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The Cryosphere Discussions

Interactive comment on "A mechanism that produces dichotomy in melt pond coverage in sea ice floes" *by* Predrag Popović and Dorian S. Abbot

Anonymous Referee #2

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This paper presents a simplified, single column model of melt pond coverage for permeable ice where the ice is in buoyant equilibrium. The objective of the model is to characterize how pond fraction changes in response to assumed melting rates of the ice in contact with the atmosphere and ice in contact with the ocean. The primary equation for the model examines the vertical rate of change of a point on the surface of the ice. Vertical change is partitioned into motion representing the rigid body of the ice plus local melting along the perimeter of ponds. Along with equations for the local melting, the authors present a combined linear equation for bare ice fractional coverage that they use to diagnose pond fraction behavior.

I liked the idea of the simple model and the authors do a nice job introducing the concepts that they are trying to simulate. Things get more confusing when the equations are presented in section 3. I had a hard time figuring out what equations 2 and 3 were

really representing and I think this section needs to be thoroughly rewritten to better explain the basis of the model. In particular, the relationship between bottom and top melting seems quite confusing when dividing between volumes of ice above or below sea level. For example, the authors state that removing a volume of ice below sea level reduces the volume above sea level by about 0.1. They then say that reducing a set volume from above sea level reduces the volume below sea level by about 0.9. These are saying the same thing in terms of total volume, and both will have the same effect on the freeboard. What I think is buried in describing the ice behavior is the effect that surface melting has relative to pond melting or relative to the old location of sea level; this is hard to extract from their description.

Particularly confusing is the statement that melting above sea level has a much greater effect on rigid body displacement in comparison with bottom melting. I understand that they are referring to a given point in the ice, but it sounds like surface melting is more "effective" in removing ice volume. So for example, when surface ice melts, the location of sea level relative to a fixed location in the ice changes much more than when the bottom melts. This is what I think the authors are trying to describe, but it is hard to follow in their presentation.

After presenting the basic equations relating ice surface motion to heat fluxes, the paper then jumps to a linear solution relating these rates to pond fraction. I think this derivation needs to be presented in the paper more explicitly; it is not obvious how they get from equation (4) to 9-10, and this is the core of their solution. Equation 11 is also not fully explained; where does the upper limit for x_o come from?

Because of the difficulty I had in following the model development, I am reluctant to accept this paper without a major revision specifically aimed at more description of the model and the basic concepts. Some of the model outcomes, for example, the need for less melting around pond edges, may have to do with simplifications that are not presented in the manuscript.

Minor Comments

Line 50-55. It is also quite possible that the overall pond distribution is tied to sea ice topography and snow depth distributions. So flat ice never develops ponds because there are never deep enough depressions that extend below sea level. There would be no need for a dichotomy if the pond distribution is determined mostly by ice and snow variability at the start of the melt season.

Line 110-125. It is also possible for ponds to grow through increased pond edge melting from “warm” pond water (from solar heating) that is in contact with the pond edge.

Line 130. Isn’t this just the definition of ice-albedo feedback with ponds?

Line 135. Wouldn’t smaller pond fractions require a smoother ice surface, e.g. perfectly flat ice will not have any ponds, whereas ice with high ice sails could potentially be much more ponded. Ice surface topography is not a model parameter, but it seems like it would be very important. Can you comment on this?

Line 320. It seems unlikely that all ponds would have less melting along the pond edge. What assumptions in your model formulation are forcing this condition?

Conclusions. Observations are one way to test your model, especially looking at the albedo near pond edges. I did not understand the comment on line 396-97 about observations from pond-free ice; did you mean in addition to the observations from ponded ice?

Another way to test the model might be by applying an explicit meltpond/sea ice model as proposed by Scott and Feltham. This would allow altering of the pond edge melting rates to see if this does indeed trigger dichotomy.

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