Reviewer #2: Review of "Network Modeling of Arcitc Melt Ponds"  
  
General comment:  
  
The paper present an algorithmic technique to map photographic images of melt ponds onto a discrete conductance network with the intention of allowing in future studies the ease of lateral flow in summer melt pond covered sea ice. The algorithm consists of 4 steps: i) preprocessing to eliminate small ponds and small elements of floating ice; ii) identification of individual melt ponds; iii) in parallel finding connections between melt ponds; iv) and small node deletion.  
  
The paper focuses on the model description and applies the algorithm to a small subsample of remote sensing images at the expense of systematically analysing extensive datasets of summer melt ponds images. While this choice can be justified in principle it calls for an extremely clear presentation of the algorithm itself. As it stands I do not think that the authors achieve a high enough standard in presenting their algorithm. I believe that in its current state the paper does not allow the reader to reproduce the method without a substantial amount of additional bibliographical research. I recommend at the very list a clearer presentation possibly including a detailed schematic of the algorithm in Appendix or as a figure. I would also urge the authors to make their algorithm available to the scientific community, maybe as supplementary material.  
  
Nevertheless I consider the approach presented here worth publication and I recommend the paper to be accepted with major revisions.

***To provide a clearer picture of the algorithm we have included a flow chart of the methods we use in the paper. We believe this is sufficient with the current text to explain the algorithm. We are also willing to make the algorithm available on the web for study.***   
  
In addition to this main comment I list below a series of suggestions that I think need to be addressed for the paper to be accepted for publication.  
  
Below I describe in more details the places that I think could be improved.  
  
Abstract:  
  
- In the version I received there are 2 abstracts and they differ. Correct

***We have corrected this, thank you.***

- You mention seal holes. Is this an important contribution to water drainage ?

***It can be in a local region, seal holes have large diameters and connect to the ocean below. If located in a large pond which is connected to many others it can be a major sink of melt water.***

- You state in the last sentence that the number of mislabels is used to evaluate performance while I find this is not done in the paper.

***This has not been done and is my task this weekend. Yay.***

- You mention graph theory. I am not an expert but it seems to me that you could be more specific here.

***Going into too much detail would lengthen the paper, instead we have chosen to use the appropriate key words for graph theory to facilitate easy cross-referencing. We have been more specific as to which elements of the theory we have used and provided more detail.***

Introduction:  
  
- L54: cite also Hunke et al, 2013 ("Sea ice, Albedo, Melt ponds, Ridging, Modeling, Arctic"), Flocco et al, 2012 (10.1029/2012JC008195).

***We have added the citations. (double check this with the authors)***

- L68-L76: Is this really needed ?

***I do not have the original PDF I cannot tell which this line was. The authors need to address this.***

- L80-L146: I am not sure if all this is directly relevant for the present paper and therefore needed ? I understand that it helps set the context of percolation phenomena but here you look at horizontal processes. As such I would more interested to have a more in depth discussion of scaling aspects of your work. For example along the lines of your reference [15]. One question that will arise later in the paper is how the conductivity values that you determine scale with your sample size. I think this kind of discussion would be more useful than a general discussion on percolation phenomena.

***This work is very preliminary, we feel that is it more important to highlight the wide use of percolation theory in different situations. It is important to us to impart the wide application of these kinds of techniques to work beyond our own. As of now we do not have a large enough data set to adequately discuss scaling with sample size.***

- L159: you mention algorithms that helped you in [15] distinguish between melt ponds and open water in leads between floes. I am not sure that you use the same methods in the current paper. I think you should. If you do not explain why.

***We now mention a possible method to distinguish between ponds and open water using the blue channels, we have also added a statement that we have only used images that do not contain open water so for this paper it is not relevant to us.***

- L161-L171: I think a more in depth discussion on scaling of melt ponds geometrical characteristics would be welcome maybe after this paragraph.

***We have added a small discussion on the transition in fractal dimension of melt ponds. (Check that this is what they did to address this)***

- Is the daily cycle relevant for your findings. For example if you measure pond characteristics at different times of the day would you expect different thermodynamic forcing and hence different conductivity maps…

***We do not have sufficient data available to really investigate this and we believe it is out of the scope of our paper. This paper is primarily focused on very general properties of the geometry of the melt ponds over a melt season, in this context daily variations are small. It is also likely that this algorithm would not be able to detect any large changes as we expect daily variations to be small.***

- L200: should you discuss melt freeze up, melt lid formation a bit more here ?

***This paper is primarily meant to deal with the melt season although we do find this interesting. f***

- L205-210: I think you should provide some reference illustrating how transverse flow of water is important, maybe Scott et al, 2009 ("Modelling the evolution of Arctic melt ponds"). How do the timescales of drainage vs horizontal flow compare for example ?

***I do not believe the authors have addressed this.***

- L214: do these technique have a name ? Can you give some examples of applications in other fields ?

***WE have elaborated on these techniques and given some examples (double check with authors)***

Method:  
  
- L241: Otsu's method, again here I am not sure if you do not mix up melt ponds and open water between floes sometimes. This could in turn affect your values of conductivities.

***We do not have any images with open water, in this way we cannot mix them up.***

- L247-255: not clear here if images are a the same resolution in HOTRAX and SHEBA and even for different days. You should provide the pixel to m conversion value or at least discuss this.

***We mention that for simplicity and initial analysis we restrict ourselves to pixels. We are more interested in the geometry of the image.***

***Note to the authors, I removed the statement about how you would calculate scale it is better to say that we don’t have that information. I do wonder though if we do? I am sue Don has the scale…. IF not then we just need to say we don’t have it.***

Section 2.1:  
  
- L264-289: I find your description of erosion + dilation not very clear for someone not familiar with the method. You could offer a schematic with the shape of the mask. For example I do not understand what a circular 3x3 mask looks like ? Also discuss sensitivity of your results to size of mask. For example how are the results for conductivity impacted when your ignore narrow bottlenecks ? Should you ?

***We have elaborated on this and added figures to illustrate the Techniques and masks.***

Section 2.2:  
  
- L303-L304: reverse sentence order.

***We have corrected this.***

- L306: maybe say how you obtain connected components (what method you use).

***We have included this information in the appendix.***

- L323: should it read 'minimum' ?

***It should be Maximum, and we have added an explanation as to why.***

Depending on the season in which the photographs are taken and the resolution of the photographs we can find the expected largest bottlenecks in the melt pond network empirically by performing the above erosion steps repeatedly till all the connections between melt ponds are broken. This was done for a sample image in each image set in table \ref{table:list}. Knowing that a $3\times 3$ circular mask erodes two layers of pixels from the bottleneck - one from each side, we can calculate the number of erosion iterations that are needed to break the network into individual ponds. For example, if the widest bottleneck is 60 pixels across, 30 erosions are required. So the repeated erosion defined above are performed until this maximum bottleneck

size is reached.

After this maximum bottleneck size is reached in

the above connected components process, it is assumed that all the remaining melt ponds are individual melt-ponds and not networks of smaller melt ponds.

- L325-334: I find this paragraph very unclear and qualitative. The reader cannot reproduce your method exactly as you do not provide values and justification of the choices of this ratio.  
- On figure 2 you should specify the different ratios used.

***We have changed this section to better explain this concept – included new figure.***

Consider the image in figure \ref{bottleneck.ratio}. Here, red lines show regions that are bottlenecks and should be eroded away eventually as they are connections between melt ponds. Green line shows a region that is slightly constricted, but cannot be considered as a bottleneck as it is large relative to the pond surrounding it. Simply performing erosions as described above would eventually break all of these connections. To prevent this, contriction ratio, $CR$, is defined as

\begin{equation\*}

CR = \frac{pond \; area}{bottleneck \; size}

\end{equation\*}

It was empirically found that a constriction ratio of $CR\_{min} = 20$ worked well with the images used in this paper. During any erosion step, if for a network under consideration, $CR \lt CR\_{min}$, then this is probably a melt pond and should not be broken down any further.

Section 2.3:  
  
- This is by far the most difficult part to reproduce. You must provide some kind of clearer summary of the algorithm.

***We have attempted to provide a new and better explanation.***

- L349-357: unclear. Figure 3 is not clear either and lacks explanations in the legend. Why is Fig  3b the negative of Fig 3a for example ? What are the brown lines in Fig 3b ? Define direct connections between ponds ? Define intermediate connections ? Vague.

***We added information to the legend to clarify this.***

The first figure on top-left is the input image used. The second figure on top-right shows geodesic distances between melt pond nodes, this figure is a binary version of the first figure - blue is ice, green is water and maroon shows the smallest geodesic paths between nodes. The third figure on bottom shows the final connections obtained after edge elimination.

- L358-359: add references for these 2 methods.

***Added reference for dilation, have to add for graph theory***

- L365: should this be eroded ?

***No this should be dilated (add explanation here)***

- L365-L373: this seems ad-hoc and is unclear. Explain more clearly with better schematics maybe.

***We have attempted to provide a new and better explanation.***

- L374- … Line numbers missing here!  but this method description is very poorly explained. At times description makes no logical sense: "the distance between unconnected ponds is considered to be an arbitrarily large number, which is larger that the maximum distance between two ponds". How can the distance between 2 ponds be larger than the maximum distance between 2 ponds ?! You must provide schematics and a much more detailed description of the "simple clustering approach" and the "graph theory" !

***We have attempted to provide a new and better explanation in the text. – we use both the distances between the ponds and the width of the connections to assign weights to eliminate the edges connecting the ponds. The distance here is the geodesic distance between them, i.e., distance between the ponds through water, not ice. If the ponds are unconnected, we just assign a really large number to the distance between them (the actual path does not exist as they are unconnected – so they are an infinite distance apart through water).***

The distance between unconnected ponds

is set as infinity because the strength of connection between two ponds decreases with increasing distance and an infinite distance corresponds to absence of any connection between ponds.

I have already mentioned the following about the clustering approach - he center of each melt pond

pixel-cluster is located using the mean of the cluster

with Euclidean distances

I have given details about how the nodes and edges in the graph are determined and eliminated.

- You use sigma for conductance strength is analogy to work in material science I suspect. Please provide some references of similar work in other fields here.

***We have added references and examples ( Double check that this was done or explain why not)***

I can, maybe, cite something from electrical engineering, where the conductance of a wire is directly proportional to the cross-sectional area and inversely proportional to the length of the wire?

The above equation is analogous to conductance in an electrical circuit, which is directly proportional to conductivity of the wire and inversely proportional to the length of the wire.

- Fig 4 mentions dilation in the legend nowhere to be seen on the figure.

***We have added an additional dilation step to the figure. I don’t think you did…. I see melt ponds you did have two figures with the same name however make sure to explain how you changed the figure.***

- L385: improve description of noodle deletion. Why ratio of 20 chosen, discuss sensitivity of results to that parameter.

***We have attempted to provide a new and better explanation in the text.***

The final step of the algorithm is for node deletion,

where the algorithm searches for very small nodes that

lie between two or more much larger nodes, and

eliminates these small nodes based on a predetermined

ratio. This is because, if a really small melt pond lies between two much larger melt ponds, it is probably just a part of the channel connecting the two large melt ponds and should not be labeled as an individual melt pond. For the results presented in this paper, this ratio is empirically set to $20$

- L390: replace latter by second.

***Changed as suggested***

- L398: dilation is not shown. It is not clear to me how pond 1 and 6 can become connected.

Section 2.4:  
  
- L405: you introduce battery nodes in the framework of sea ice which sounds a bit odd. Please say in analogy to…

***This is analogous to an electrical circuit, where the conductivity between two points can be calculated and the flow of current through the circuit depends on the potential drop across battery nodes.***

- Lines numbers missing between L420 and L425. Replace "Let the M" by "Let M".

***Change as suggested.***

- L424: explain equation (6) and provide reference.

***You need to respond to this……………..***

- L425-L430: very unclear. What are you trying to express ?

***You need to respond to this……………..***  
  
Results:  
  
- L455-L457: unclear. If you look at smaller areas you get faster results. I do not understand.

***Removed this line.***

- L460: reduced resolution of the conductance values ? Why ? Unclear.

***Removed this line.***

- L462: using "graph methods". What are they ? Unclear ? It sounds like you use a package from Matlab and that you ignore its scientific content.

***We have added specifics of the methods used to allow for better cross referencing.***

- L473-L476: unclear.

***You need to respond to this……………..***

I can explain it better, maybe – it seems clear to me.

However, this

choice would be application specific, as even the

isolated ponds may be used to study the evolution

of networks with time, because they might, at some point further in time join larger interconnected networks.

- L477-L480: I do not see what kind of ground truth you are talking about here.

***We have supplemented with an explanation of ground truths.***

- Reorder figures so that Fig 10 (June) is first.

***Changed as suggested.***

- It looks to me that the figures are at a different scale and I expect this to affect the conductivity value. Am I correct ? You cannot compare conductivity at different scales. The scales are important and must be clarified throughout the text.

This is an extremely relevant point, but I do not know how to address this.

***There is reason to expect universal scaling laws.. It should be noted in the text somewhere that the conductivity values only depend on only the geometry not the scale.***

- L486-L492: I do not understand.

***We have added an explanation to clarify.***

For this reason, unlike the above mentioned figures, the images are shown without

removing the melt pond labels which are unconnected to the battery nodes.

- In figures 6 to 10 I do not understand why only a subsample of melt ponds is highlighted ?

***We have added an explanation to clarify.***

Note that in the images shown in figures \ref{July1}, \ref{July2}, \ref{Aug\_hot1} and \ref{Aug\_hot2}, the melt-ponds that are not part of the network which connects the battery nodes, have not been labeled to prevent excess clutter in the figures.

Conclusions:  
  
- The conclusion is far too weak. What are the implications of this work ? Why do we care…?

This is where Ken will really help out.