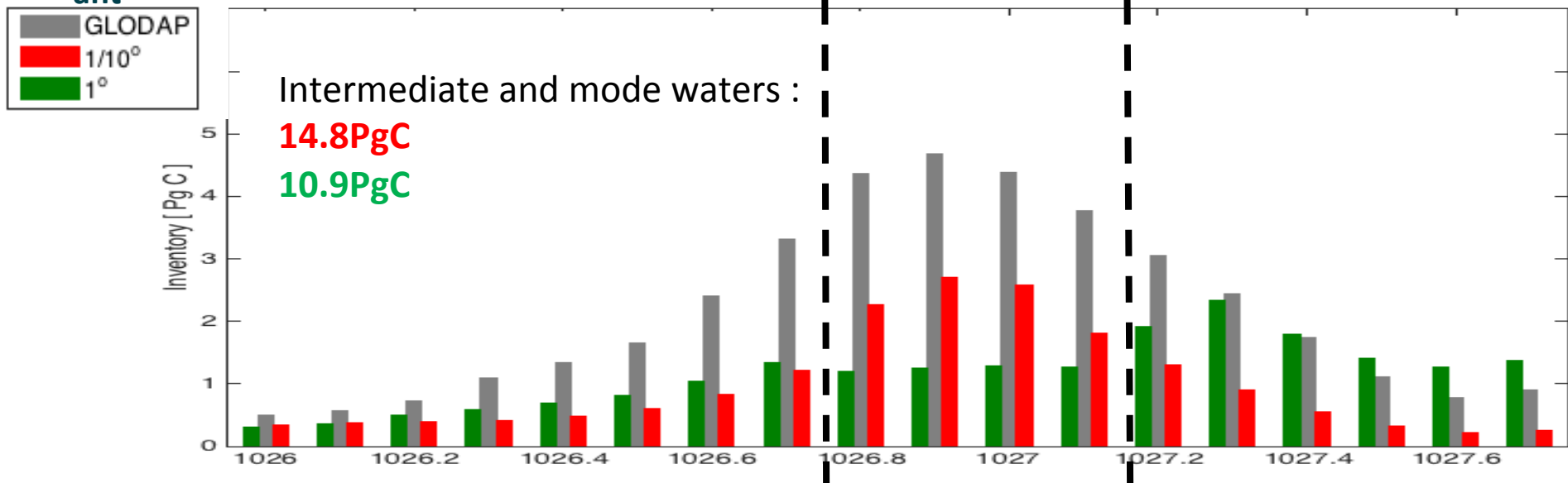
ACO₂ Air-sea fluxes 2007-2012



C_{ant} Subduction = transfer through winter mixed layer 2007-2012

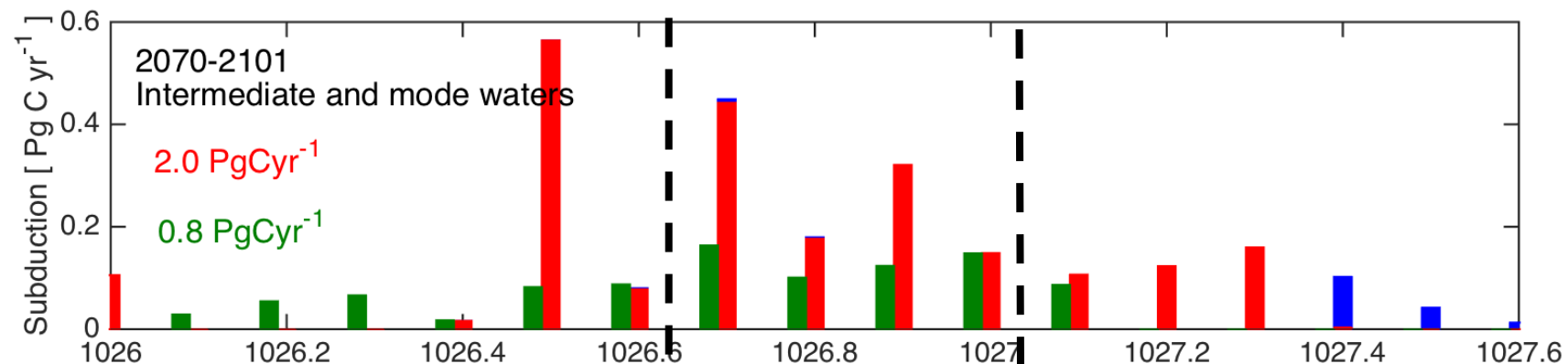
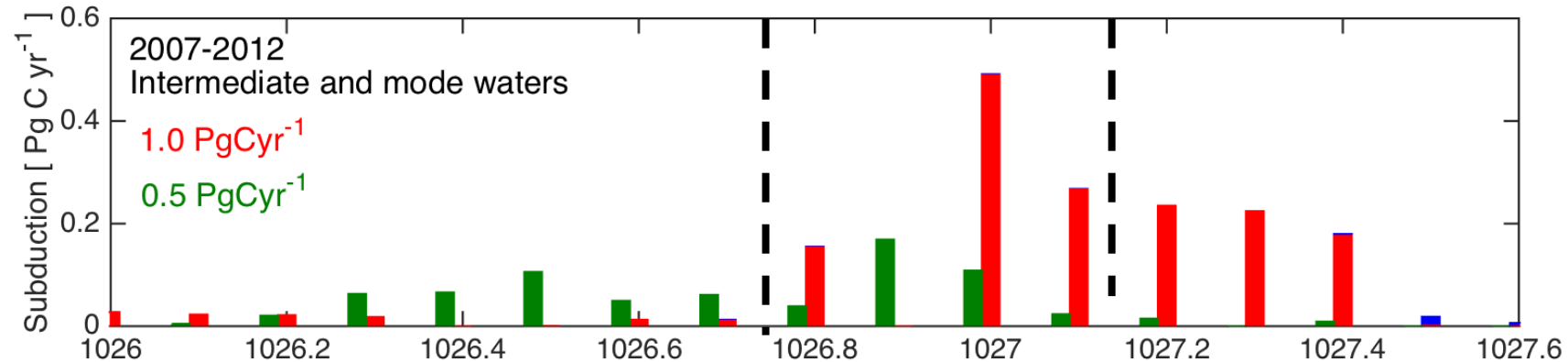


C_{ant} Inventory below the mixed layer from 30°S to PF 2007-2012



Subduction = transfer through winter mixed layer 2070-2100

1/10⁰
1⁰



1/10⁰ :

- +100%
- Shift in subducted density classes: +0.3kg/m³

SAF

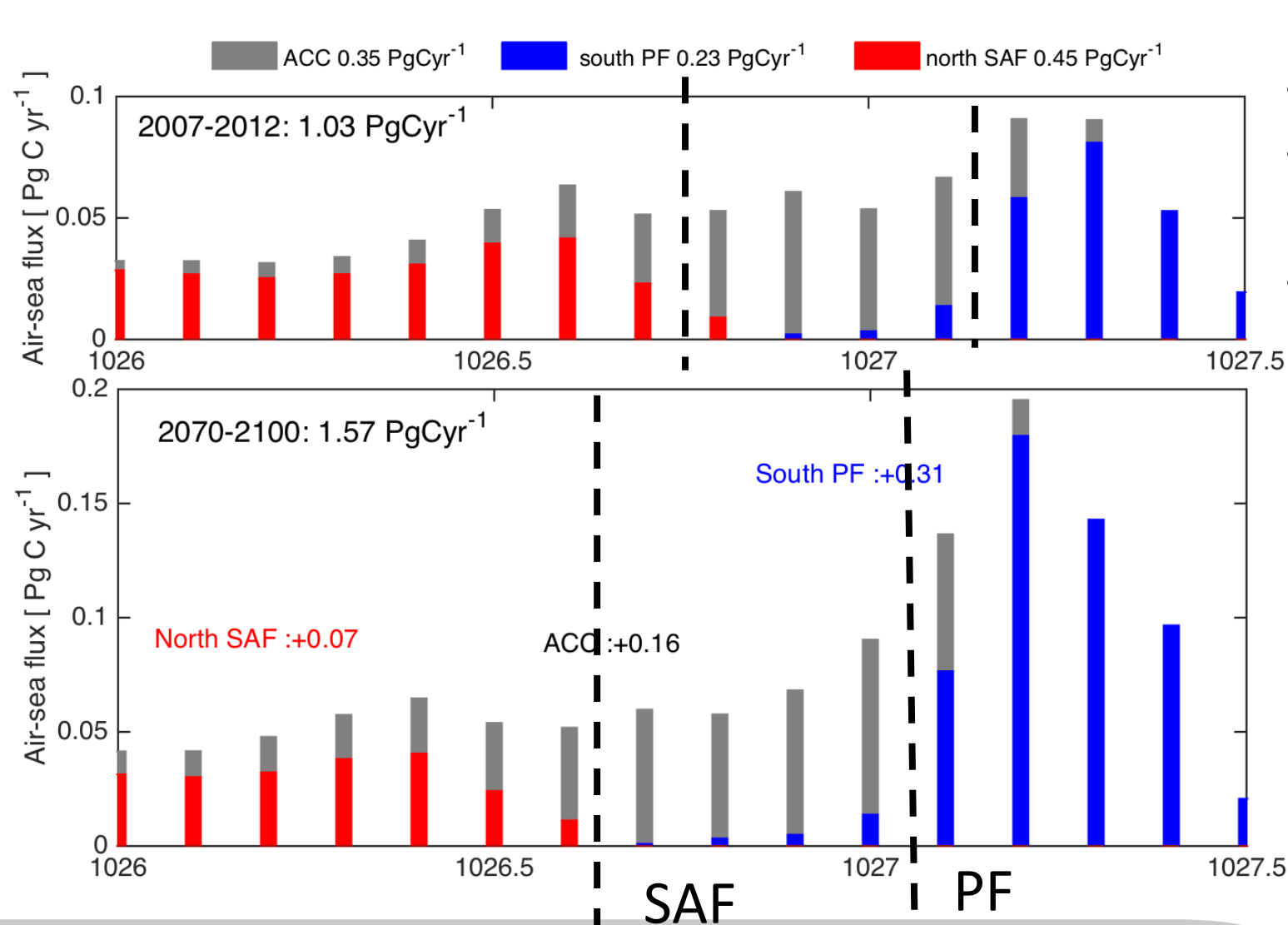
PF

1⁰ :

- +60%
- Shift in subducted density classes?



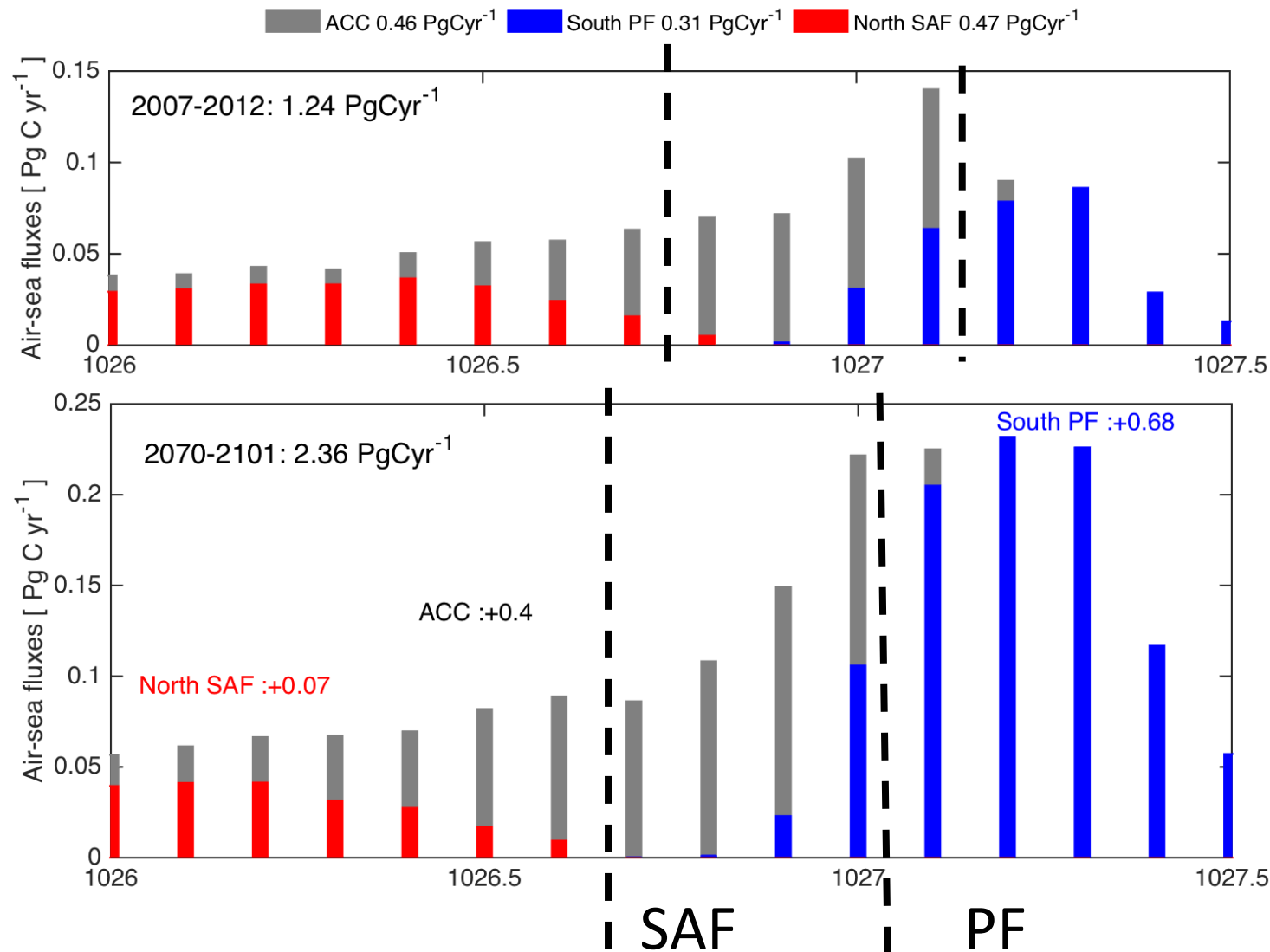
ACO₂ air-sea fluxes 2070-2101



1/10⁰ :

- +50%
- Mainly south of PI
- +0.1kg/m³

Air-sea CO₂ fluxes 2070-2101



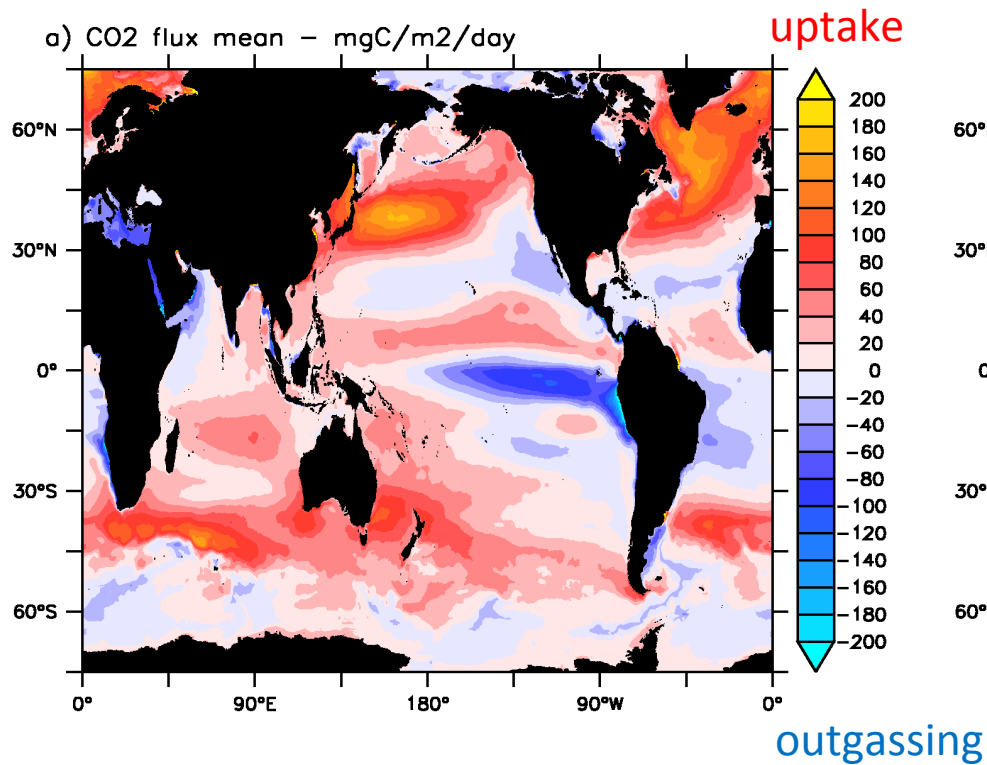
1/10° :

- +50%
- Mainly south of PF
- Warming: +0.1kg/m³

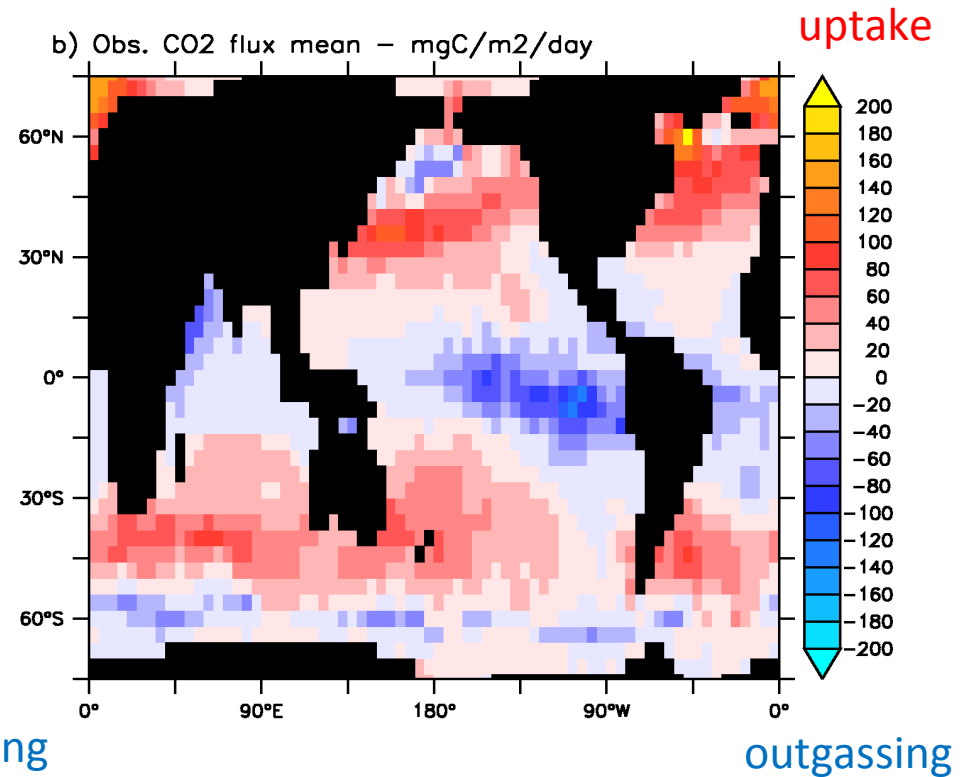
1° :

- +90%
- Mainly south of PF
- Warming: +0.1kg/m³

Air-sea CO₂ fluxes

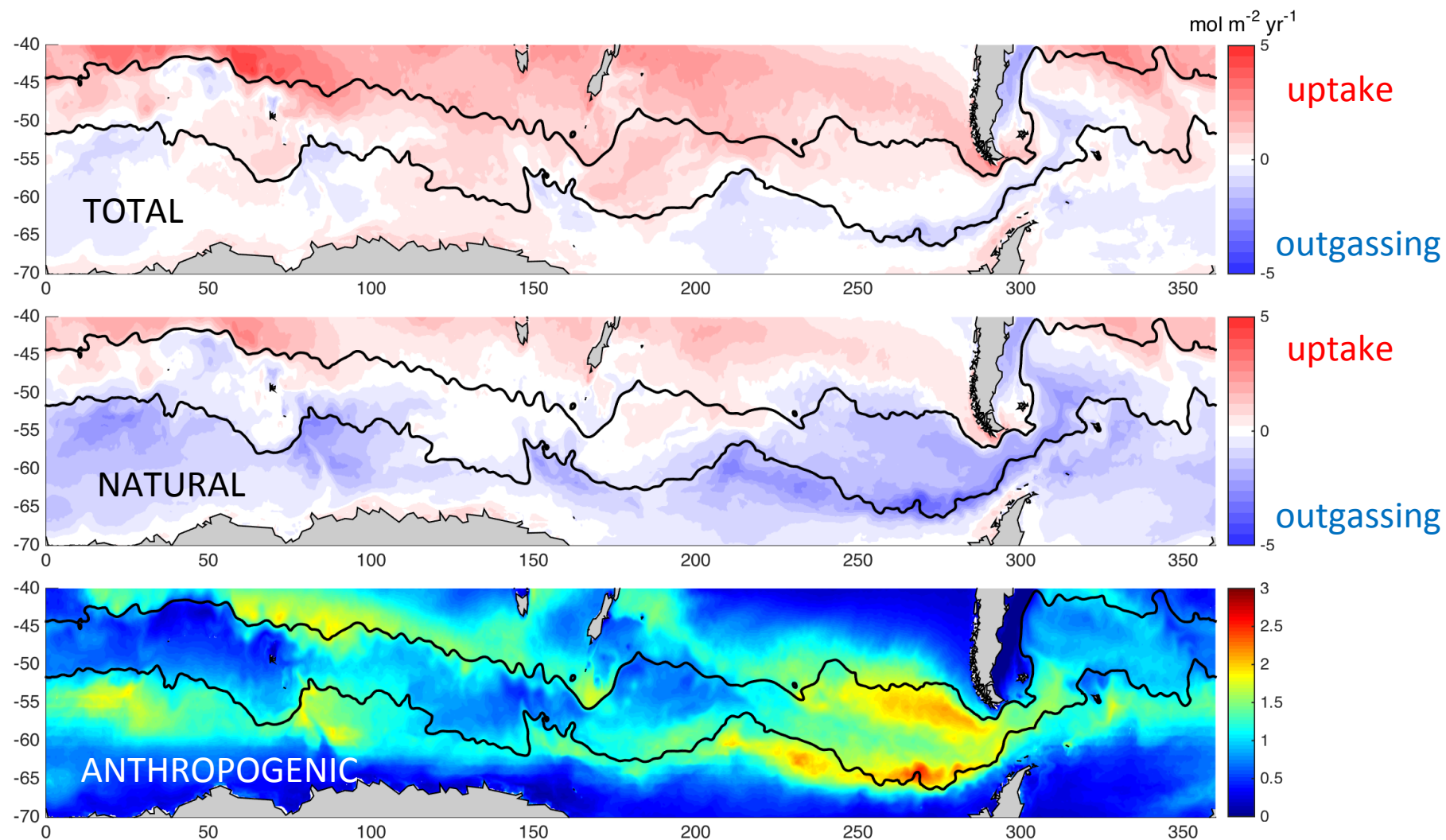


Historical
OFAM3 JRA55

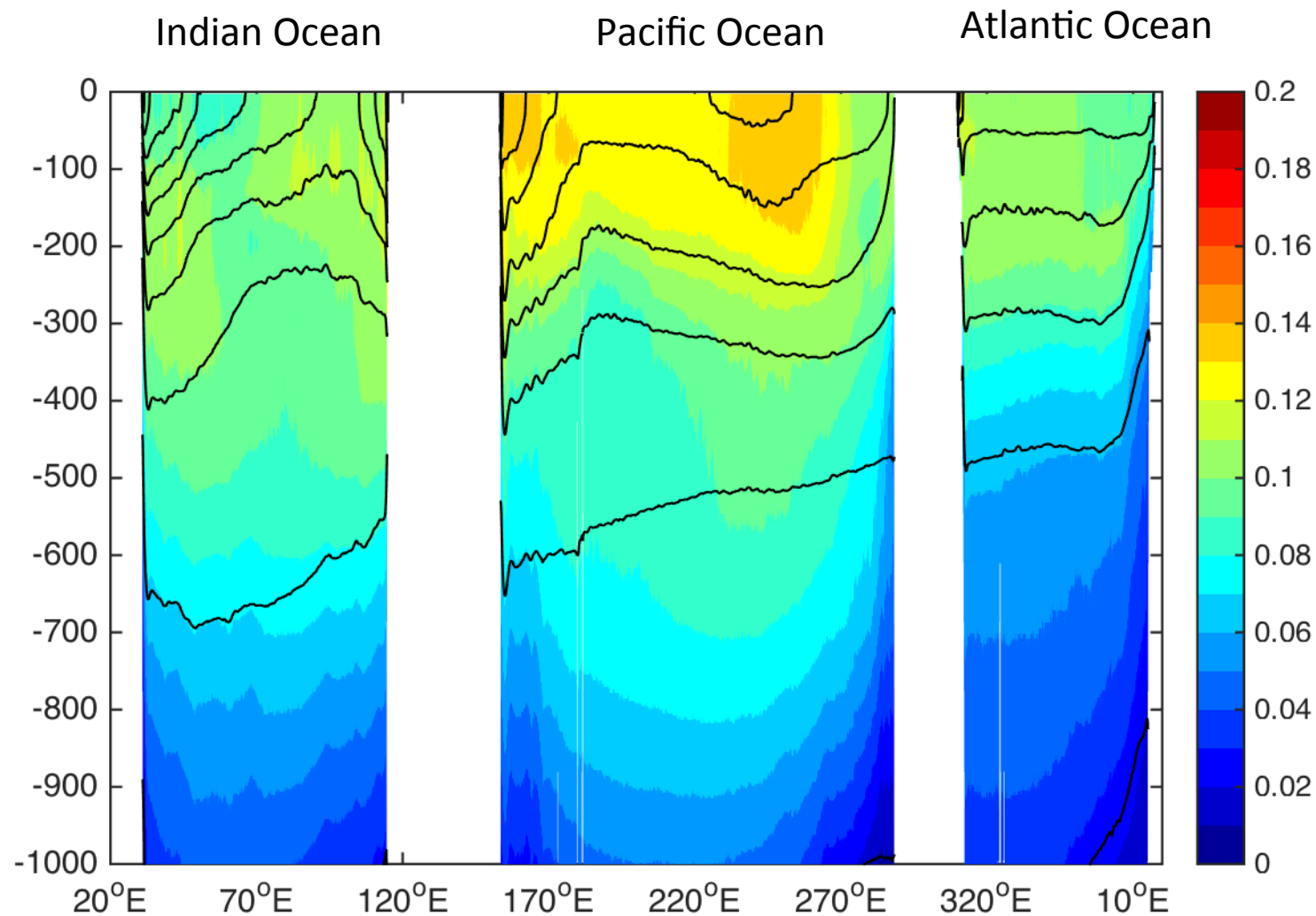


Observations
Takahashi et al., 2009
nominal year 2000

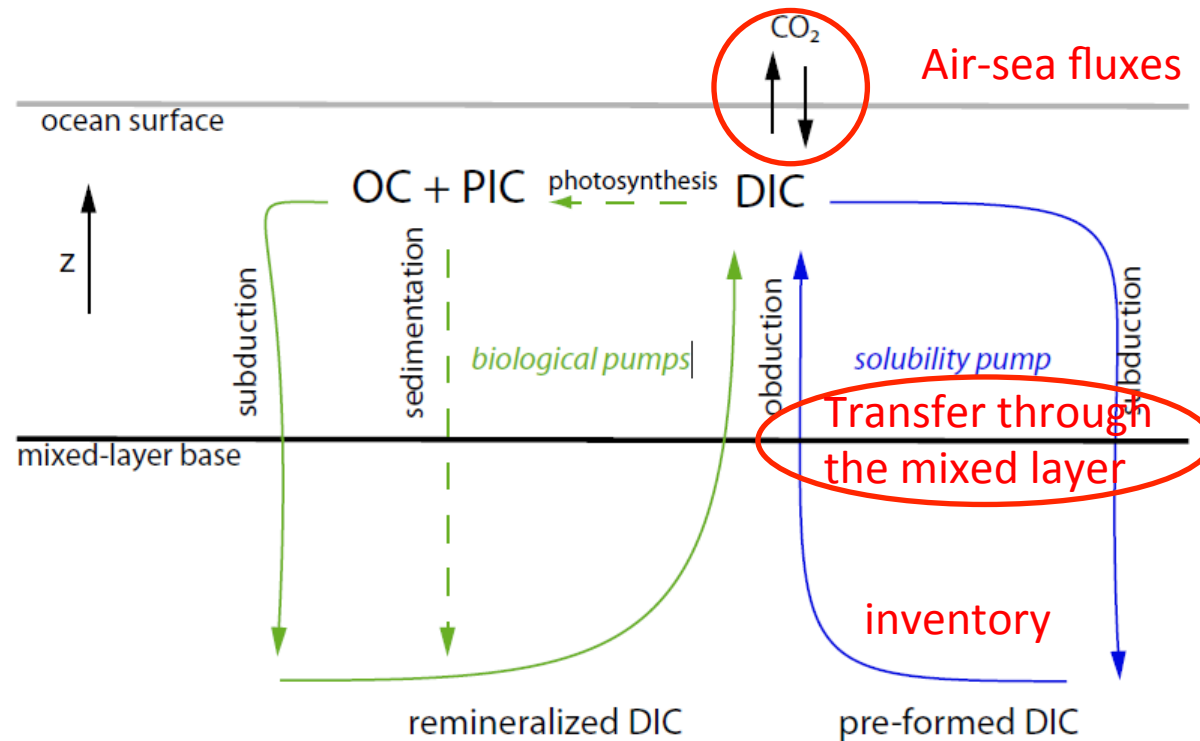
Air-sea CO₂ fluxes 2007-2012



Anomaly of Total C at 30°S (2090-2100)-(2010-2020)



Physical pump



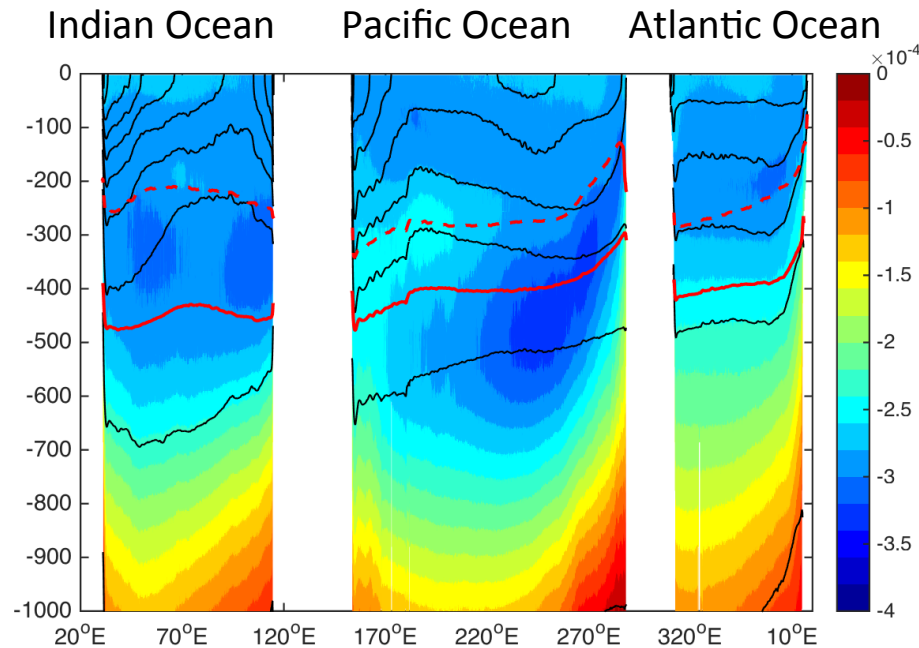
Importance of
ocean circulation on
 C_{ant}

Impact of ocean
model resolution
 $1/10^\circ$ versus 1°

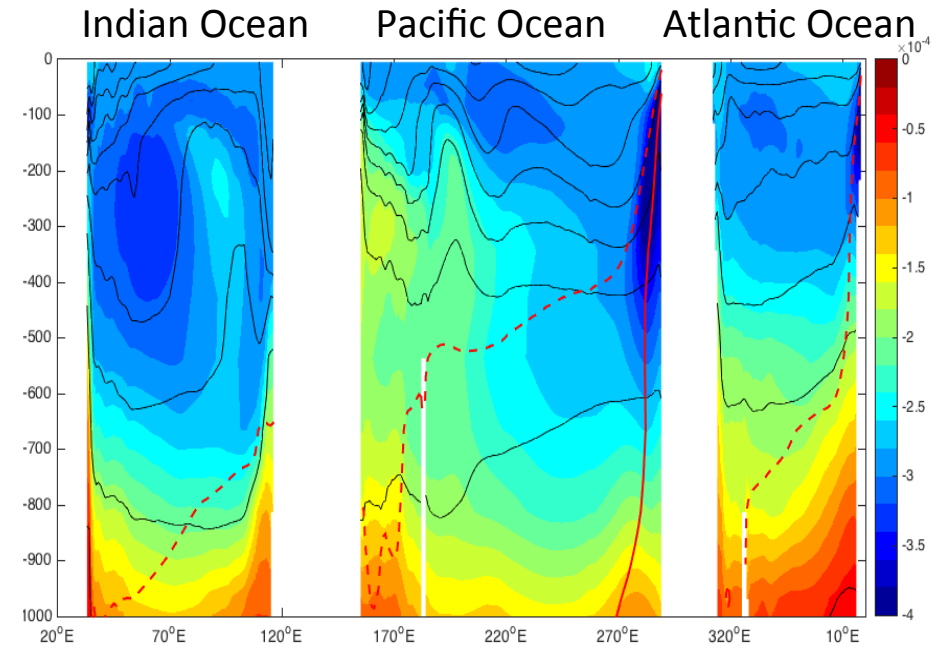
Levy et al., 2013

Anomaly of pH and Ω_a undersaturation depth at 30°S (2090-2100)-(2010-2020)

1/10°



1°



— 2010-2020
- - - 2090-2100