Paper summaries and notes

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1 (Scaife *et al.*, 2011)

Showed with their ocean only simulations that the SST bias off Newfoundland is significantly alleviated by increasing the horizontal resolution (from 1°to 0.25°) (End of section 4) - maybe include in Intro & Background too. The atmosphere only model provided mean bias and blocking error greatly alleviated at *both* resolutions.

- Shows importance of a resolved North Atlantic Current.
- Mentions the SST bias off Newfoundland.
- Uses NEMO 1°and 0.25°models.
- Same number of vertical levels in both.
- Highlights importance of accurate SSTs. Atlantic SSTs can affect surface baroclinicity, thermal winds and baroclinic eddy growth.

2 Greatbatch1991

(Greatbatch, Fanning, and Goulding, 1991)

- Importance of JEBAR (mentioned in Section 3)
- GS transport decreases for 80Sv to 50Sv from 1955-1959 to 1970-1974
- Transport stream function for climatological mean state with JEBAR set to 0 is very different. Transport stream function for climatological mean state with WIND set to 0 is very similar. Implies that JEBAR give significant contribution.
- 1°model solving for streamfunction.
- Equations showing BPT & sverdrup relation in section 4

- "It is also apparent that there is significant bottom pressure torque forcing to the south-east of the Gand Banks of Newfoundland and that this, together with that enhancing the transport of the subtropical gyre, is important for determining the maximum transport (80 Sv) of the diagnosed Gulf Stream. Indeed, it can be seen from Figure 6 that bottom pressure torque alone accounts for over 70Sv of this transport." (after eqn (21)).

- Figures 5 & 6 support the views from Wunsch and Roemich (1985) that transport in the North Atlantic driven by bottom pressure torque is likely of comparable magnitude to that driven by the surface wind stress curl. Similar magnitudes of Ψ_B and Ψ_S in figs 5 & 6 support this.

- Eqn(25) shows that the JEBAR differs from the bottom pressure torque by a term that is the corresponding torque associated with the vertically averaged pressure.

- Fig 1 & 5 differences show the effect of bottom pressure torque missing from modles which assume a flat bottom. Eqns also demonstrate (16) & (17) onwards. (though note fig 5 soln doesn't include the effect of friction - but friction only essential in palaces where $\frac{f}{H}$ contours terminate - pg6). See below for eqns.

- Splits the stream function into different parts.(By Eqn (21) & elsewhere) Ψ_S and Ψ_B with $\Psi_B = \Psi - \Psi_s$. Fig 6 shows Ψ_B the part of fig 1 driven by bottom pressure torque. BPT accounts for over 70Sv of GS transport alone.

- Can see that the effects of bpt can displace the subpolar gyre southward - big impact on British Isles.

Include this in intro? Links to importance

- P10 explains why JEBAR so important in NE Atlantic. Verift importance by overlaying contours of potential energy Φ and depth H. As $JEBAR = J(\Phi, \frac{1}{H})$ it will be nonzero in regions where these regions cross. The NE Atlantic is one such region.

- For subtropical gyre - bottom pressure torque effect more important than density compensation.

- Change between pentads due to JEBAR dominates that due to WIND. (Section 4)

- Change in bpt between pentads is responsible for the weaker subtropical gyre and the increased Ψ values along 41°N and 28°W latitude to the west. These two combined accound for a 45Sv transport reduction around 40°N - explaining the 35Sv reduction in the Gulf Stream.

- In subpolar gyre - bpt responsible for shiting the SE part Nward but no change in transport.

- When looking at changes to Φ above 1500m only - and calculating the Ψ due to these changes, it accounts for roughly half of the total Ψ and approx 24Sv transport in the Gulf Stream region.
- Transport of GS is 30Sv less for 70-74 than 55-59. 20Sv of this is due to a dramatic decrease in the strength of the subtropical gyre. This 20Sv is due to a change in bottom pressure torque forcing on the W side of the Mid-Atlantic Ridge (nr 35°N and 28°W). The remaining 10Sv is due to changes in bottom presure torque in the Eastern Atlantic (nr 41°N and 28°W). About half is due to changes in the density field in depe water below 1500m - this may be unreliable but the remaining half (above 1500m) is reliable & still significant.
- JEBAR split in two: a part associated with the bottom pressure torque & a part associated with the compensation by the density stratification for the effect of variable bottom topography. -¿ This leads to the split of the streamfunction (See below).
- JEBAR separation leads to Ψ split: $\Psi = \Psi_W + \Psi_C + \Psi_B$. Ψ_W - uniform density ocean. Ψ_C - driven by density compensation part of JEBAR. Ψ_B - driven by bottom pressure torque. $\Psi_S = \Psi_W + \Psi_C$ is the prediction of the flat-bottomed Sverdrup relation.
- subpolar gyre affected by Ψ_C and Ψ_B (with the latter extending the gyre southward rather than enhancing circulation).
- subtropical gyre afected by Ψ_W and Ψ_B (with the latter leading to enhanced gyre circulation).
- Nearly all changes between tthe two pentads is due to the bpt part of Ψ (Ψ_B).
- Calculation of Ψ_B depends on Ψ_S and thus on the quality o the surface wind stress fields.

Explanation of discrepancy between fig 1 & fig 5 That the flat bottom sverdrup relation shows the results of removing the bottom pressure torque.
Start with momentum equations:

$$-fv = -\frac{1}{a\rho_0 cos\phi}\frac{\partial p}{\partial\lambda} + \frac{1}{\rho}\frac{\partial\tau_(z\lambda)}{\partial z} \tag{1}$$

$$fu = -\frac{1}{a\rho_0}\frac{\partial p}{\partial\phi} + \frac{1}{\rho}\frac{\partial\tau_(z\phi)}{\partial z} \tag{2}$$

Vertivally integrate the momentum eqns. Assume bottom stress to be 0 (as when deriving (7) and (8)

$$-fV = -\frac{1}{a\rho_0 cos\phi}[\frac{\partial}{\partial\lambda}(\int_(-H)^0 pdz) - p_b H_\lambda] + \frac{\tau^s_\lambda}{\rho_0} \tag{3}$$

check why bottom stress is 0

$$fU = -\frac{1}{a\rho_0}[\frac{\partial}{\partial\phi}(\int_(-H)^0 pdz) - p_b H_\phi] + \frac{\tau^s_\phi}{\rho_0} \tag{4}$$

Now do $\frac{\partial 4}{\partial\lambda} = \frac{\partial cos\phi 3}{\partial\phi}$ and using:

$$\frac{1}{acos\phi}(\frac{\partial U}{\partial\lambda} + \frac{\partial}{\partial\phi}(Vcos\phi)) = 0 \tag{5}$$

and

$$aU = -\Psi_\phi quadaVcos\phi = \Psi_\lambda \tag{6}$$

we have:

$$(\frac{df}{d\phi}\Psi_\lambda = \frac{1}{\rho_0}J(p_b, H) + \frac{a}{\rho_0}[\frac{\partial}{\partial\lambda}(\tau^s_\phi) - \frac{\partial}{\partial\phi}(cos\phi\tau^s_\lambda)] \tag{7}$$

an alternative way to express 7 is:

$$\beta V = \frac{1}{\rho_0}[\hat{k}\dot{c}url(p_b\nabla H) + \hat{k}\dot{c}url(\tau^s)] \tag{8}$$

which makes it clear that the $J(p_b, H)$ term in 7 corresponds to the bottom pressure torque $\hat{k}\dot{c}url(p_b\nabla H)$. and if bpt everywhere is 0 7 becomes the flat-bottomed Sv relation used to obtain fig 5.

Show relationship between JEBAR and bottom pressure torque Integrate the hydrostatic relation1G

$$\frac{\partial p}{\partial z} = -\rho_0 b \tag{9}$$

to get

$$p = p_b - \rho_0 \int_(-H)^z bdz \tag{10}$$

and now integrate vertically to get:

$$H(\bar{p} - p_b) = -\rho_0 \int_(-H)^0 \int_(-H)^z bdz'dz \tag{11}$$

where $\bar{p} = \frac{1}{H}\int_(-H)^0 pdz$. Applying integration by parts to the RHS & using $\Phi = \int_(-H)^0 zbdz$, 11 can be written:

$$H(\bar{p} - p) = \rho_0\Phi \tag{12}$$

and so using $JEBAR = J(\Phi, \frac{1}{H})$ ((10) in paper) it follows:

$$JEBAR = \frac{1}{\rho_0 H}[J(p_b, H) - J(\bar{p}, H)] \tag{13}$$

Hence, JEBAR differs from bpt by a term corresponding to the torque associated with the vertically averaged pressure $\bar{p}$. (Remeber: $\bar{p} = \frac{1}{H}\int_(-H)^0 pdz$)

Splitting the Stream function Ψ can be split into two parts: Ψ_S calculated form the flat-bottomed Sverdrup relations and Ψ_B due to the bottom pressure torque. We can futher split Ψ_S into two parts: Ψ_W given by integrating

$$J(\Psi, \frac{f}{H}) = JEBAR + WIND \tag{14}$$

with $JEBAR = 0$ and Ψ_W=0 at the eastern boundary. This is the Ψ field for a uniform density ocean. See fig2a. $\Psi_C = \Psi_S - \Psi_W$ is then part of Ψ obtained by integrating 14 with $JEBAR = JEBAR_c$ ($JEBAR_c$ is a nonzero $JEBAR$ mentioned in the paper), $WIND = 0$ and $\Psi_C = 0$ at the Eastern boundary. It is the part of Ψ associated with compensation by the density stratification for the effect of bottom topography.
Total Ψ is $\Psi = \Psi_W + \Psi_C + \Psi_B$. $\Psi_B + \Psi_C$ is the part driven by JEBAR shown in fig2b. Thus $JEBAR$ can be split into two parts: a part associated with density compensation ($JEBAR_C$) and a part associated with bottom pressure torque ($JEBAR - JEBAR_C$). Each part can be obtained by differentiating the respective streamfunction (i.e. Ψ_B or Ψ_C along $\frac{f}{H}$ contours. NOTE: These two parts don't correspond to the two parts in 13.

References

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