EGU GENERAL ASSEMBLY 2020

CR5.7: *ICE SHELVES AND TIDEWATER GLACIERS - DYNAMICS, INTERACTIONS, OBSERVATIONS, MODELLING*

PRESENTATION EGU2020-9665:

THE EFFECT OF THE ABATING OF OCEAN WAVES IMPACT BY THE ELASTIC CREVASSE-RIDDEN ICE SHELF

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Introduction

- Forced ice shelf vibration modeling was performed using a full 3D finite-difference elastic model, which takes into account sub-ice seawater flow. The sea water flow was described by the wave equation, which includes the pressure perturbations in the shallow water layer under the ice shelf.
- The modeling provides the spectra analyses in the problem of ice shelves and ocean waves interaction, what yields the eigen-frequencies and eigenmodes of the ice shelf vibration (e.g. Holdsworth and Glynn, 1978). The investigation of the dispersion spectra (the dispersion curves describing the wavenumber/periodicity relation) reveals a qualitatively difference between the spectra obtained for the ice shelf with and without crevasses (Freed-Brown and others, 2012).
- The obtained dispersion spectra reveal gaps (inter-mode spaces) that provide the transition from n-th mode to (n+1)-th mode. These gaps (inter-mode spaces) are observed both for an intact ice shelf free of crevasses and for a crevasse-ridden ice shelf. They are aligned with the minimums in the amplitude spectrum. Moreover, the dispersion spectra obtained for a crevasse-ridden ice shelf reveal the “band gaps” – the frequency ranges there no eigenmodes exist (Freed-Brown and others, 2012).

FIELD EQUATIONS

- The momentum equations that describe the ice-shelf flexures, based on the Hook's law, are expressed as (e.g., Landau & Lifshitz, 1986)

- $$\begin{cases} \frac{2(1-\nu)}{1-2\nu}\frac{\partial^2 U}{\partial x^2} + \frac{\partial^2 U}{\partial y^2} + \frac{\partial^2 U}{\partial z^2} + \frac{1}{1-2\nu}\left(\frac{\partial^2 V}{\partial x\,\partial y} + \frac{\partial^2 W}{\partial x\,dz}\right) = \frac{2(1+\nu)}{E}\rho\,\frac{\partial^2 U}{\partial t^2}; \\ \frac{\partial^2 V}{\partial x^2} + \frac{2(1-\nu)}{1-2\nu}\frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} + \frac{1}{1-2\nu}\left(\frac{\partial^2 U}{\partial y\,\partial x} + \frac{\partial^2 W}{\partial y\,\partial z}\right) = \frac{2(1+\nu)}{E}\rho\,\frac{\partial^2 V}{\partial t^2}; \\ \frac{\partial^2 W}{\partial x^2} + \frac{\partial^2 W}{\partial y^2} + \frac{2(1-\nu)}{1-2\nu}\frac{\partial^2 W}{\partial z^2} + \frac{1}{1-2\nu}\left(\frac{\partial^2 U}{\partial z\,\partial x} + \frac{\partial^2 V}{\partial z\,\partial y}\right) - \frac{2(1+\nu)}{E}\rho g = \frac{2(1+\nu)}{E}\rho\,\frac{\partial^2 W}{\partial t^2}; \\ 0 < x < L;\, y_1(x) < y < y_2(x);\; h_b(x,y) < z < h_s(x,y); \end{cases} \quad (1)$$

- where (XYZ) is a rectangular coordinate system with X axis along the central line, and Z axis is pointing vertically upward; U, V and W are two horizontal and one vertical ice displacements, respectively, and ρ is ice density. The geometry of the ice shelf is assumed to be given by lateral boundary functions $y_{1,2}(x)$ at sides labeled 1 and 2 and functions for the surface and base elevation, $h_{s,b}(x,y)$, denoted by subscripts s and b, respectively.

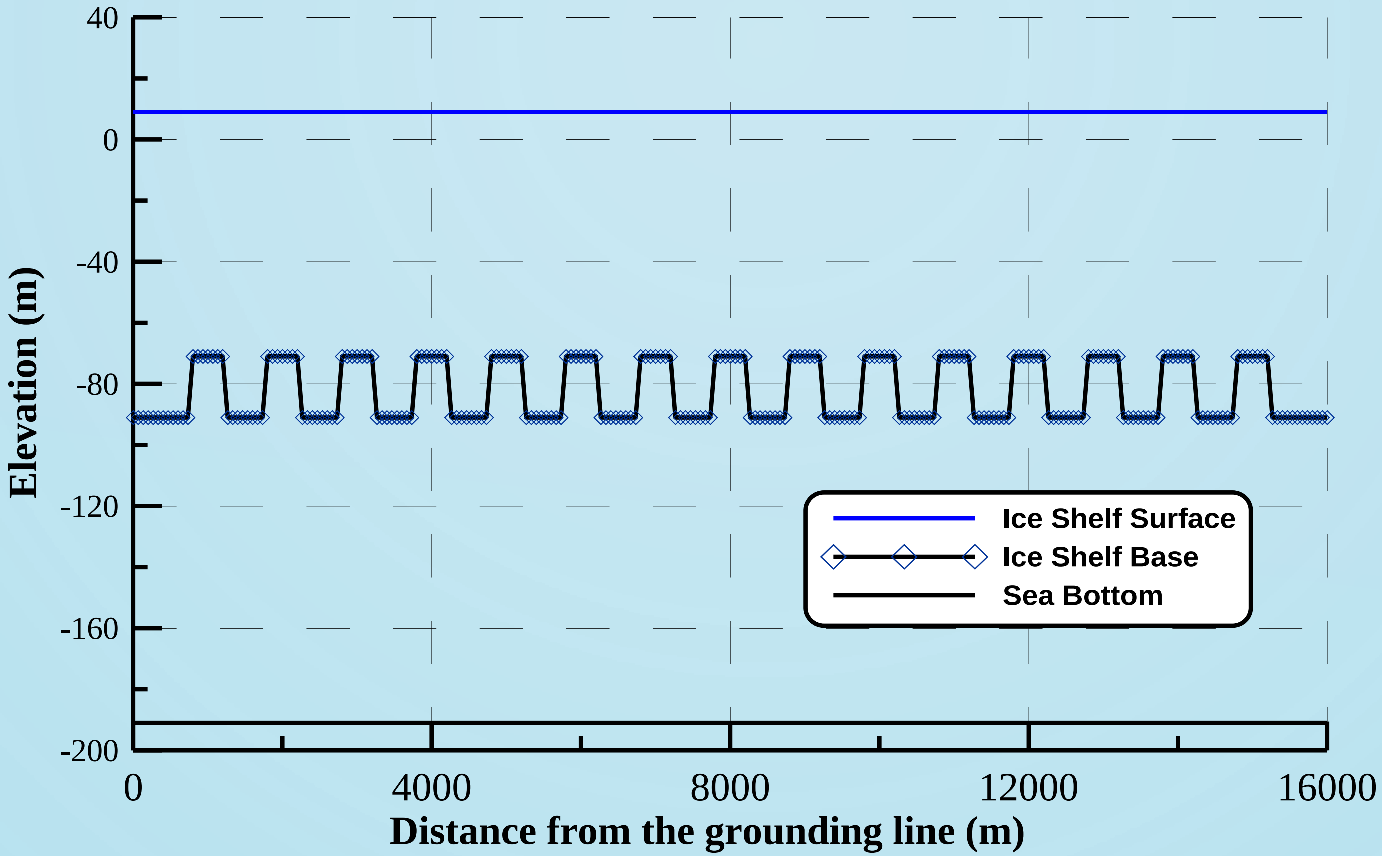
- The shallow sub-ice water flow is described by the wave equation (Holdsworth and Glynn, 1978):

- $$\frac{\partial^2 W_b}{\partial\, t^2} = \frac{1}{\rho_w}\frac{\partial}{\partial\, x}\left(d_0\frac{\partial\, P\prime}{\partial\, x}\right) + \frac{1}{\rho_w}\frac{\partial}{\partial\, y}\left(d_0\frac{\partial\, P\prime}{\partial\, y}\right), \quad (2)$$

- where ρ_w is sea water density; $d_0(x,y)$ is the depth of the sub-ice water layer; $W_b(x,y,t)$ is the vertical deflection of the ice-shelf base, and $W_b(x,y,t) = W(x,y,h_b(x,y),t)$; and $P'(x,y,t)$ is the deviation of the sub-ice water pressure from the hydrostatic value.

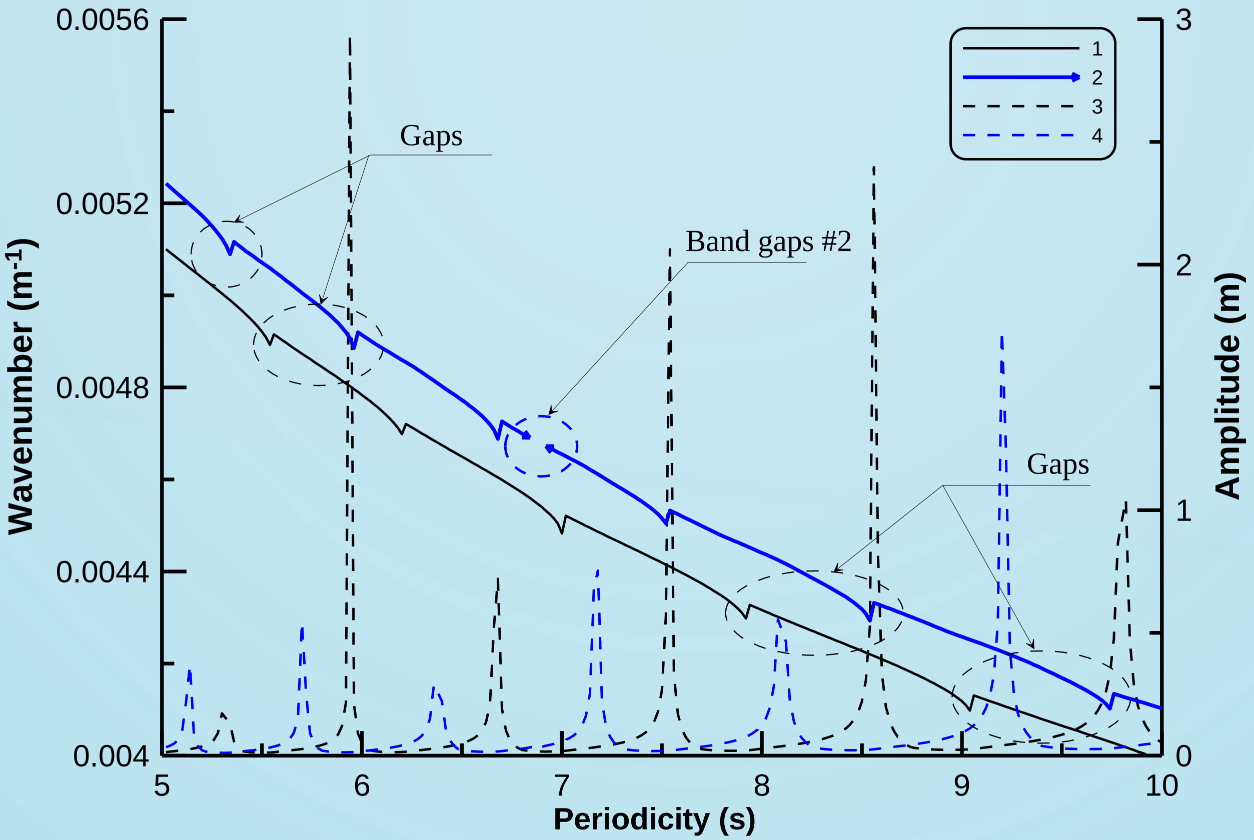
- The full list of equations of the model are presented in (Konovalov, 2019).

ICE SHELF GEOMETRY CONSIDERED IN THE NUMERICAL EXPERIMENTS



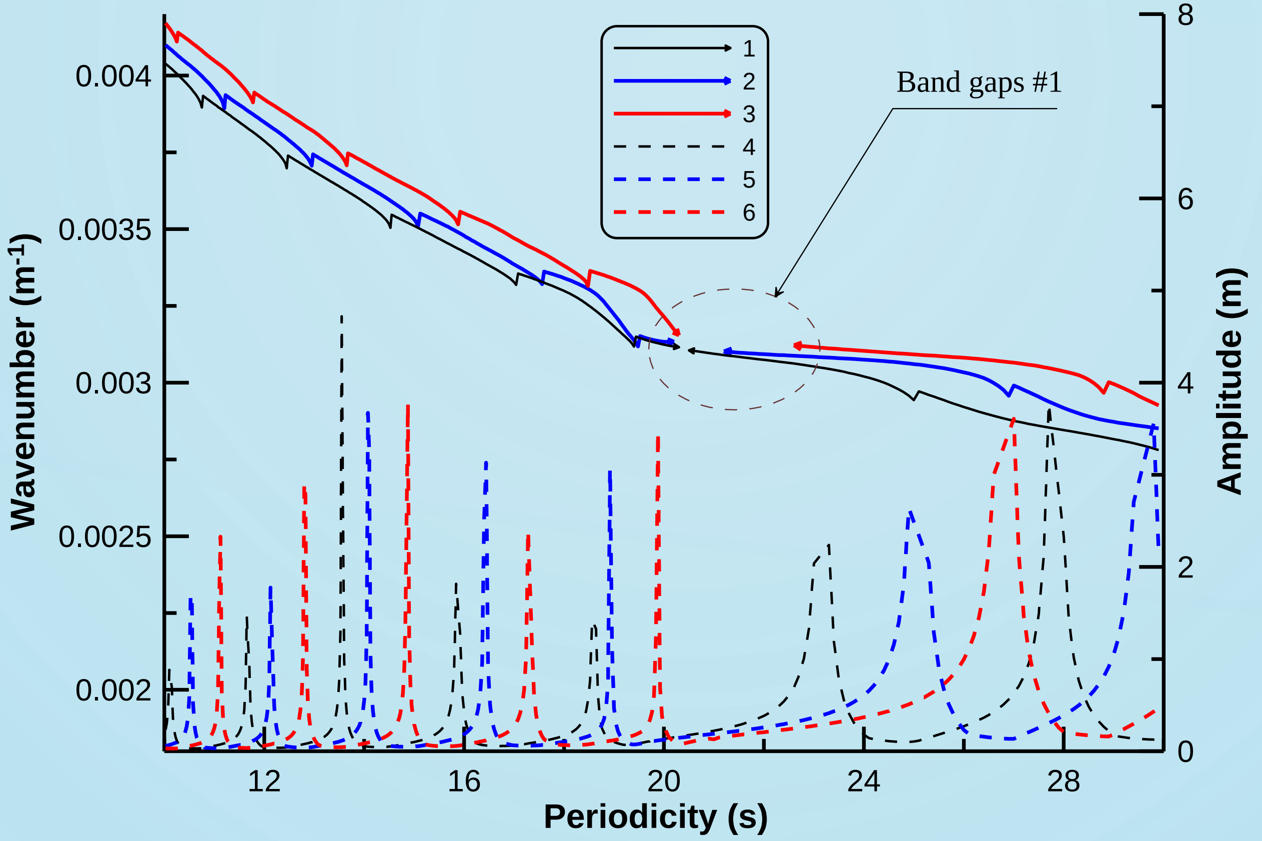
- **Figure 1.** The crevasse-ridden ice-shelf geometry and the cavity geometry that are considered in the numerical experiments. Spatial periodicity (Δl_{cr}) of the crevasses is equal to 1 km. The width of the crevasses (w_{cr}) is equal to 500 m and the penetration depth (d_{cr}) of the crevasses is equal to 20 m.

Results: The dispersion spectra in the periodicity range of 5..10s



- **Figure 2.** The dispersion spectra (curve 1-2) and the amplitude spectra (curves 3-4). The ice shelf length is 16 km, the width is 0.8 km and the thickness is 100 m. **1** – the dispersion spectrum obtained for the intact ice shelf free of crevasses. **2** – the dispersion spectra obtained for the crevasse-ridden ice shelf ($d_{cr} = 20m$). Curves **3** and **4** are the amplitude spectra obtained respectively for the intact ice shelf free of crevasses and for the crevasse-ridden ice shelf ($d_{cr} = 20m$). Spatial periodicity of the crevasses is equal to 1km.

RESULTS: THE DISPERSION SPECTRA IN THE PERIODICITY RANGE OF 10..30S



- **Figure 3.** The dispersion spectra (curves 1-3) and the amplitude spectra (curves 4-6). The ice shelf length is 16 km, the width is 0.8 km and the thickness is 100 m. Curves **1 – 3** are the dispersion spectra obtained for the crevasse-ridden ice shelf: **1** – $d_{cr} = 10m$;. **2** – $d_{cr} = 20m$; **3** – $d_{cr} = 30m$. Curves **4 – 6** are the amplitude spectra obtained for the crevasse-ridden ice shelf: **4** – $d_{cr} = 10m$; **5** – $d_{cr} = 20m$; **6** – $d_{cr} = 30m$. Where d_{cr} is the crevasses depth. Spatial periodicity of the crevasses is equal to 1 km.

Conclusions

- The dispersion spectra that is the relationships between the wavenumber and periodicity (frequency) of the forcing reveal the two types of discontinuities of the function. The first type of these discontinuities is ordinary separately located discontinuity points of the first kind. These discontinuity points (inter-mode spaces) are aligned with the minimums in the amplitude spectrum. These gaps (inter-mode spaces) are observed both for an intact ice tongue free of the crevasses and for the crevasse-ridden ice tongue.
- The second type of the discontinuities observed in the dispersion spectra is the ranges of the discontinuity points and these ranges are known as “band gaps” (Freed-Brown and others, 2012). They are observed only for the crevasse-ridden ice tongue. In particular, in the range of the periodicities from 5 s to 250 s considered in this study there are two “band gaps” for the crevasse-ridden ice tongue, which is 16 km in longitudinal extent, 0.8km width and 100m thick (in the case of intact ice tongue). The modes of the ice tongue vibrations change rapidly inside the “band gaps” and this change cause the discontinuities in the “bang gaps”.

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