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Discussions

Interactive comment on "Latitude and bathymetry modify lake warming under ice" *by* Cintia L. Ramón et al.

Anonymous Referee #1

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In this paper the authors consider how late winter solar radiation driven convection may be controlled by the relative strength of Coriolis force. As many as half the lakes in the world freeze and are located at high latitudes where Coriolis forces could be important. However it is very hard to do field work under these lakes, and while the process of solar driven convection is somewhat well known, how Coriolis forces interact with lateral temperature gradients to drive basin wide circulation is not well known. This paper represents an important first step to address some of these issues. The paper is well written, and my comments below are mainly about putting this new work into context of existing literature of Coriolis effects on convection. Addressing these comments does not require any changes to figures, rather just some careful thought to some of text so should be somewhat straight forward and will make the paper stronger.

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Discussion paper

1) I think it would be very helpful for authors to emphasize some caveats and qualifications to the generality of their study. What might happen in the many lakes that are long and narrow? Do you expect multiple gyres? Could the authors comment on whether the Rossby number is time dependant in a real lakes, due to increases in buoyancy forcing as the length of the day increases? This might mean change in sense of circulation patterns over the end of winter . How typical is the strong stratification that is as warm as 4C at bottom? Many large but relatively shallow lakes are less stratified and maybe be 2C or 3C at base (see https://aslopubs.onlinelibrary.wiley.com/doi/abs/10.1002/lno.11543 as one example). In these less stratified lakes you are much more likely to see gravity currents going to base of lake, so are circulation patterns are possibly different?

2) I was also wondering if the title might be slightly qualified? Rather than "Latitude and geometry", I'd suggest order be "geometry and latitude", as I think geometry is more important. You find the vast majority of dimictic lakes from about 40 to 70oN (Northern America and Northern Europe) where f varies from 0.935 to 1.367 10-4sˆ-1. So most of the variation in Rossby number between lakes is not primarily due to latitude, but rather their scale (and possibly magnitude of radiation which is indirectly also related to latitude).

3) I think you need to qualify that statement on line 20 that "Yet, as we move from planetary to smaller-scale systems, the importance of rotation in affecting convective processes remains overlooked. This is the case in lakes." I think you want to change or qualify the word "overlooked". In terms of convection there have many studies of the "spring thermal bar" where heating of lakes that are below 4oC drives a radial geostrophic flow near the shore, (https://en.wikipedia.org/wiki/Thermal_bar). This seems to be very closely related physics, so It would be worth reminding the reader of the connection between your study and this well known process in larger lakes (which is probably at low Ro end of your simulations). This is a well known example of Coriolis limiting heat transfer from edges to interior.

What I am confused about is that all observations and models thermal bar suggest you'd get an anti-clockwise flow (cyclonic) near the shore in Northern Hemisphere. I think this is opposite however to what is shown in low Rossby number case for Figure 3. There are many theoretical papers from 1970s on thermal bar, one example is https://doi.org/10.1080/03091927208236071 Huang, Joseph Chi Kan. "The thermal bar."ÂăGeophysical Fluid DynamicsÂă3, no. 1 (1972): 1-25.

This article mentions that "The results show a dominant meridional cyclonic flow along the perimetric edge of the lake and an anticyclonic flow in the middle portion of the lake.Âă" I am confused what is the key difference between that classic field observation and your simulations for low Rossby number? I may be confused here, but if the sense of circulation is fundamentally different it would be useful to explain what is the key difference in setting up your simulations.

4) There is a recent paper by Jazi Davarpanah et al. (2020) on rotating gravity currents using the Coriolis facility in Grenoble that goes into great detail on Rossby number effects and is a better reference than Wells, 2009 on line 32

https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2019JC015284

This study would also qualify your statement on line 149-150 that "When R/U > f gravity currents are affected by Earths rotation" - rather the large Grenoble experiments found that there is a gradual transition in gravity current dynamics that starts at Rossby number greater than 1,

5) A number of studies in last 40 years have studied convection in rapidly rotating "dishes" - as an analog to understanding zonal jets in gas giants like Jupiter. Physically one might expect that these should have same or similar circulation patterns as your low Rossby number simulations (although they lack stratification). Hence it would be worth briefly commenting to what degree the circulation patterns look similar or different to your Figure 3. I appreciate the experiments below are not stratified, but for many physicists these would be the rotating experiments they are familiar with.

One recent example from Grenoble os

Read, P.L., Jacoby, T.N.L., Rogberg, P.H.T., Wordsworth, R.D., Yamazaki, Y.H., Miki-Yamazaki, K., Young, R.M., Sommeria, J., Didelle, H. and Viboud, S., 2015. An experimental study of multiple zonal jet formation in rotating, thermally driven convective flows on a topographic beta-plane.ÂăPhysics of Fluids,Âă27(8), p.085111.

Before computer simulations were easier this type of system was also used in some high profile papers in 1980-1990s, see figure 2 in

Condie, Scott A., and Peter B. Rhines. "A convective model for the zonal jets in the atmospheres of Jupiter and Saturn."ÂăNatureÂă367, no. 6465 (1994): 711-713.

Sommeria, J., Meyers, S.D. and Swinney, H.L., 1989. Laboratory model of a planetary eastward jet.ÂăNature,Âă337(6202), pp.58-61.

also used to think about the modes of convection driven circulation under sloping geometry of Lake Vostok - see for instance the change from differential heating to columnar vortices in https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2007GL032162

6) There are a few more key studies on ice covered lakes that can be compared directly to the simulations. In particular in old studies on Tub lake, the scale and geometry looks like about exactly scale as in the present student study. The lake is symmetric and has a profile from 0-4C, so is probably as similar as you could find, so a good question is whether the sense of circulation in studies by Likens is the same? They inferred basal heating was very important (as have other under ice studies during winter I.) but I feel this should be somewhat similar to radial differences in temperature gradients in winter II.

LIKENS, G. E., AND A. D. HASLER. 1962. Movements of radiosodium (NaZ4) within an ice-covered lake. Limnol. Oceansgr. 7: 48-56.

LIKENS, G. E., AND R. A. WACOTZKIE. 1965. Vertical water motions in a small ice-covered lake. B. Geophys. Res. 70: 2333-2344.

Likens, G.E. and Ragotzkie, R.A., 1966. Rotary circulation of water in an ice-covered lake: With 6 figures and 1 table in the text. Internationale Vereinigung für theoretische und angewandte Limnologie: Verhandlungen, 16(1), pp.126-133.

Another old paper shows possible sinking near boundaries, consistent with your observations

Welch, HE, & Bergmann, MA (1985). Water circulation in small arctic lakes in winter. Canadian Journal of Fisheries and Aquatic Sciences , 42 (3), 506-520.

I hope all these comments are helpful in providing some more context to your interesting simulations.

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