Different sea-ice characteristics influence on wave damping

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With increasing temperatures, sea ice is thinning and weakening, making it more prone to changes from atmospheric forcings such as waves. In the Marginal Ice Zone (MIZ), the waves-in-ice dynamics are complex. It is hard to implement these physical processes in models due to the large differences in ice characteristics. However, research has found that waves in this area is affected by the sea ice, the waves are dampened by the ice. This dampening effect differs depending on ice thickness, floe size and ice distribution. Further this poster will explain some of the difficulties with models and observations and show how with an increasing ice thickness and increasing floe size, the attenuation and dampening of waves are greater than for thinner smaller ice floes. At last, there are mentioned some of the impacts caused by waves as the climate is changing.

Waves in ice

Everyone knows there are waves in open ocean, but did you know there are also waves in sea ice?

The location where waves occur in ice is in the MIZ, the area where you go from open ocean to main pack ice. When we characterize these waves-in-ice, we often use the terms spectral attenuation rate ($\alpha(f)$) and significant wave height (H_s) (see Box 1 for explanation).

Measurement methods

Observations:
- Satellites or buoys, but they are sparse.

Model runs:
- Gain more knowledge
- Easier to set the conditions such as ice thickness, floe size and energy input.

However, there are difficulties to model waves in ice as there are more advanced dynamics:
- collisions between ice floes
- break up of ice due to internal stress in the ice itself
- rafting floes
- ice is of different sizes

From satellite images it is possible to estimate the significant wave height and floe size distribution (Fig. 1). The estimated H_s decreased about 0.16 m after moving 200 km into the ice (Collard et al, 2022), telling us that the energy of the wave has attenuated.

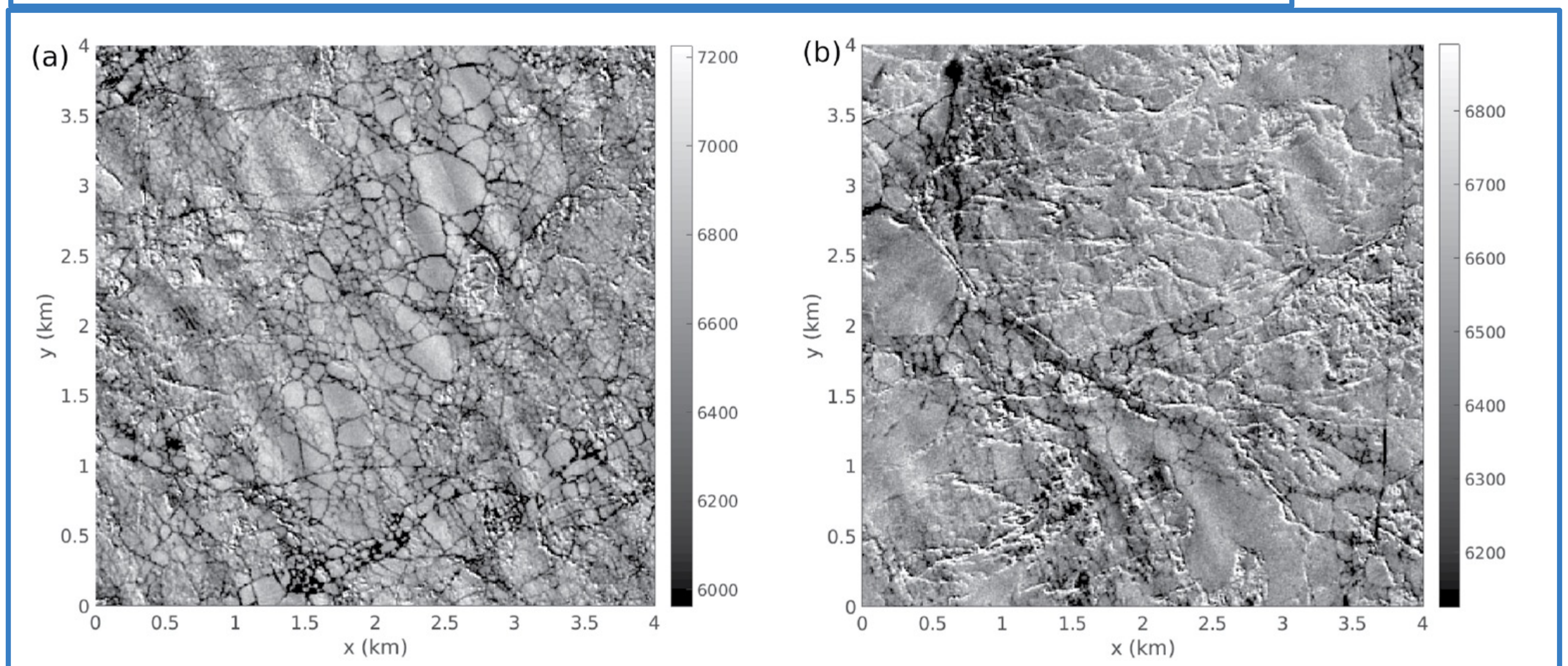

Figure 1: Wave patterns in sea ice taken with Sentinel 2 11:07 UTC on 23rd March 2019. (Collard, 2022)
a) 78.79N, 50.12E, estimated wave height is 0.36 m
b) 79.07N, 50.80E, estimated wave height of 0.2 m.

Box 1

α(f) – the rate at which the energy in the wave dissipate, *f* is the frequency of the wave, and the attenuation increases with increasing frequency (Wadhams et al., 1988).

H_s – the average height of the highest waves, it is dependent on the energy of the wave propagation *E(f)* given below, *f* is frequency which reduces with distance x into the ice (Thomson, 2022).

$$E(f,x) = E(f,0)e^{-\alpha(f)x}$$

The wave height is less as we move with x (Fig. 2), as described above, there is an exponential decay of energy.

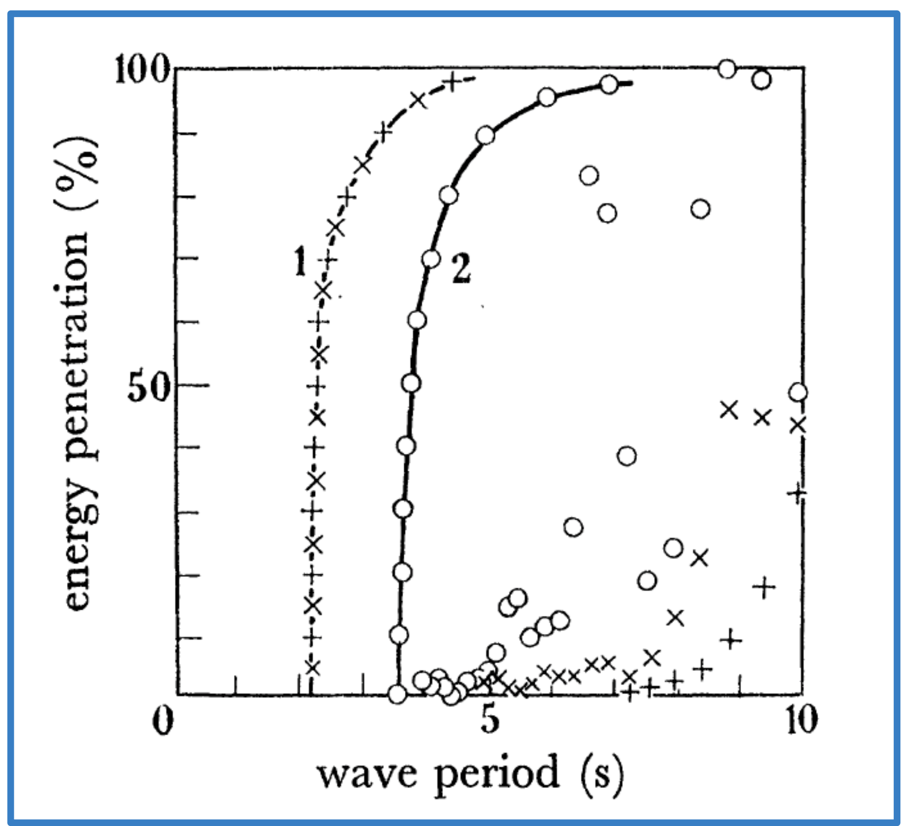

Figure 3: Energy penetration of different ice thickness and floe size in Antarctica compared to the wave period, so the inverse of the frequency. Theoretical curves 1) 1,2 m ice thickness. 2) 3 m ice thickness. Observations: o, 3 m thick, 10 m diameter. (57.5 S); x, 1 m thick, 20 m diameter. (65.0 S); +, 1 m thick, 20 m diameter (67.4 S). (Robin, 1963)

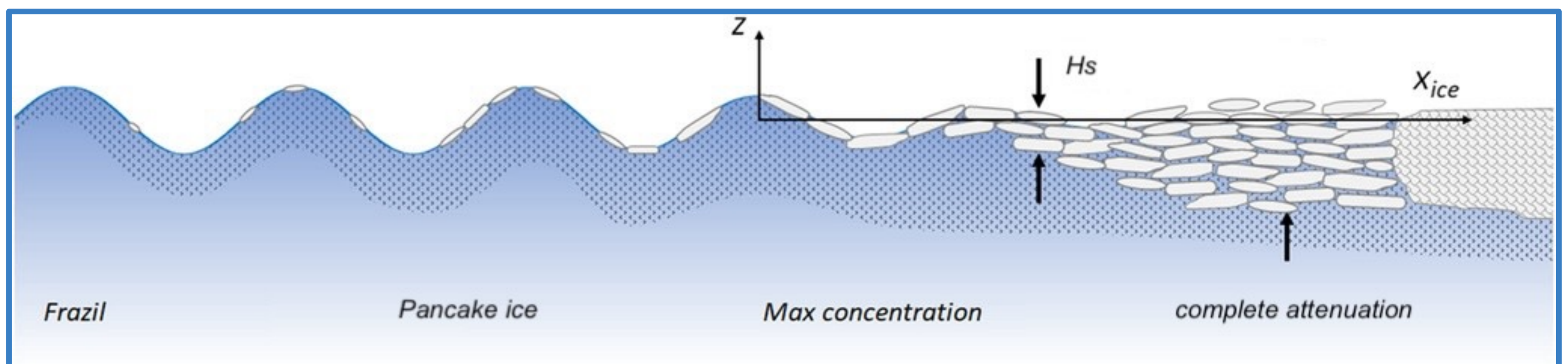

Figure 2: Frazil ice in open water which freeze and form pancake ice as one move inward the MIZ. As one reach max concentration of sea ice (no more open water) the wave starts attenuate strongly, whereas it eventually completely attenuates when reaching pack ice. (Modified from Sutherland & Dumont, 2018)

Sea ice thickness and floe size

As ice thickness increases, so does the wave attenuation. However, if the floe size of the thinner ice is larger than for thicker, it has a larger impact on the attenuation. The energy penetration is largest for small floe sizes with thicker sea ice (o), whereas for the larger ice floe where the ice is thinner (x and +), the energy penetration is less (Fig. 3).
Key point: Waves are more affected by large ice floes, than the ice floes only being thicker.

Impacts from climate change

- Arctic melts – leading to thinner and weaker sea ice
  - Mechanically weakening of sea ice make it more prone to changes (Thomas, 2017), breaking up the ice leading to changes in Arctic Ecosystems.
- Loss of pack ice - leading to increased wave energy
  - Increasing wave energy could contribute to more coastal erosion in Arctic areas (Hošeková et al, 2021).

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