Comments by Wolf-Gerrit Früh on
Nonlinear Processes in Geophysics Discussion 2-1507-2015
A.M. Matulka, Y.Zhang and Y.S. Afanasyev:
Complex environmental beta-plane turbulence: laboratory experiments with altimetric imaging velocimetry

My understanding of the paper

This paper reports on spectral analysis of free-surface altimetry data from experiments in a rotating tank where the flow is forced by one of two different methods, where one method is thermal forcing through heating at the base of the fluid, and the other due to the addition, and subsequent instability, of a relatively thin layer of fresh water above the main body of saline water.
After estimating the quasi-geostrophic surface velocity field from the surface elevation measurements, presented evidence that the Rhines scale plays a role in the evolution of the velocity fields.
Finally, the authors defined a one-dimensional wave number, based on the locally radial and tangential wave numbers. The key results are that both types of forcing result in an energy scale with a wave number spectral slope of – 5/3 from the forcing length scale to larges scales (lower wave numbers). While the thermal forcing resulted in a slope of – 3 in the enstrophy range (from the forcing length scale to smaller scales) the slope from the two-layer forcing was found to be -5 over almost an order of magnitude of wave numbers.

Questions or suggestions to the authors

Thermal forcing

1. Thermal forcing: I found it difficult to interpret the results in Figure 3 without knowing the shape and size of the heating elements. It would help to describe the heating wires in a bit more detail in the experimental technique section (and show a top view of the tank to show the wires). My initial thought was that it would be a spiral of a resistive wire, from the centre to the perimeter but looking at the results it appears to be a set of parallel wires. What is the spacing of the wire? Are the wires on top of the bottom surface as Figure 1 suggests, or are they embedded in the base – if so, how deep? As that would expect how strongly localised the heat source is to the line of the wire or slightly broadened through the heat conduction through the base.
2. Thermal forcing and experimental time: I presume the clock starts counting after the (initially stagnant and isothermal) fluid has reached solid-body rotation, and at the instant when the heating is switched on. Is that right? Is the heat dissipation from the wires maintained at a constant level throughout the duration of the experiment?

Saline forcing

3. Salinity: Can you explain the procedure in a bit more detail? If I understand it correctly, the forcing is more through the baroclinicity caused by the density difference between the salt and fresh water, rather than by salinity gradients. Is that right? If so, what is the temperature difference (or the corresponding Brunt-Vaissala frequency / Froude number)? Also, the instability will depend on the depths of the two layers. Can you quantify that?

4. Fundamental mechanism: If I understood the previous item correctly, I presume that the forcing mechanism is through baroclinic instability rather than direct forcing, since you are setting up a stably-stratified two-layer system. Is that right?
5. Implementation: How do the fresh-water addition and the experimental observation actually relate? It seems from some late comments, that the experiment time starts at the end of the water addition. Is that correct? If so, could you explain what actually happens during the fresh water addition and after? And, would then seem that the experiment would go through a cycle of baroclinic instability (caused by the velocities set up during the water addition), growth of 'baroclinic waves', followed by decay of these waves through friction and possibly other instabilities (e.g. wave breaking / frontal barotropic instability / vertical mixing of fresh-salt water). If so, what are the typical life-spans of the various stages, or the total cycle?

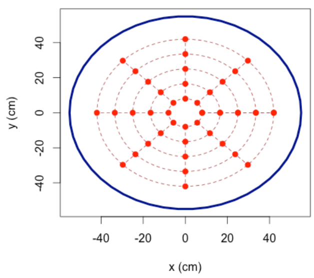
   As you can see, I struggle to understand and interpret your saline forcing experiment and its results and would welcome more explanation.

Spectral Analysis

I am not entirely sure on the area over which you carry out the spectral analysis, and how valid your assertion is that the Cartesian FFT-based spectral analysis is sufficiently accurately in the cylindrical domain is not entirely clear without getting a bit more information.

6. Can you explain and discuss the domain for the spectral analysis a bit better, and what effects turning the cylindrical coordinates into a local Cartesian has?

   Did I understand it correctly that you are using an annular domain with an inner radius of 8 cm and an outer radius of 42 cm? It might be helpful to show an illustration of the tank and of the analysis domain (with a highly reduced set of points for the 'Cartesian' grid); maybe something like



7. If the coordinate system is Cartesian centred at r_0 = 25 cm, then the distance between two adjacent points on the inner-most ring is made equal to that at the outermost ring. With a radius ratio or 8cm/42cm = 0.19, or a width-to-mean radius of curvature of 34cm/25cm = 1.36, your analysis domain is definitely a 'wide-gap' geometry, where the changes in local curvature would be expected to be fairly large.

8. Presumably the wave numbers are equally stretched/compressed at radii different from r_0 ? What does that mean for 'equating' k_x at r = 8 cm (or y= – 17cm) with the same k_x at r= 42 cm (or y = + 17 cm)?

   Would you not expect that small-scale turbulence (of length scale << $2\pi r$) should not be expected to be effected much by the curvature (and hence a true size of a certain size is dynamically similar to features of the same size but at a different radius)?

At the other end of the scale, for features approaching the 'length' of the channel, eg. $2\pi r/N$, where N is smaller than, say 5, the 'available' space affects the feature. Would we not expect the wave number N to be more important than the local length scale – and the stretching of the tangential component is valid?

Do you think it might be worth generating contour plots of spectral amplitude of in the tangential direction (ie, plot contours of $E(k_x, y)$ against k_x and y) ?

9. By the way, the circles and figure-of-eight in Figure 4 are virtually invisible. Is there any way you can make them more prominent?

10. For the discussion of the 1D spectra in Figure 5, it would be helpful to indicate the location (e.g. by a vertical line) of the forcing length scale (spacing of the heating wires 1.4 cm^{-1} and/or of the thermal forcing length scale 2.5 cm^{-1} ; the radius of deformation 1.2 cm^{-1} and the most unstable wave number 0.77 cm^{-1}) and the Rhines scale of 0.45 cm^{-1}

11. Any ideas what determines the length scale of the thermal forcing?

12. How do you achieve a spectral range for the 1D wave number of substantially larger than 10 cm^{-1} with your spatial resolution of 0.2cm x 0.2cm (as you stated earlier)?

13. Page 1520, line 1: 'The steeper slope in the second experiment is due to the particular nature of this two-layer baroclinic flow.' Can you explain or interpret this a bit more?

Other comment

14. Not everybody might be familiar with the Sobel gradient operators (p.1512, line21). Could you provide a reference?

Typographical points

Convention used: <add> ; ~~delete~~ ; {comments}

- p.1508, line 5: top of <a> saline layer
- line 16: <The> β-effect …
- line 17: spectra in ~~the~~ wavenumber space {either: become} ~~of a~~ {or: form} a figure <of> eight {It is more commonly referred to as 'figure-of-eight' rather than just 'figure eight'}
- p.1511, line 7: surface of <the> rotating
- line 10: obtain <the> velocity
- line 18: It <is>, however<,> ~~is~~ perfectly
- line 20: <The> paraboloidal … used ~~as a~~ <like the> mirror of ~~the~~ <a> Newtonian
- p.1512, line 3: <The> barotropic

- p.1513, line 1-2: Note that in a stratified fluid<,> ~~(~~ as … forcing ~~)~~ <, the> velocity.. is, in fact ~~, a~~ <the> barotropic …
- line 6: 2015) ~~and~~ <but> is
- p. 1514, line 12: Rayleigh {missing i}
- p. 1515, line 9: water, ~~an~~ <the>
- line 10: Thus, <a> two-layer
- p.1517, line 2: <The> two-dimensional…
- p.1518, line 21: resembles <a> figure <of> eight
- p.1519, line 2: that <the> turbulent
- line 5: instead <a> (linear)
- line 6: towards <the> k_y
- line 28: presence of <the> – 3 slope
- p.1520, line 1: <The> steeper…
- line 5-6: {This is a bit ambiguous as to whether 'both' refers to the two references cited in the previous sentence or to your two experiments. It would be much clearer to refer to your experiments if you simply started a new paragraph.}
- line 9: wavenumber ~~that~~ <which> indicates
- p.1521, line 2: {'certain': what do you mean by 'certain universality? As opposed to uncertain? If so, why are you certain? If not, do you mean certain as in synonymous with 'specific'? If so, be specific and explain which universality it is}
- line 4: is in ~~a~~ reasonable agreement