Manuscript # tc-2021-83 by Reza Zeinali-Torbati, Ian D. Turnbull, Rocky S. Taylor, Derek Mueller: "A probabilistic model for fracture events of Petermann ice islands under the influence of atmospheric and oceanic conditions"

Dear Reviewer,

We would like to thank you for your time reviewing our manuscript. Given your feedback, we have developed the following plan to refine our paper, which will significantly improve the quality of our manuscript. In anticipation of being invited to resubmit the manuscript, the changes were already made to our own internal version.

We provide a table of responses that include our point-by-point response to each of your corrections/recommendations.

Thanks again for your insightful review.

Comments/suggestions	**Authors' Responses**
1) This study presents a probabilistic model of iceberg fracture based on a series of ice islands generated from calving events from the Petermann ice tongue with the goal of stepping towards providing a real world practical operational forecast model. The authors analyzed the role of wind speed, air temperature, ocean current speed, water temperature and something called the wave energy index along with mean air temperature and sea ice concentration. As someone who works largely on the mechanical side I don't have experience with the operational side or the statistical framework. Someone who works more closely on that side of the field will have a better idea of the appropriateness of the methodology and relationship to prior work. Overall, however, I don't see any obvious objections to the statistical tests or procedures used. A minor comment is that it would be helpful to relate the probabilistic model more closely to process	Thank you very much for your review, feedback, and suggestions. It is a pleasure to see your positive feedback on our paper. As you noted, it would certainly be an interesting topic for a future work to investigate how the presented probabilistic model relates to process level models for iceberg deterioration. Please find below a complete response regarding your comments and suggestions.

level models of iceberg decay, although that may follow in subsequent work.	
2) Overall, I only have a few minor comments. 1. How reliable are the inputs fed into the model? We are presented with a probabilistic model driven by inputs. Reanalysis and wave forecasts all have strengths, but also uncertainties. Hence the question from a non-expert as to whether the uncertainty in the model inputs small enough to be neglected?	We have looked into the documentations for the reanalysis data that we used to explore if there are any reported error/uncertainty on the extracted data that we used in our study. However, these products have not reported on the errors in the datasets created. We have, however, found a few studies that reported on the accuracy of some ocean products in other regions. Surface currents are expected to be the most uncertain variable in drift forecasting models. The mean error in the speed of surface currents from CMEMS Global Ocean Physics Reanalysis model was reported to be 0.08 m s^{-1} (Lellouche et al., 2018). CMEMS water temperature data were reported to be within 1.2 °C of measured data, with RMS error at sea surface being around 0.4 °C (Sukresno et al., 2019). The Root Mean Square Error (RMSE) in significant wave height estimates from ECMWF was reported to be less than 0.37 m (Wang et al., 2019). The mean Recursive Prediction Error (RPE) for wave height and wave period was reported as 12.5% and 7.7%, respectively. Also, a bias of 1.5 °C and 0.16 m s^{-1}, respectively, was noted for air temperature and wind speed from NARR (Boccara et al.,

2008).

We acknowledge the error in the input data. However, we should note here that given our model setup, in which the level of data is reduced to binomial level (Table 1), we expect the presented model to be less vulnerable to the errors in the input data, unless the values are too close to the median values.

References:

- Boccara, G., Hertzog, A., Basdevant, C., and Vial, F. (2008). Accuracy of NCEP/NCAR reanalyses and ECMWF analyses in the lower stratosphere over Antarctica in 2005. Journal of Geophysical Research: Atmospheres, 113(D20).
- Lellouche, J. M., Greiner, E., Le Galloudec, O., Garric, G., Regnier, C., Drevillon, M., ... and Le Traon, P. Y. (2018). Recent updates to the Copernicus Marine Service global ocean monitoring and forecasting real-time 1/12° high-resolution system. Ocean Science, 14(5), 1093-1126.
- Sukresno, B., Murdimanto, A., Hanintyo, R., Jatisworo, D., and Kusuma, D. W. (2019, March). The

	use of CMEMS and Argo Float data for Bigeye Tuna fishing ground prediction. In IOP Conference Series: Earth and Environmental Science (Vol. 246, No. 1, p. 012002). IOP Publishing. • Wang, J., Li, B., Gao, Z., and Wang, J. (2019). Comparison of ECMWF significant wave height forecasts in the China sea with buoy data. Weather and Forecasting, 34(6), 1693-1704.
3) The analysis considers wave energy, but is it also possible to consider wavelength in addition to amplitude? The wavelength of ocean swell relative to the flexural wavelength of the ice island could be important in determining if bending stresses are large enough to fracture the island. In fact, modest swell events are sufficient to breakup the sea ice pack when the ocean swell as an appropriate period, but long wavelength swell penetrates the sea ice pack with minimal effect.	We appreciate the point and explanation that you provided. It is certainly interesting to investigate the addition of a new variable such as wavelength to our model, but the ECMWF ERA Interim dataset does not report on wavelength values. However, our "wave energy index" variable is dependent on wave period (Eq. 1), a component that is tightly correlated with wavelength. Also, given the limited number of fracture events in the CI2D3 database, we have restrictions on the number of input variables (and their state combinations) that can be used in the presented model. So, we have insufficient data to allow for the addition of a new variable, otherwise our model would be saturated. We also looked into the wave height values to investigate if the ice islands

	were exposed to exceptionally large weight heights over their lifetime to cause significant bending stress. However, our analysis of the extracted data shows that only ~5% of the wave heights were above 2m, with maximum wave height being ~5m. The wave heights over the drift path of the studied ice islands were mostly less than 2m, which is much smaller than the sail height of large ice features such as the ice islands. Therefore, we expect the waves to have minimal impact on the bending stress exposed the studied ice islands. We, however, acknowledge here that waves could have significant impact on sea ice breakup events driven by bending stress.
4) Can the authors provide a sentence or two providing the motivation and sensitivity for selecting the prior probability distribution? My own experience with Bayesian analysis is that selecting on appropriate prior can be tricky and, unless there is a large amount of data, the prior can play a role guiding predictions. That is not to say that this is the case here, but a few sentences describing the motivation and sensitivity may be useful.	Given the fairly large amount of data in our database, the prior probability of fracture event occurrence was calculated based on our knowledge on the number of fracture events (328) and the number of all observations (17755), before some evidence (metocean conditions) is taken into account. A sentence has been added to explain how the prior probability was calculated. This added sentence reads: "**Given the large size of the CI2D3 database, the value of $P(X)$ was estimated as the frequency of fracture events (*i.e.,***

	the number of fracture events divided by the total number of observations) before any criteria set based on metocean conditions was considered." (*lines 255-257*).
5) I had a hard time initially interpreting Figure 3 and others. I think what we are supposed to do is compare the figure on the left with the figure on the right to see the enhancement of fracture events at warm ocean/atmosphere temperatures compared to the frequency of observations of warm ocean/atmosphere temperatures. This is quite convincing after contemplating the figures. I wonder if stepping readers not used to this type of plot through what we are supposed to see would be helpful. Alternatively, would it be more useful/intuitive to plot the ratio of the left and right panels to show the enhancement of fracture events in warmer conditions relative to the occurrence of these conditions? In a plot of this type, values close to one would imply that fracture events are as likely to occur as the frequency of observations. Values large compared to one would indicate that fracture events are more likely to occur than the frequency of observations and values less than one would imply that fracture events are less likely to occur relative to the frequency of observations.	We thank the reviewer for bringing this point into our attention, which can certainly provide more intuitive representation of the conditions where fracture events are more likely to occur. Therefore, we have added three panel figures in the Appendix section (Figs. A1-A3) to show the ratios of the relative frequency for fracture events and all observations over the range of our variables (section 6). We have also added a paragraph in section 3.2 to describe the added figures, which reads: "**The enhancement of fracture events under the conditions where the ice islands experienced higher values of metocean variables was investigated through ratios of the relative frequency for fracture events and all observations over the range of variables presented in Figs. 3-5. These results are presented in Appendix A (Figs. A1-A3), where values close to one imply that fracture events are as likely to occur as the frequency of observations. Values large compared to one indicate that**

	fracture events are more likely to occur than the frequency of observations. Values less than one imply that fracture events are less likely to occur relative to the frequency of observations. The results in Figs. A1-A3 reveal that the ratio of the relative frequency for fracture events and all observations generally increases with the values of metocean variables, which clearly indicate a tendency for fracture events to occur under more extreme conditions." (*lines 361-368*).
6) Line 71 extra space in "w ave"—>wave	This error was corrected (*line 71*).