

Interactive comment on “On the characteristics of sea ice divergence/convergence in the Southern Beaufort Sea” by J. V. Lukovich et al.

Anonymous Referee #1

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In September 2009, 11 buoys (beacons) were deployed on the sea ice of the southern Beaufort Sea. The authors group these beacons into 5 triangles (triplets, labeled A-E) and analyze the motion and area of each triplet during Sept-Oct-Nov 2009.

First I would like to comment on the quality of the figures. I printed a hard-copy of the pdf, and most of the accompanying figures are too small to read the axis labels and/or too small to see what's going on. This seems to be partly the fault of the journal and partly the fault of the creators of the figures. In my opinion, figures should be fully legible and intelligible when printed. I can read the main body of the text perfectly well in the hard-copy printout, but not the figures. The authors should use font sizes for the axis labels and legends that are the same size as the main text, and the journal should not shrink figures in order to squeeze multiple panels onto a single page if doing so

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makes the figures illegible.

I have three main comments about the paper.

1. The authors use the change in area of the triangles to measure divergence, as in equation (1): $(1/A)dA/dt = \text{divergence}$. This is theoretically valid, but in practice the use of only 3 points leads to large error estimates and extreme sensitivity. Thorndike (Kinematics of Sea Ice, Chapter 7 in The Geophysics of Sea Ice, NATO ASI Series, vol 146, 1986) finds that the ratio of estimation error variance to signal variance is about 0.7 when using 3 points to estimate divergence (see Fig 23b and the discussion at the top of page 536). Furthermore, a simple analysis of the area of a triangle, $A = (1/2)\text{base} \times \text{height}$, shows that for a constant base b and variable height h , divergence $= (1/A)dA/dt = (1/h)dh/dt$ so when h is small, the divergence is extremely sensitive to small changes in a single vertex of the triangle (the one that's not part of the constant base). Figure 2 shows that in fact there are many highly elongated triangles in this data set. The problem is this: in estimating the divergence of a region using a discrete set of boundary points, the implicit assumption is that the points adequately resolve the material boundary of the region. In other words, as the shape evolves over time, there should not be a flux of ice into or out of the region. But a region of sea ice defined by a highly elongated triangle will almost certainly violate this implicit assumption in a big way. The sides of the triangle will almost certainly not be material boundaries. If one could track (say) 10 points along one side of the triangle, one would often find that after one time step, the 10 points no longer fell along that side of the triangle. In other words, 3 points do not accurately resolve a large material element of sea ice, especially when that element is highly elongated. As Thorndike (1986) showed, 6 points provide much better accuracy. It's too bad the authors did not group the beacons into sets of 6. The bottom line is: I question the quality of the divergence measurements from this data set.

2. The "Results and discussion" section is mainly a detailed description of the figures. Page 4292 describes Figure 2. Pages 4293-4 describe Figures 3 and 4. Page 4295

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describes Figure 5. And so on, through most of the section. It is frankly rather tedious.

3. The actual main results seem to be that the ice behaves differently near the ice edge, near the coast, and in the interior of the pack; the wind affects the ice motion in different ways; and there are episodes of large divergence.

Specific Comments

Page 4284, lines 10-11. What does it mean for "spatial scaling" to have "high values"?

Page 4287, lines 23-24. "increase in triplet area characteristic of non-divergent flow". But if the area is increasing, doesn't that imply divergence? See equation (1).

Page 4289, lines 9-10. Wow, E is an extremely elongated triangle, with shortest leg 11 km and longest leg 400 km!

What is the temporal resolution of the beacon data? In other words, when you plot a time series like Figure 3, are you plotting one value per day? 10 values per day?

Page 4290, line 4. The formula for delta-A is not dimensionally correct, so an algebra error must have occurred somewhere. Since a,b,c have dimensions of length (L), the expression inside the square root has dimension L^6 and so the overall expression has dimension $L^3/L^2 = L$, not L^2 .

Page 4293, line 17. Not sure what is meant by "signature of regional small-scale constraints". See also page 4299 line 2.

Page 4294, line 14. In Fig 4b, I don't see much of a positive slope for triplet E.

Page 4297, line 21. There is no scale bar in Fig 7a so it's impossible to tell that the floe sizes are 2 to 10 km. Or does that information come from another source?

Page 4298, line 9. Spell out what SIC stands for.

Page 4298, lines 24-25. The authors define "loop reversal events" as "the spiraling motion of a triplet beacon", and "meander reversal events" as "advection exceeds ro-

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tational motion". First, I don't understand how these "reversal events" are calculated, and second, why not use the beacon triplet positions to calculate the vorticity of the triangle, if the goal is to describe rotation?

Page 4298, lines 27-28. "loop reversal events are observed throughout the array ... (Fig 9)." I can't make out anything in Fig 9. Where should I see a loop reversal event?

Figure 4b. Wow, the aspect ratios of the triangles are sometimes 100 or more.

Figure 6. The units on the Y-axis are given as 1/sec but this cannot be correct. Probably it should be 10^{-6} /sec.

Figure 8 caption, "within a 0.21 degree ... radius" – does this mean 0.21 degrees of latitude? Can you give the radius in km instead?

Figure 9. I can't figure out what I'm supposed to be seeing.

Figure 10. The wind vectors appear to be plotted on top of one another. I cannot distinguish the wind for one triplet from the wind for another.

Technical Corrections

In the Abstract, after the first occurrence of the word "beacon" on line 7, insert "(buoy)" to clarify the meaning of beacon.

Page 4284, line 25. Insert "is" after "the ice cover".

Page 4287, section heading "Triplet analysis and (oceanic and sea ice) applications". I suggest either removing the parentheses or removing the entire parenthetical phrase.

Page 4288, line 27. Antarctic should be Antarctica.

Page 4289, line 4. "Sea ice drift data were determined from...". Probably better to say "were obtained from".

Page 4290, line 21. Put the word "forcing" immediately after the word "atmospheric".

Page 4292, line 26. "the time rate of change of which monitors ice convergence". Better to say "measures ice convergence". People and gadgets can monitor things, but time rates of change do not monitor things.

Page 4293, line 19. Same comment about monitored vs. measured. Page 4296, line 1. Same comment.

Page 4298, lines 25-26. I don't see Griffa et al (2008) or Lukovich et al (2014) in the References. Please check all references.

Page 4300, line 3. Delete "in" after the word "highlight".

Page 4311, Table 1. Correct the 3 typos in the caption.

Page 4313, Table 3. In the column labeled "Intervals" I see the notation "09/10-09/24" and "10/09-10/26". Are these meant to be dates in the format MM/DD? The dates in the final column are in the format YY/MM/DD so "09/10" looks like it could be 2009 October or it could be September 10 with the year 2009 implied.

Conclusion and Recommendation

This paper is basically a long description of the motions of 11 buoys in the southern Beaufort Sea in Sept-Oct-Nov 2009. There is nothing technically wrong with it, once a few minor details are corrected and the figure quality is improved.

I leave it to the editor to decide whether such a paper belongs in The Cryosphere.

Interactive comment on The Cryosphere Discuss., 8, 4281, 2014.

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