

Title:

Chlorophyll-a concentration effects on equatorial Atlantic Ocean mean-state and interannual variability

Authors

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I appreciate the additional work carried out by the authors, The paper is well written and the results should be published. However I am still unhappy about the interpretation around lines 206 of the revised paper and believe the interpretation needs further work.

Wind stress, equatorial currents and the tropical cell

As far as I know Stommel (1959) was the first to investigate the terms of Eqn. 4 and showed, using a one layer model, that for a steady zonal wind, the vertically integrated Ekman transport balanced the vertically integrated geostrophic term.

In fact he showed that the balance works in both the meridional and zonal directions. In the meridional direction the vertical structure of Ekman transport results in the tropical cell. In the zonal direction the balance results in the sea surface slope, the equatorial current and the equatorial undercurrent. The terms are also discussed in my own note Webb (2018).

This zonal net transport is also consistent with the Sverdrup relation, which requires a wind curl to generate a vertically integrated north-south transport and with Munk's theory of the wind generated circulation, which even at the Equator requires a non-zero wind curl to generate a vertically integrated transport.

Of course single-layer models are a bit simplistic. A better analytic model is that of McCreary (1981). He is only talking about the equatorial current and undercurrent but as far as I can tell the theory also applies to the tropical cell.

He takes into account the vertical density structure of the ocean and the changes in viscosity. The additional of the baroclinic terms is found to be important but besides that, as stated in the discussion section:

"The response varies weakly with the shape of the pycnocline below the mixed layer and also with the magnitude of friction in the deep ocean".

However he does find:

"The depth of the mixed layer does affect the speed of the surface drift, but other properties of the flow to a much lesser degree".

Application to the present paper

1. Figures 3c and 3d show that the maximum vertical velocity occurs at around 100m, near the depth of the maximum vertical temperature gradient. As discussed in the papers referred to above the maximum vertical velocity occurs at the interface of the upper and lower branches of the tropical cell. Above this level the pole-ward Ekman velocity term is greater than the pressure term, giving a net pole-ward velocity. Below this level the pressure term dominates giving an equator-ward velocity.

2. Figures 3c and 3d also indicate that the Ekman term must be significant down to around 150m. I would expect that this to match the depth of the core of the undercurrent in the model.

3. The results mean that the Ekman transport is not constrained to the surface mixed layer and so the parts of the text which are based on this assumption need correction.

4. The results show that biology does have a non-trivial effect on the structure of the tropical cell. It reduces the depth of the interface between the upper and lower parts of the tropical cell. It increases velocities above the interface and reduces velocities below.

5. From the figures it is not obvious whether the changed velocities are only due to the same transport being squeezed into a shallower layer above the interface, and a thicker layer below, or if it is partly due to a change in the total transport. For this you would have to see if the maximum vertical velocity increased.

The one thing I could not explain was the small change in velocity at the surface. Whenever I tried to modify a plot of the Ekman transport as a function of depth, changing the depth at which the transport balance the pressure term but keeping the vertical integral constant, the simplest forms always changed the velocity near the surface. It may not be for this paper but at some stage it would be interesting to know why the effect on the surface velocity was so small.

6. I may have missed the reference in the text but if it is not there it may be worth adding something about the depth of the upper part of the cell being very similar to the depth where the light level is at 1% of the surface value in a clear ocean. I understand that this is the limit for photosynthesis.

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@article{Stommel_1960,
  author = {Stommel, H.},
  doi = {10.1016/0146-6313(59)90088-7},
  journal = {Deep Sea Research},
  pages = {298--302},
  title = {Wind-drift near the Equator},
  volume = {6},
  year = {1960}
}
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@techreport{Webb_2018a,
  author = {Webb, D. J.},
  institution = {National Oceanography Centre, Southampton, U.K.},
  pages = {1--15},
  title = {A Note on Stommel's Theory of the Tropical Cell},
  type = {{Research and Consultancy Report, No. 63}},
  url = {http://nora.nerc.ac.uk/id/eprint/520018},
  year = {2018}
}
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@article{McCreary_1981,
  author = {McCreary, J. P.},
  journal = {Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences},
  number = {1444},
  pages = {603--635},
  title = {A Linear Stratified Ocean Model of the Equatorial Undercurrent},
  volume = {298},
  year = {1981}
}
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