What drives mean flow in the Mid-Atlantic Bight?

(A very preliminary look)

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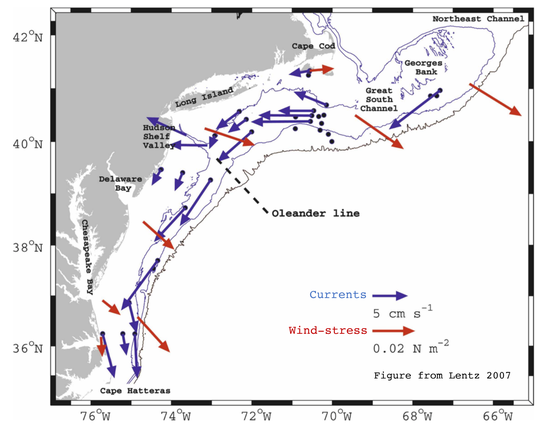
What is the Mean flow?



"Causes" from Lentz 2007:

- Not wind (too weak, wrong way)
- Not alongshore density gradient in domain (too weak)
- Zhang et al. 2016 attributes to forcing from outside domain
- Locally "driven" by $d\eta/dy=1.0 \times 10^{-7}$
- But is this a "forcing"?

How to think about?

Linear PV model on β-plane with depth-averaged stratification; bottom friction parameterized by near bottom geostrophic flow. Assumes Rd<<Topographic length scale. Following Csanady 1985 and Vennell & Malanotte-Rizzoli 1987.

$$\Gamma_x(z) = \int_z^0 \frac{\rho_x}{\rho_0} dz' \qquad \theta_x = \int_{-H}^0 \Gamma_x dz'$$

$$-fV = -gH\eta_x - g\theta_x + \frac{\tau^x_{\text{wind}}}{\rho_0} - \frac{\tau^x_{\text{bot}}}{\rho_0}$$

$$fU = -gH\eta_y - g\theta_y + \frac{\tau^y_{\text{wind}}}{\rho_0} - \frac{\tau^y_{\text{bot}}}{\rho_0}$$

$$\rho_0\tau^x_{\text{bot}} = -\frac{gr}{f}(\eta_y + \Gamma_y(-H))$$

$$\rho_0\tau^y_{\text{bot}} = +\frac{gr}{f}(\eta_x + \Gamma_x(-H))$$

Which leads to

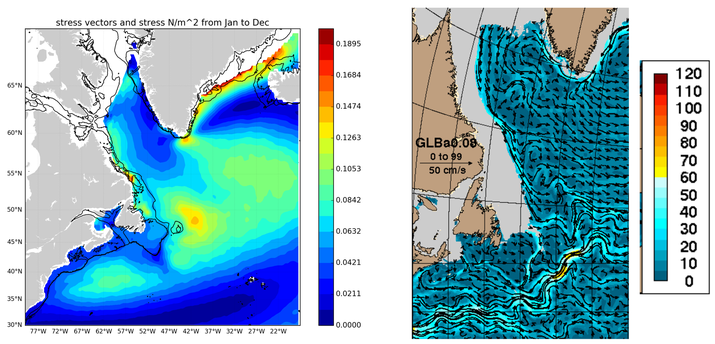
$$0 = -J(\eta, H/f) + r\vec{\nabla}\cdot\left(\nabla\frac{\eta}{f^2}\right) + \nabla\times\frac{\vec{\theta}}{f} + r\vec{\nabla}\cdot\frac{\vec{\Gamma}_H}{f^2}$$

$$\vec{\Gamma}_H = \hat{\imath}\Gamma_x(-H) + \hat{\jmath}\Gamma_y(-H) \quad \text{and} \quad \vec{\theta} = \hat{\imath}\theta_x + \hat{\jmath}\theta_y$$

P.V. written H/f for numerical stability. No flow through coast and no gradient at open boundaries as BC. (If you ever need to implement these BC's, ask me.) You can think of this as including JEBAR; or you can think about it an easier way…

Can it be remote winds and slope currents?

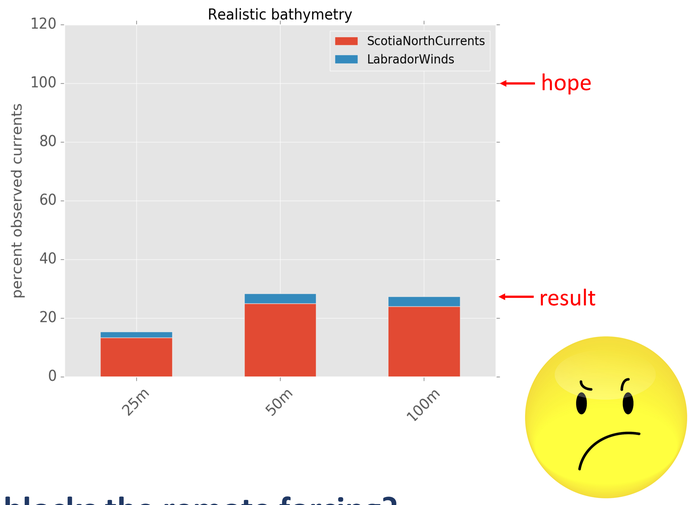
Annual average winds from SCOW and slope currents from HYCOM:



Force PV model with 30 cm/s slope currents Scotian Shelf and poleward; idealized/reasonable winds on Labrador shelf.

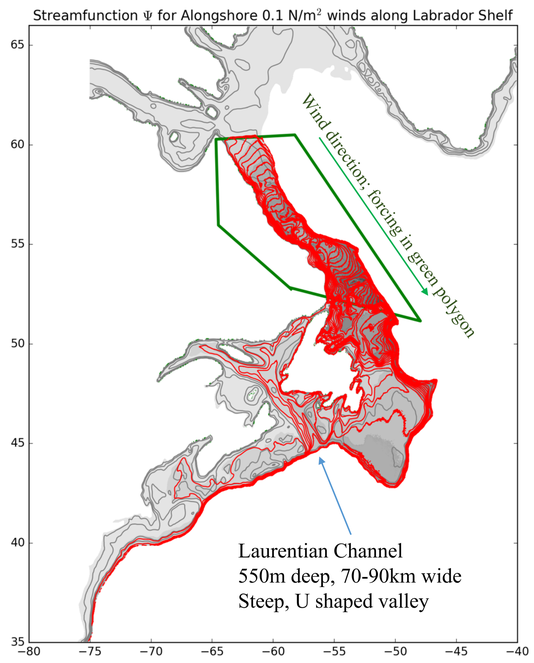
NOT forcing from north of Laurentian Channel!

Currents in MAB from model relative to Lentz 2007 observations:



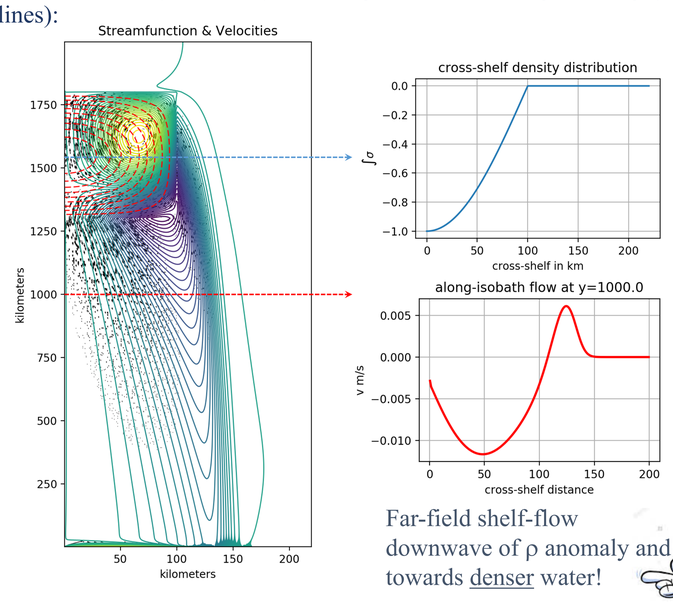
What blocks the remote forcing?

The Laurentian Channel. Circulation forced by Labrador wind forcing:

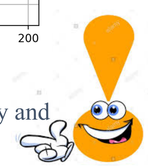


Could it be remote density forcing?

Streamfunction (solid lines) caused by idealized density anomaly (red-dashed lines):

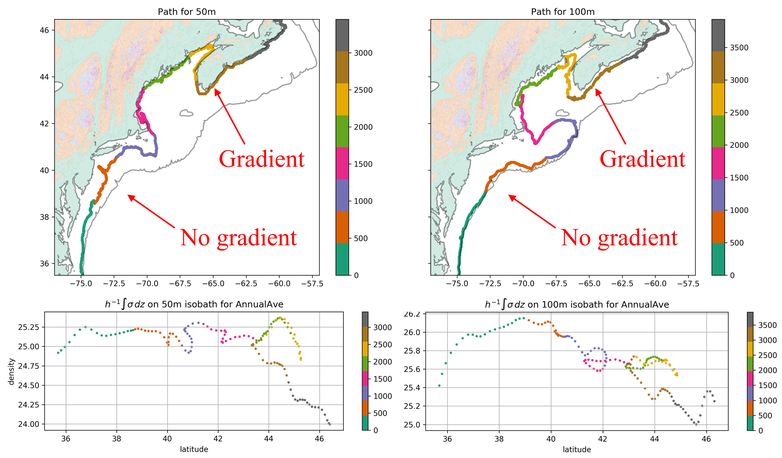


Far-field shelf-flow downwave of ρ anomaly and towards denser water!



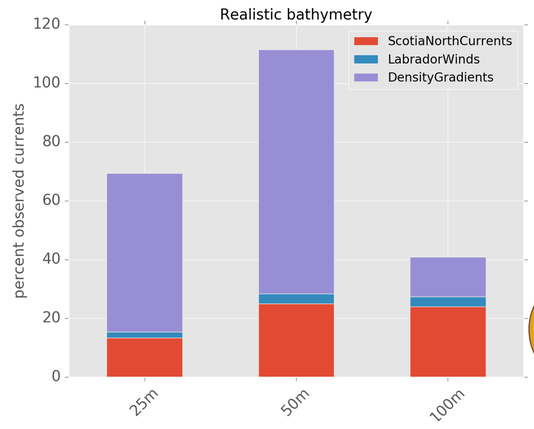
Annual Average Density

Depth-averaged WODS profiles averaged along isobaths

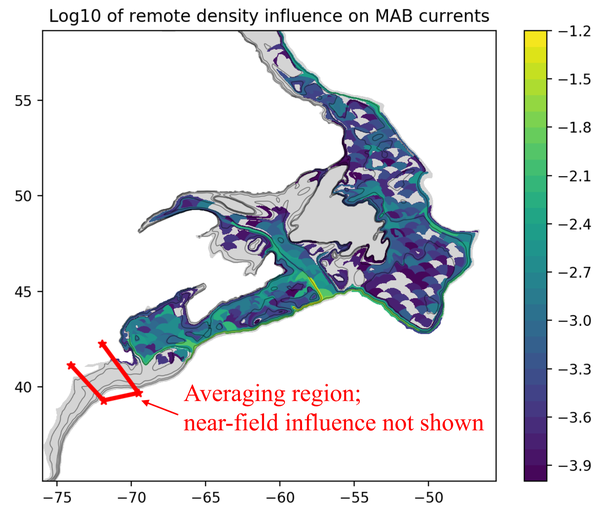


Does this explain the mean flow?

It comes much closer… (VERY PRELIMINARY RESULTS!)



Where are the most important density gradients?



Conclusions:

- Mean flow in MAB in large part driven by along-isobath density gradients in Gulf of Maine, Scotian Shelf and Laurentian Channel.
- Next I must see if this is consistent with seasonal cycle of mean flow!
- Must refine numerics of model and density fields used to force it.
- How does shelf-density driven flow couple to deep ocean flow?

Csanady GT (1985) "Pycnobathic" Currents over the Upper Continental Slope. J Phys Oceanogr 15:306–315
Vennell R, Malanotte-Rizzoli P (1987) Coastal Flows Driven by Alongshore Density Gradients. J Phys Oceanogr 17:821–827
Zhang S, Luo Y, Rothstein LM, Gao K (2016) A Numerical Investigation of the Interannual-to-Interpentadal Variability of the Along-shelf Transport in the Middle Atlantic Bight. Cont Shelf Res