Mixing and Water Mass Transformation along the Antarctic Continental Slope

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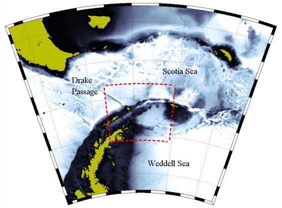
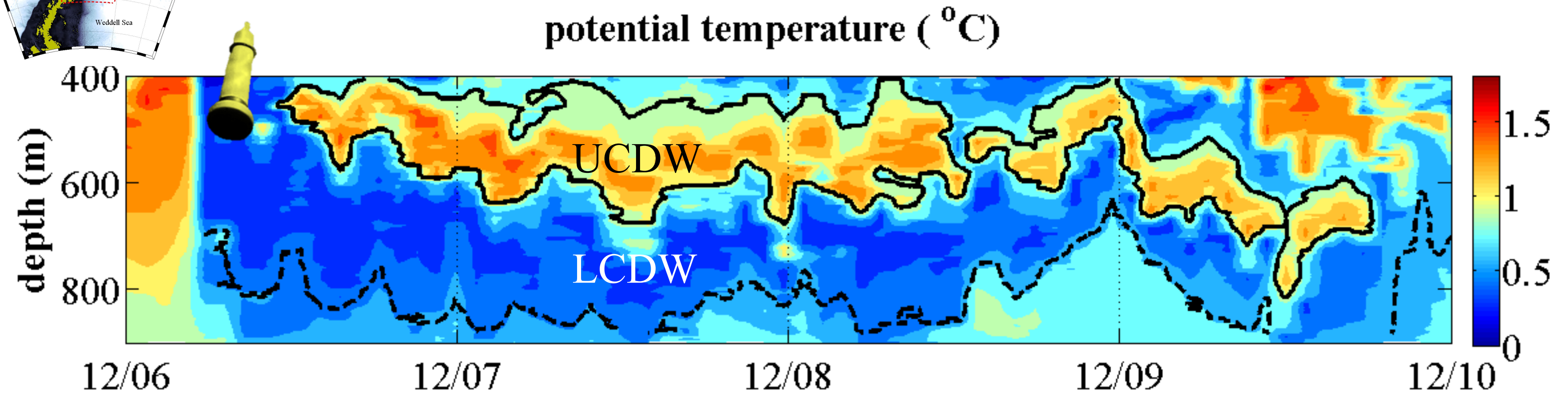
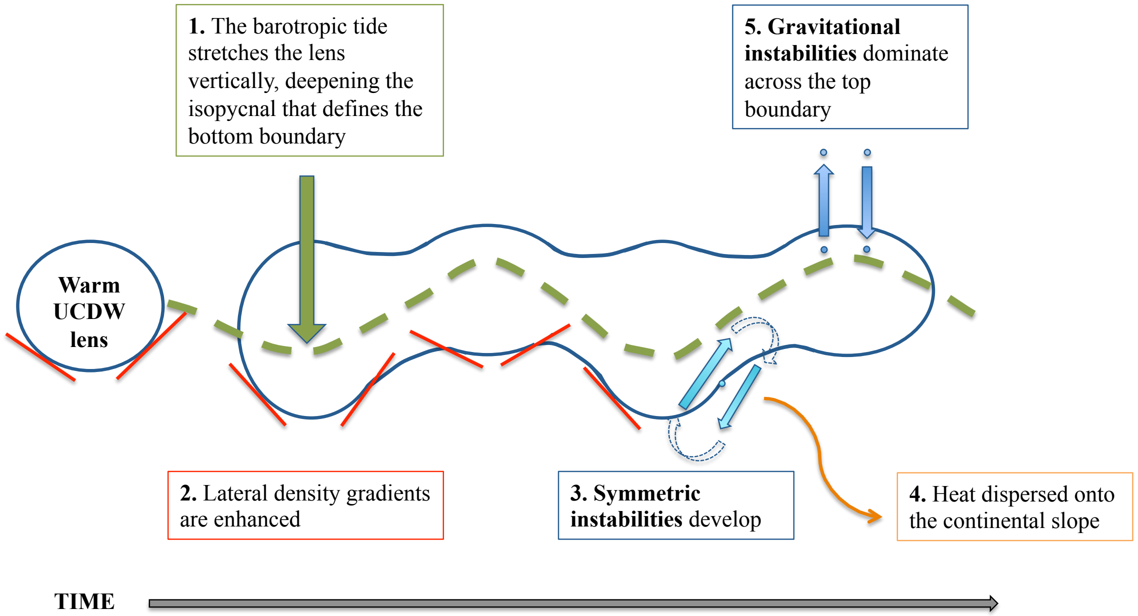
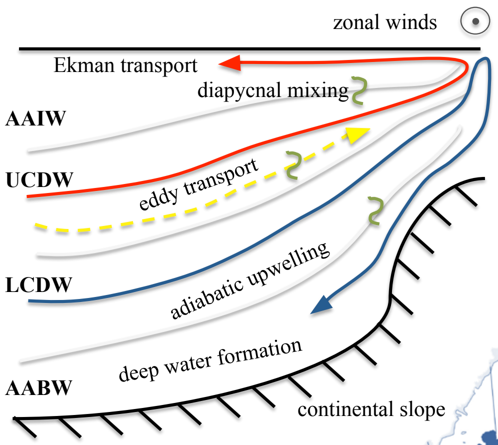
Water Mass Transformation along the Antarctic Peninsula

UCDW: Upper Circumpolar Deep Water
LCDW: Lower CDW

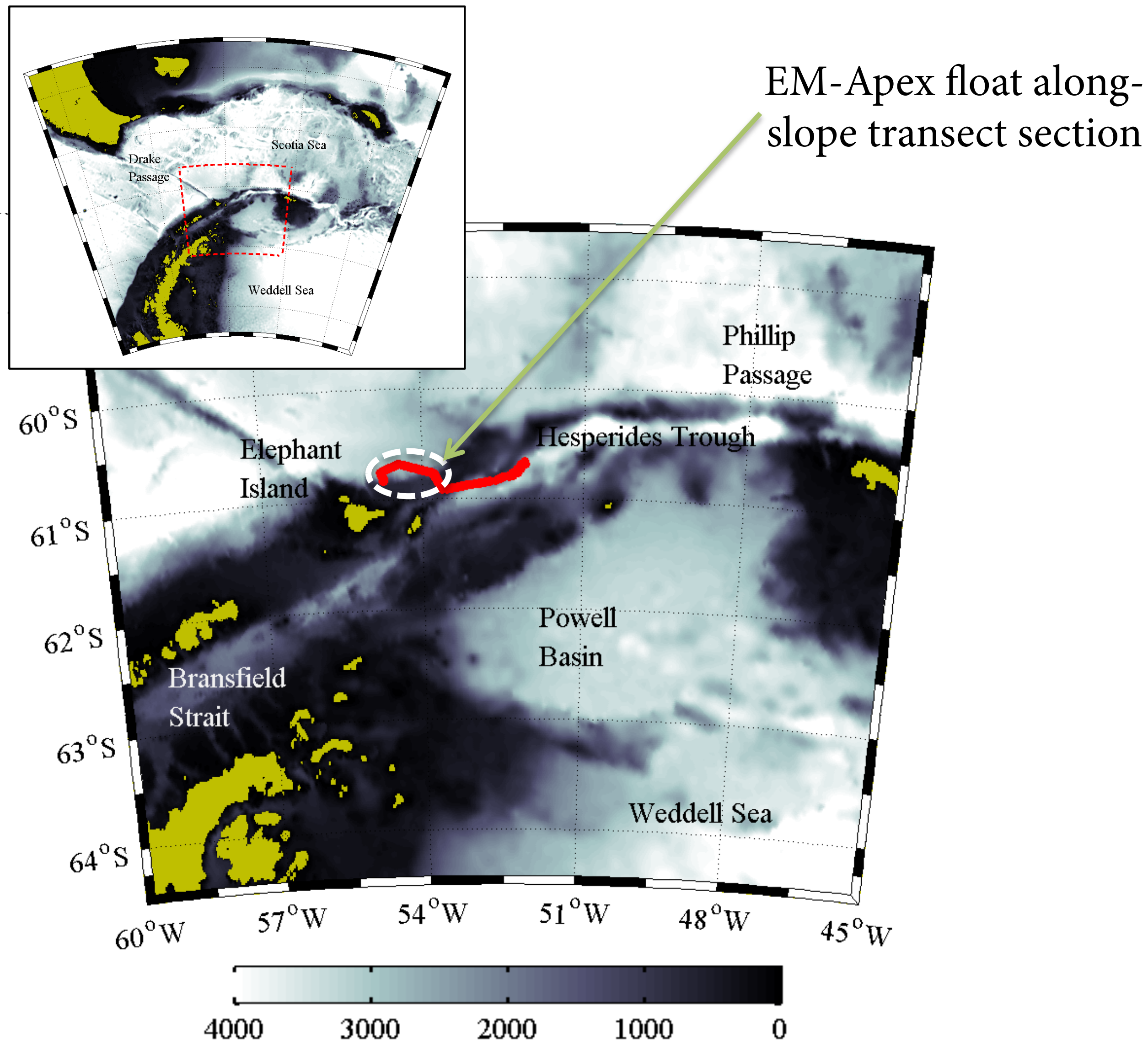






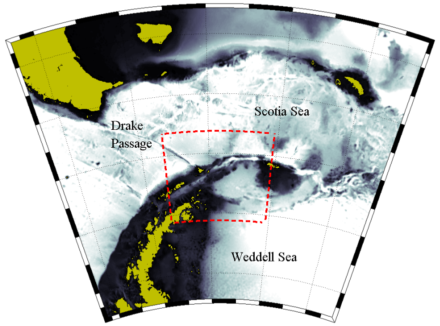


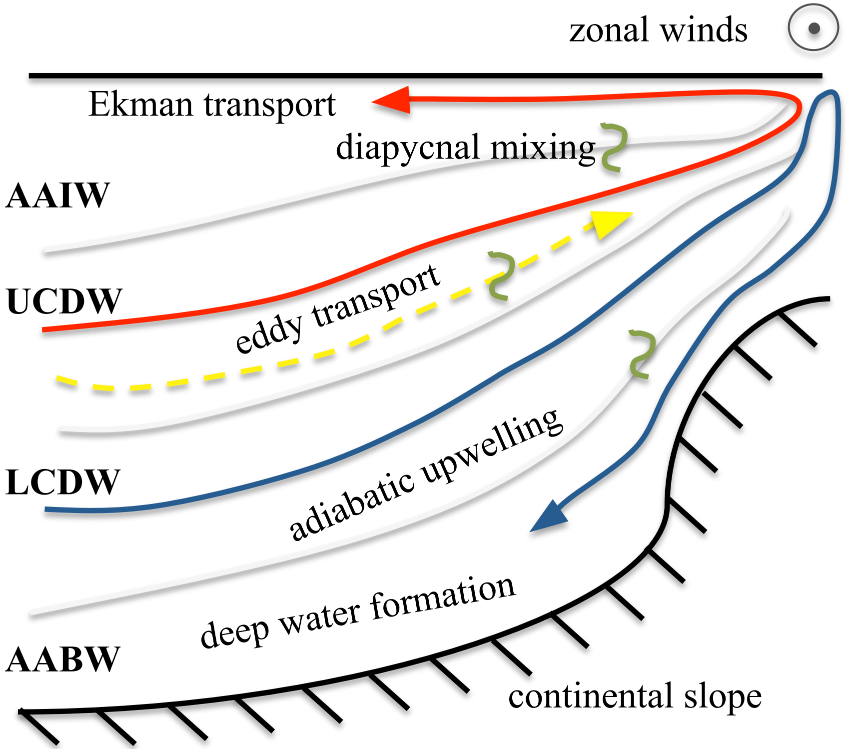
Water Mass Transformation along the Antarctic Peninsula

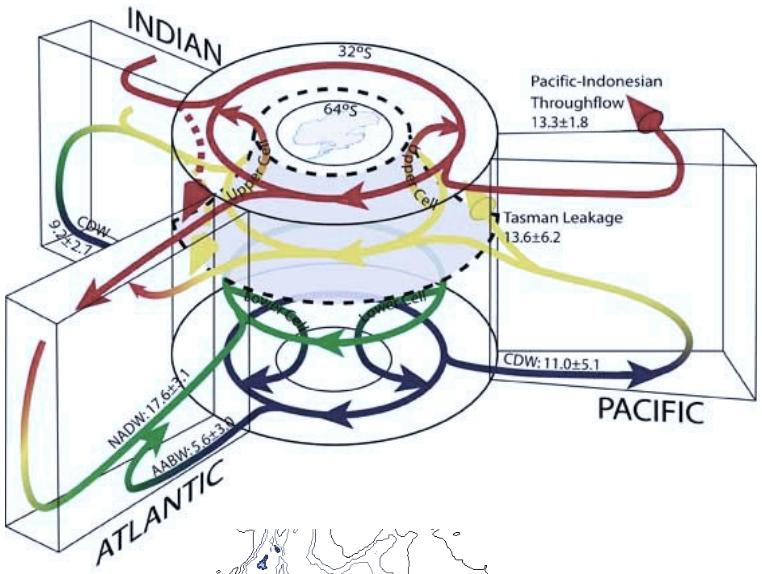


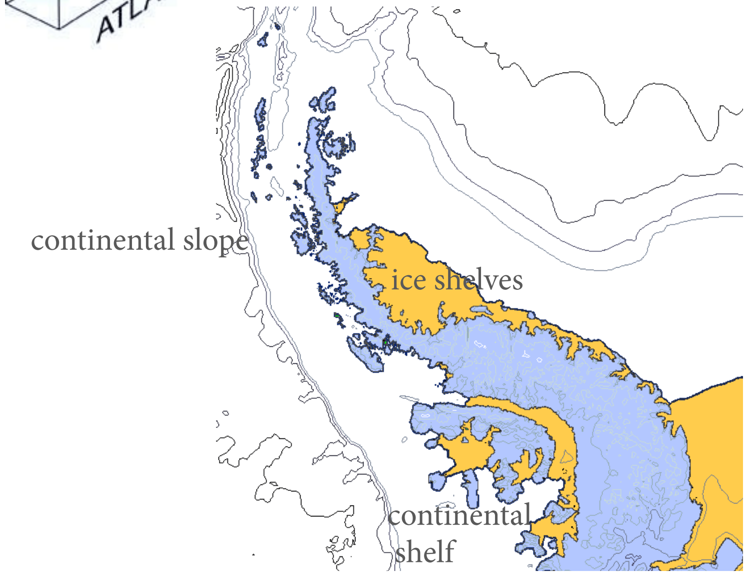
Transect along the continental slope of the Western Antarctic Peninsula

Water Mass Transformation along the Antarctic Peninsula









1. Adiabatic upwelling waters complete global overturning circulation
2. Water masses also transform at mid-depths before reaching the surface
3. UCDW-core eddies transport warm waters onto the continental slope

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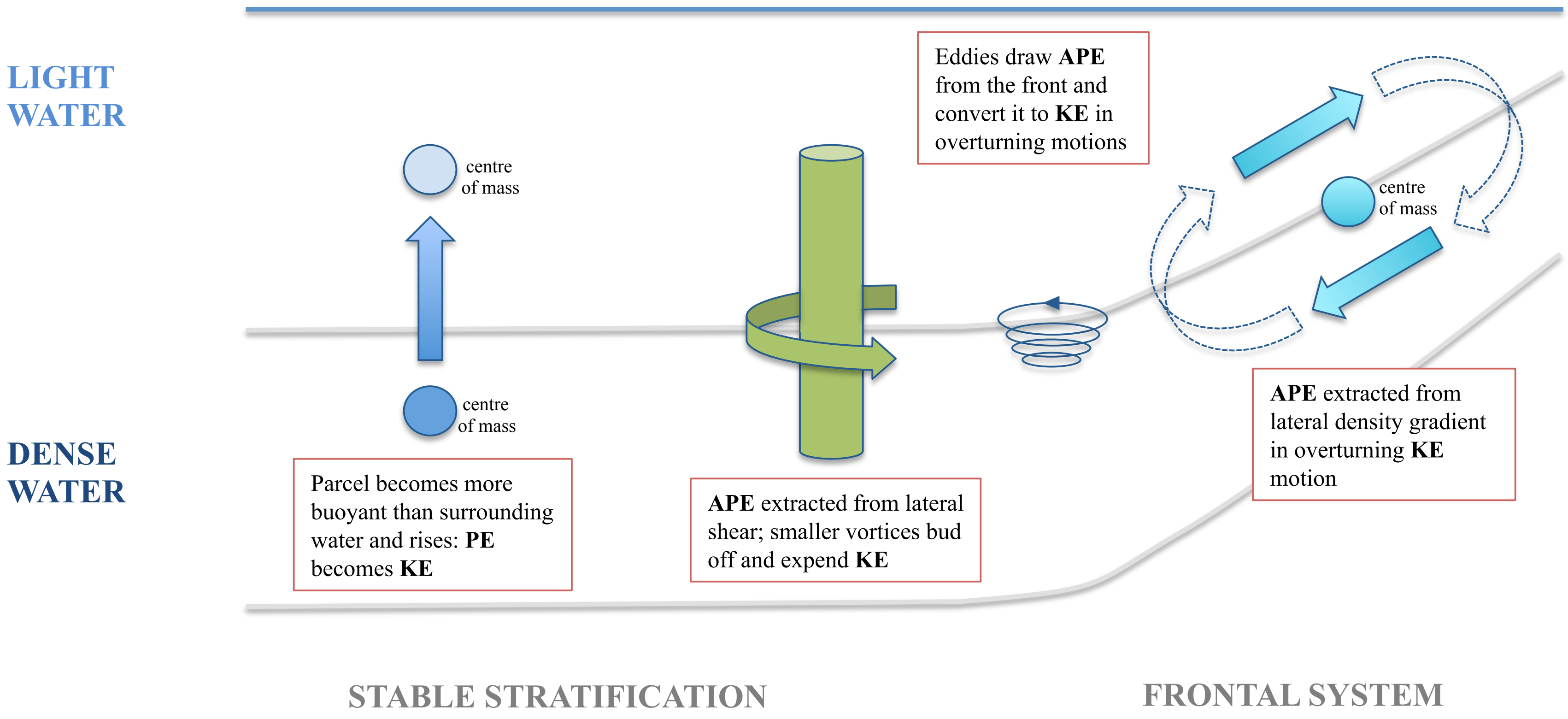
INSTABILITY:	GRAVITIONAL	CENTRIFUGAL	SYMMETRIC
CONDITION:	$N^2 < 0$	$\zeta < -f$	*PV* changes sign



Energy extracted from instabilities can drive a forward cascade of energy to turbulence length-scales

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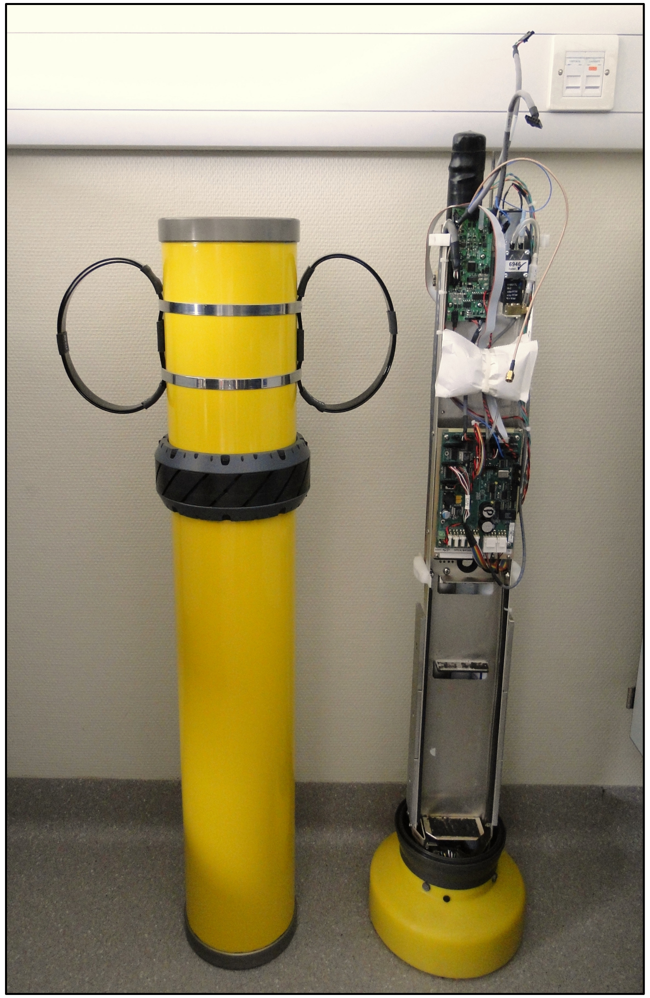
EM-Apex float No. 4980a



Yo-yo dive pattern

12 days (up-down cycle ~ 1 hr 45 mins)

onboard instrument	**bin size (m)**	**parameter**	**accuracy**
Pumped SeaBird Electronics CTD	2.2	pressure	±2 dbar
		temperature	$\pm 2 \times 10^{-3}$ °C
		salinity	$\pm 2 \times 10^{-3}$
Electromagnetic Subsystem	3	horizontal velocities	

Surfaces every few days to communicate via iridium link

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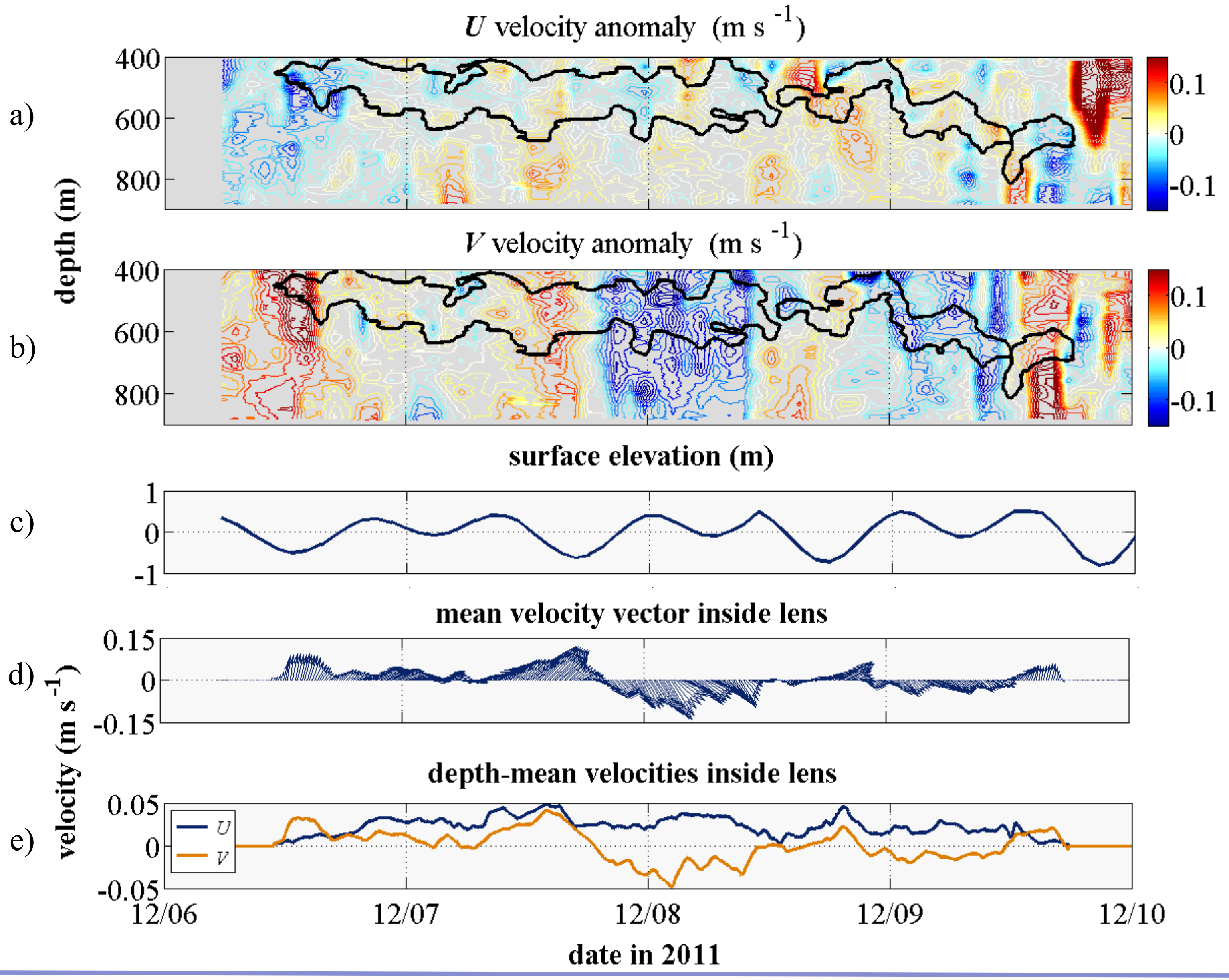
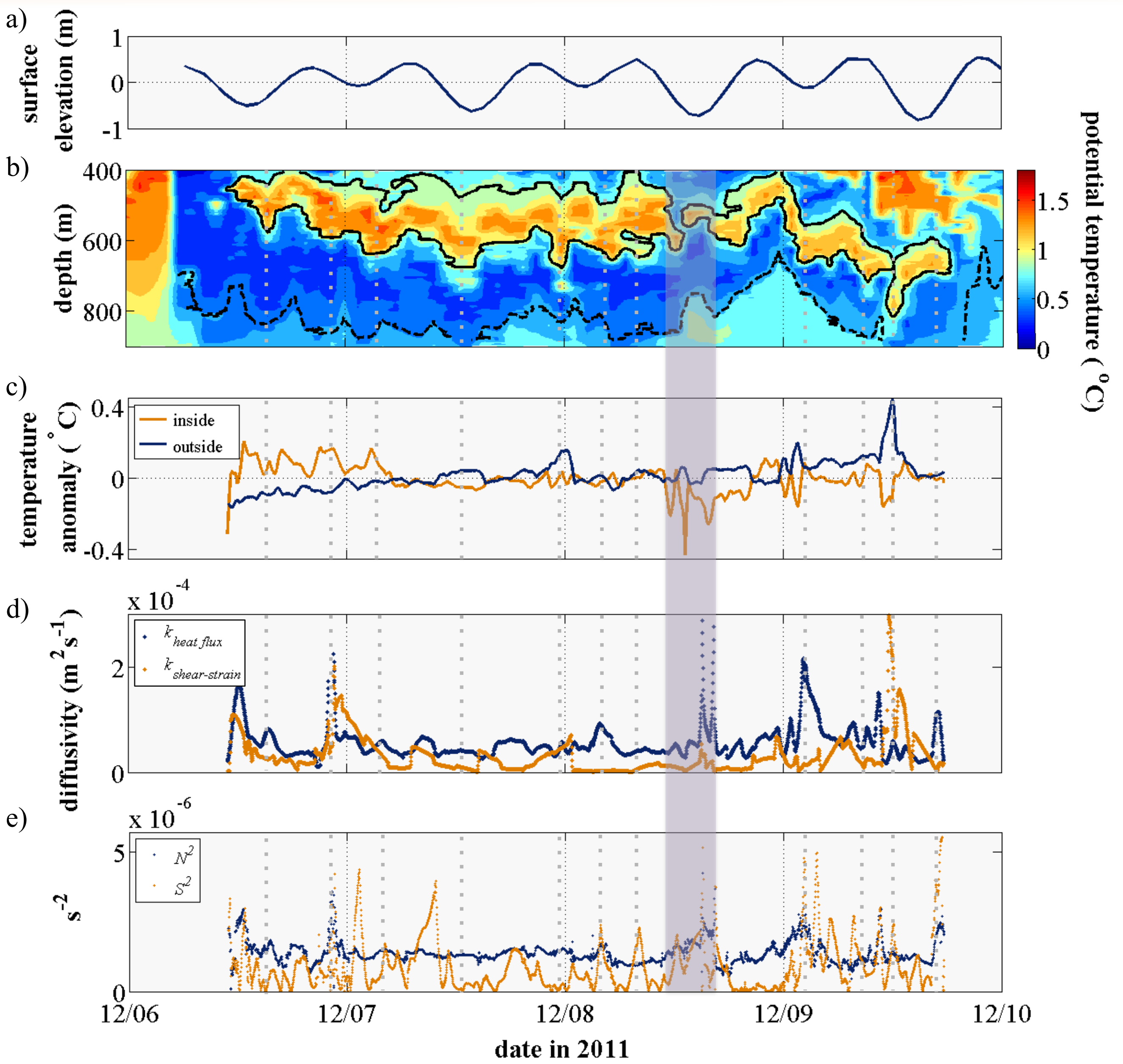
Heat content	$Q = \int \rho C_p T dz$
Heat flux	$Q_{flux} = \rho C_p \int \frac{dT}{dt} dz$
Richardson number	$Ri = N^2/(dU/dz)^2 + (dV/dz)^2$
Ertel potential vorticity (2D approximation)	$EPV_{2D} = f b_z + V_z b_x - V_x b_z$
Balanced Richardson number	$R_{IB} = \frac{f^2 N^2}{M^2}$
Shear-strain parameterisation	$K = K_0 \frac{\langle V_z^2 \rangle^2}{_{\mathrm{GM}}\langle V_z^2 \rangle^2} h_1(R_\omega) j\left(\frac{f}{N}\right)$ $h_1(R_\omega) = \frac{3(R_\omega + 1)}{2\sqrt{2}R_\omega\sqrt{R_\omega - 1}}$ $R_\omega = \frac{\langle V_z^2 \rangle}{N^2 \langle \xi_z^2 \rangle}$ $j(f/N) = \frac{f \operatorname{arccosh}(N/f)}{f_{30} \operatorname{arccosh}(N_0/f_{30})}$
Osborn’s relation	$k_{shear-strain} = \Gamma \frac{\varepsilon}{N^2}$

Water Mass Transformation along the Antarctic Peninsula



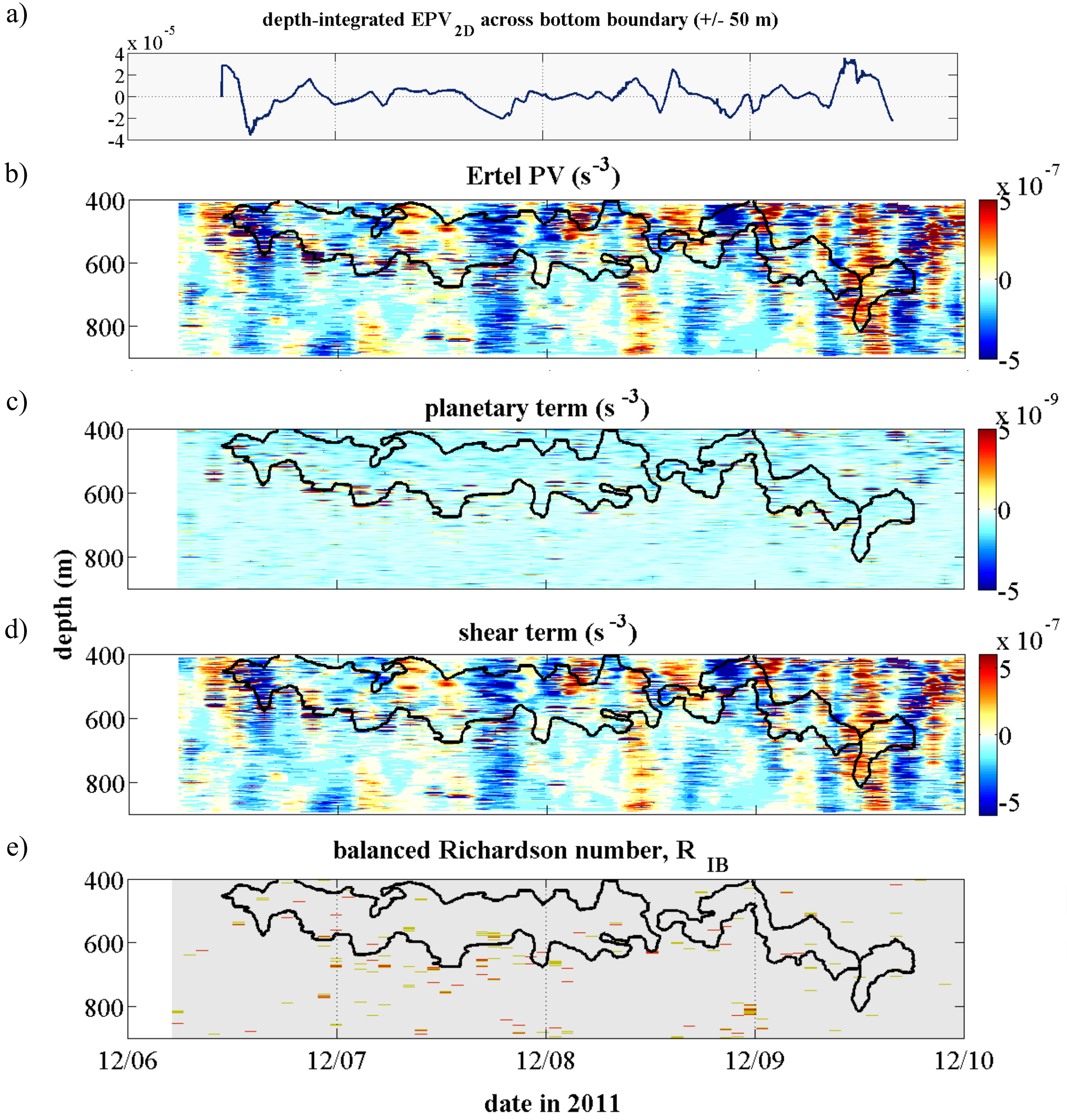
- diurnal variability on cross-slope velocity (V)
- semi-diurnal banding of velocities
- no clear eddy rotation

Water Mass Transformation along the Antarctic Peninsula



UCDW lens loses heat to LCDW beneath as shear instability drives turbulent mixing

Water Mass Transformation along the Antarctic Peninsula



$$EPV_{2D} = fb_z + V_z b_x - V_x b_z$$

$$fb_z$$

$$V_z b_x - V_x b_z$$

Instability

- gravitational
- gravitational/symmetric
- symmetric

Potential vorticity flux, enhanced shear and symmetric instabilities along bottom boundary

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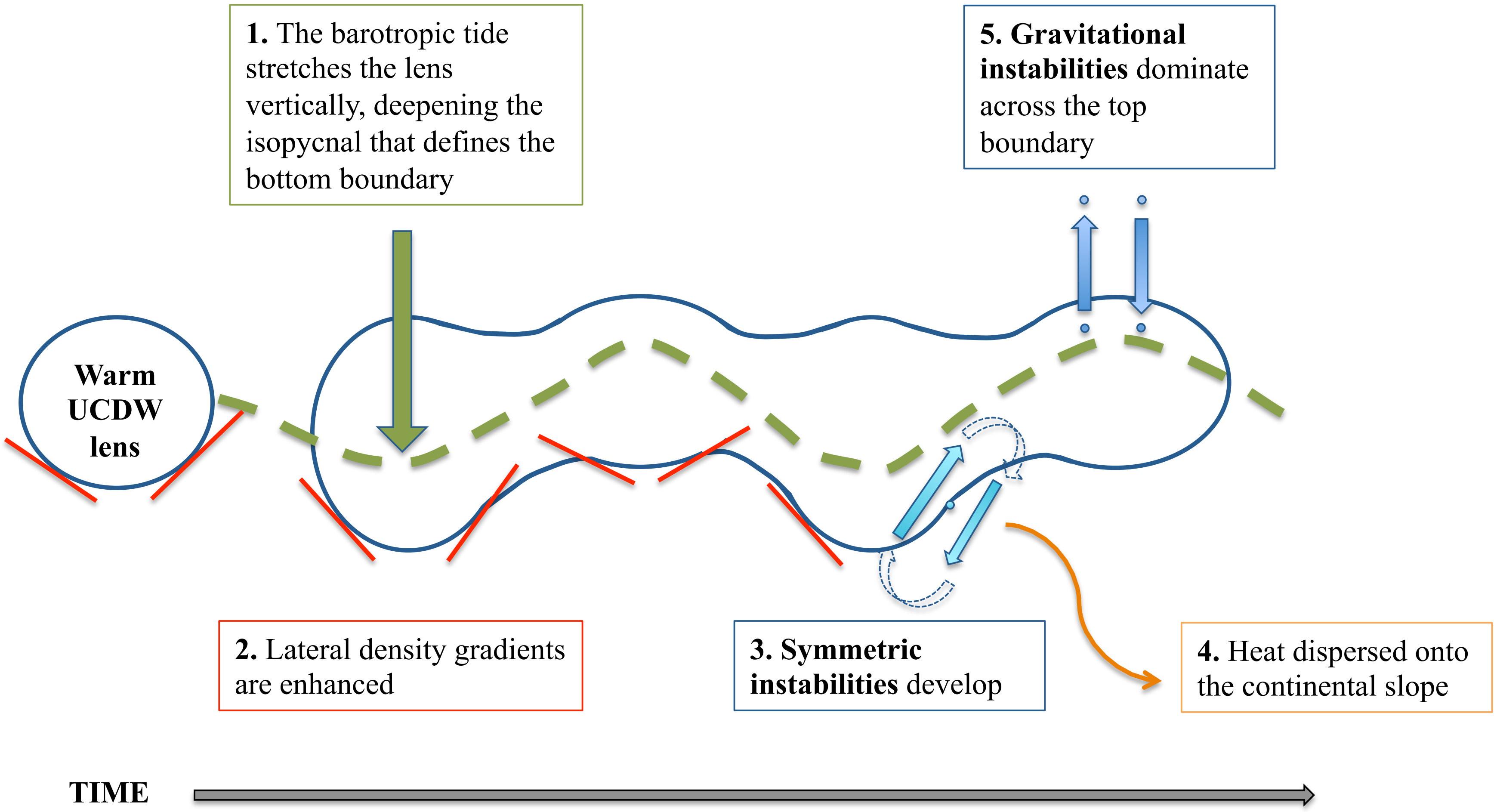

Eddy-tide interaction enhances submesoscale instabilities

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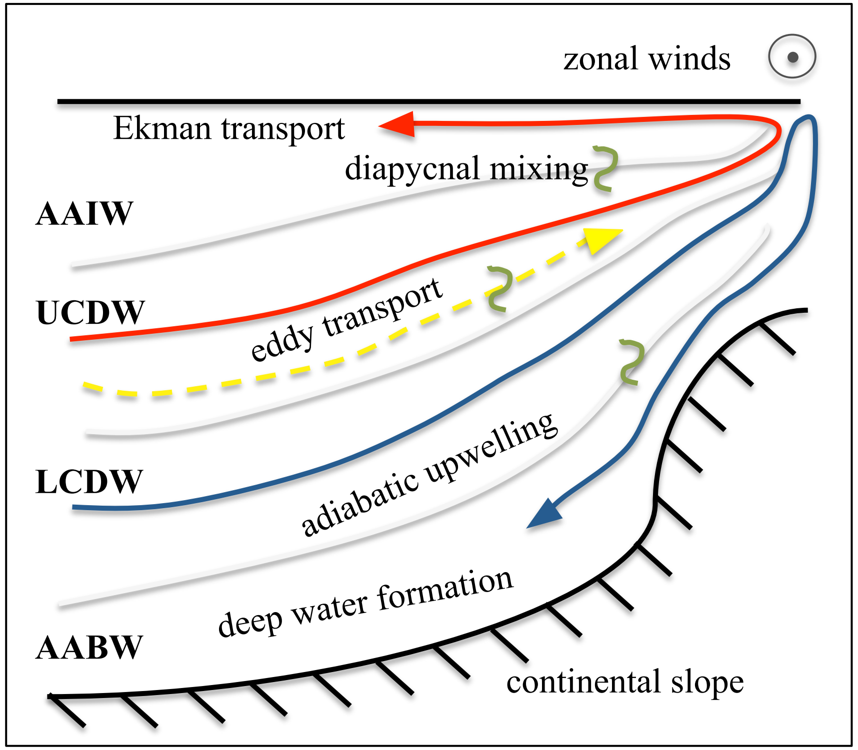

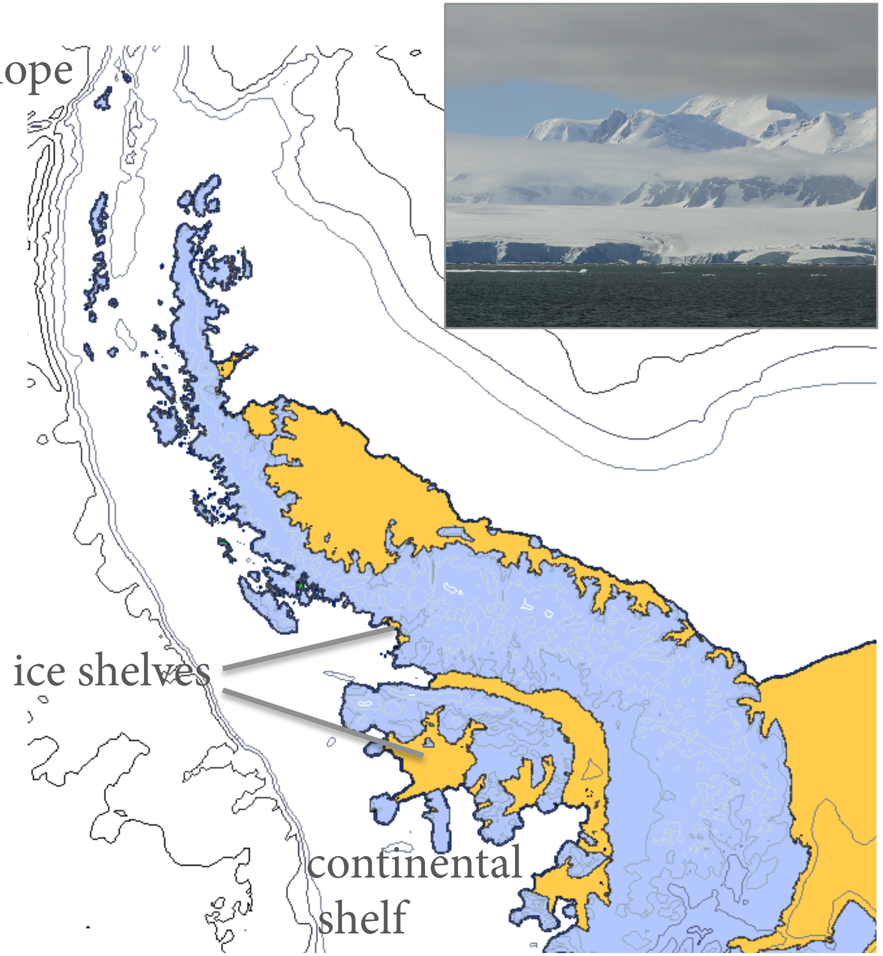

- Further evidence of mid-depth watermass transformation over the Antarctic continental slope
- Mechanism by which UCDW-core eddies can disperse heat onto the continental slope at mid-depths where marine glacier melt is sensitive to ocean heat content

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1. A submesoscale lens of UCDW propagates along-slope within LCDW;
2. is modified semi-diurnally;
3. loses heat to LCDW across the bottom boundary;
4. where diffusivities are elevated and shear instabilities arise.
5. Shear-dominated EPV along the bottom boundary is consistent with a gradient flux from UCDW to LCDW;
6. and associated with symmetric instabilities forced by the barotropic tide.

Shear instabilities drive turbulent mixing across the UCDW-LCDW boundary.

Summary

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Conclusions

1. Water masses transform at depth over the Antarctic continental slope;
supports the hypothesis that diabatic processes contribute to mid-depth watermass transformation.

2. Eddy-tide interactions can enhance submesoscale instabilities, driving turbulent mixing;
a mechanism by which UCDW-core eddies can disperse heat onto the slope and at mid-depths, where the melting of marine glaciers is linked to ocean heat content.