Evidence of Jet-Scale Overturning Ocean Circulations in Argo Float Trajectories

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in collaboration with:

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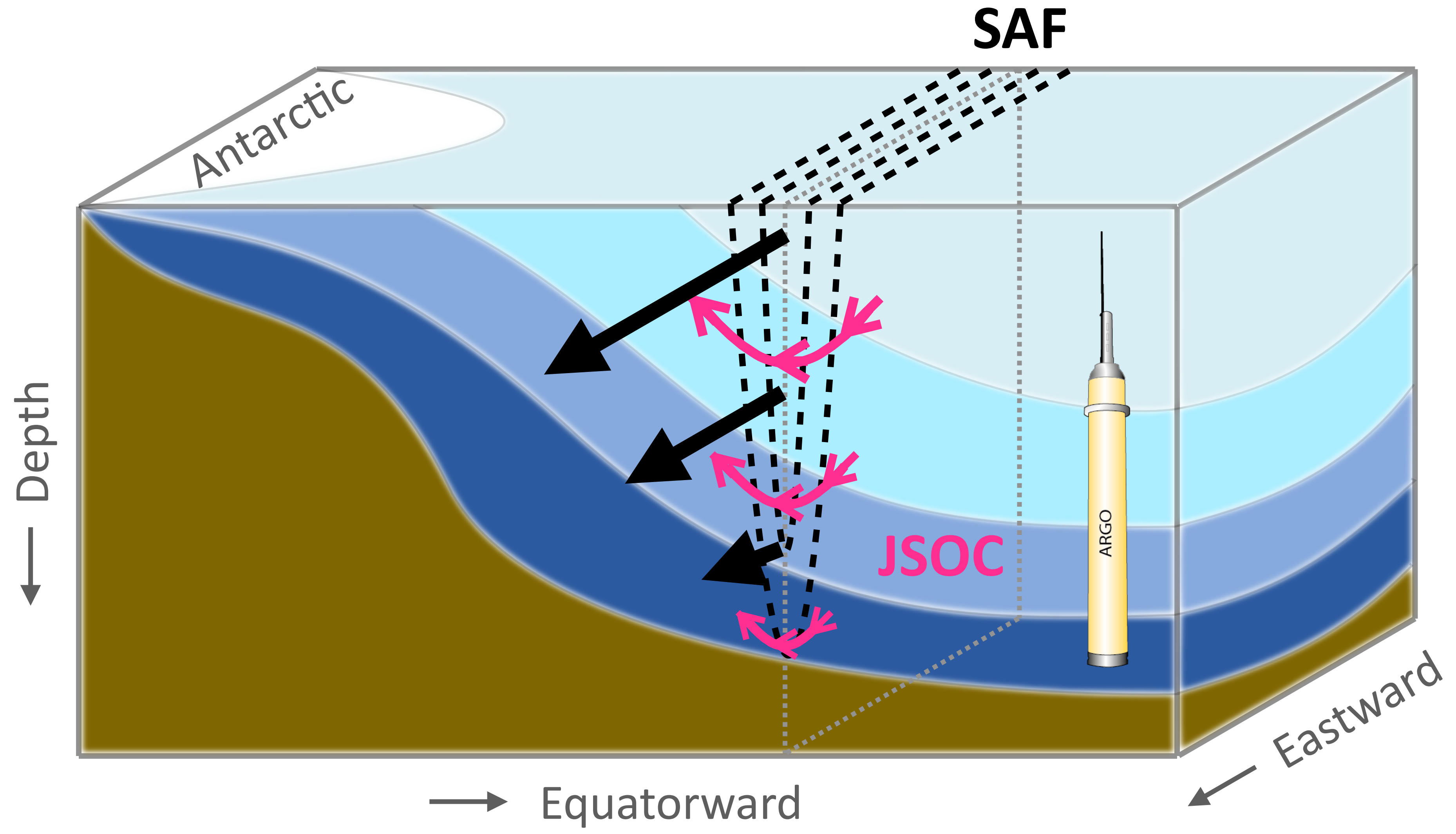


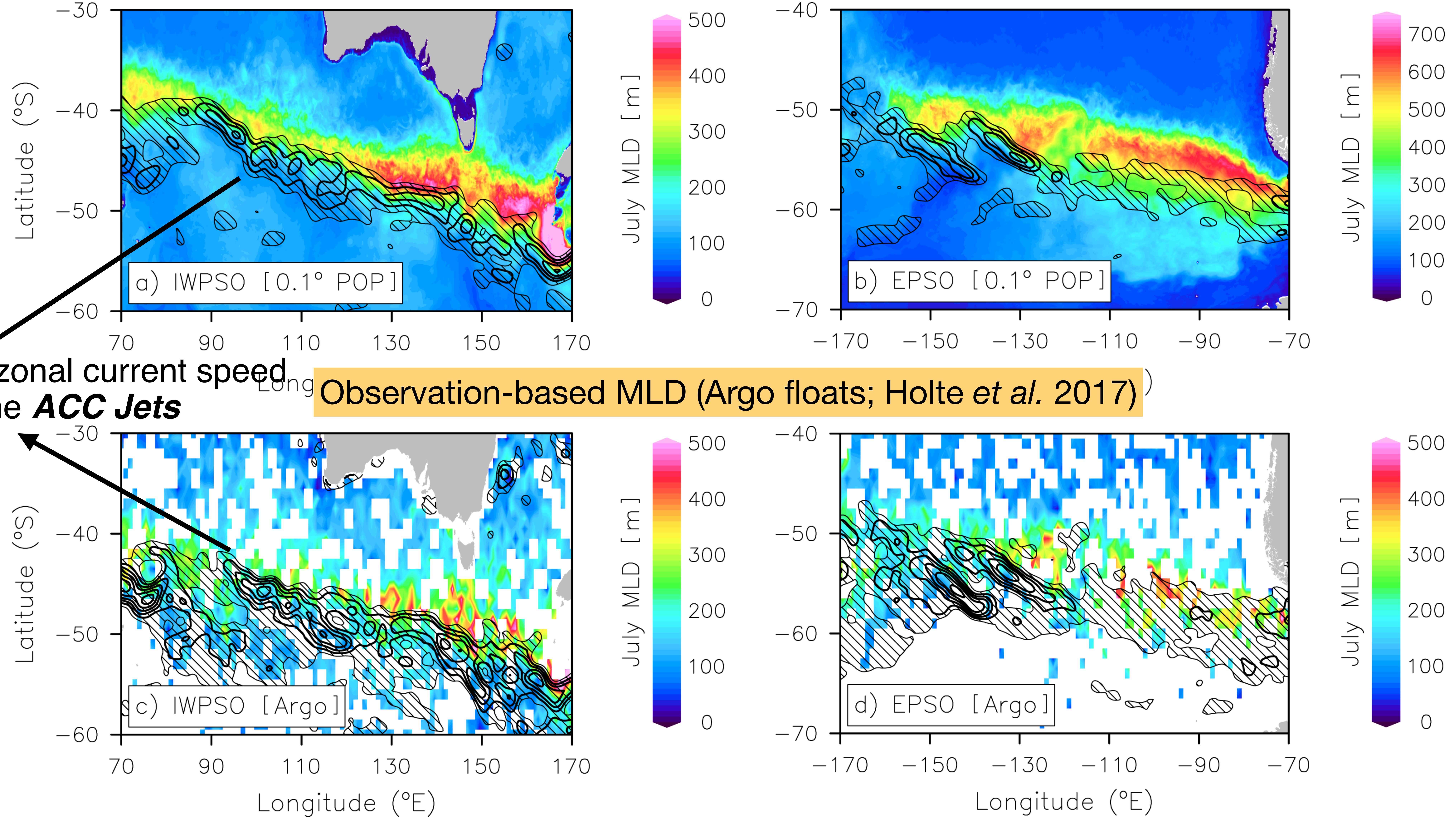
Sources and Sinks Ocean Mesoscale Eddy Energy Workshop, Tallahassee

March 12, 2019

Filamented Southern Ocean MLD (color) at the early stage of austral winter (July)

The deepest MLDs are located just on the equatorward flank of the ACC jets.

Indo-western Pacific SO | Model-simulated MLD (0.1°-resolution POP) | **Eastern Pacific SO**



Contours: zonal current speed indicating the ***ACC Jets***

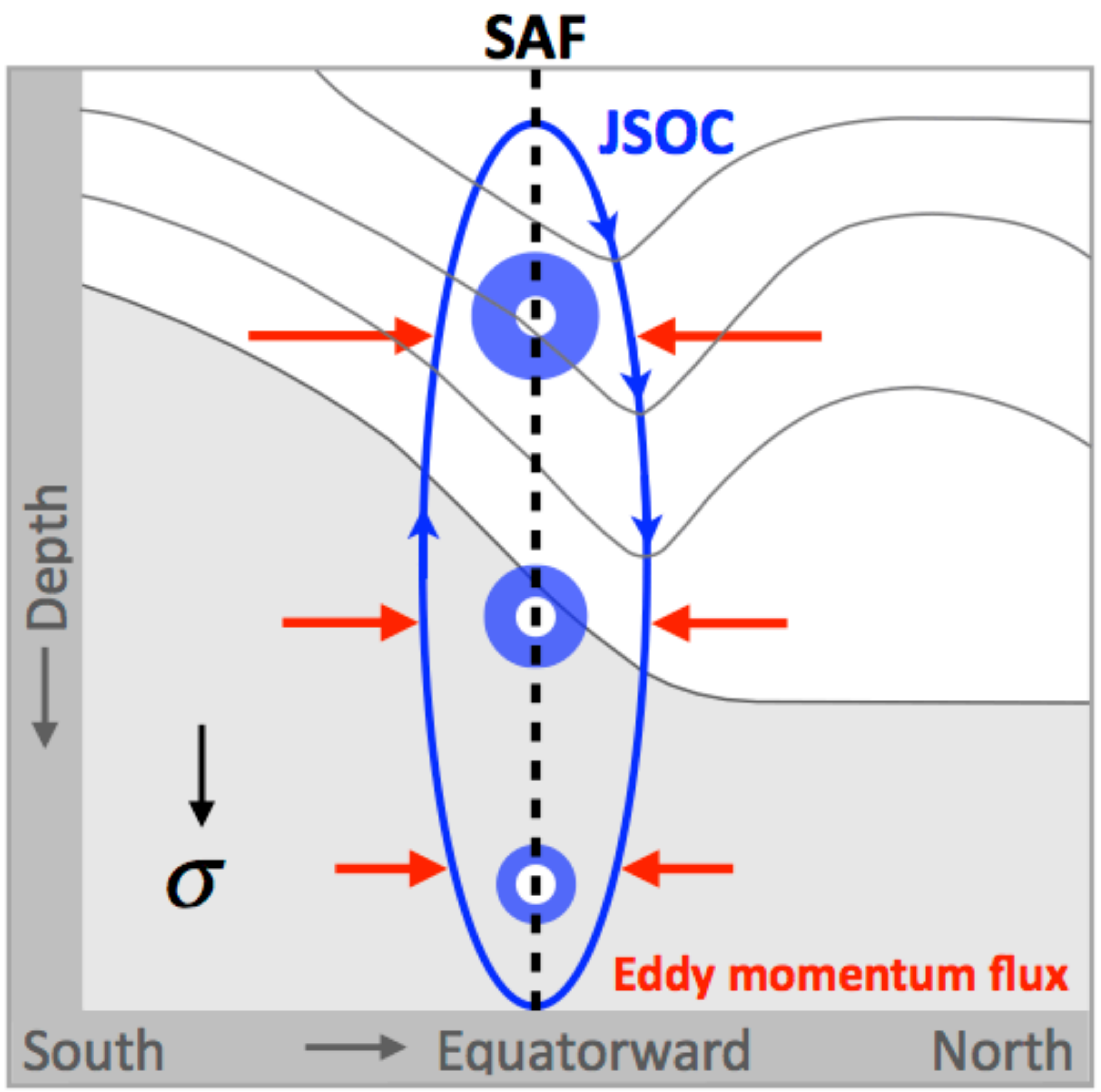
Observation-based MLD (Argo floats; Holte *et al.* 2017)

Background about Jet-Scale Overturning Ocean Circulation (JSOC):

The JSOC is responsible for the formation of the deep mixed layers.

Mechanisms for the winter mixed layer formation in the SO:

- ***Air-sea buoyancy loss*** *(Sallée et al. 2006; Dong et al. 2008; Hogg 2010)*
- ***Ekman advection of buoyancy*** *(Rintoul and England 2002)*
- ***Mesoscale eddy buoyancy transport*** *(Sallée et al. 2010)*
- ***Langmuir turbulence associated with the Stokes drift*** *(Belcher et al. 2012)*



[Li & Lee 2017, *JPO*]

At the early stage of austral winter

On the equatorward flank of the jet:

↓

JSOC brings down light water

↓

destratifies the water column

↓

deepens the MLD

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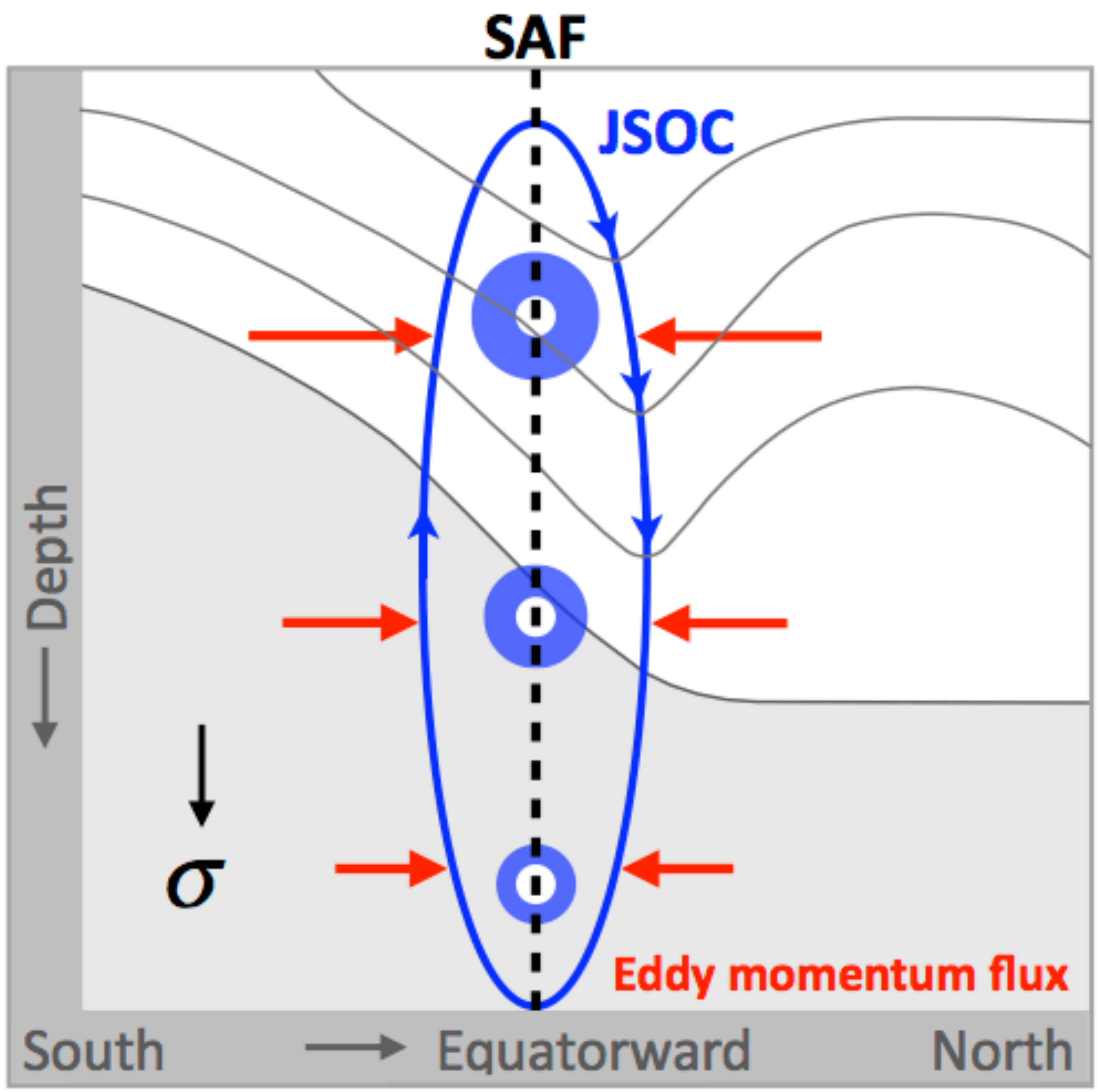

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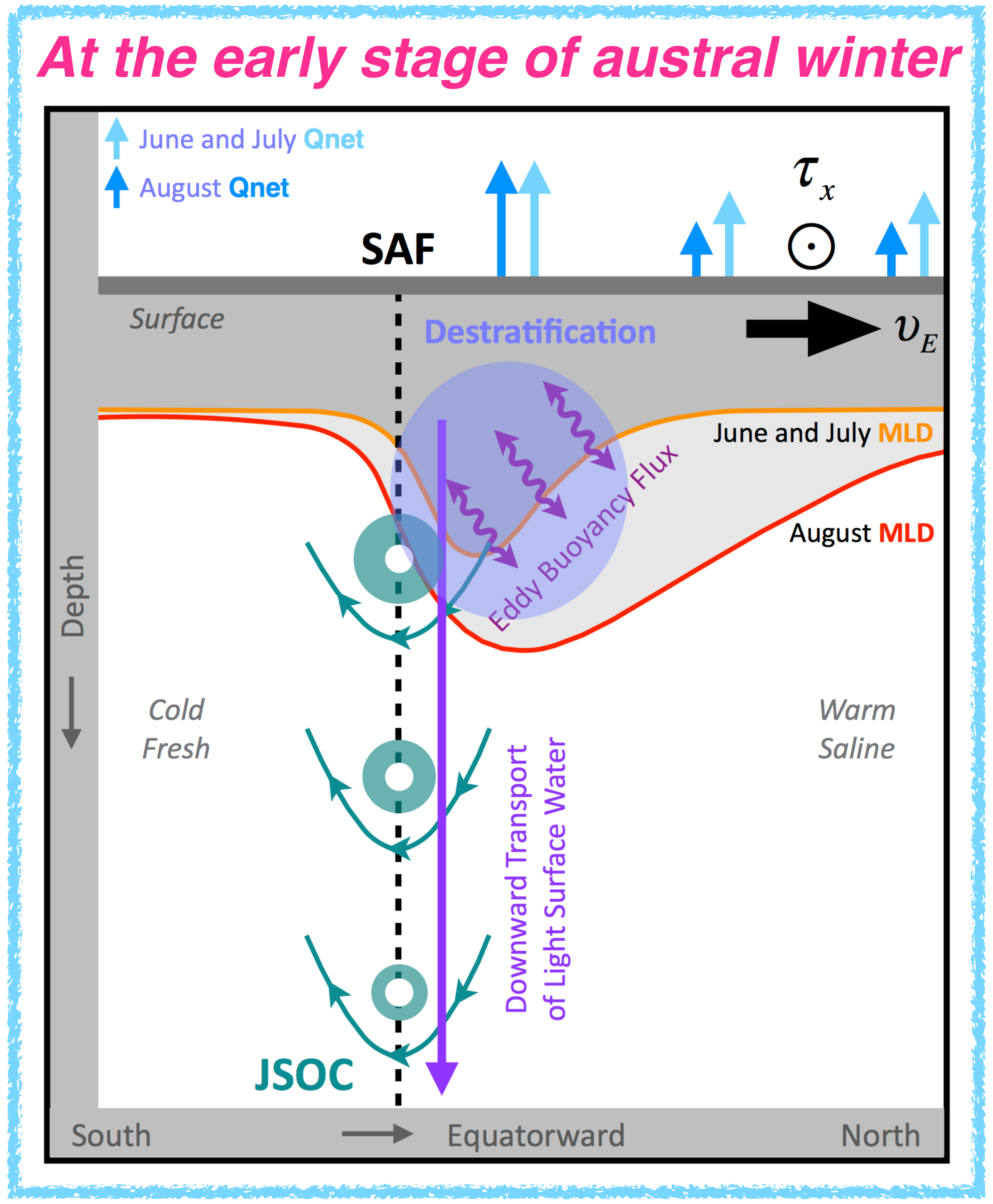
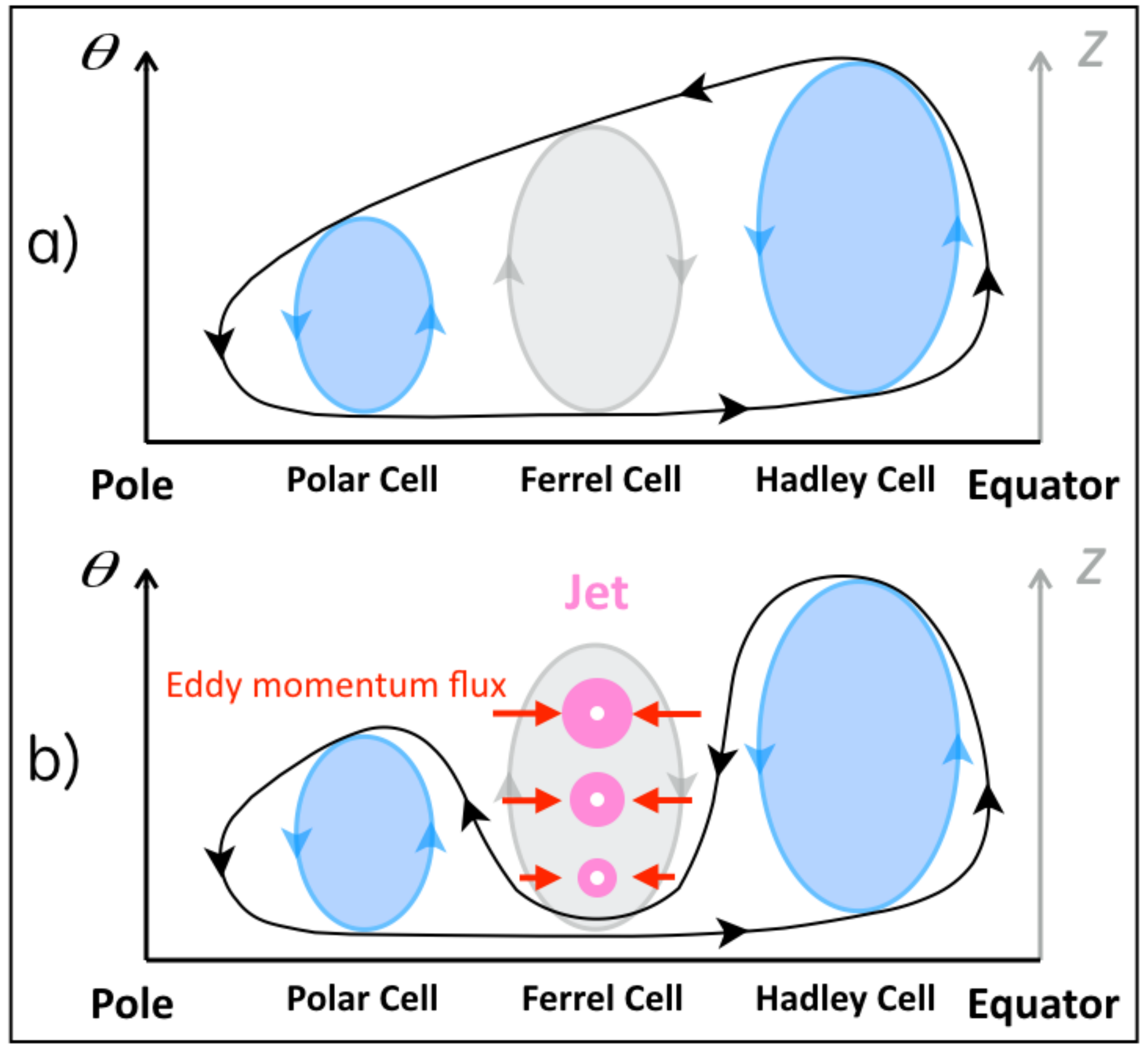


Eddy momentum flux can drive multiple jets and JSOCs

JSOC is strong enough to show in the transformed Eulerian mean (TEM) circulation

- **Example from the atmosphere:**



Residual-mean meridional circulation:

$$[v^\dagger] = [v] - \frac{\partial}{\partial z}\left[\frac{1}{N^2}v^* b^*\right]$$

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QG zonal momentum and buoyancy equations:

$$\frac{\partial [u]}{\partial t} = f_0[v^\dagger] - \frac{\partial}{\partial y}[u^* v^*] + \frac{\partial}{\partial z}\left[\frac{f_0}{N^2}v^* b^*\right] + [F]$$

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Thermal wind balance

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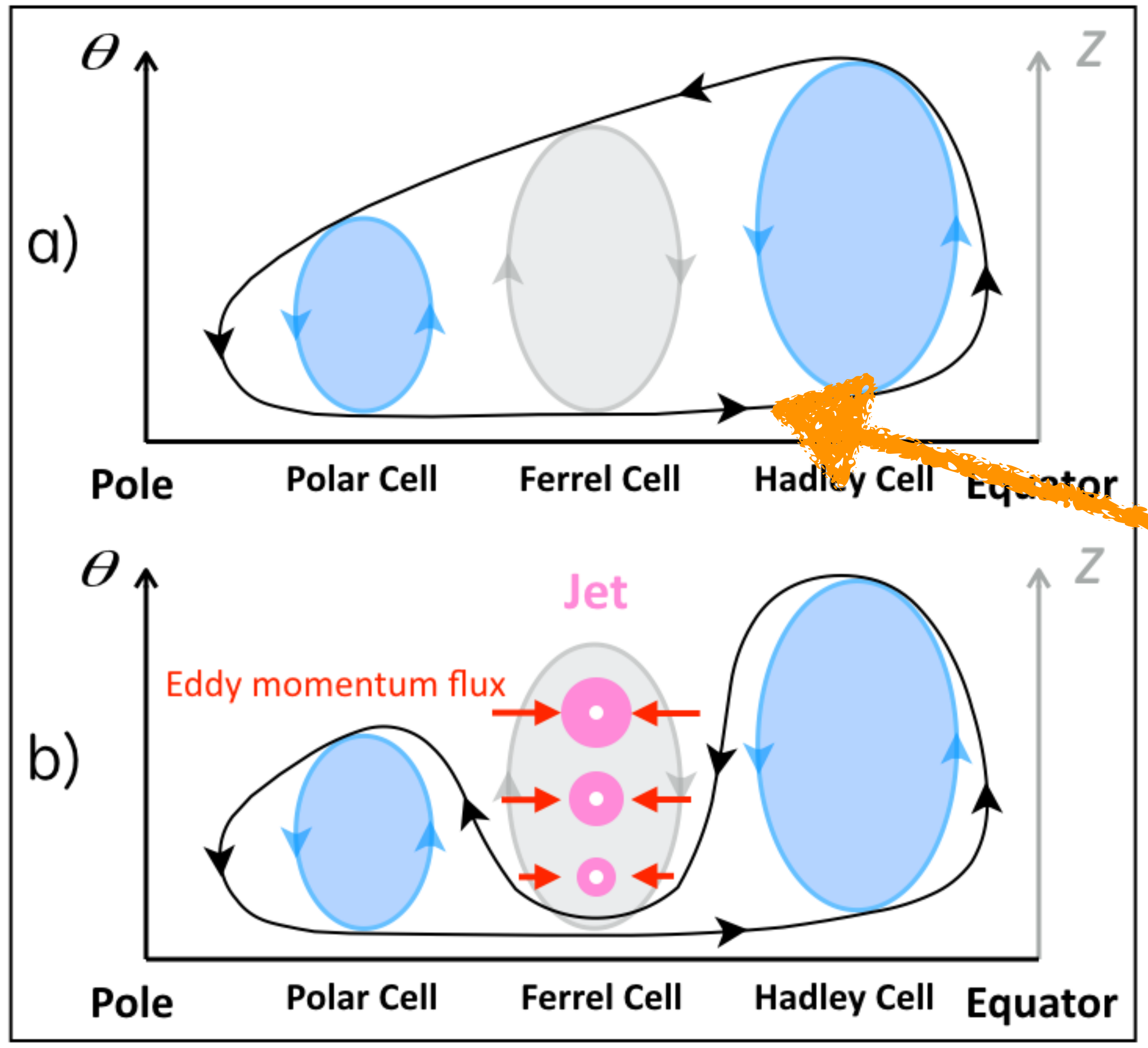

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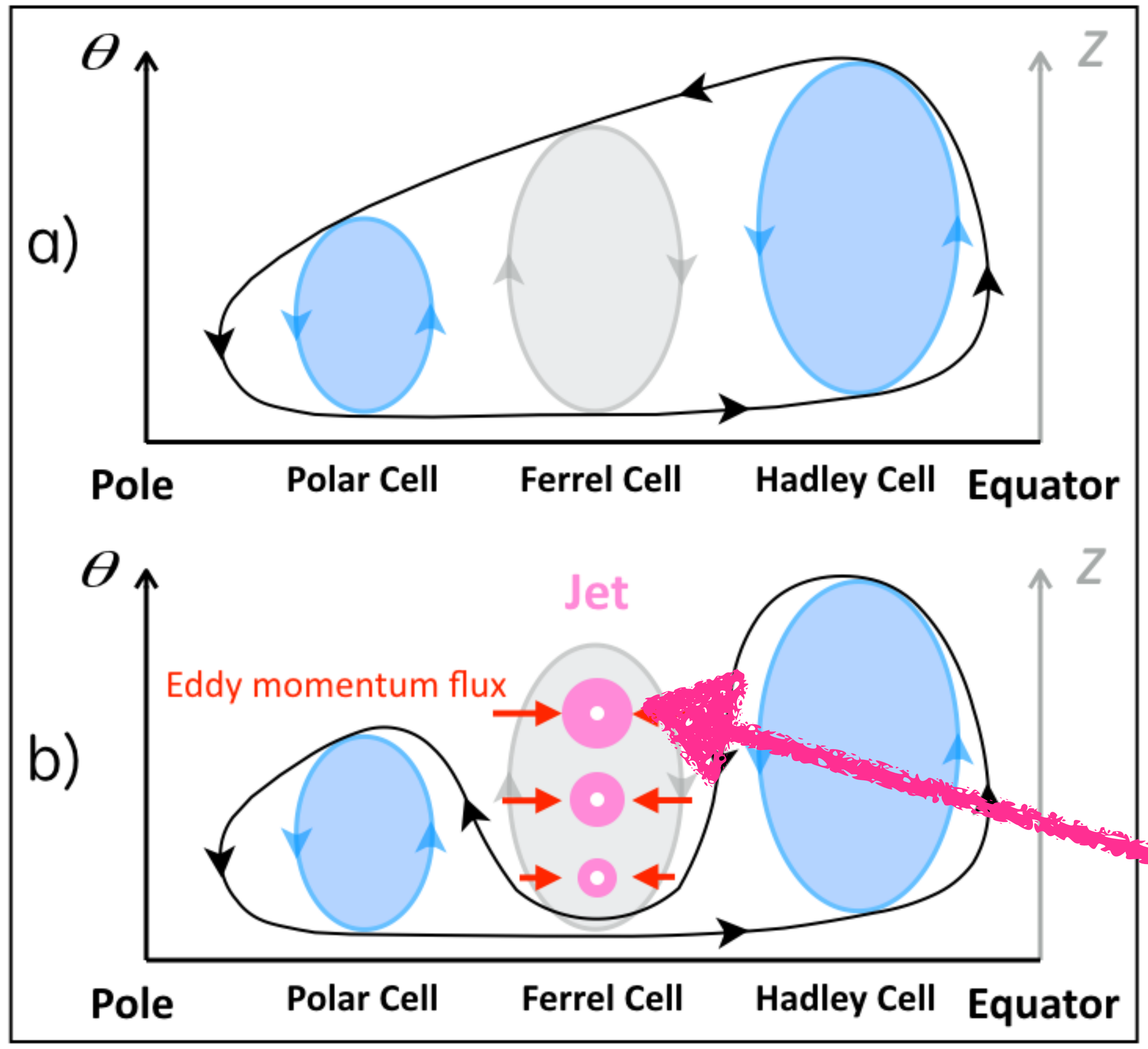

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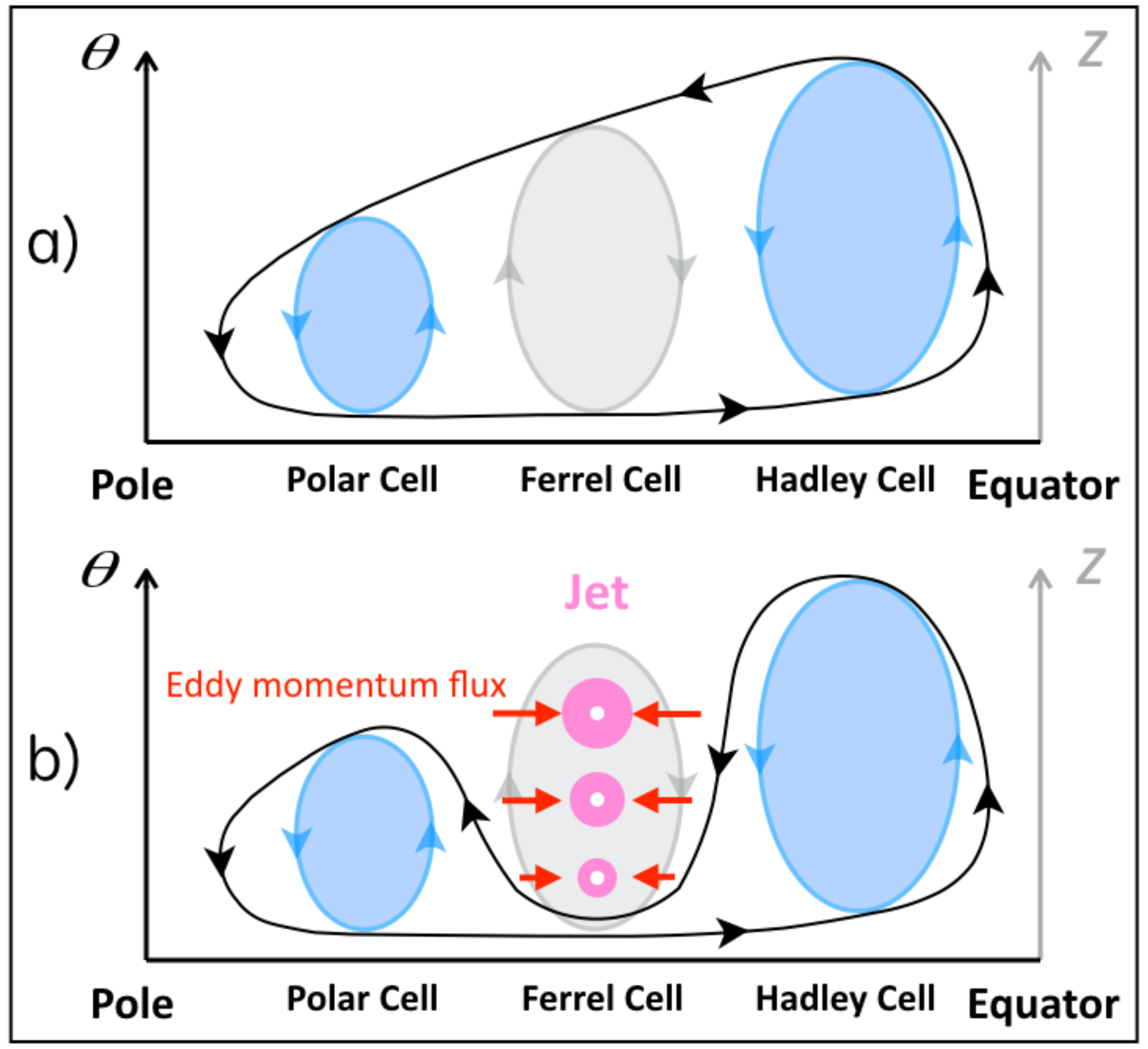

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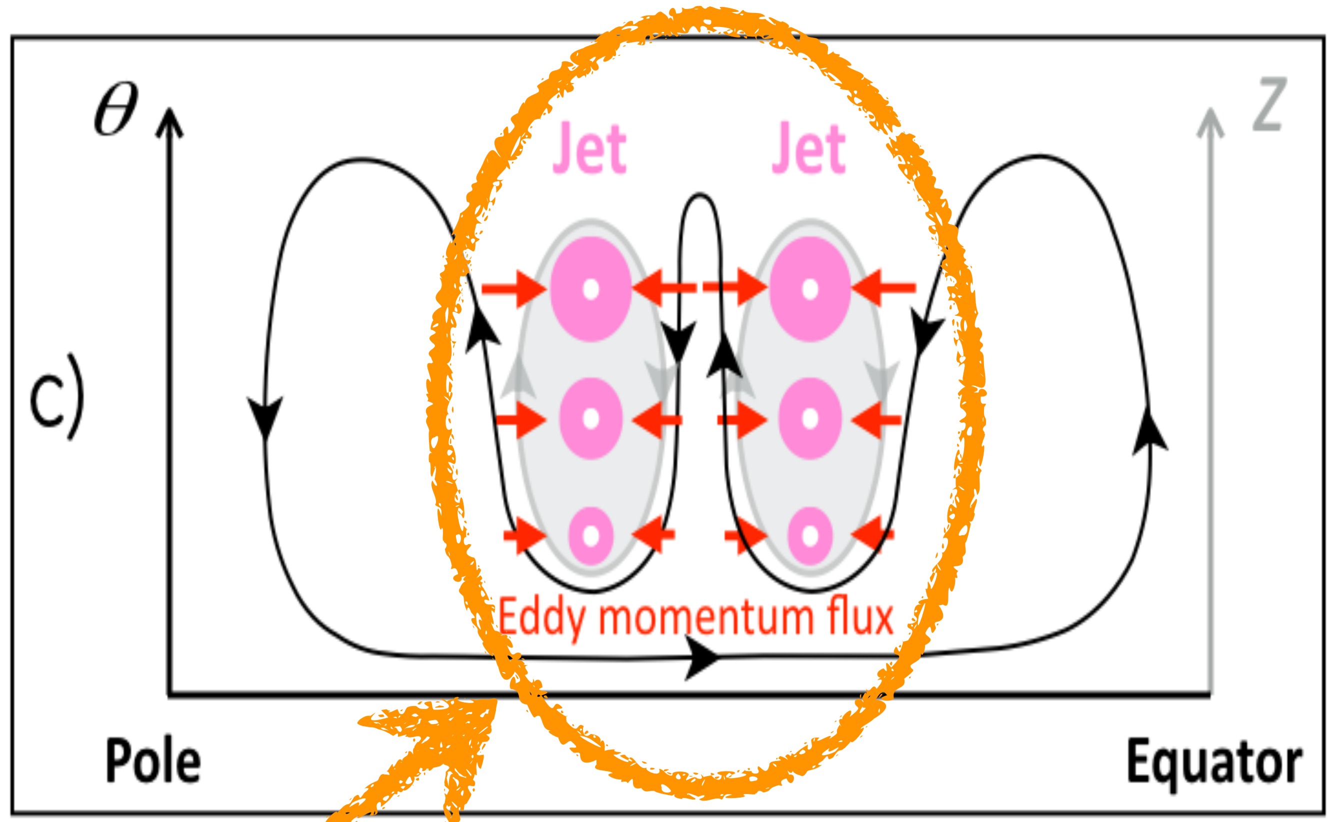

ACC scale

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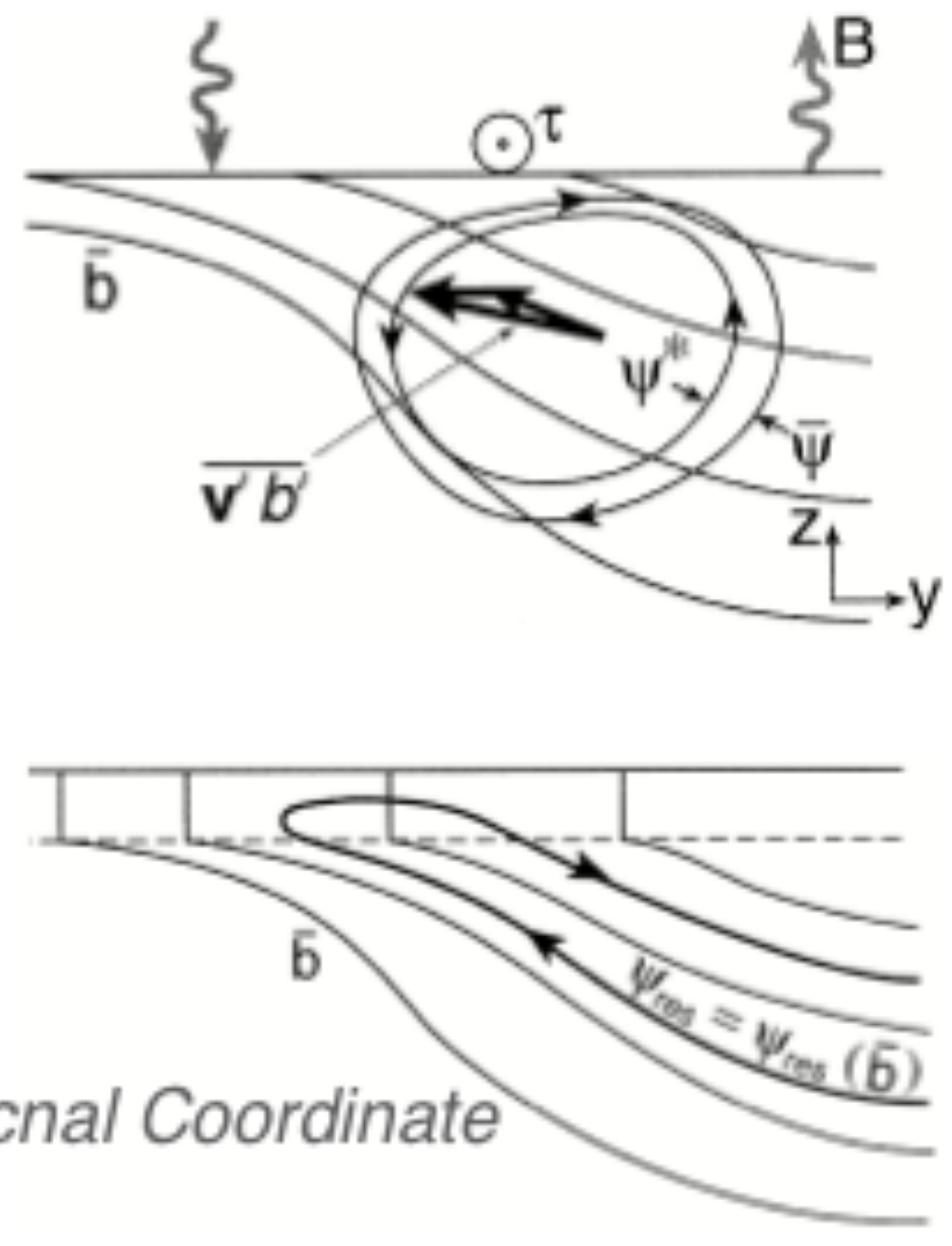
A balance between *wind-driven* MOC and *eddy-buoyancy-flux-driven* MOC



[Marshall and Radko 2003]

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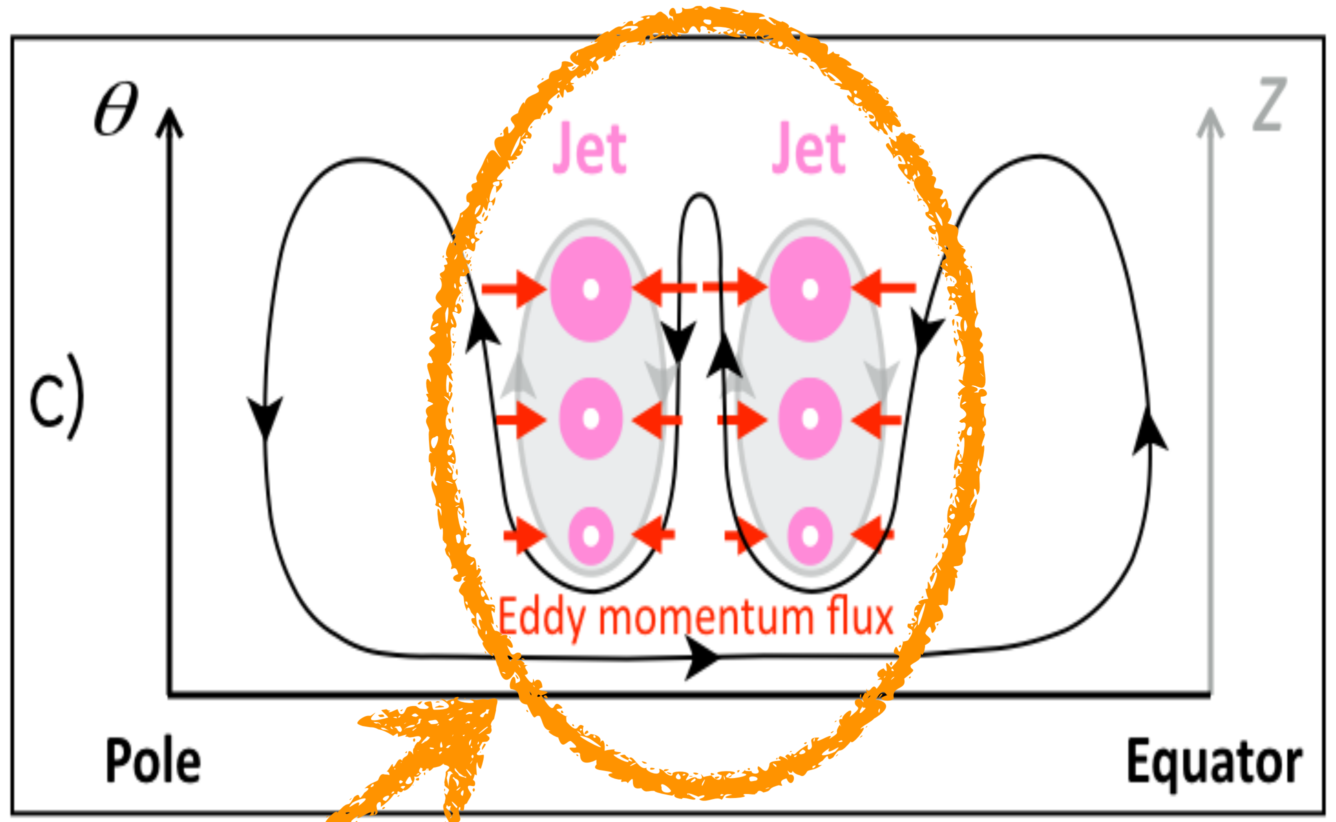

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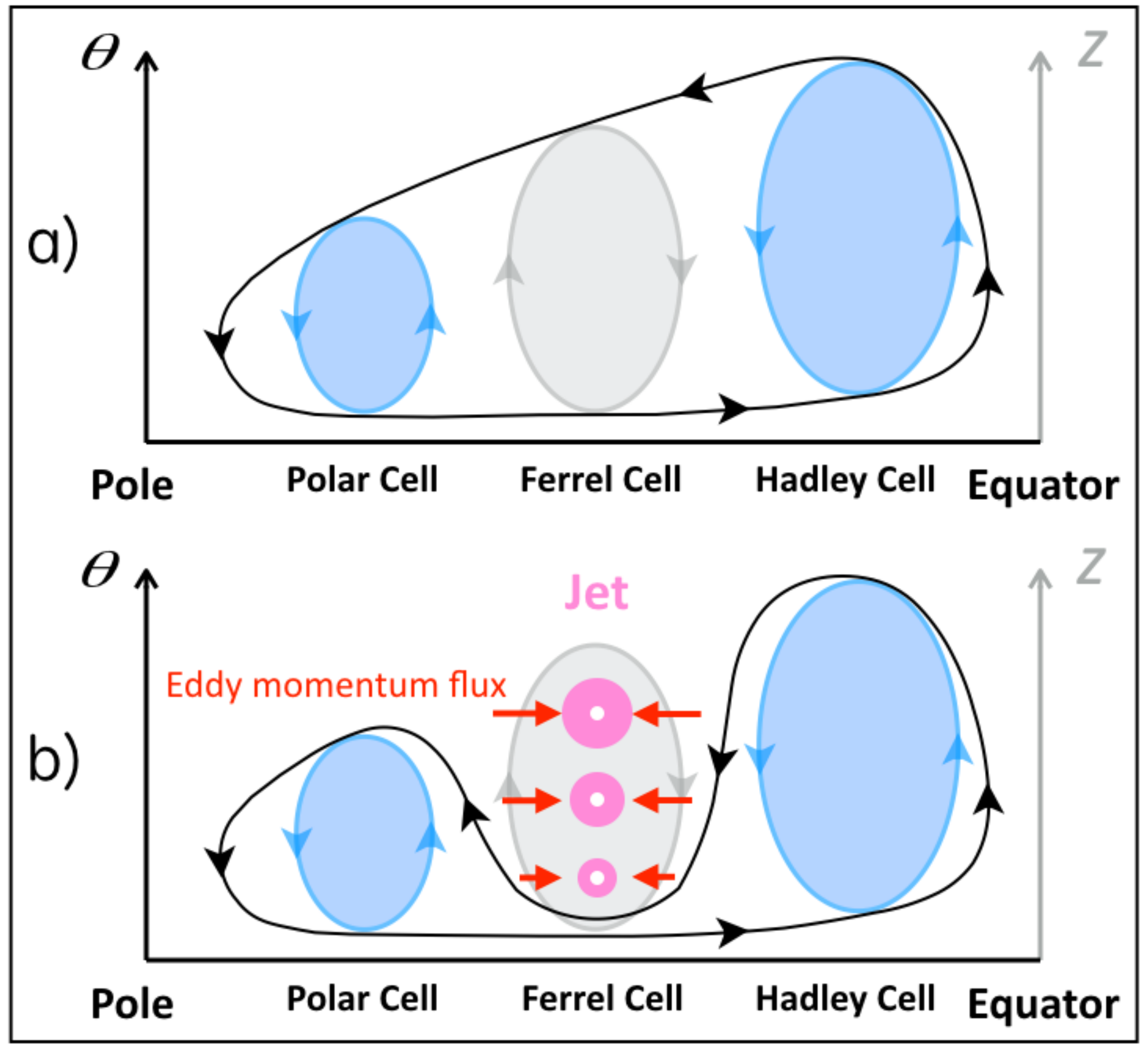

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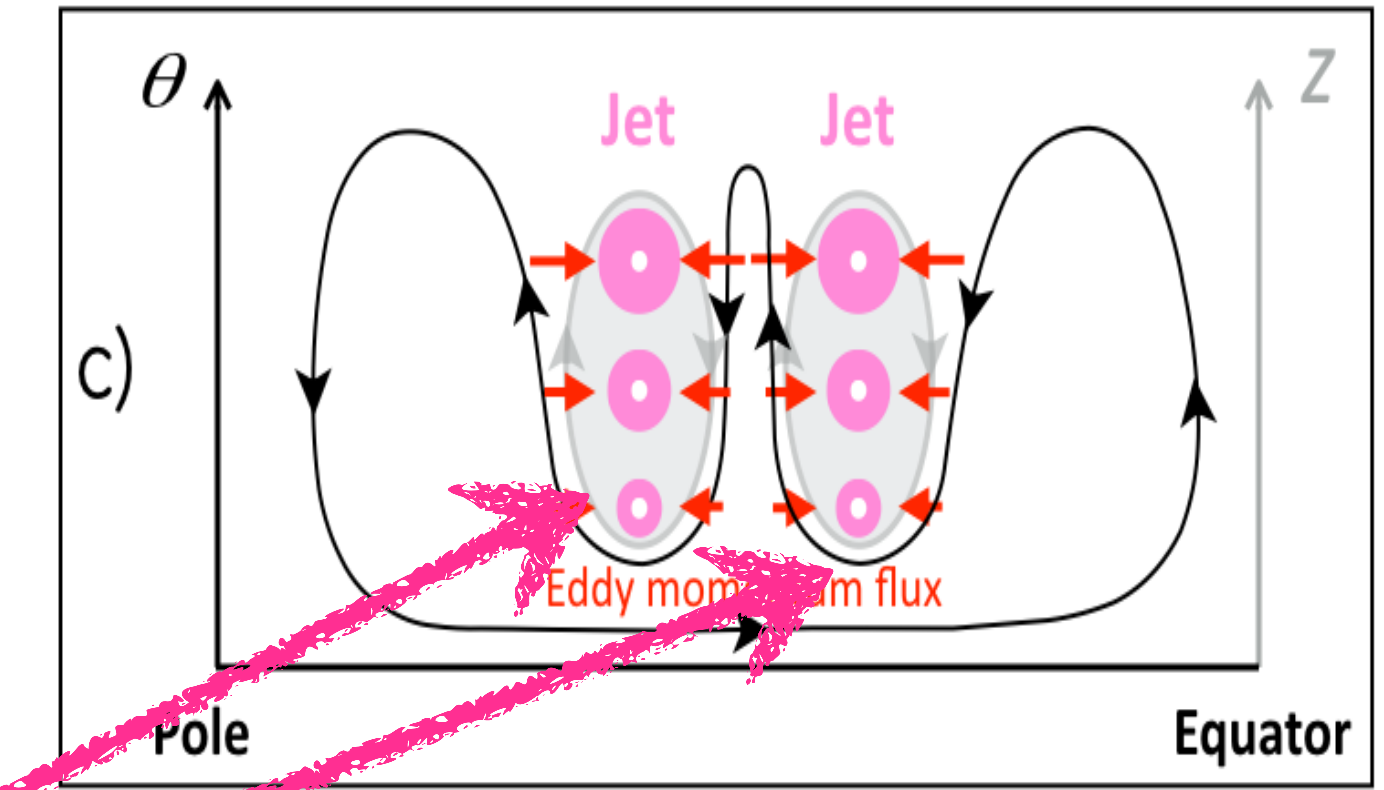
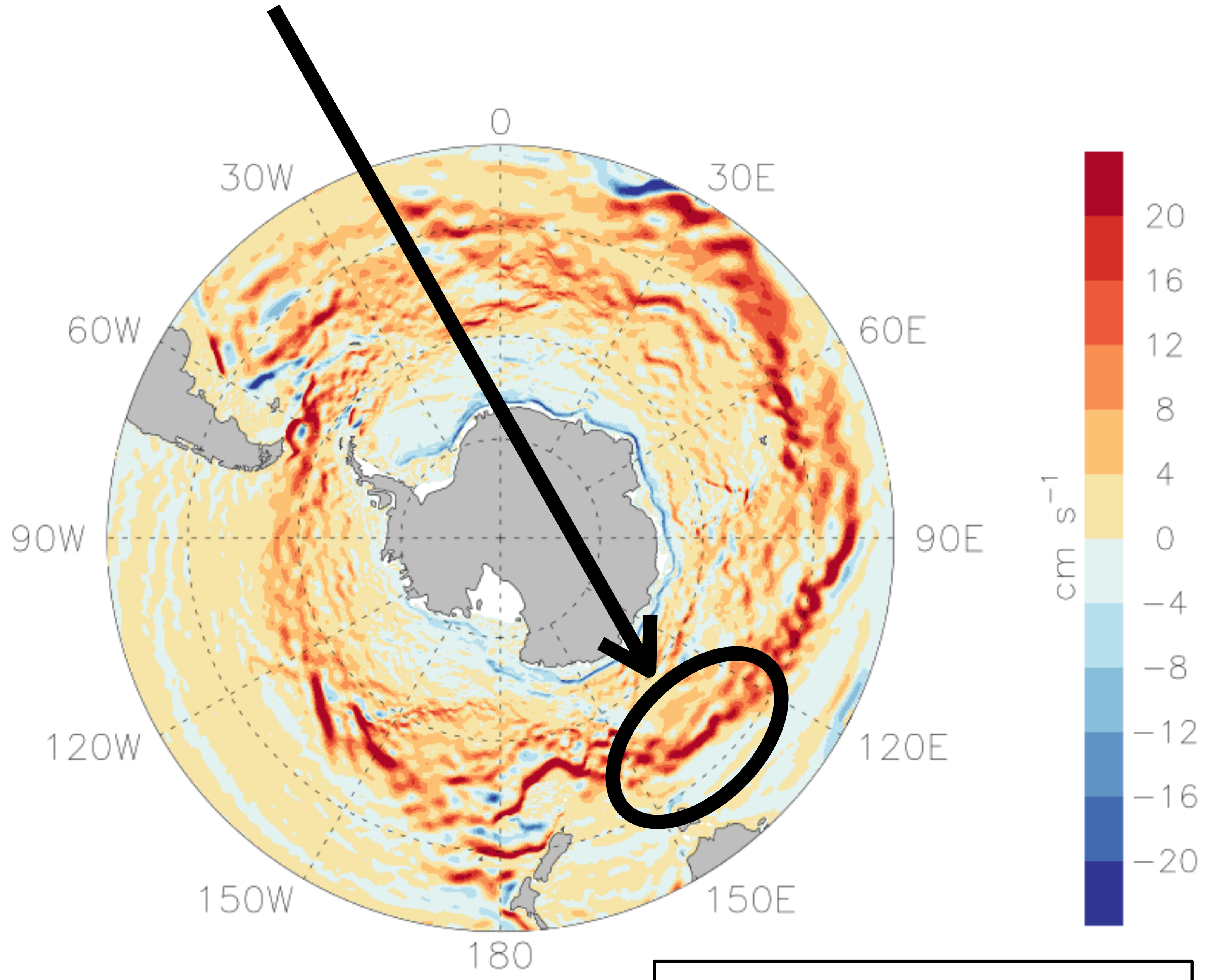


Jet scale

[Li, Lee, Griesel 2016, *JPO*]

JSOCs are found in the 0.1°-resolution ocean model

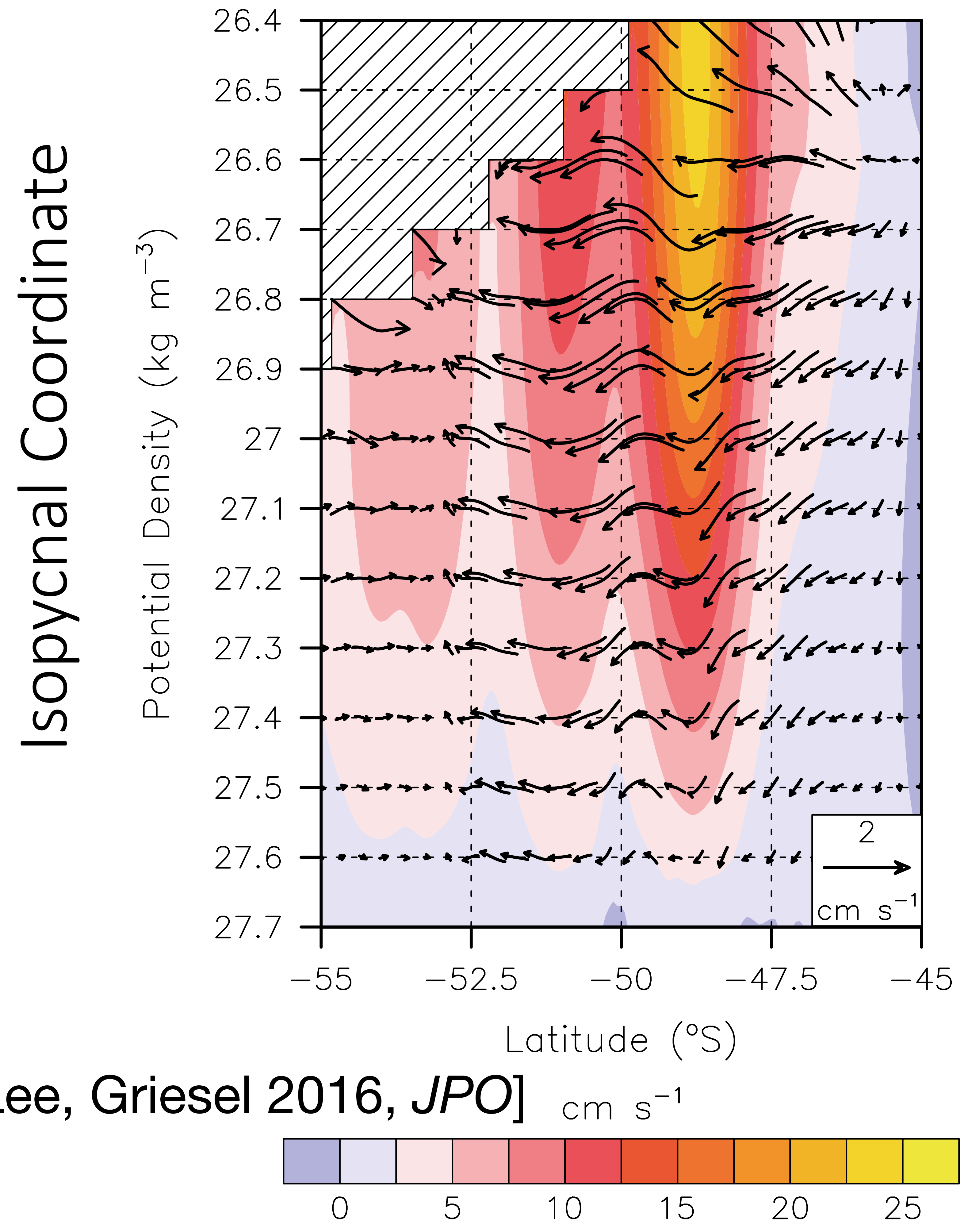
Analysis region:
Indo-western Pacific Southern Ocean



Zonal Current Speed

- The POP model forced by CORE-IAF
- Horizontal resolution: ~1/10°
- Vertical resolution: 42 levels
- Period: 1994-2007 (14 years)
- Acknowledgements: Matt Maltrud, Elena Yulaeva, Julie McClean

120E-144E: Zonal velocity (color)
Meridional and vertical velocities (vectors)



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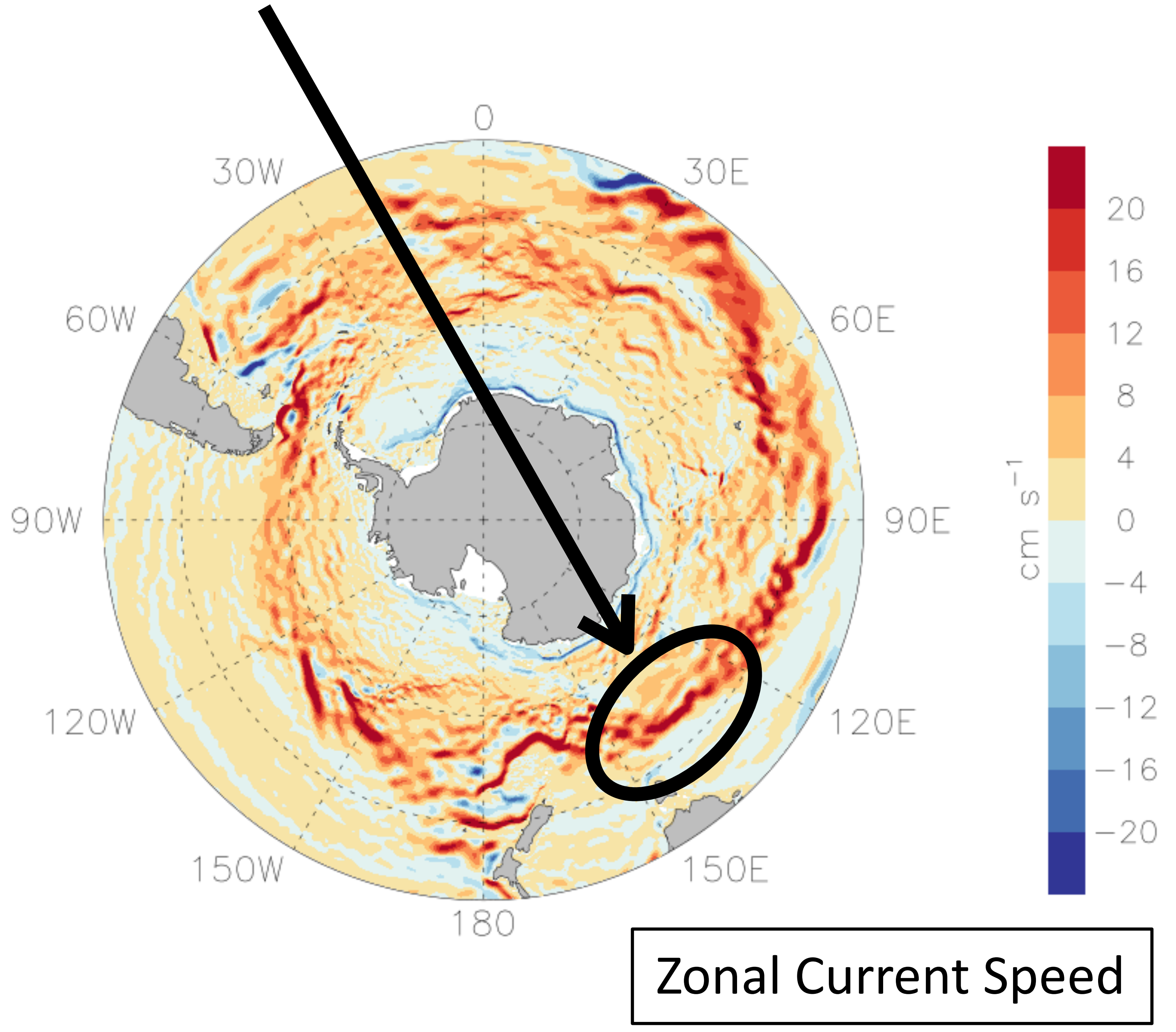

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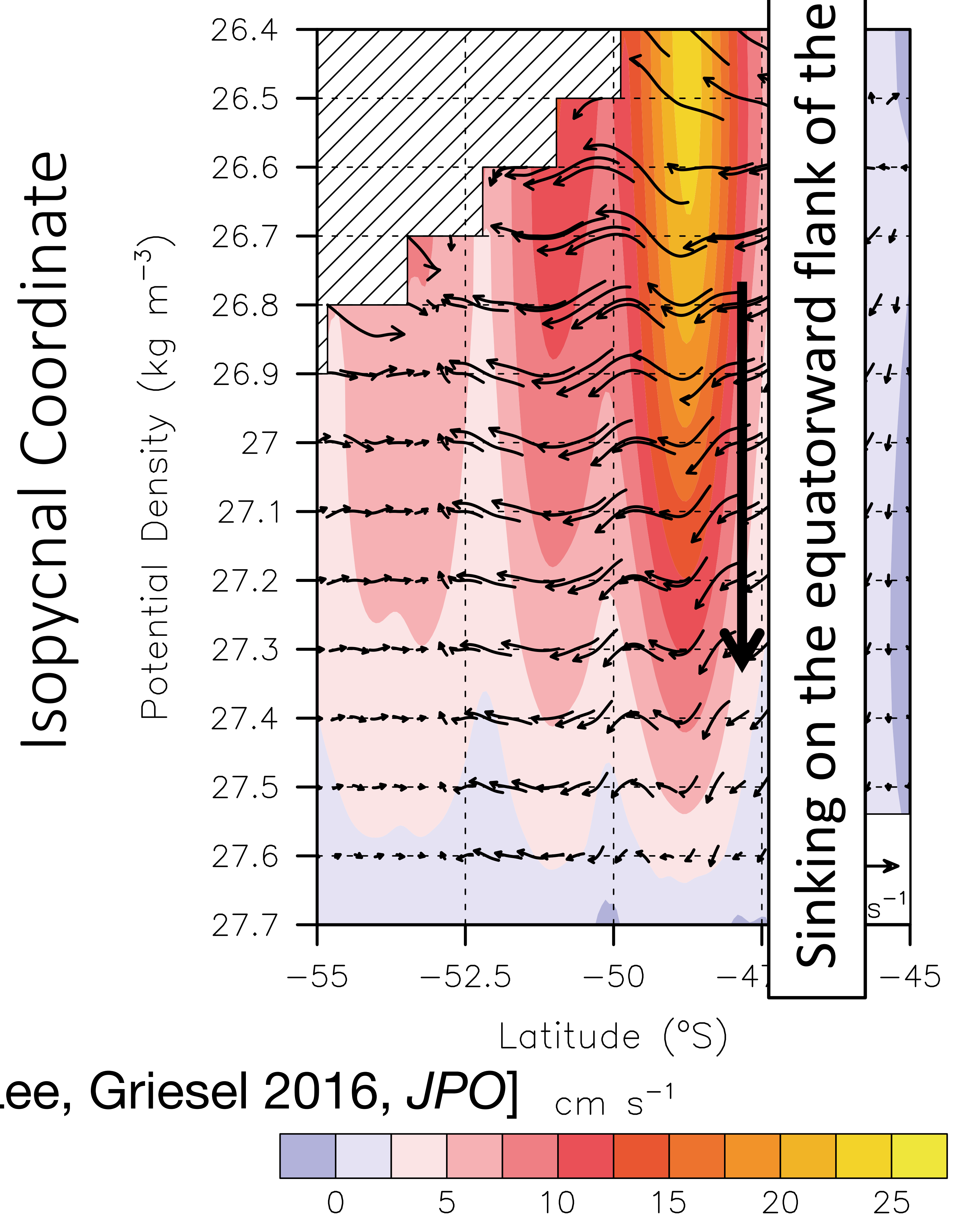

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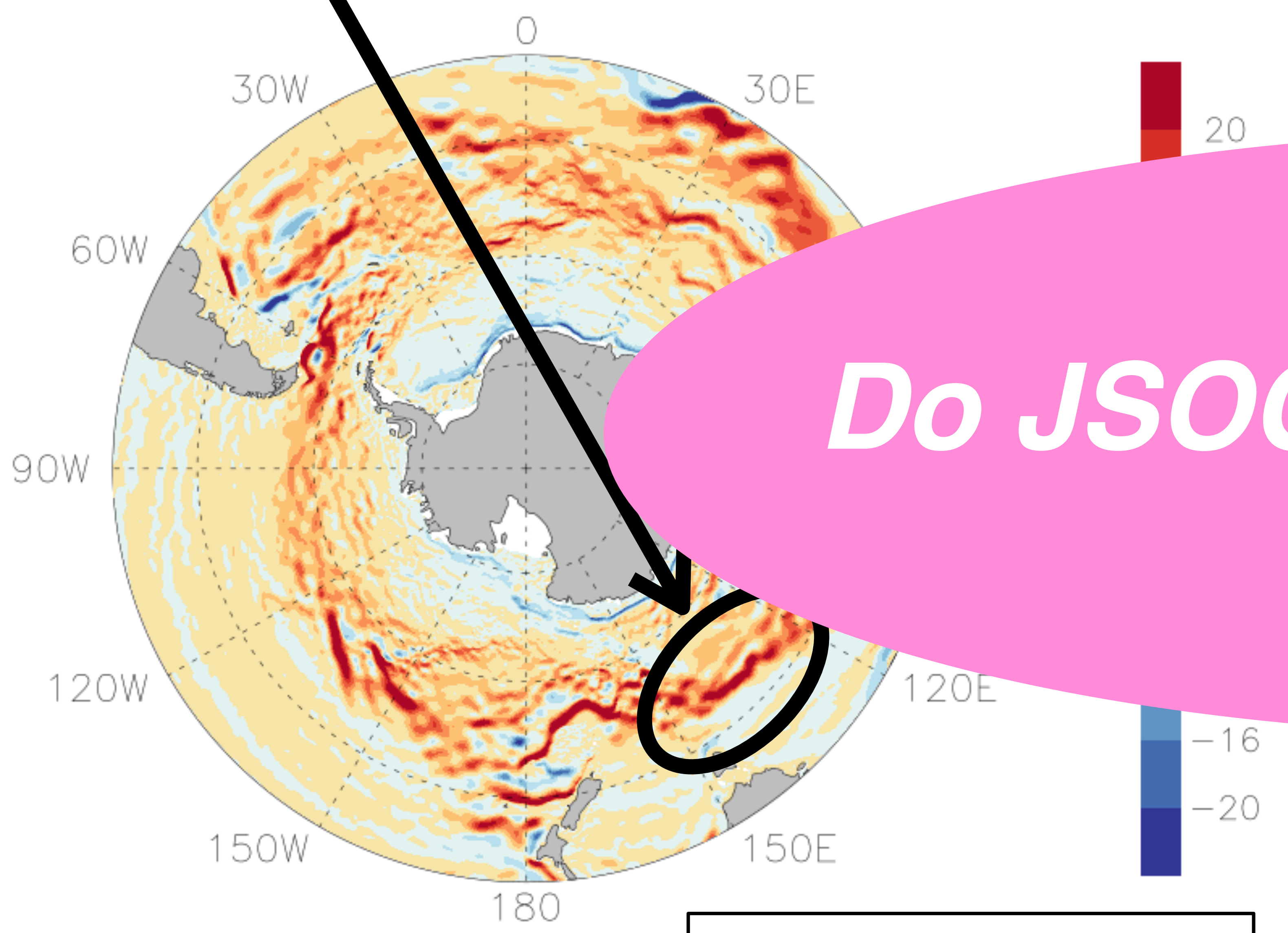

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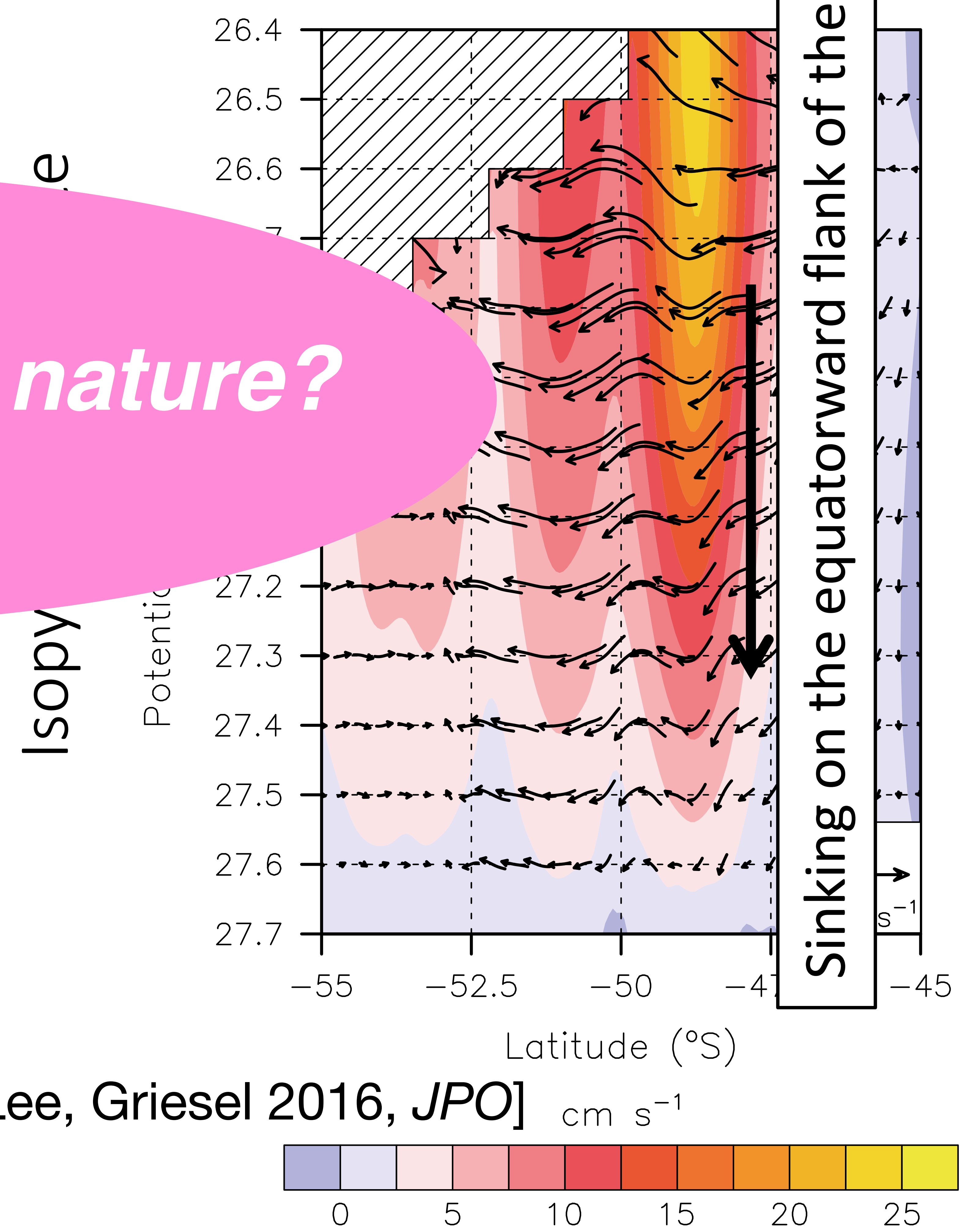

Do JSOCs exist in nature?

[Li, Lee, Griesel 2016, *JPO*]

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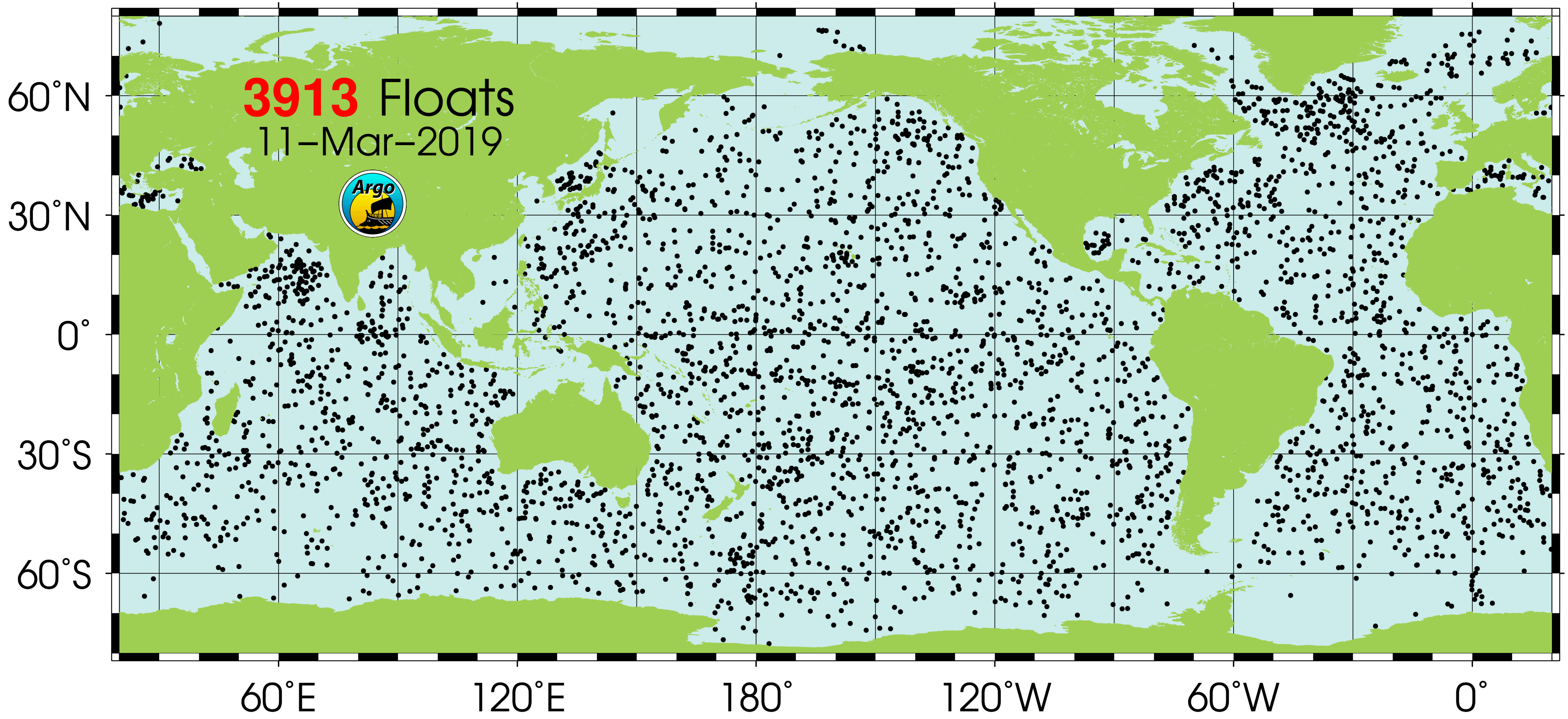
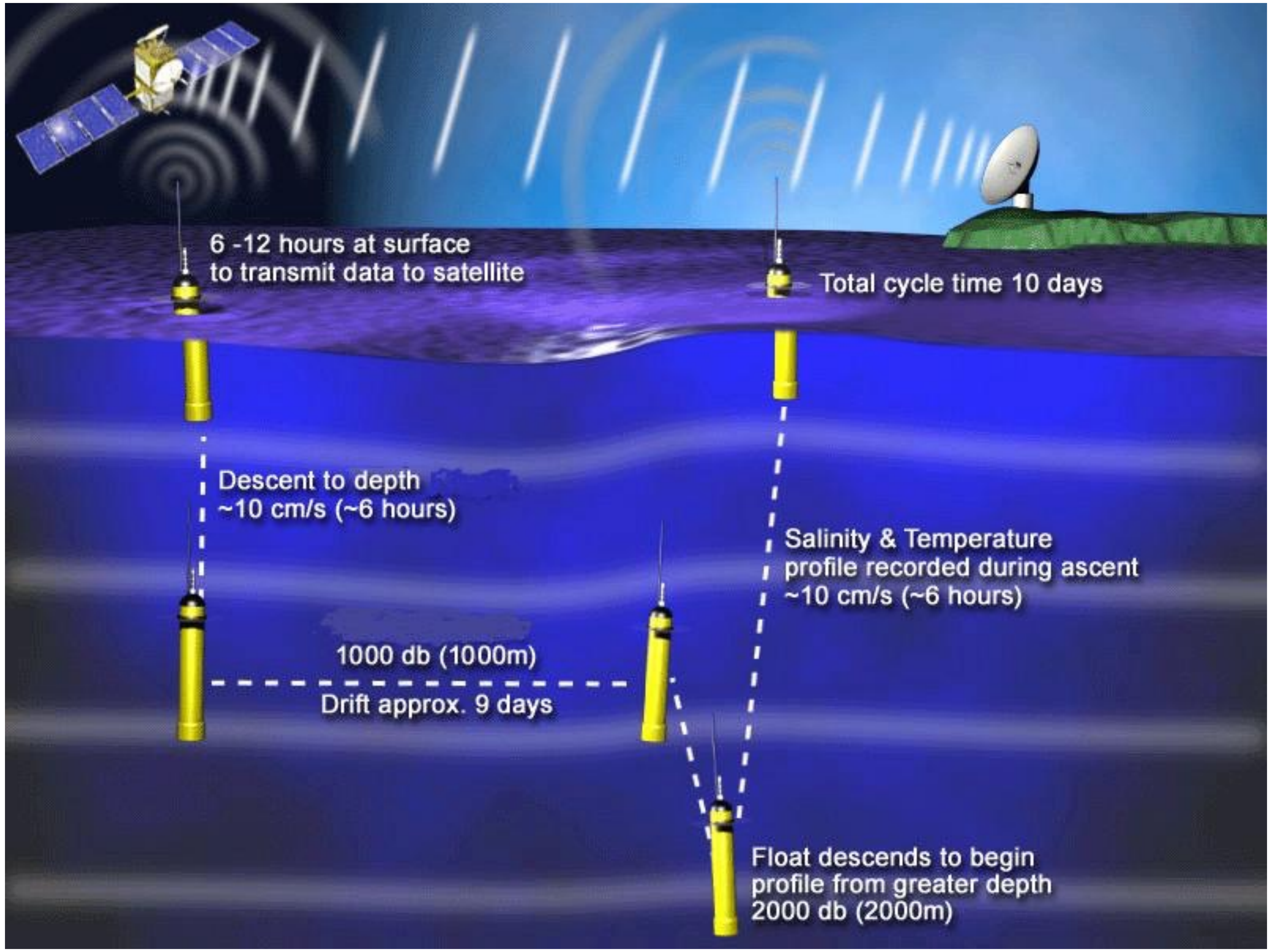
Argo: **Observing** the Ocean in Real Time



http://www.argo.ucsd.edu/

The **Observed** Ocean Current Velocities

An Argo Float Mission



- ***Subsurface*** velocities at ~1 km (Argo parking level)

$$\begin{cases} u_p = \dfrac{X_{asc} - X_{des}}{t_{asc} - t_{des}} \\ v_p = \dfrac{Y_{asc} - Y_{des}}{t_{asc} - t_{des}} \end{cases}$$

Descending: X_{des}, Y_{des}, t_{des}

Ascending: X_{asc}, Y_{asc}, t_{asc}

[Schmid et al. 2007]

The **Observed** Ocean Current Velocities

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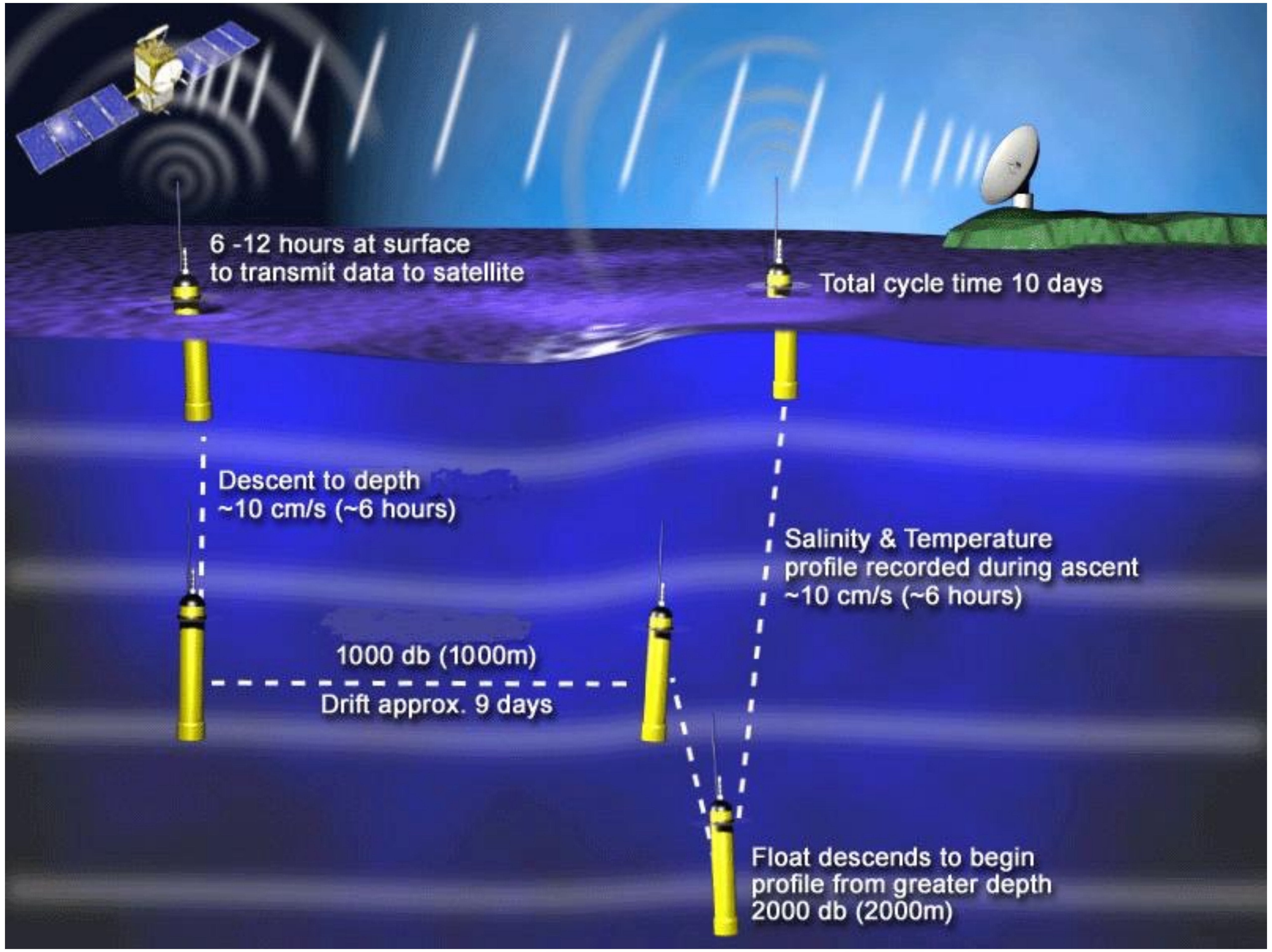

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- ***Surface*** geostrophic velocity:

$$\begin{cases} u_g = -\dfrac{g}{f}\dfrac{\partial \eta}{\partial y}, \\ v_g = \dfrac{g}{f}\dfrac{\partial \eta}{\partial x} \end{cases}$$

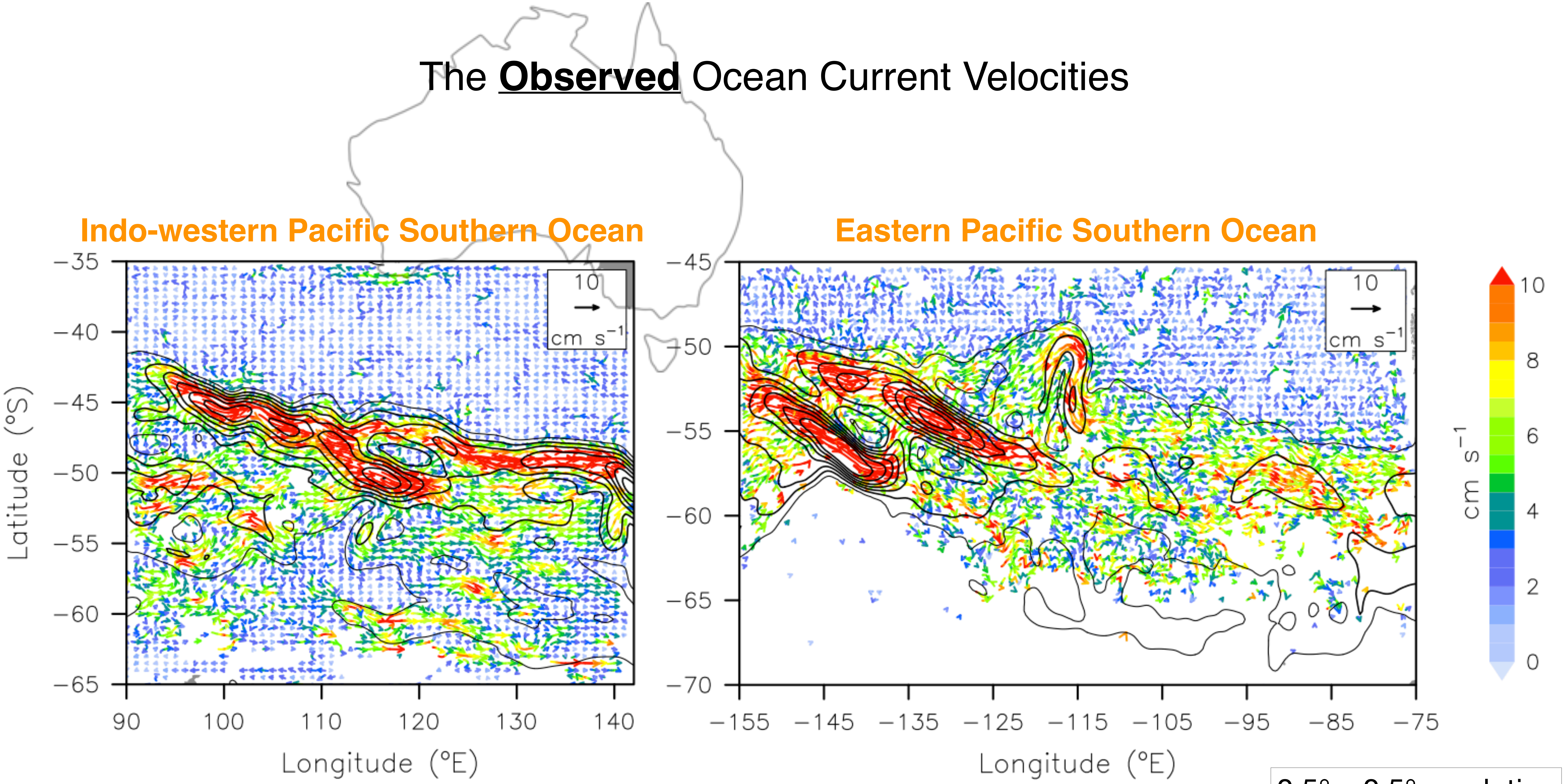
Sea Surface Height

Descending: X_{des}, Y_{des}, t_{des}

Ascending: X_{asc}, Y_{asc}, t_{asc}

[Schmid et al. 2007]

The **Observed** Ocean Current Velocities



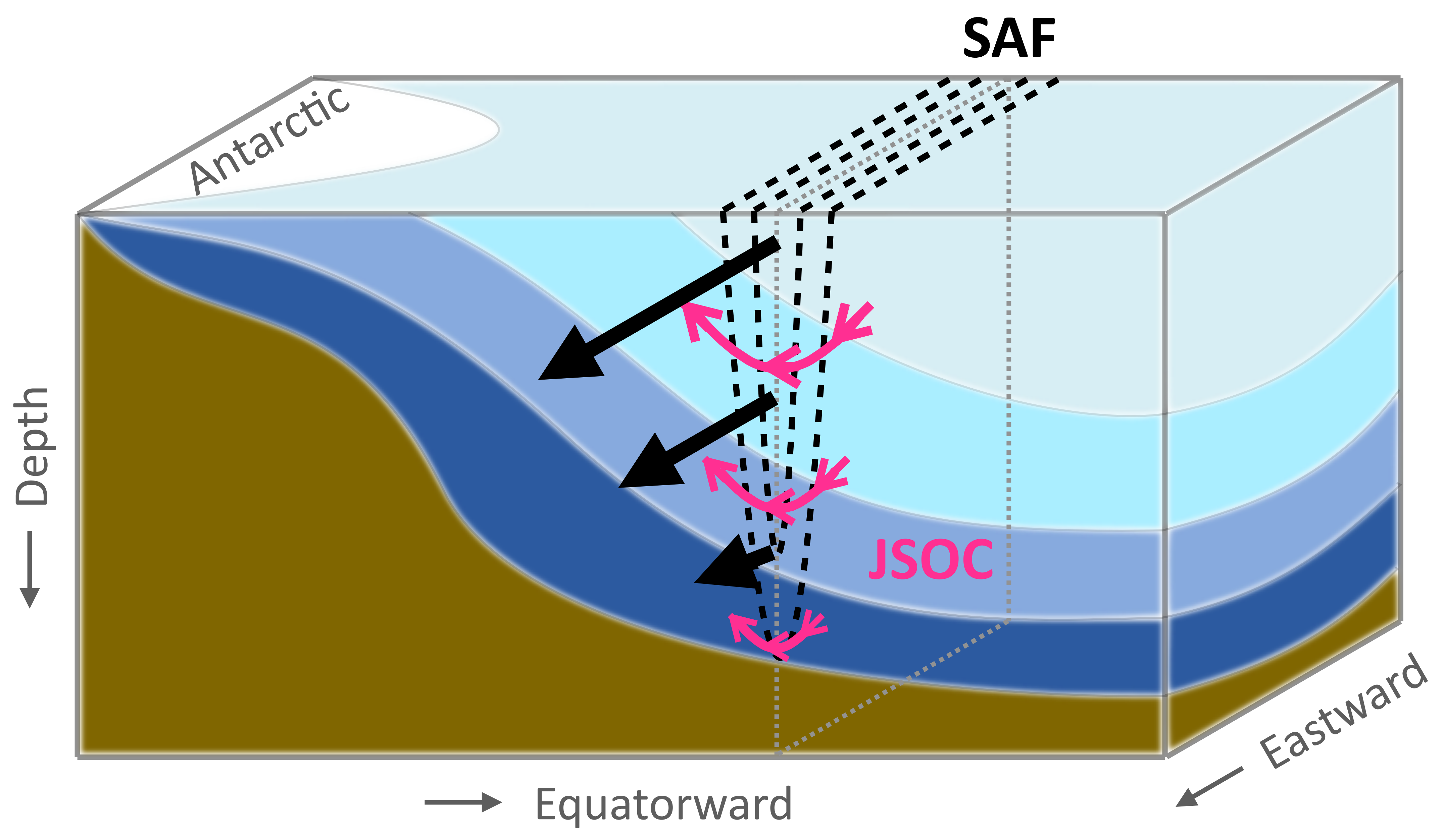
0.5° x 0.5° resolution

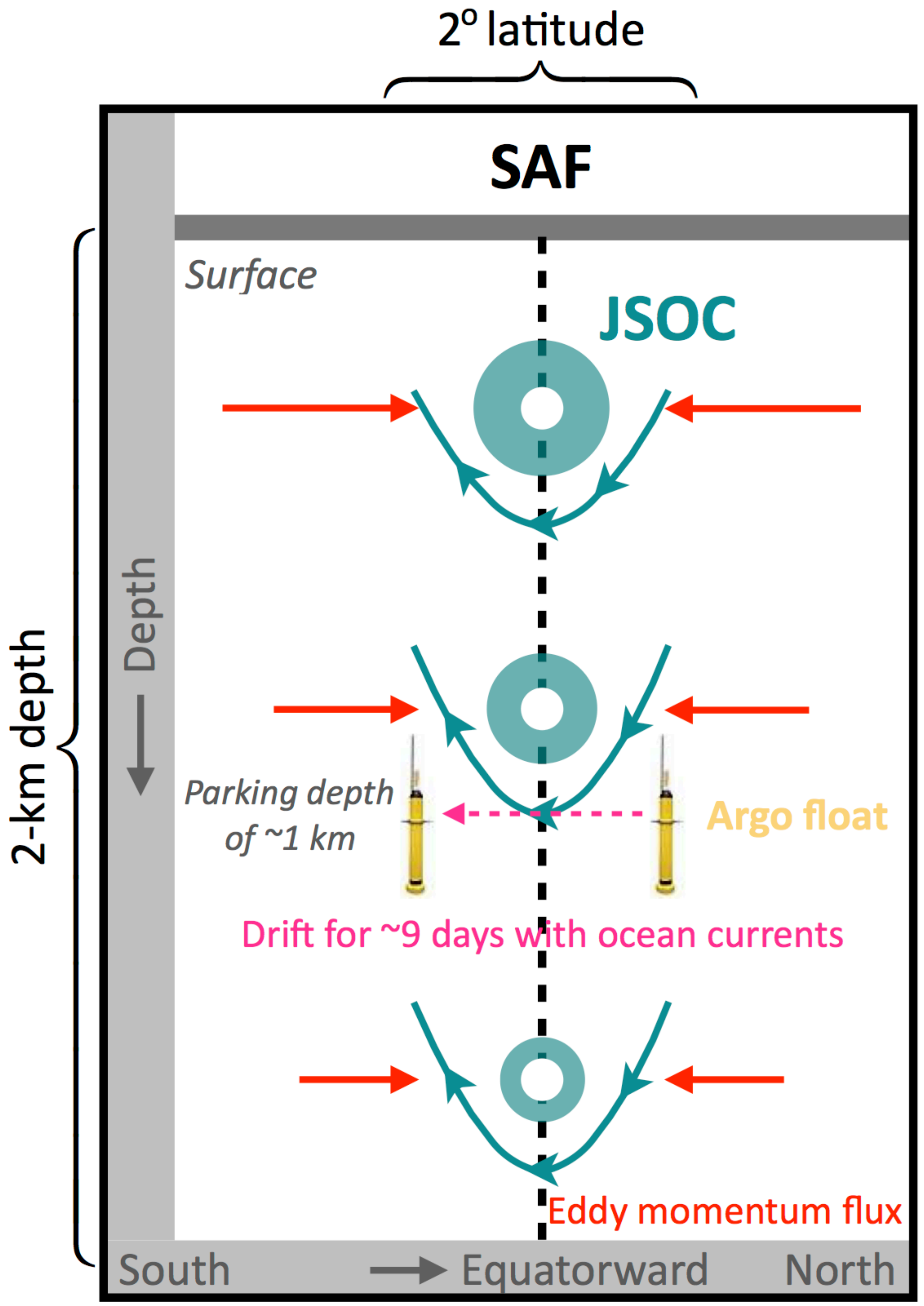
[Li, Lee, Mazloff 2018, *GRL*]

- *Contours:* AVISO SSH-based ***surface geostrophic current speed*** (above 5 cm s^{-1})
- Vectors/color: Argo-float-trajectories-based ***subsurface (at ~1 km) velocity/magnitude***

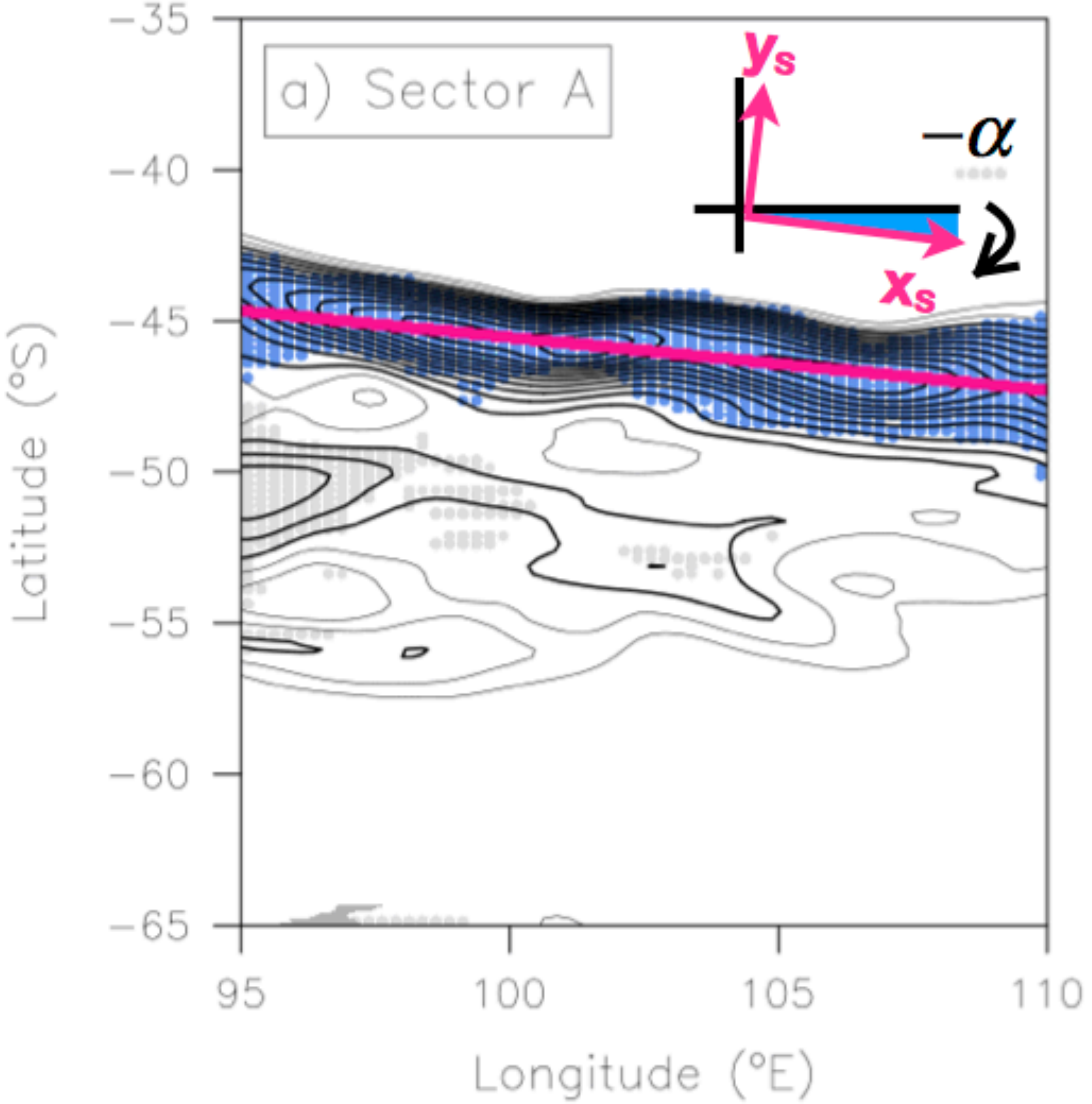
Structure of the Theoretical JSOC

Schematic diagram of the SAF (→) and JSOC (→)





ACC Jets are tilted



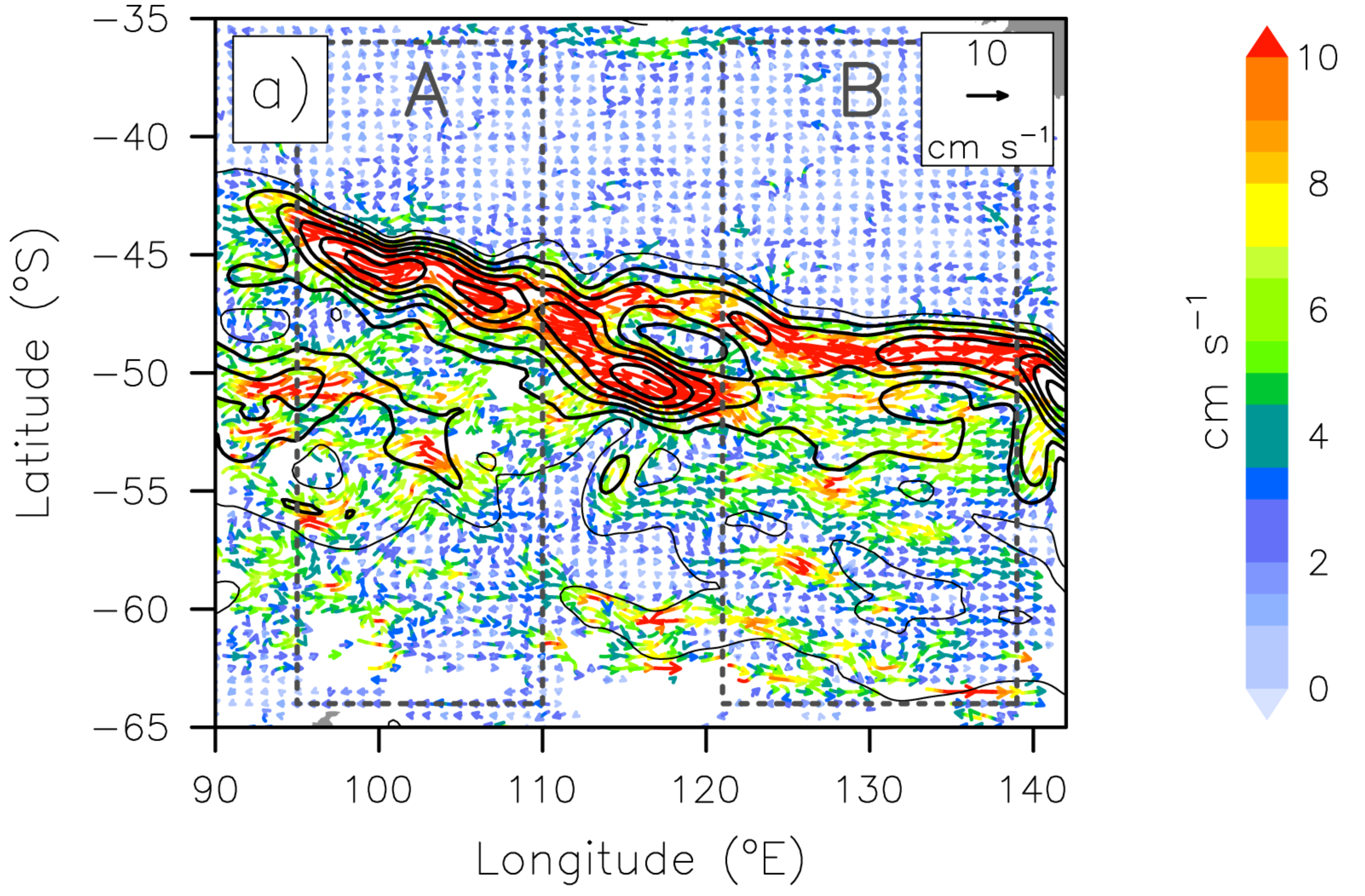
Streamwise Coordinate

Streamwise velocity	$\begin{cases} u_s = u_p \cos\alpha - v_p \sin\alpha \\ v_s = u_p \sin\alpha + v_p \cos\alpha \end{cases}$
Cross-stream velocity	

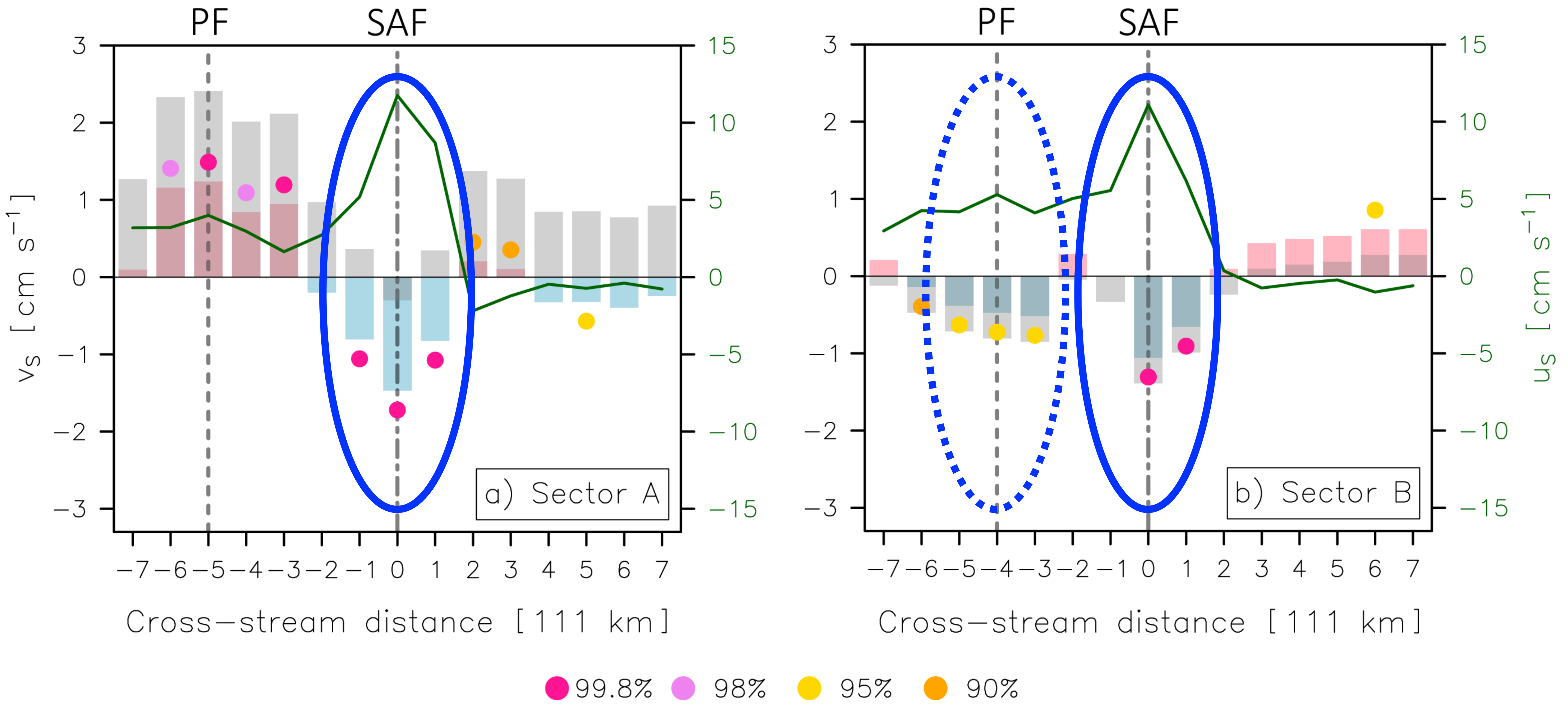
- *Dots:* Daily positions of the speed maxima in the AVISO SSH-based ***surface geostrophic current speed.***

Detecting Horizontal Motion by Argo Float Trajectories

Indo-western Pacific Southern Ocean



Negative <u>cross-stream</u> motion across the jets



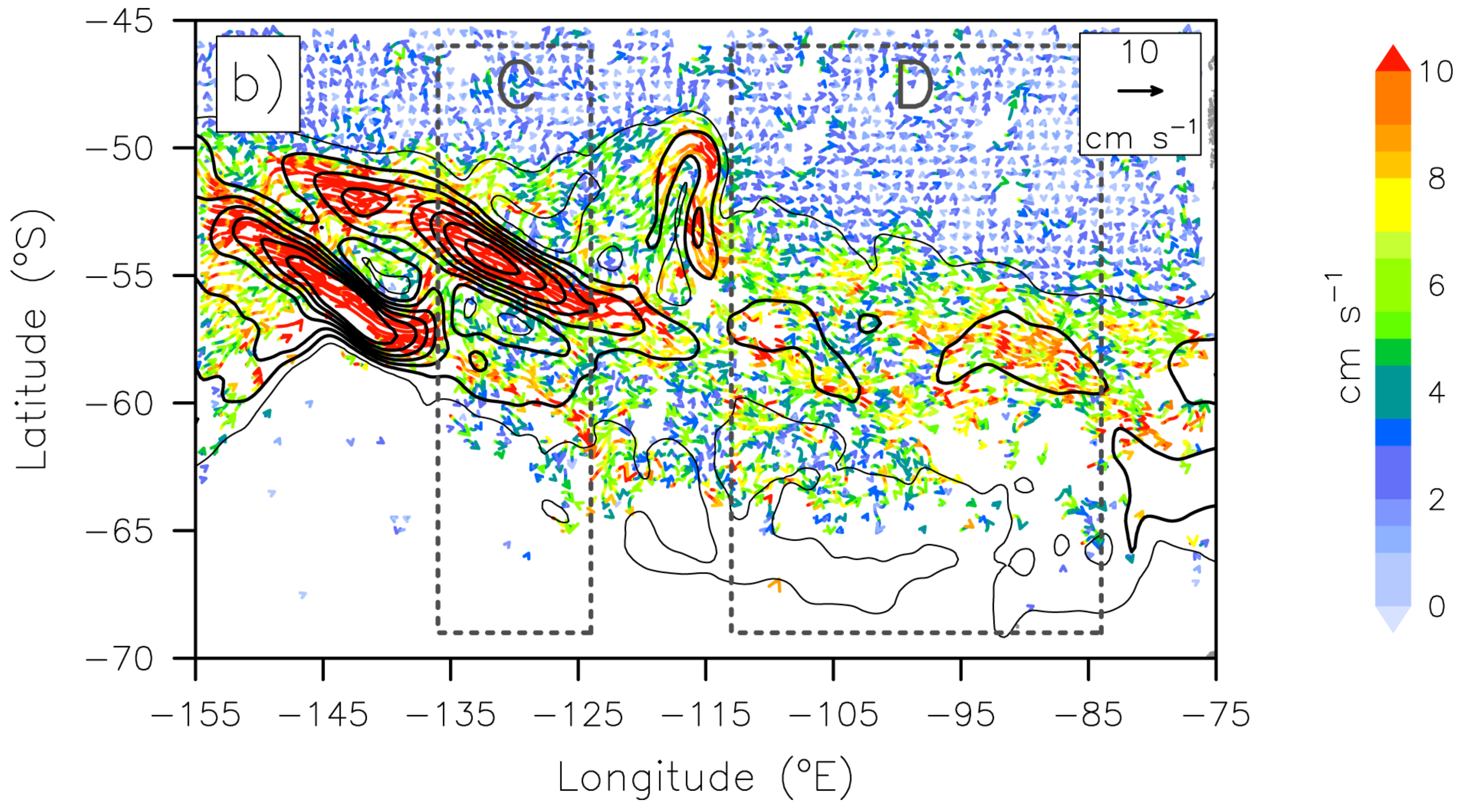
[Li, Lee, Mazloff 2018, *GRL*]

<u>Lines:</u> Streamwise velocity (u_s)

<u>Bars:</u> Cross-stream velocity (v_s)

Detecting Horizontal Motion by Argo Float Trajectories

Eastern Pacific Southern Ocean



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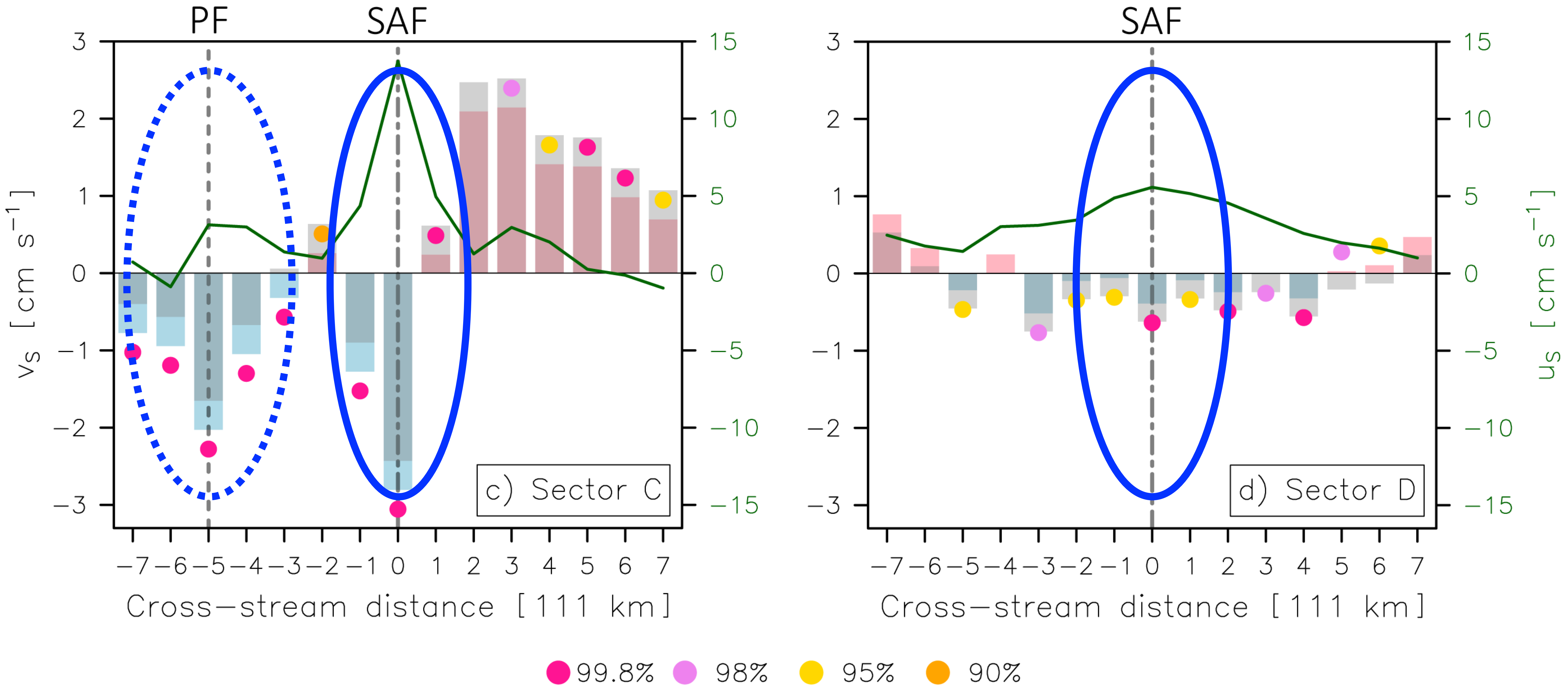

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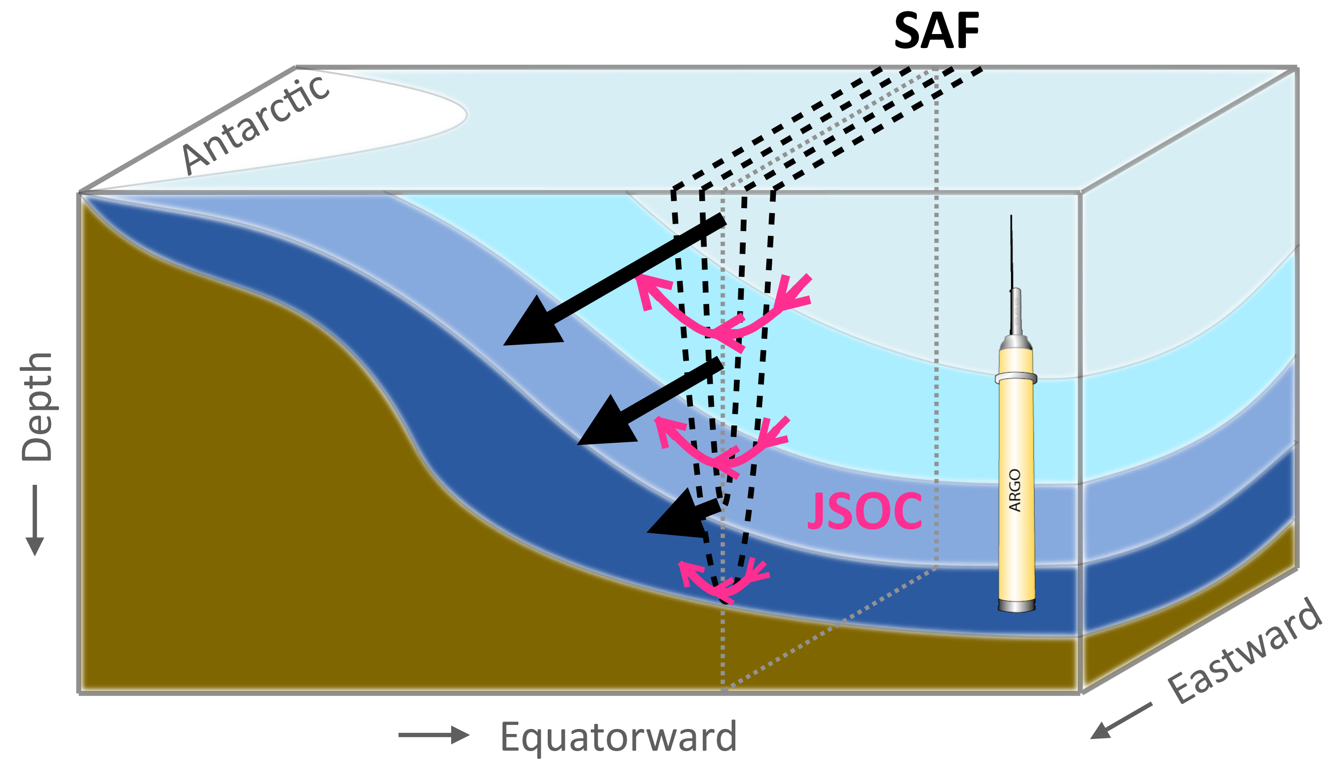
[Li, Lee, Mazloff 2018, *GRL*]

Conclusions



- In the Indo-western Pacific SO, where the jets are relatively well-defined, the analysis shows that ***eddy momentum fluxes*** drive the ACC jets and ***jet-scale overturning circulations (JSOCs)***.
- Analogous to the Ferrel Cell, the JSOCs are ***thermally indirect*** with sinking/rising motions on the equatorward/poleward flank of the jets.
- The ***negative cross-stream motion*** is revealed across the jets by Argo float trajectories. It suggests that ***the JSOCs indeed exist in nature***.
- The eddy-driven JSOC associated with the SAF plays an important role in ***initiating the narrow and deep mixed layer wedge*** that forms north of the SAF.

Reference:

- Li, Q., S. Lee, and M. R. Mazloff, 2018: Evidence of jet-scale overturning ocean circulations in Argo float trajectories, *Geophysical Research Letters*, 45, 11,866–11,874.
- Li, Q., and S. Lee, 2017: A mechanism of mixed-layer formation in the Indo-western Pacific Southern Ocean: preconditioning by an eddy-driven jet-scale overturning circulation, *Journal of Physical Oceanography*, 47, 2755–2772.
- Li, Q., S. Lee, and A. Griesel, 2016: Eddy fluxes and jet-scale overturning Circulations in the Indo-Western Pacific Southern Ocean, *Journal of Physical Oceanography*, 46, 2943-2959.