Dynamics paradigm of geostrophic cross-isobath transport (GCT) over a highly variable shelf topographic regime

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Geostrophic cross-isobath transport (GCT) dynamics

For small Rossby number,

Barotropic PV equation

$$U^*\frac{f}{H^2}\frac{\partial H}{\partial x^*}=\nabla\times\left(\frac{\tau_b}{\rho_0 H}\right)-\nabla\times\left(\frac{\tau_s}{\rho_0 H}\right)$$

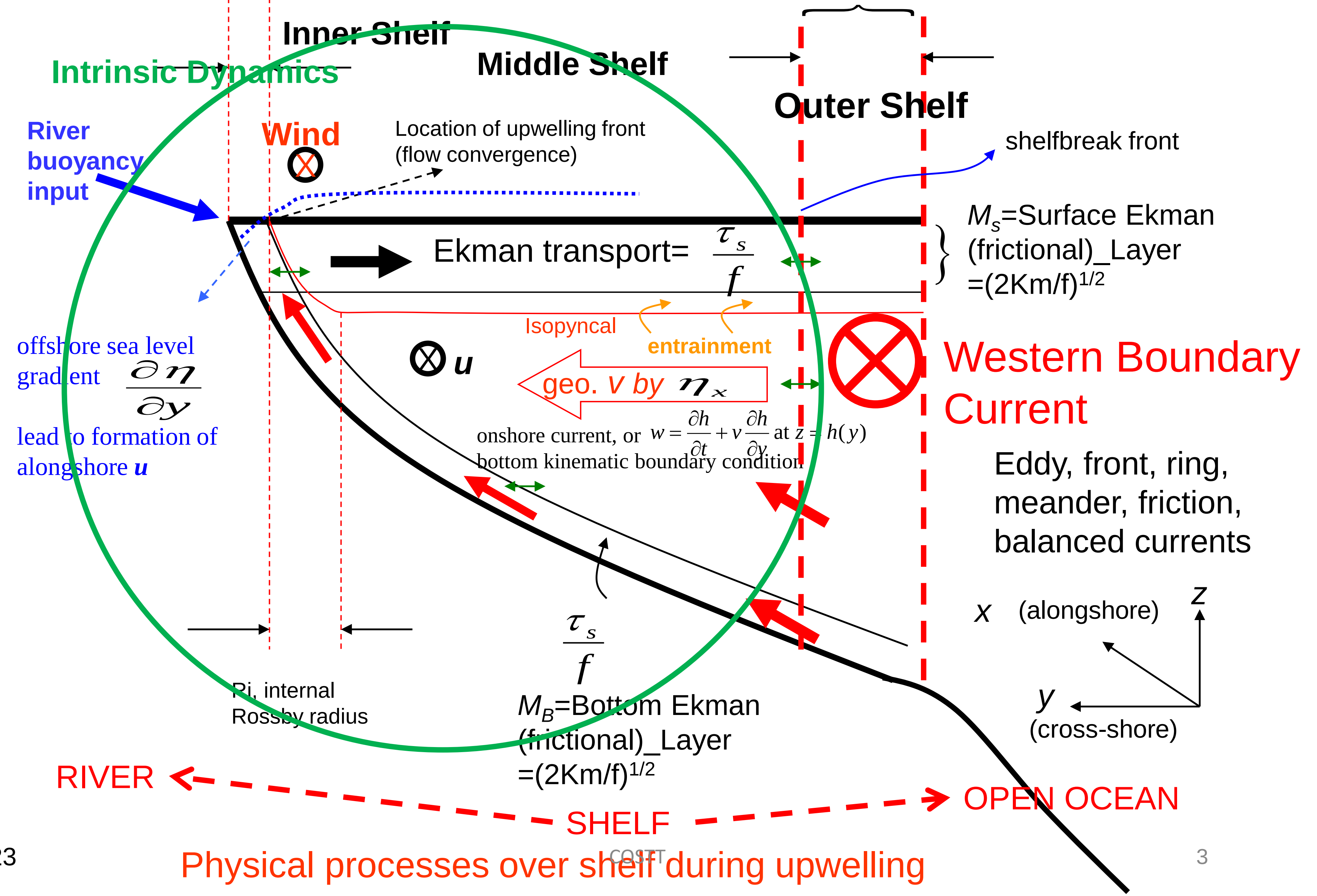
$$U^*=\frac{1}{f}\left[\boxed{H\frac{\nabla\times\tau_b-\nabla\times\tau_s}{\rho_0}\left(\frac{\partial H}{\partial x^*}\right)^{-1}}+\boxed{\frac{(\tau_{sy^*}-\tau_{by^*})}{\rho_0}}\right]$$

Cross-isobath transport

Geostrophic Transport

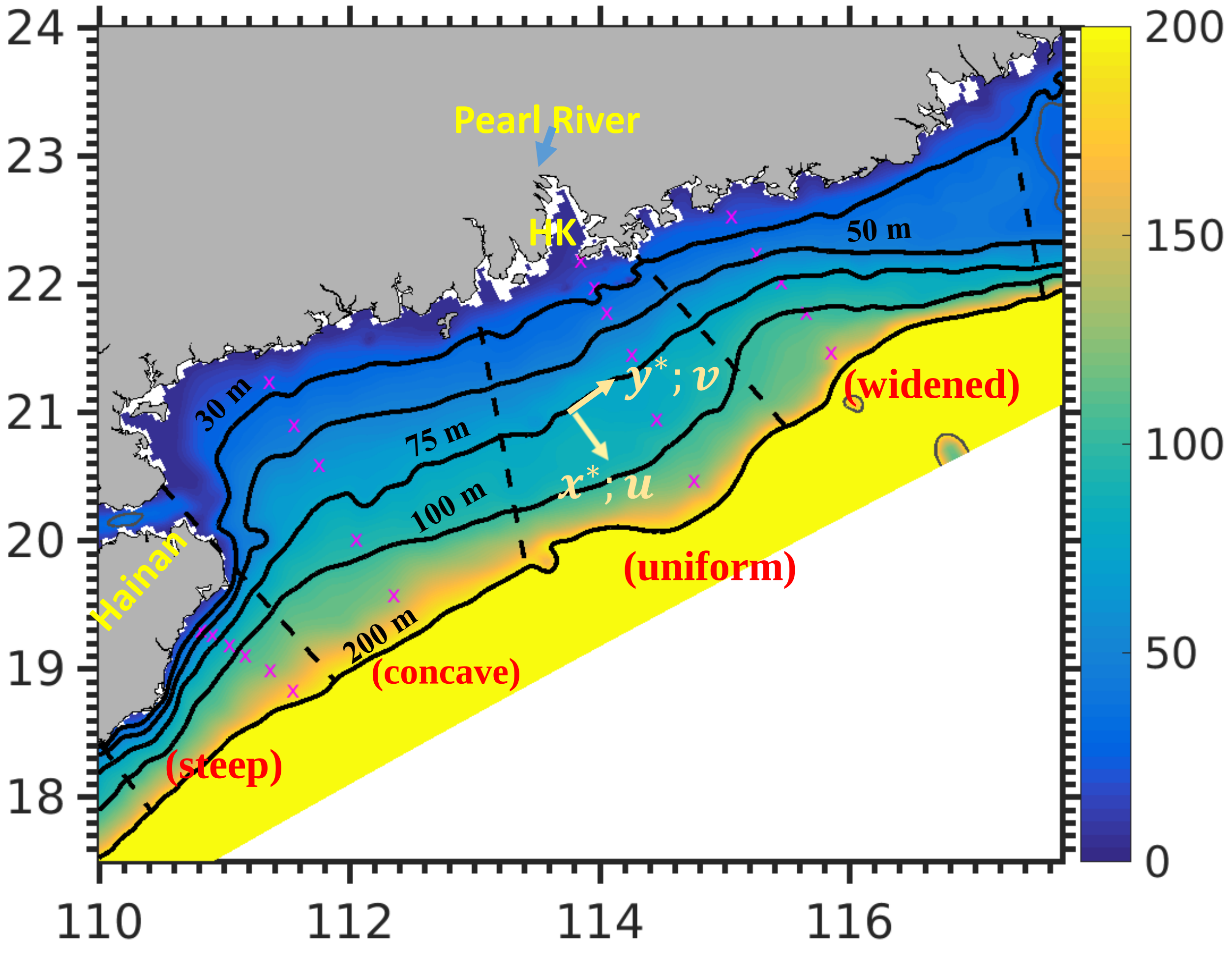
Ekman Transport

Two-dimensional Upwelling Dynamics



Physical processes over shelf during upwelling

Variable shelf topography in the northern South China Sea



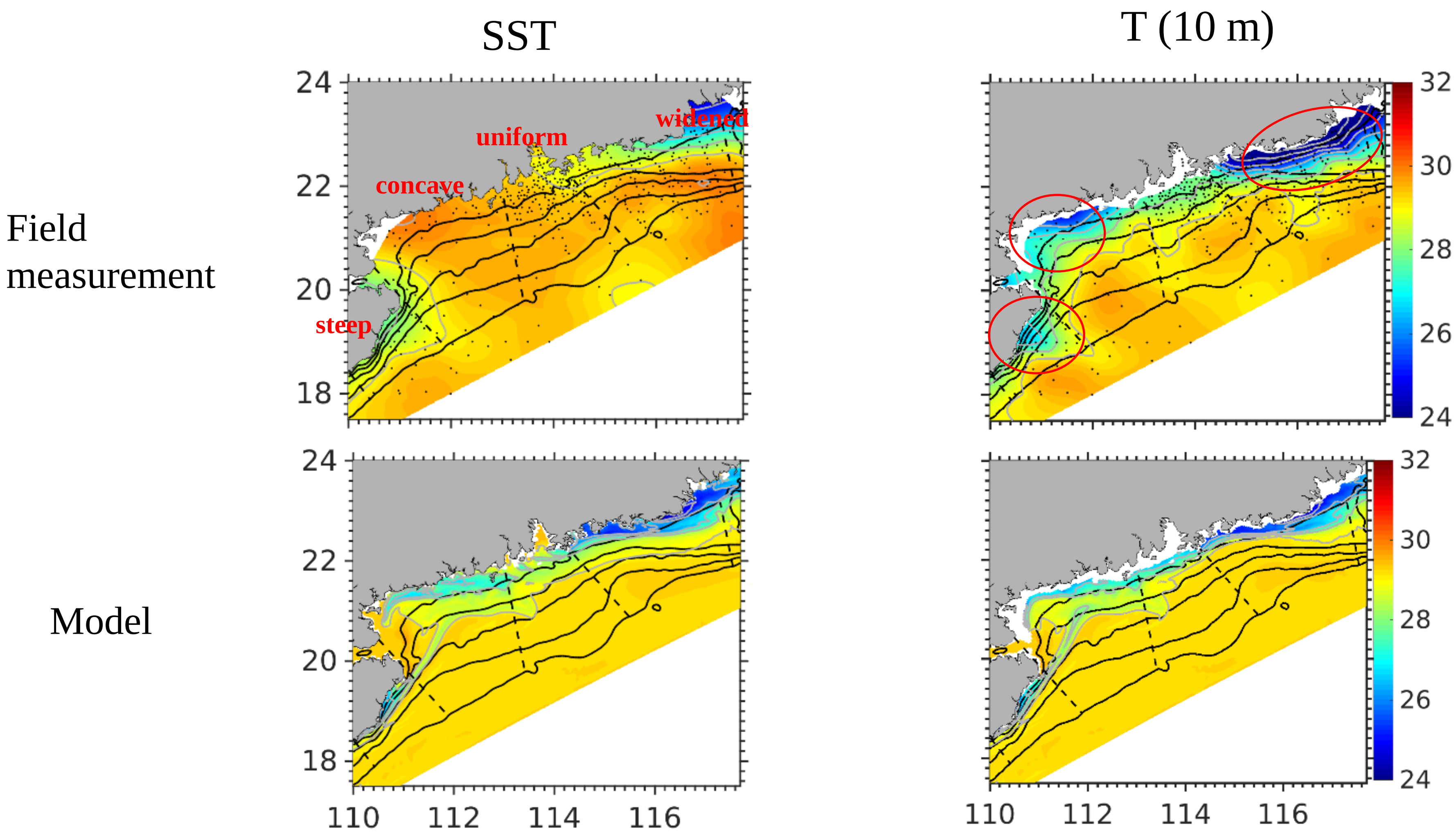
Scientific questions:

-what is the 3-dimensional response to upwelling-favorable wind forcing over the unique varying topography in the different regions of the NSCS?

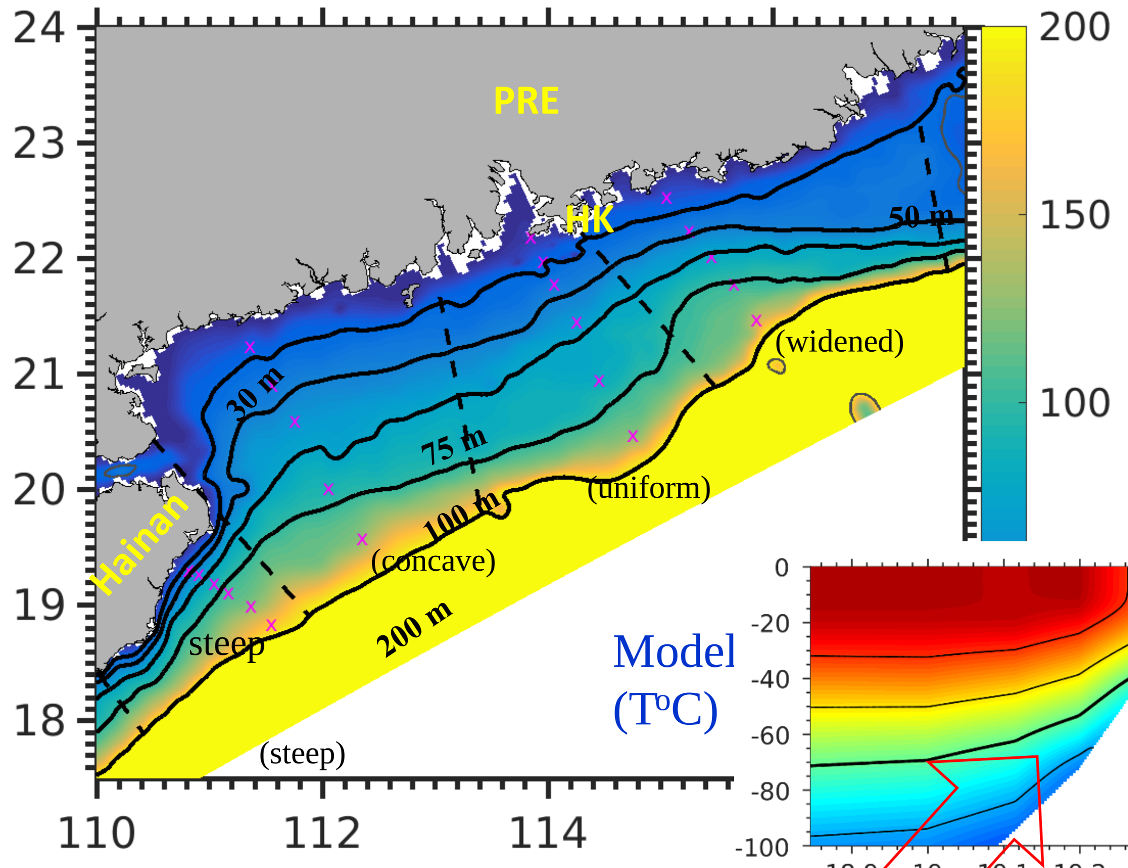
-what is the inter-connection and transitional effect among the neighboring regions along the changing of topography?

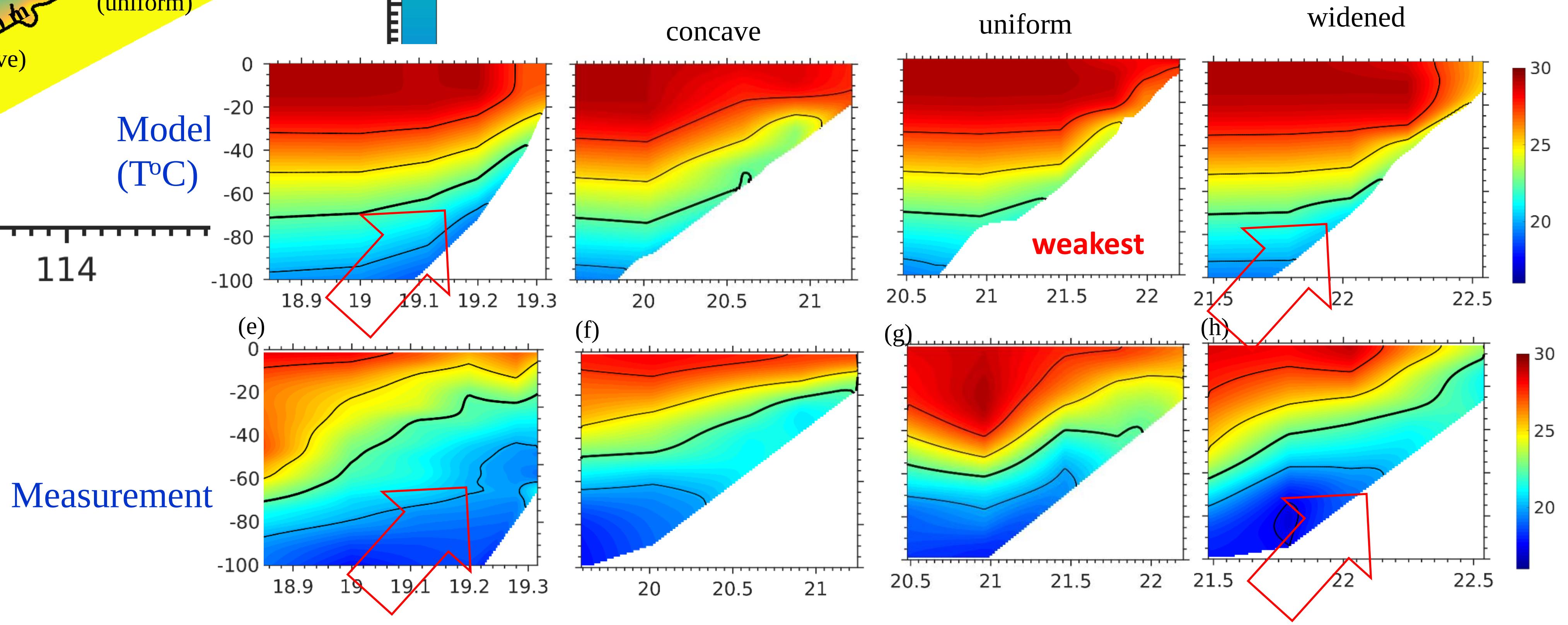
-what is the underlying flow-topography dynamics in different topographic regimes?

Characteristic response

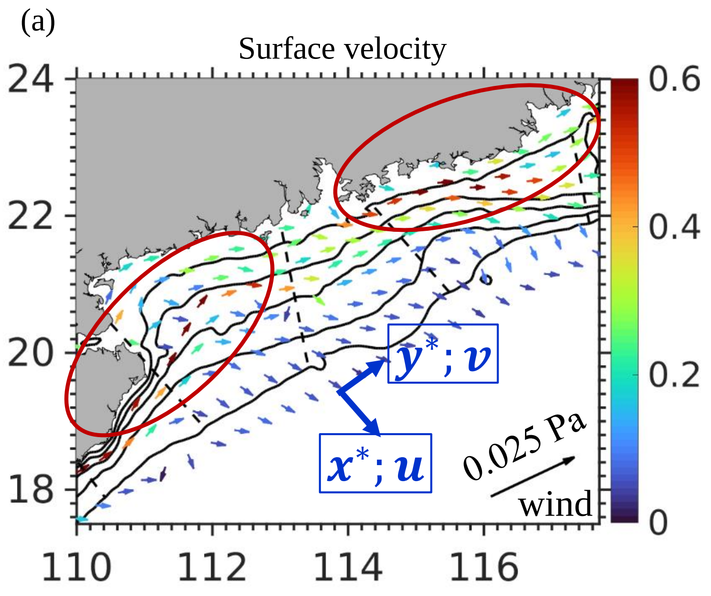


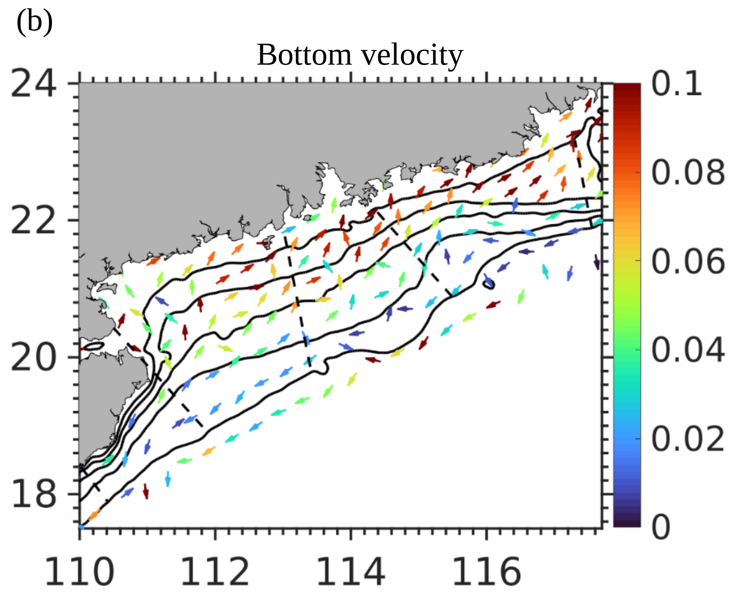
Characteristic upslope transport

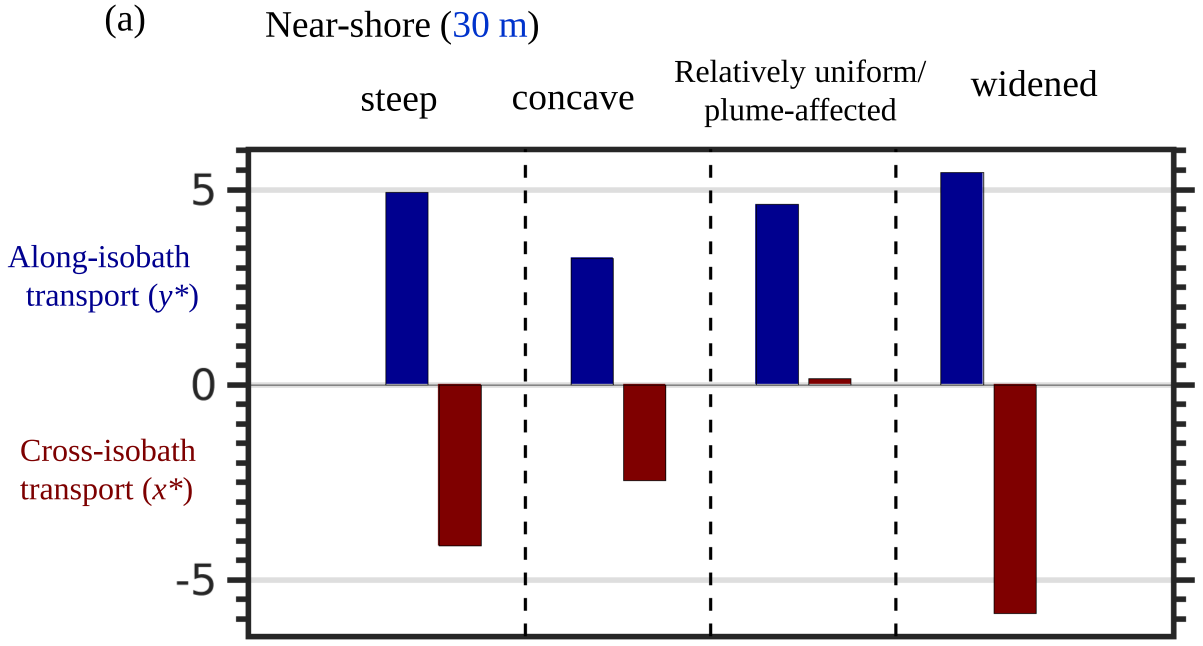


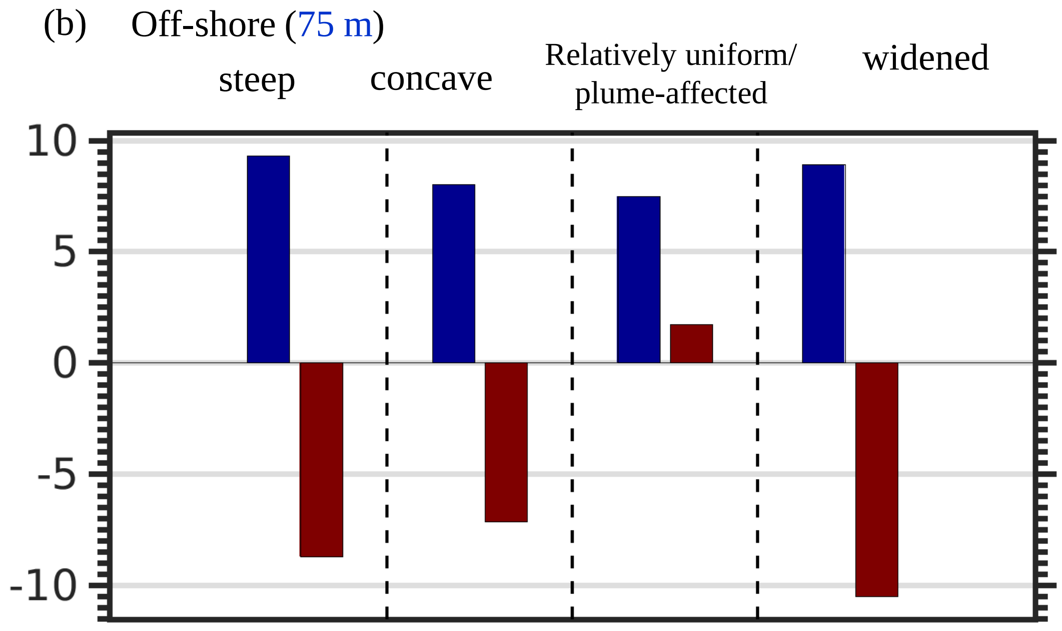


Characteristic along- and cross-isobath transport







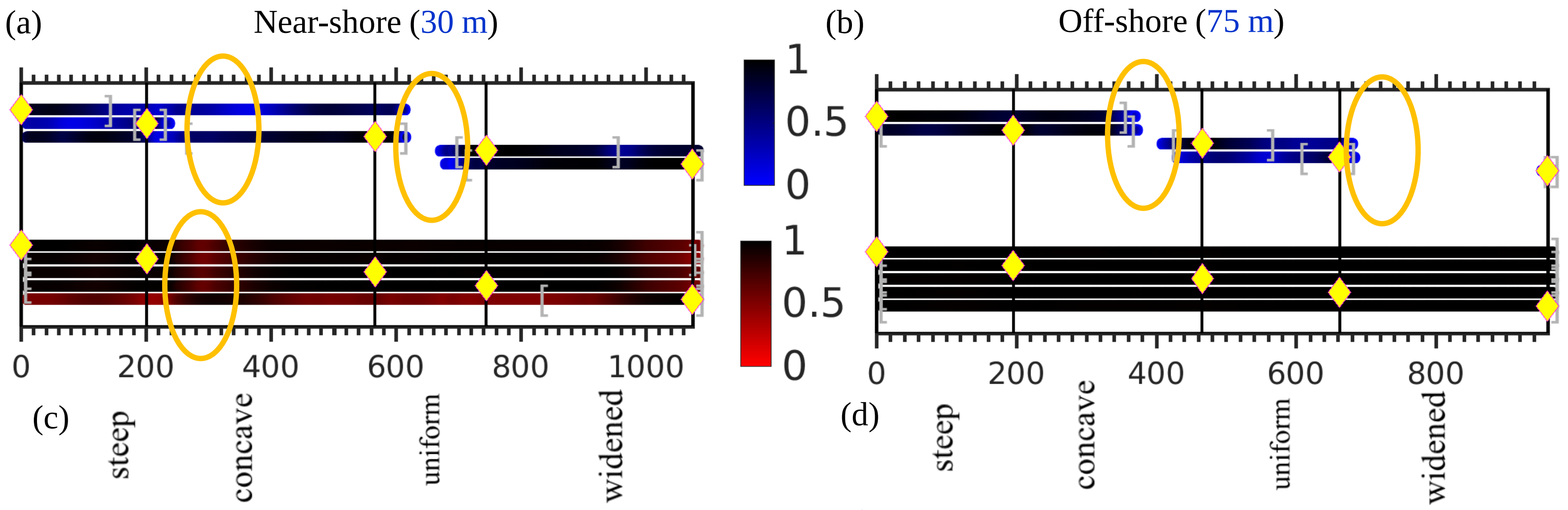


Along-shore inter-connection

Remote effect vs. Local effect

cross-isobath (u)

along-isobath (v)

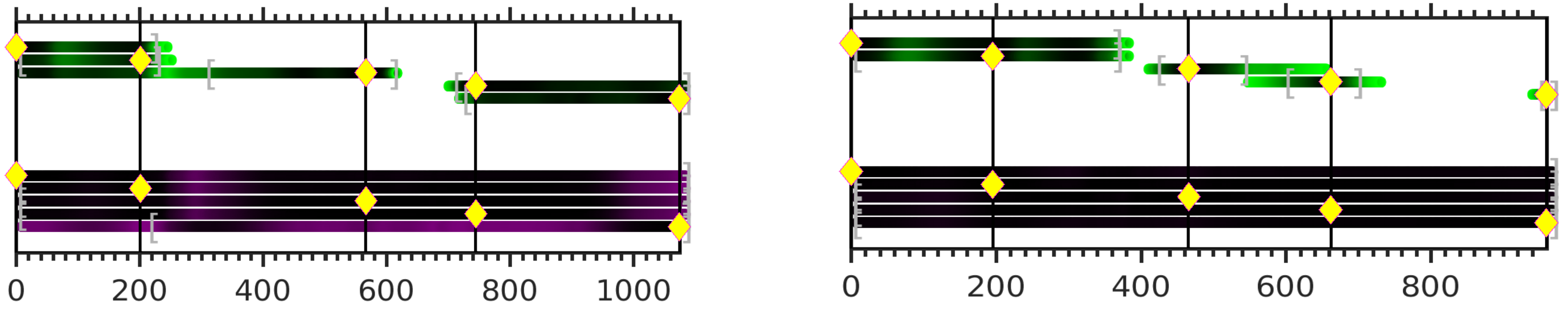


[ ] represents the range of correlation (> 0.5)

The yellow diamond represents the start point of calculating the correlation. The colorbar indicates the correlation coefficient.

along -isobath geostrophic balance transport/cross-isobath transport

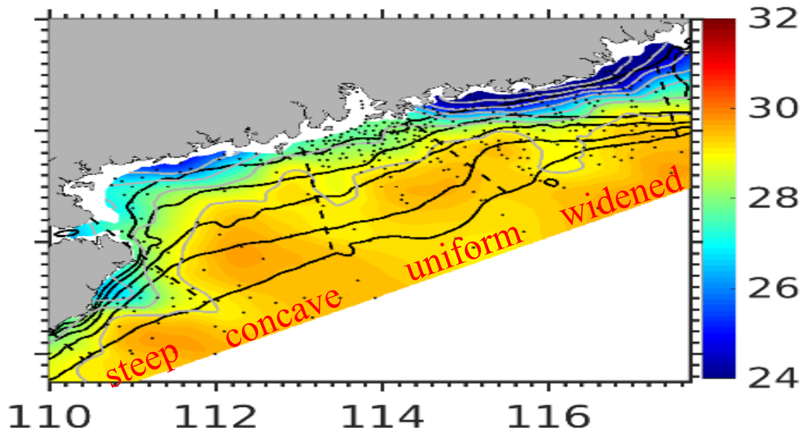
cross-isobath geostrophic balance/along-isobath transport

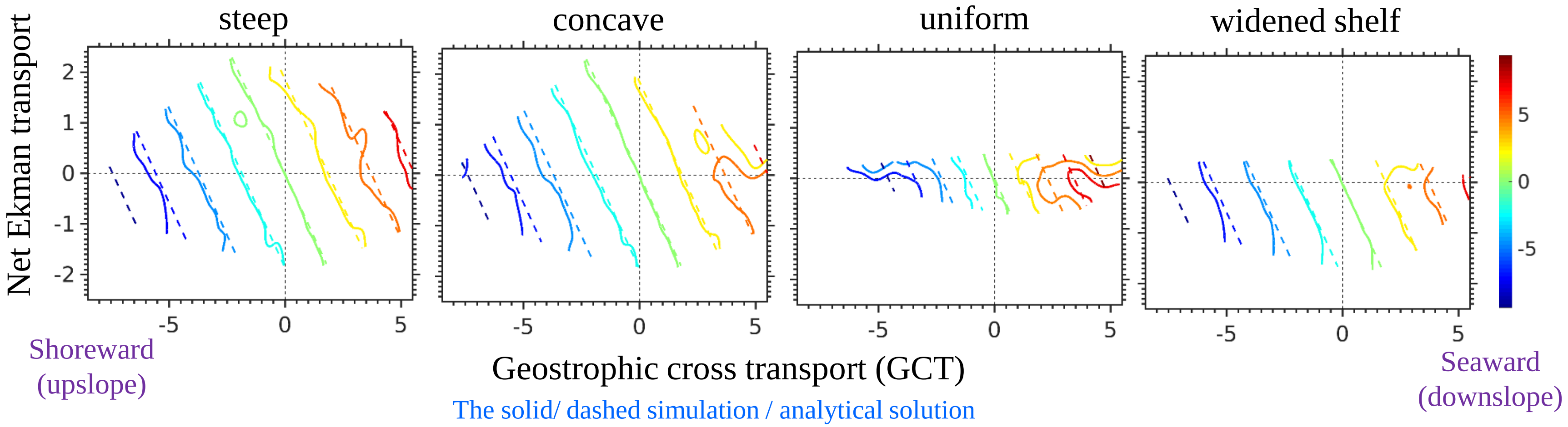


Dynamic understanding: barotropic GCT

For low Rossby number, barotropic cross-isobath transport U^*

$$U^* = \underbrace{\frac{1}{f}[H\frac{\nabla\times\tau^b-\nabla\times\tau^s}{H_{x^*}\rho_0}}_{\text{GCT}} + \underbrace{\frac{\tau^{sy^*}-\tau^{by^*}}{\rho_0}]}_{\text{Ekman}}$$





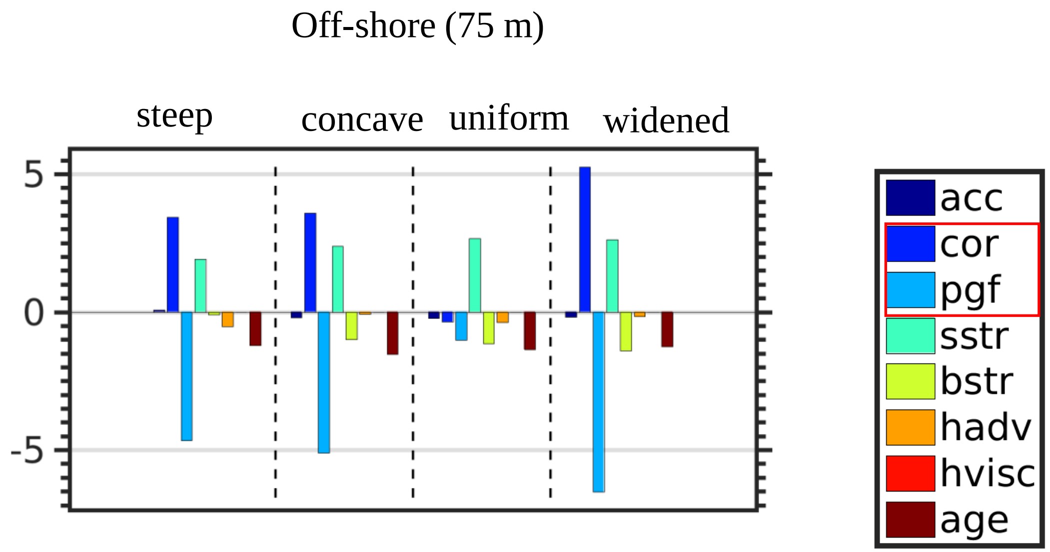
The solid/ dashed simulation / analytical solution

GCT upslope transport

Along-isobath momentum equation:

$$\overbrace{\frac{\partial(\overline{v^*D})}{\partial t}}^{ACC} = [-\overbrace{\left(\frac{\partial \overline{u^*v^*D}}{\partial x^*}+\frac{\partial \overline{v^{*}}^{2}D}{\partial y^*}\right)}^{HADV} \boxed{\overbrace{-f\overline{u^*}D}^{COR}\overbrace{-\frac{1}{\rho_0}\overline{P_{y^*}D}}^{PGF}} + \overbrace{\overline{DF_{y^*}}}^{HVISC} + \overbrace{\frac{\tau_s^{y^*}}{\rho_0}}^{SSTR} \overbrace{-\frac{\tau_b^{y^*}}{\rho_0}}^{BSTR}],$$

*u** is upslope transport



Geostrophic dominant

Source of along-isobath pressure gradient force in GCT upslope transport

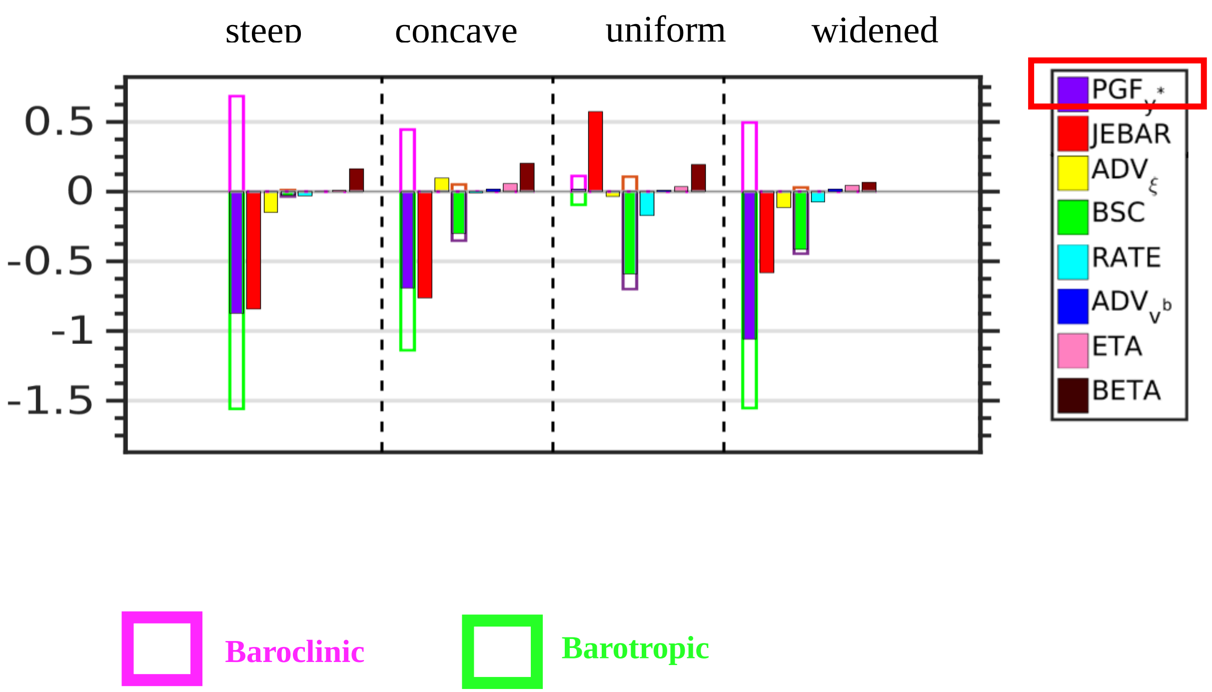
$$\boxed{\overbrace{-\frac{1}{\rho_0}\overline{P_{y*}}D}^{\mathrm{PGF}_{y*}}}$$

$$= \overbrace{-\frac{D^2}{D_{x*}}J\left(\chi,\frac{1}{D}\right)}^{\mathrm{JEBAR}} + \overbrace{\frac{H}{H_{x*}}\int_{-H}^{\eta}(u\xi)_{x*}+(v\xi)_{y*}dz}^{\mathrm{ADV}_{\xi}} + \boxed{\overbrace{\frac{H}{H_{x*}}\nabla\times\frac{\tau_b-\tau_s}{\rho_0}}^{\mathrm{BSC}}} + \overbrace{\frac{H}{H_{x*}}\nabla\times\int_{-H}^{\eta}\boldsymbol{v}_t dz}^{\mathrm{RATE}}$$

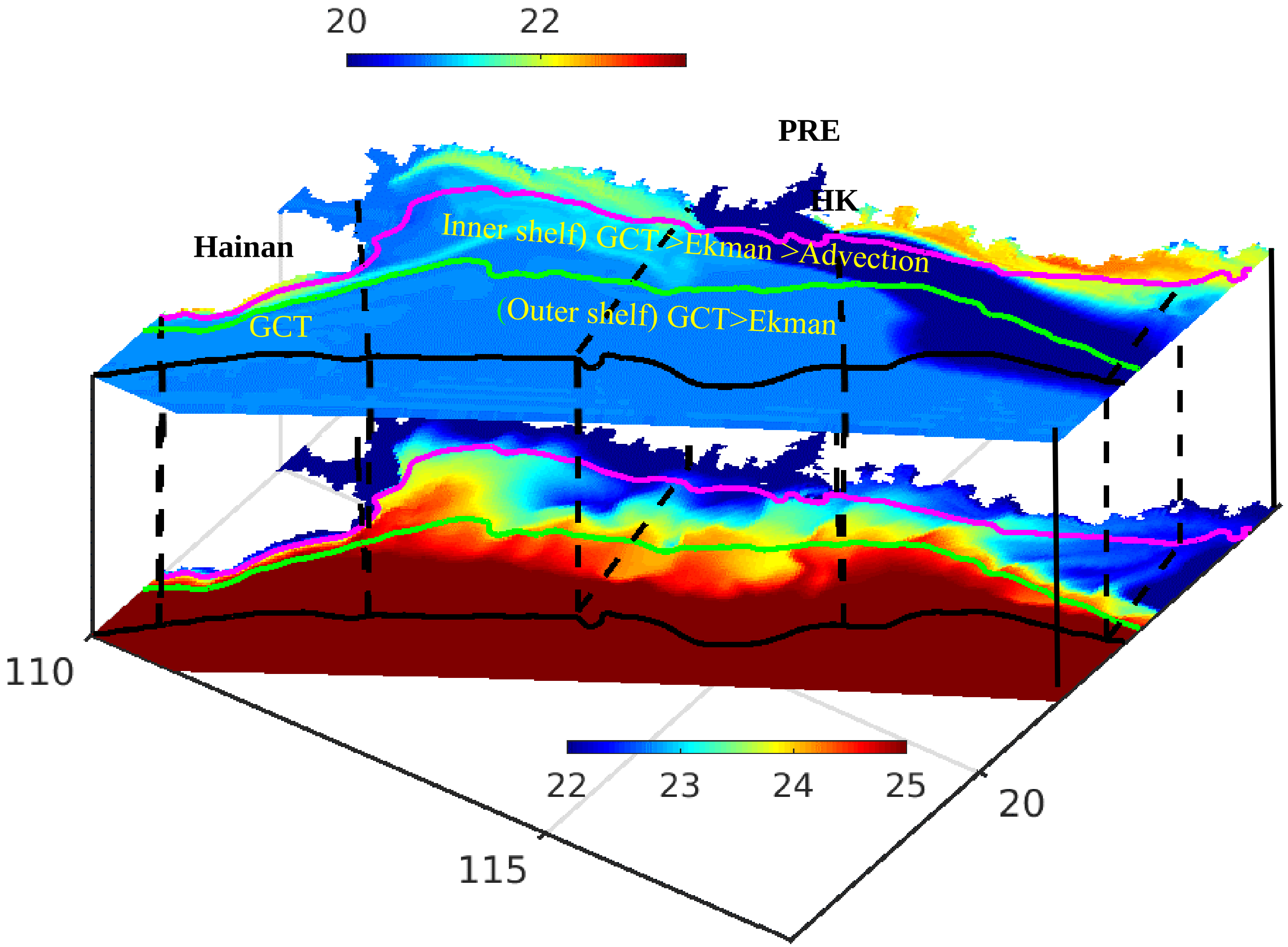
$$+ \overbrace{\frac{H\eta_{y*}}{H_{x*}}\left(uu_{x*}+vu_{y*}\right)^s + \frac{H\eta_{x*}}{H_x *}\left(uv_{x*}+vv_{y*}\right)^s - \frac{H}{H_{x*}\rho_0}J(P^S,\eta) - \frac{\eta_{y*}\chi_{x*}}{D_{x*}} - \frac{Hf}{H_{x*}}\frac{\partial\eta}{\partial t}}^{\mathrm{ETA}}$$

$$+ \overbrace{\frac{H}{H_{x*}}\int_{-H}^{\eta}\beta v^N\,dz}^{\mathrm{BETA}} + \overbrace{H\left(uv_{x*}+vv_{y*}\right)^b}^{\mathrm{BHADV}} + \overbrace{\frac{H}{H_{x*}}\nabla\times\int_{-H}^{\eta}\boldsymbol{hvisc}\,dz}^{\mathrm{HVISC}}$$

along the 75 m isobath



Summary



1. GCT dominates and intensifies in the topographic regime with highly variable shelf (steep, concave and widened shelf);

2. GCT is mainly induced by JEBAR effect baroclinically and bottom stress curl barotropically.