

Dear Editor,

Thank you for your careful reading of our manuscript and your insightful comments. Following the comments and suggestions, we have included several changes in the manuscript. Below, we give a detailed reply to the comments.

it states that it that the methodology is introduces...new" yet there's a reference to published work in which the method is developed. It is thus not new.

We re-wrote the sentence, and now it reads, "This paper newly introduces that the use of our recently developed tool, that was originally designed for data-driven discovery of coherent sets in fluidic systems, can in fact be used to indicate early warning signs of critical transitions in ice shelves, from remote sensing data."

"Our approach adopts...considering..." I am not sure "considering" is the right word...

Our approach adopts a directed spectral clustering methodology in terms of developing an asymmetric affinity matrix and the associated directed graph Laplacian.

"We generally apply" as opposed to specifically apply??

Thank you. we replaced "generally" with "specifically."

"(post-cast) predict" do you mean forecast?

Thank you very much. We added the following clarification for the term "post-cast": (such benchmarking using data from the past to forecast events that are now also in the past is sometimes called "post-casting," analogously to forecasting into the future)

"We can do so months earlier before" rewrite

Thank you. The sentence now reads: "Our method indicates the coming crisis months before the actual occurrence, and furthermore, much earlier than any other previously available methodology, particularly those based on interferometry".

The discussion on warming is not properly framing either the problem you wish to consider or how warming and calving and other fracture events connect with each other. I think you are trying to say that with warming there are more sheet-cracking events... but the reader is left with the question: 'I can see how warming might have something to do with cracking' but is this fundamental to the methodology to be presented? is warming a requisite for the methodology to be applicable?

Thank you very much for the insightful comment. The discussion on warming is highly reduced to two sentences, and considers your comment.

"Still, this contribution..." I don't understand the use of "Still"  
Reference to calving and the change in the 21st century?

We re-wrote the sentence and added a reference to calving and the change in the 21st century.

l26-31 "Most of Antarctica...dramatic warming" then it says that it has warmed 2.5degC...in my book this is dramatic, is it not?

Thank you. Yes, it is a dramatic warming. We re-wrote the sentence so that now it states: "Antarctica already experienced dramatic warming. Especially, the Antarctic Peninsula, which juts out into relatively warmer waters north of Antarctica, has warmed 2.5 degrees Celsius (4.5 degrees Fahrenheit) since 1950"

l32 "probably due to" either it is or not or there's contradicting or incomplete evidence for this...as it reads, it sounds like it is your opinion.

Thank you. The sentence now reads: "A large area of the Western Antarctic Ice Sheet is also losing mass, attributed to warmer water up-welling from the deeper ocean near the Antarctic coast."

Finally when it gets to methodologies it mentions interferometry...fine, what's wrong with this method? instead of stating you need to contrast your method with interferometry, why don't you actually contrast them? and further, can't you construct an extrapolation based upon interferometric data to suggest what happens next?

Thank you very much. We have reviewed and modified our discussion to better present our point of view. The main perspective is that interferometry is clearly an excellent and powerful tool that is well suited to the job of detecting ice surface velocity. However, it is not specifically a "prediction" method in of itself. It is a tool that provides information that can be used as a starting point to apply further and different types of analysis that can conclude some "predictions." On the other hand, applying our method, which is originally designed for detecting and tracking coherent structures, to a rigid body can provide different insights and give an early indication of the possible critical transitions. See line 82-85.

showed "high performance in successfully detecting" meaning what? less false positives, more positives, etc? how was this vetted? and what are "fluidic systems" (and do fluids have cracks, are we talking about multiphase flow?)

We re-wrote the sentence, so that now it reads: ``We showed that our method is analytically a data-driven analogue to the transfer operator formalism designed for detecting, which was originally designed for coherent structures in fluidic systems, such as ocean flows or atmospheric storms.’’

191 “what underlies a notion...we must understand directionality” this sentence is muddled

Thank you. We re-wrote the sentence, and now it reads: ``The key difference is what underlies a notion of coherent observations that we must also consider the directionality of the arrow of time.’’

‘The rest of this section needs a serious, sentence by sentence analysis and revamping so that the grammar is up to basic standards for publication. In fact, the whole paper needs this treatment.

Thank you. We have taken this to heart. We have continued to carefully edit the text throughout. Some of which are here, but much of it is minor but numerous improvements.

how are you quantifying color and what is the resolution? Cal S and Cal C could be radically different in sizes, so there must be some sort of normalization...is there?  
The parameter alpha also has to be accounted for in this regard.

Thank you. We clarify the quantification and the scale of S and C. We also provide a discussion about the effect of the alpha value on the results. See lines 137-143.

The results have very little by way of quantitative analysis. You declare the method superior, but I do not see evidence for this, or it is rather circumstantial, at best.  
If this section had more compelling outcomes the reader might be incentivized to try it.

The referee’s point is well taken, that statements of a superior method suggest that a statistical analysis would follow to show what it is the fractional improvement over the other methods. In this case, we do not know of other forecasting methods, and even our method is not necessarily a forecasting method. However, we do show that this important event showed itself from the perspective of our data driven approach, months in advance, and we know of no other comparison for this striking observation. So, we hope this pictorial evidence, Figs. 6-8, and B1-B7 processed in the manner of the presented algorithm, in of itself, serves as a demonstration utility to detect this rare event.

There’s a serious missed opportunity to discuss the color issue. Surely, there are “better” color than others. In any event, I am not expecting that this issue will be addressed here, but I will suggest doing so in order to produce a more compelling paper.

Thank you very much. Yes, we agree that it is interesting issue to address and discuss, and it will be a subject for our future work.

#### Section 4

one very obvious issue to address is the role of noise in the data. I can imagine that if the data is not prepared properly that noise will lead to a lot of false details. You averaged the data over a month...is there some quantitative guidance for data preparation?

Thank you. In line 225-228, we discussed the effect of noise, and how we excluded some noisy images because of their effect on the results. Also, we added a new figure, Fig.B.8, that shows a sample of the noisy images that was excluded.

The idea of connecting mechanics to this data-driven method is sensible, but I am not sure I would agree that it'd be productive to consider an asymptotic-in-time method like Lyapunov vectors and exponents with something that seems to be designed for short time events? At the very least you'll need to explain yourself here (or omit).

Thank you very much. You are right. We said too little for this to be meaningful, and we decided it would take too much space to clearly make this otherwise auxiliary comment. So, we decided to take your advice and omit the comment.

Sincerely,

Abd AlRahman AlMomani and Erik Bollt