Reviewer#2.

The authors are most grateful for your comments. We have followed your suggestions and revised the manuscript accordingly in many places. Please, find our responses below.

This paper presents a numerical investigation of ISWs propagating under ice. A Reynolds averaged Navier-Stokes solver is utilised and both smooth and ridged ice is considered. The wave propagates from open water to under ice and two cases are focussed upon namely smooth ice and ridged ice. In the smooth ice case, a blocking parameter is shown to be the main control variable and flow dynamics in keeping with previous results by the first author and co-workers for an ISW of elevation over a step are seen. In the ridged case both the blocking parameter and a second parameter describing the ratio between keel depth and distance between keels are used to classify the flow.

The paper is original and interesting and I am supportive of publication subject to the minor remarks below.

The paper contains a lot of typographical and grammatical errors, these need to be fixed in advance of publication.

Answer: The paper was checked to remove errors.

The citation is not thorough enough. Key papers are cited but the authors often fail to compare their work with published literature.

Answer: We added discussion and comparison of our simulation results with published experimental and numerical studies.

L. 102 "These results demonstrate a weak effect of free surface on ISW dynamics in considered cases which made it possible in this problem to replace the conditions on the free surface with conditions on the rigid lid. Note that in laboratory experiments (Carr et al., 2008; Luzzato-Fegiz and Helfrich, 2014) the influence of a free surface on the stability of waves with a trapped core was shown. This effect has been interpreted as the influence of surfactants essential in laboratory-scale processes, however, these Marangoni effects have a negligible impact on the interior of full-scale oceanic waves (Luzzatto-Fegiz and Helfrich, 2014)"

L. 212 "In the limiting case of the interaction of ISW with a single keel (Zhang et al., 2022b), the maximum energy dissipation was about 25% which is somewhat less than in our calculations, but we need to keep in mind the differences in the calculation parameters and turbulence parametrization. Zhang et al. (2022b) used constant eddy coefficients whereas in our study the model of turbulence was used where eddy coefficients vary in space and time."

L. 225 "In another limiting case ISW of elevation propagates over a corrugated bottom when the bottom element length was much less than the ISW wavelength (Carr et al., 2010) a comparison with ISW propagated under an ensemble of ice keels of horizontal scales greater than ISW wave length was not straightforward. In addition, Reynolds equations with turbulent closure describe real-scale processes in the ocean, in contrast to laboratory scales in (Carr et al., 2010). Unlike (Carr et al., 2010) we cannot describe in detail the instant spatial-temporal dynamics of high shear region near the ice. However, the Fig. 6b showed wave-induced currents over the keels, their interaction with the apex of the keels and a sequence of lee vortices formed as a result of such interaction (see Fig. 6b T=1h 35 m, T=1h 41m). Similarly to (Carr et al., 2010) the vortices developed after the main wave passed over the keel (see Fig. 6b at T=1h 44 m, T=1h 45m*)* resulting in deformation of the overlying pycnocline and, in some instances, significant vertical mixing."

Abstract second sentence – you refer to 'breaking IWs' at the edge. How do they break? Do they always break? Is there evidence for this? May be the word 'breaking' should be deleted?

Answer:
Thank you for your comment. We have made changes in the text accordingly:

L. 2 "Transformation of the internal waves at the edge of the ice cover can essentially enhance the mixing and melting of ice in the Arctic Ocean and Antarctica."

Abstract 3rd line – you talk about generation of ISWs, is this specific to polar oceans or in general?

Answer: We have made changes in the text accordingly:

L. 3 "In the Polar Oceans the internal solitary waves (ISWs) are generated by various sources, including tidal currents over the bottom topography, the interaction of ice keels with tides, varying in time winds, vortices, and lee waves."

*Line 31. ISW shear, convective instabilities, and breaking on topographic inhomogeneities extract kinetic energy from ISWs for turbulence and **subsequent mixing increases the melting of ice**. Is the last part of this sentence true? If so can you give a suitable reference?*

Answer: We have changed the text to explain a sequence of processes:

L. 31 The transformation of an ISW under an ice keel can cause the advection of water below the ice layer, whereas ISW shear and convective instabilities result in turbulent mixing. The heat advection and turbulent flux both will contribute to the vertical heat flux and consequently the change in temperature under the sea ice and increase of melting (Zhang et al., 2022b).

Line 50 – you say your wave goes from open water (with a free surface) to under-ice. Is this reflected in the numerical model or does the open water have a rigid lid in the numerical work? If so this should be made clear and potential differences with a free surface discussed.

Answer: Thank you for your comment. We have refined the text as

L. 51 "In this study, a numerical investigation of the transformation of ISW propagating from ice-free water in the stratified sea under the edge of the ice cover is carried out to compare the depression ISW transformation and loss of energy on smooth ice surfaces, including those on the ice shelf, with the processes beneath the ridged underside of the ice."

To get around the difficulties associated with the numerical solution of the nonhydrostatic model equations in the presence of an ice layer, we considered the setting mirrored for the upper surface of the ocean, in which the ice layer was replaced by a step on the bottom. This approach requires using the rigid lid boundary condition at the ocean surface. Therefore, we estimated the effect of free surface on the wave characteristics (L. 101). See answers on next comment.

Line 100 – you have compared free slip and no slip and found little difference however it is known that the upper boundary condition can effect wave properties such as amplitude and stability at least on the lab scale (see e.g. Carr et al 2008 PoF, Luzzatto-Fegiz & Helfrich 2014 JFM). Why does it not matter here? Is it because surface tension effects aren't as important on your scale? Did you do any sensitivity test on the upper boundary condition?

Answer: We have not compared free-slip and no-slip cases. In both model setups friction was taken into account only on the ice-water surface, whereas free-slip conditions were used at the rest of the boundaries (L. 85). The aim of tests with ISW the same amplitude propagating as a wave of depression and as a wave of elevation (see L. 97) was to estimate the effect of free surface on the wave characteristics for free-slip conditions. It was found that the difference in the horizontal velocity field between the two configurations of the model does not exceed 1% demonstrating a weak effect of free surface on ISW dynamics in considered cases. We have added text to clarify this conclusion

L. 101 "The tests aimed to estimate the effect of free surface on the wave characteristics for free-slip boundary conditions."

L. 102 "These results demonstrate a weak effect of free surface on ISW dynamics in considered cases which made it possible in this problem to replace the conditions on the free surface with conditions on the rigid lid. Note that in laboratory experiments (Carr et al., 2008; Luzzato-Fegiz and Helfrich, 2014) the influence of a free surface on the stability of waves with a trapped core was shown. This effect has been interpreted as the influence of surfactants essential in laboratory-scale processes, however, these Marangoni effects have a negligible impact on the interior of full-scale oceanic waves (Luzzatto-Fegiz and Helfrich, 2014)"

Line 168 – you talk about reflected waves off the solid boundary step. Would you expect the same for real ice? Is there any way of assessing or inferring what will happen if the ice isn't solid for e.g in the MIZ when the ice is mushy?

Answer: We assume that the ice layer is rigid and does not interact with ISWs (L. 65). The ISW interaction with floating ice plates and open water in MIZ is out of the scope of this study.

Line 200 how does this statement compare with published papers on the generation of IWs by ice keels see e.g. Zhang et al 2022 J. Ocean Limnol, Zhang et al 2022 JGR:Oceans, M. McPhee & L. Kantha. 1989 J. Geophys. Res.

Answer: The study of wave generation mechanisms is not discussed in this article. Investigation into the interaction of ISW with an ensemble of keels has not yet been carried out before our study. We added a discussion of the results of our simulations with two limiting cases: interaction ISW with a single keel (Zhang et al., 2022), and ISW propagation over a corrugated bottom when the bottom element length was much less than the ISW wavelength (Carr et al., 2010). The text has been added accordingly:

L. 212 “In the limiting case of the interaction of ISW with a single keel (Zhang et al., 2022b), the maximum energy dissipation was about 25% which is somewhat less than in our calculations, but we need to keep in mind the differences in the calculation parameters and turbulence parametrization. Zhang et al. (2022b) used constant eddy coefficients whereas in our study the model of turbulence was used where eddy coefficients vary in space and time.”

L. 222 “If we assume that the tidal flow around the keels is the source of internal waves (Zhang et al., 2022), then we can conclude on the basis of our simulations that under conditions of strongly ridged ice, the waves excited by the tidal flow disperse in the vicinity of their formation.”

L. 225 “In another limiting case ISW of elevation propagates over a corrugated bottom when the bottom element length was much less than the ISW wavelength (Carr et al., 2010) a comparison with ISW propagated under an ensemble of ice keels of horizontal scales greater than ISW wave length was not straightforward. In addition, Reynolds equations with turbulent closure describe real-scale processes in the ocean, in contrast to laboratory scales in (Carr et al., 2010). Unlike (Carr et al., 2010) we cannot describe in detail the instant spatial-temporal dynamics of high shear region near the ice. However, the Fig. 6b showed wave-induced currents over the keels, their interaction with the apex of the keels and a sequence of lee vortices formed as a result of such interaction (see Fig. 6b T=1h 35 m, T=1h 41m). Similarly to (Carr et al., 2010) the vortices developed after the main wave passed over the keel (see Fig. 6b at T=1h 44 m, T=1h 45m) resulting in deformation of the overlying pycnocline and, in some instances, significant vertical mixing.”

Line 212 – the statement about ice roughness- is this in comparison to the blocking parameter?

Answer: The text has been refined accordingly:

L. 190 The simulations showed a weak dependence of energy loss on the friction parameter CD (Fig. 5b)

Line 222 - could the authors say more about this? How might this be represented within their numerical model for example?

Answer: The text has been added accordingly:

L. 254 “The next step could be an explicit representation of heat and salt fluxes between the ice cover due to the ISW interaction with the ridged ice, e.g. following flux parametrization by McPhee et al.,(1987).”