Salinity’s role in tropical Atlantic instability waves – a unique vantage point from Aquarius/SAC-D

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TIWs affect ocean, climate, biogeochemistry

Aquarius reveals TIWs salinity structure for the 1st time from space.

New finding: $c=1$ m/s near equator ($0.5$ m/s off equator).

17-day (33-day) TIWs dominate near (away) from equator.

Implications to energy transfer & mixing

Lee, Lagerloef, Gierach, Yueh, Dohan (2012)
Observations of Tropical Atlantic TIWs using TMI SST (Caltabiano et al. 2005): TIWs strongest in the eastern-central part (10-20W), very weak in the west.
Tropical Atlantic TIWs: new features seen from SSS

- SSS show strong TIWs in the northwest tropical Atlantic (in contrast to SST).
- S may play a larger role than T in eddy-mean flow interaction in the NW.
- Active interactions with Amazon River plume, North Brazil Current retroflection, & ITCZ.
Tropical Atlantic TIWs: propagation in SSS
Perturbation Potential Energy (PPE)

PPE indicates baroclinic energy transfer (between mean the mean state and TIWs):

\[ PPE = g \rho' \rho_0' \ \text{(surface density perturbation, } \rho_0' \text{ – mean } \rho \text{ gradient across mixed layer).} \]

Based on linear equation of state for sea water (surface – zero pressure):

\[ \rho' = (\alpha T' + \beta S') \rho_0 \ \text{(thermal expansion coefficient, } \beta \text{ – saline contraction coefficient)} \]

\[ \rho'^2 = \left(\alpha T' \right)^2 + \left(\beta S' \right)^2 - 2 \alpha \beta T'S' \rho_0^2 \]

So has \( T' \) contribution, \( S \) contribution’, and contribution by \( T'S' \) covariability (either positive or negative; but mostly positive for TIW because meridional \( T \) gradient is +, that for \( S \) is – at the northern edge of cold tongue).

A previous study (Grodsky et al. 2005) based on mooring at 23W & auxilliary data, found that \( S \) effect enhances baroclinic energy conversion rate by 5 times. A challenging calculation due to incomplete obs (t,s,u,v) and various assumptions.

This study:

• A unique vantage point from Aquarius/SAC-D: basin-wide view of \( S \).

• Direct estimate of PPE without having to calculate energy conversion rate.
Salinity contribution to energetics (Perturbation Potential Energy – PPE)

T’ effect somewhat larger than S’ effect in the east
Salinity contribution to energetics
(Perturbation Potential Energy – PPE)

S’ effect begins to increase in the central-eastern part
Salinity contribution to energetics
(Perturbation Potential Energy – PPE)

S’ & T’ effects are comparable in the central-western part
Salinity contribution to energetics
(Perturbation Potential Energy – PPE)

S’ is the primary controlling factor for PPE & baroclinic energy transfer in the west
Contributions of T’, S’ & T’S’ to PPE (time mean)

<table>
<thead>
<tr>
<th></th>
<th>PPE(T,S)</th>
<th>PPE(T)</th>
<th>PPE(S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15W, 0N</td>
<td>1.52</td>
<td>0.70</td>
<td>0.25</td>
</tr>
<tr>
<td>23W, 0N</td>
<td>0.44</td>
<td>0.12</td>
<td>0.16</td>
</tr>
<tr>
<td>30W, 2N</td>
<td>0.50</td>
<td>0.19</td>
<td>0.16</td>
</tr>
<tr>
<td>40W, 4N</td>
<td>0.43</td>
<td>0.06</td>
<td>0.26</td>
</tr>
</tbody>
</table>

- Direct effect of S’ increases towards the west, becoming dominant in the west.
- PPE(T,S)-PPE(T)-PPE(S) indicates the effect of T’S’, which is very significant.
- Note how small the effect of T’ alone is.

Consistent with Grodsky et al. (2005) at 23W
In the west, TIWs are not necessarily strongest in late spring/early summer as previously reported in the east – seasonality of meridonal velocity shear different?
Summary

• Tropical Atlantic TIWs remain strong in the west although SST signature is weak.

• S effect on PPE is somewhat weaker than T effect in the east, but increases dramatically towards the west where it becomes much more dominant – effect of Amazon plume & retroflection into NBC that set up a large dS/dy.

• S effect on PPE has a direct effect (to density) & an indirect effect (due to T’S’), which is very significant.

• Seasonality of the growth/decay of TIWs are somewhat different between east & west, probably due to the differences in processes that set up the meridional velocity shear.