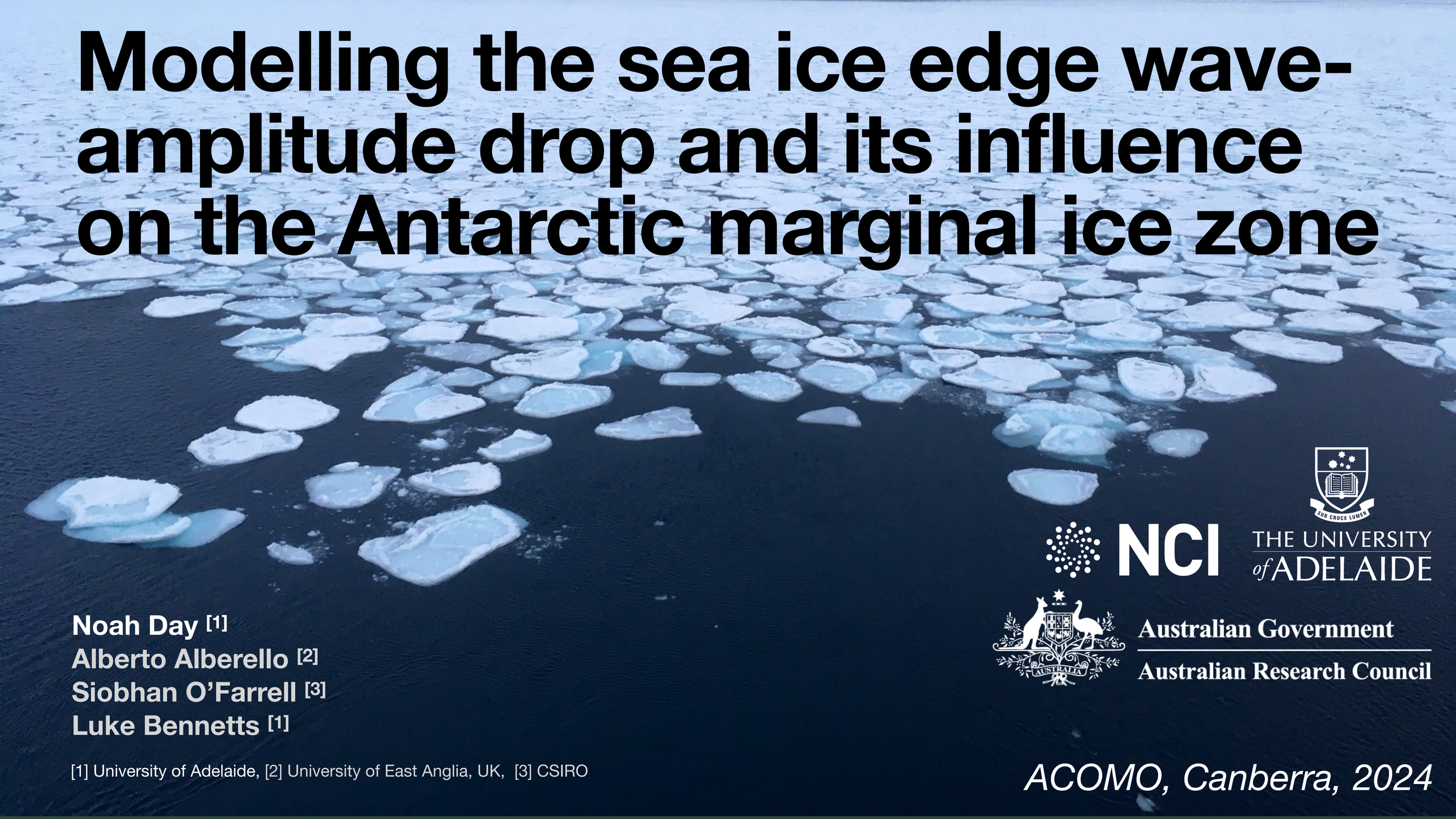
Modelling the sea ice edge wave-amplitude drop and its influence on the Antarctic marginal ice zone



Noah Day [1]
Alberto Alberello [2]
Siobhan O'Farrell [3]
Luke Bennetts [1]

[1] University of Adelaide, [2] University of East Anglia, UK, [3] CSIRO

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Australian Government
Australian Research Council

ACOMO, Canberra, 2024

Wave-ice interactions: standard perspective

Image: Dumas-Lefebvre and Dumont, *Cryosphere*, 2023

Wave-ice interactions: standard perspective

Open ocean | **Unconsolidated ice** | **Consolidated ice**

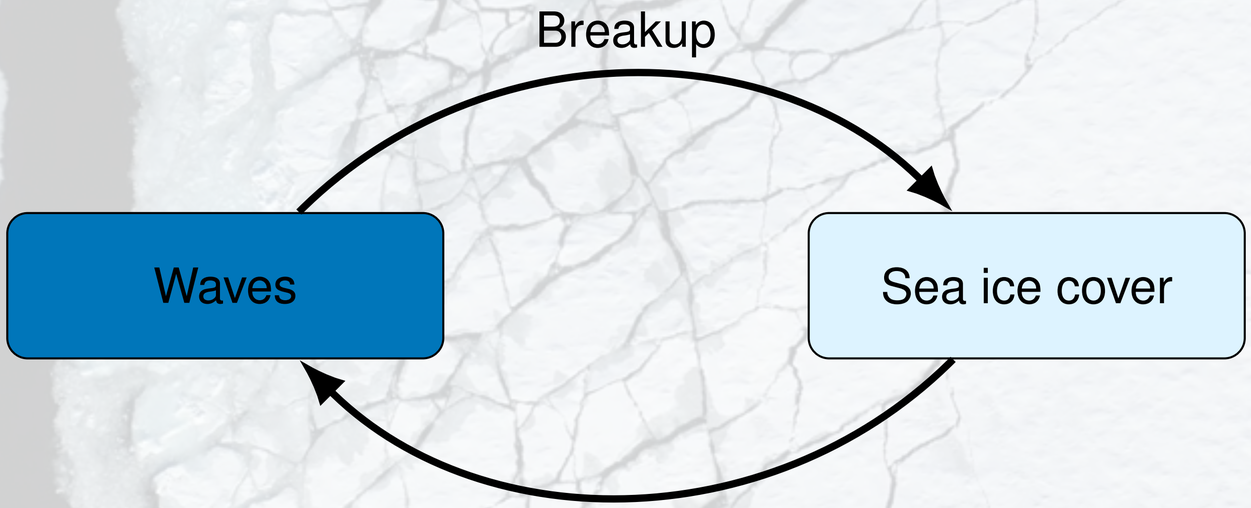


Image: Dumas-Lefebvre and Dumont, *Cryosphere*, 2023

Wave-ice interactions: standard perspective

Open ocean **Unconsolidated ice** **Consolidated ice**

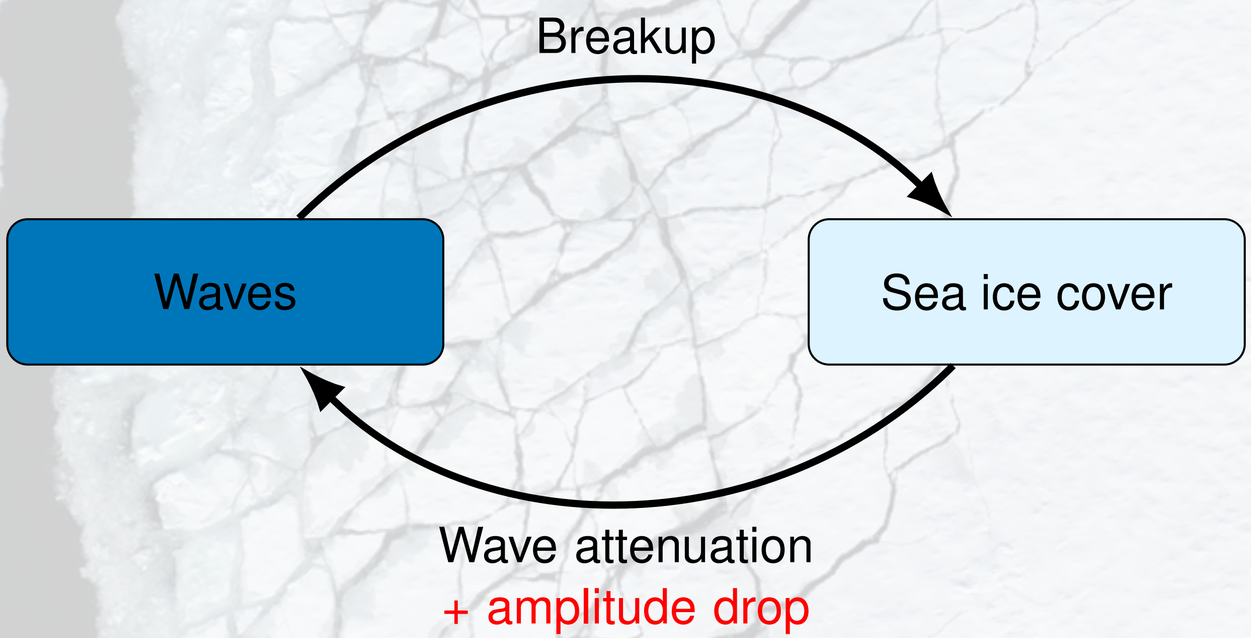
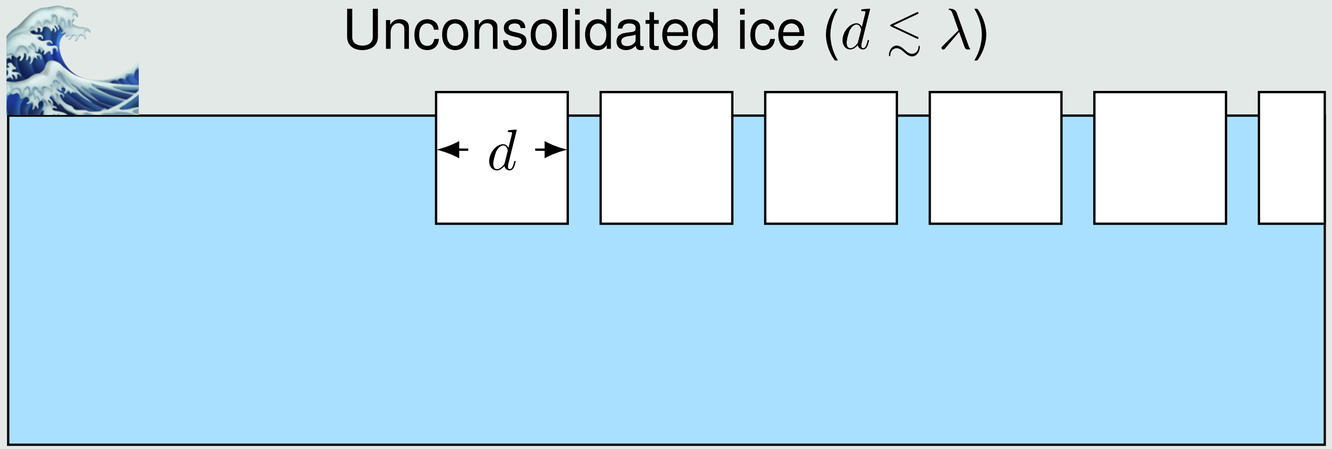
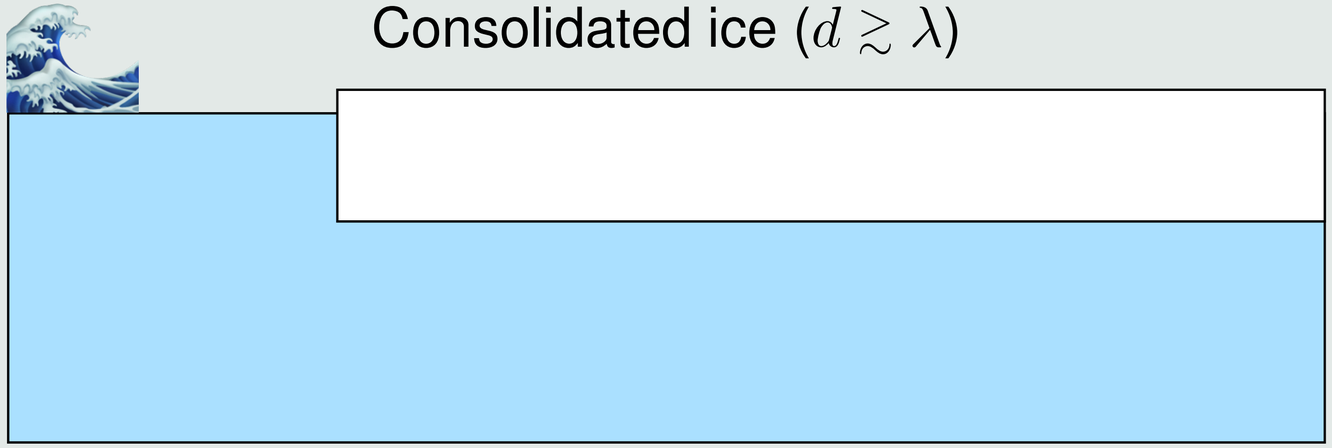


Image: Dumas-Lefebvre and Dumont, *Cryosphere*, 2023

Motivation for a new interpretation of wave attenuation

The transition from unconsolidated—consolidated ice covers





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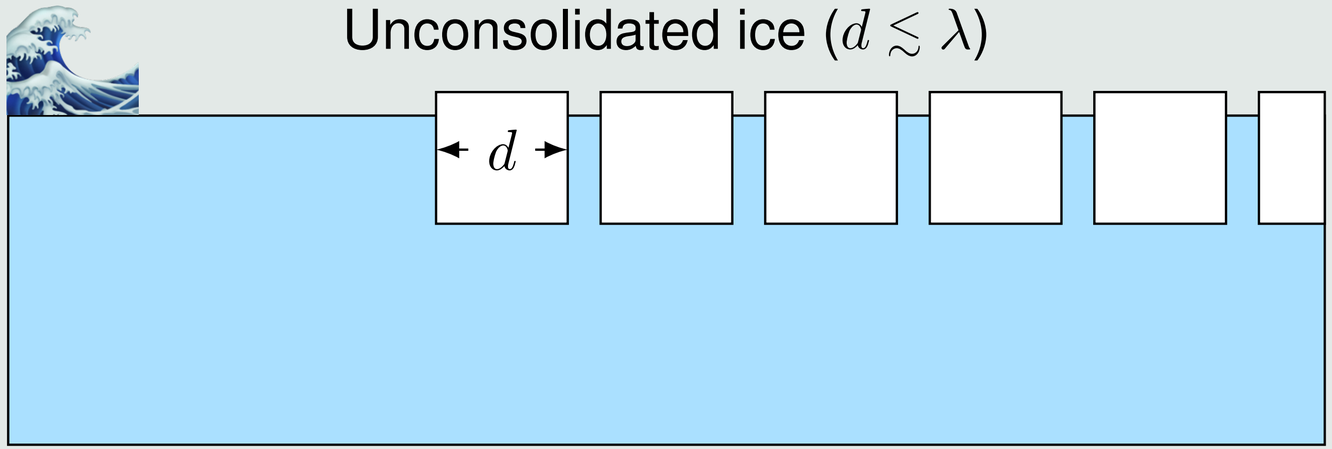

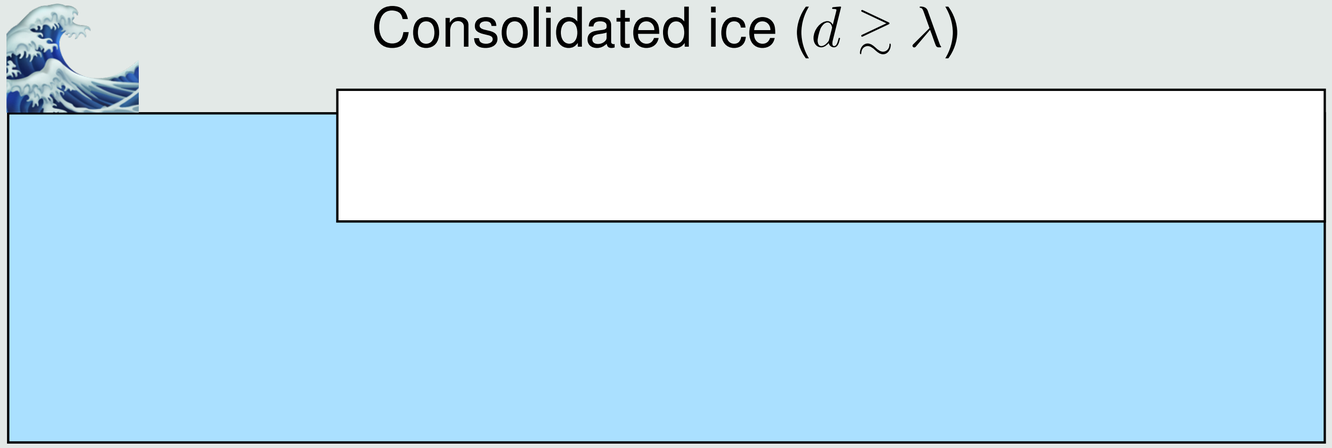

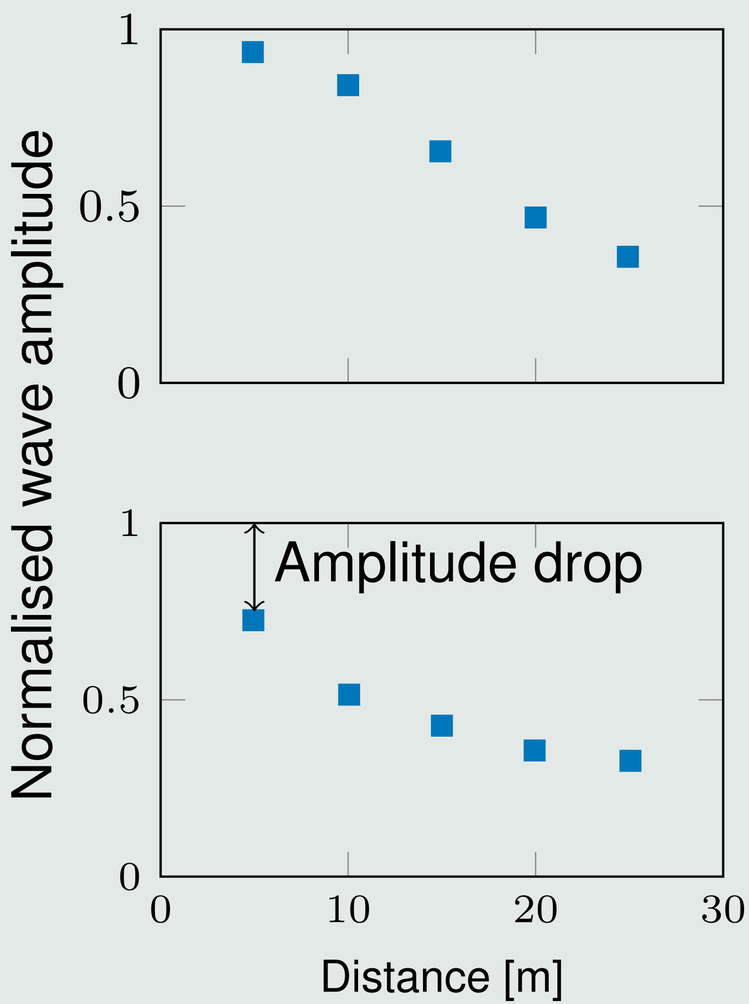

[1] Passerotti et al., *JPO*, 2022

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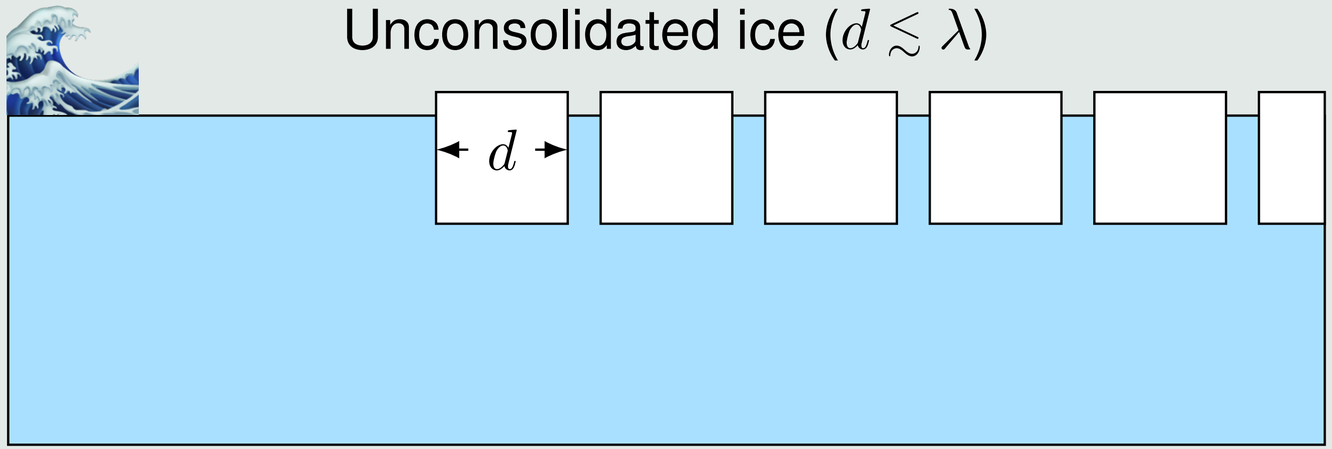

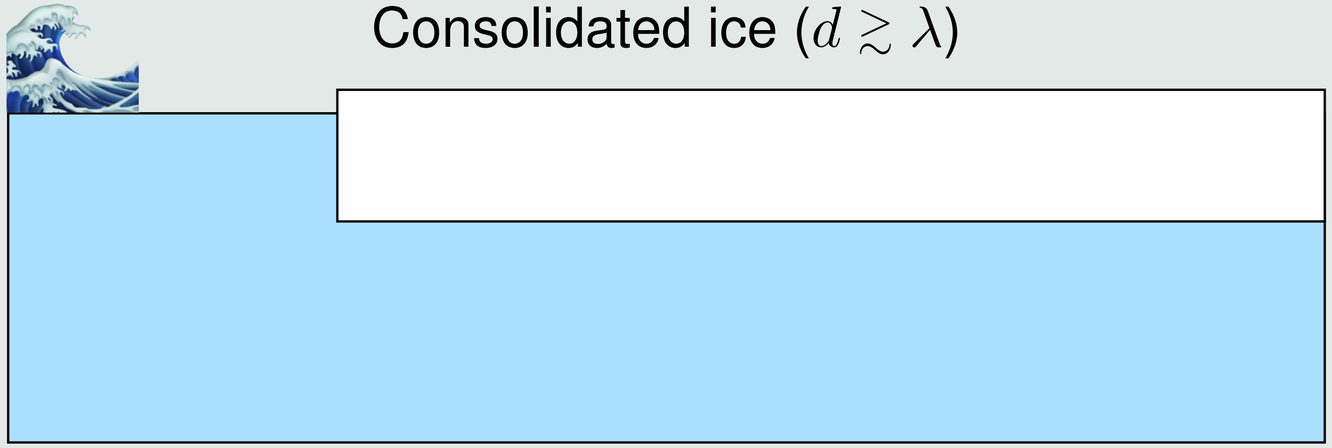

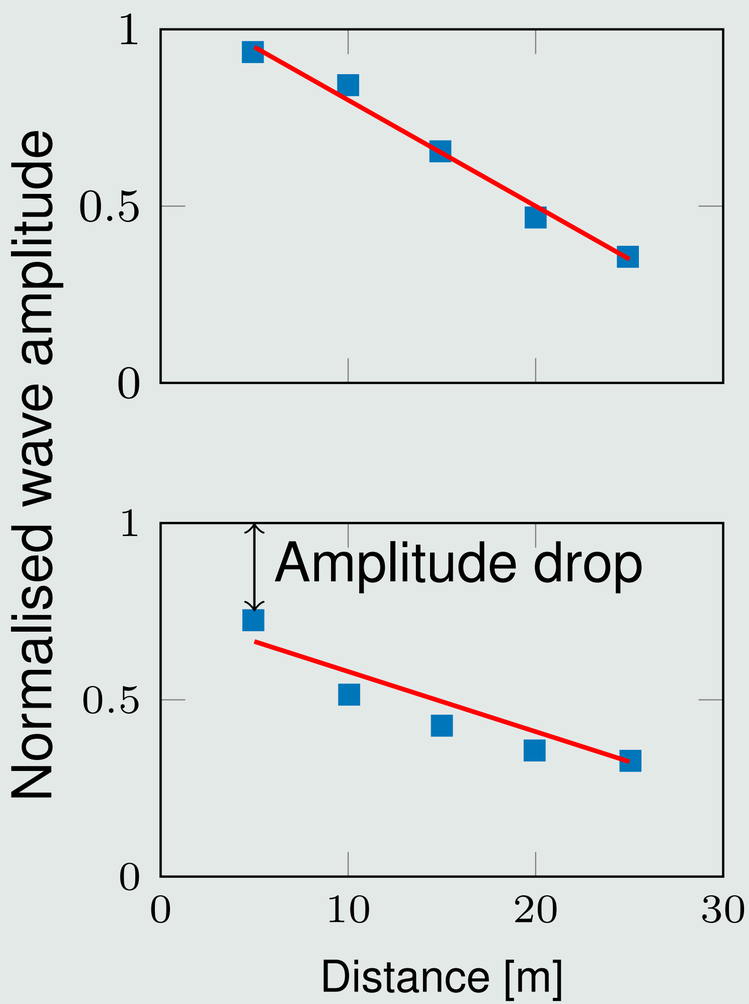

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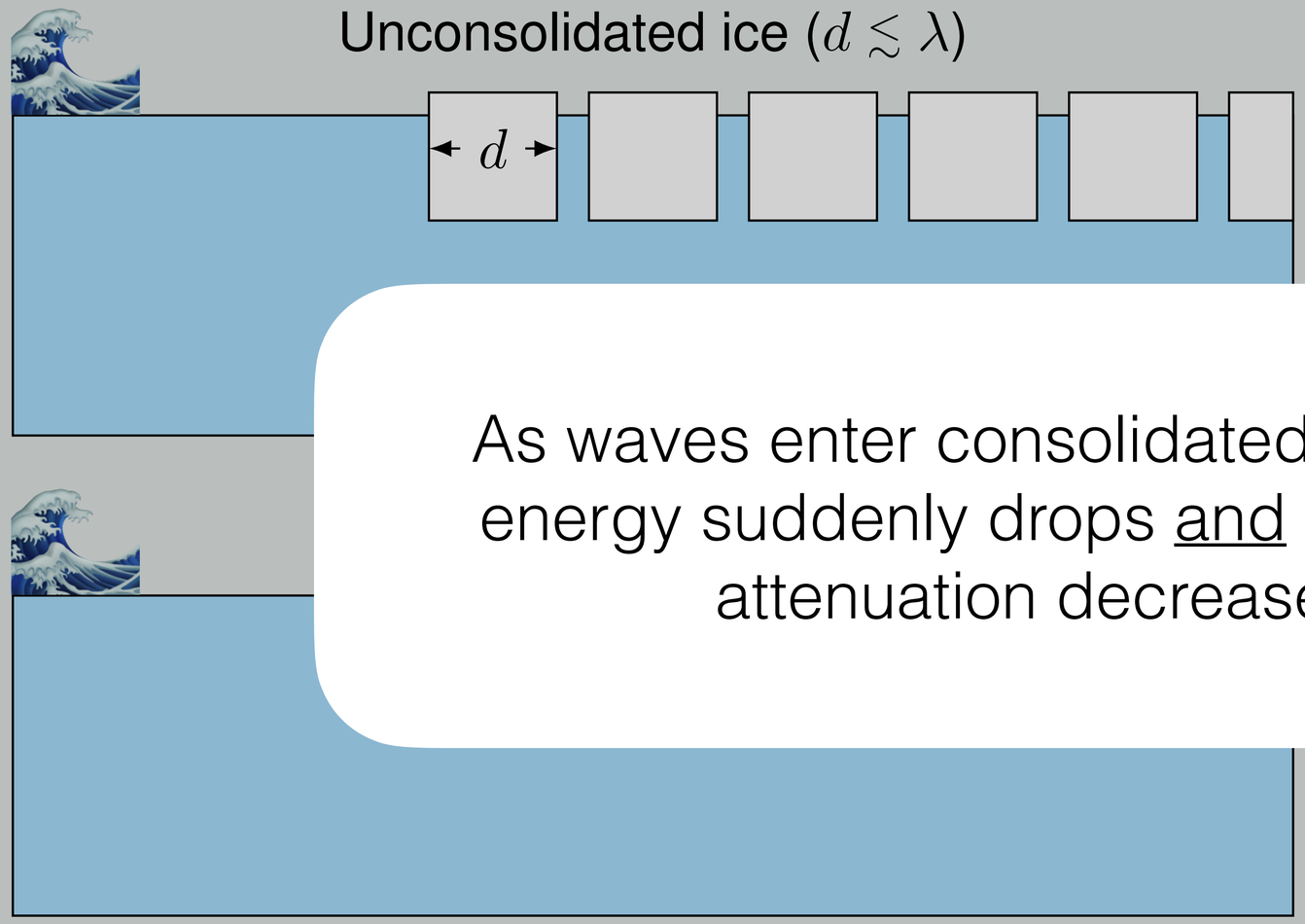
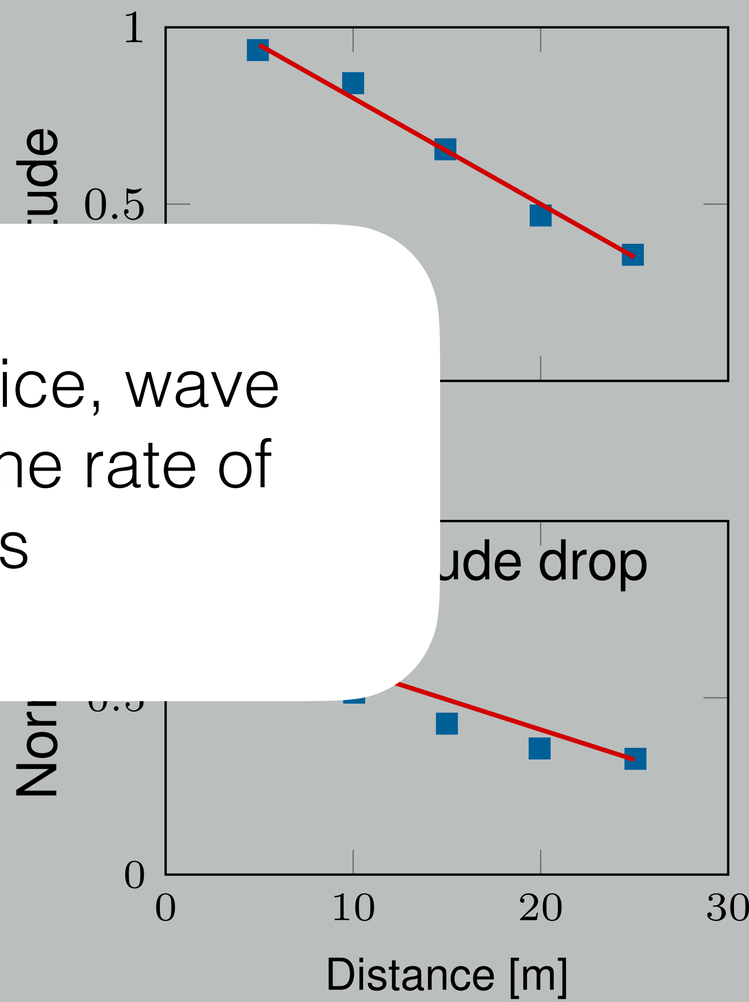
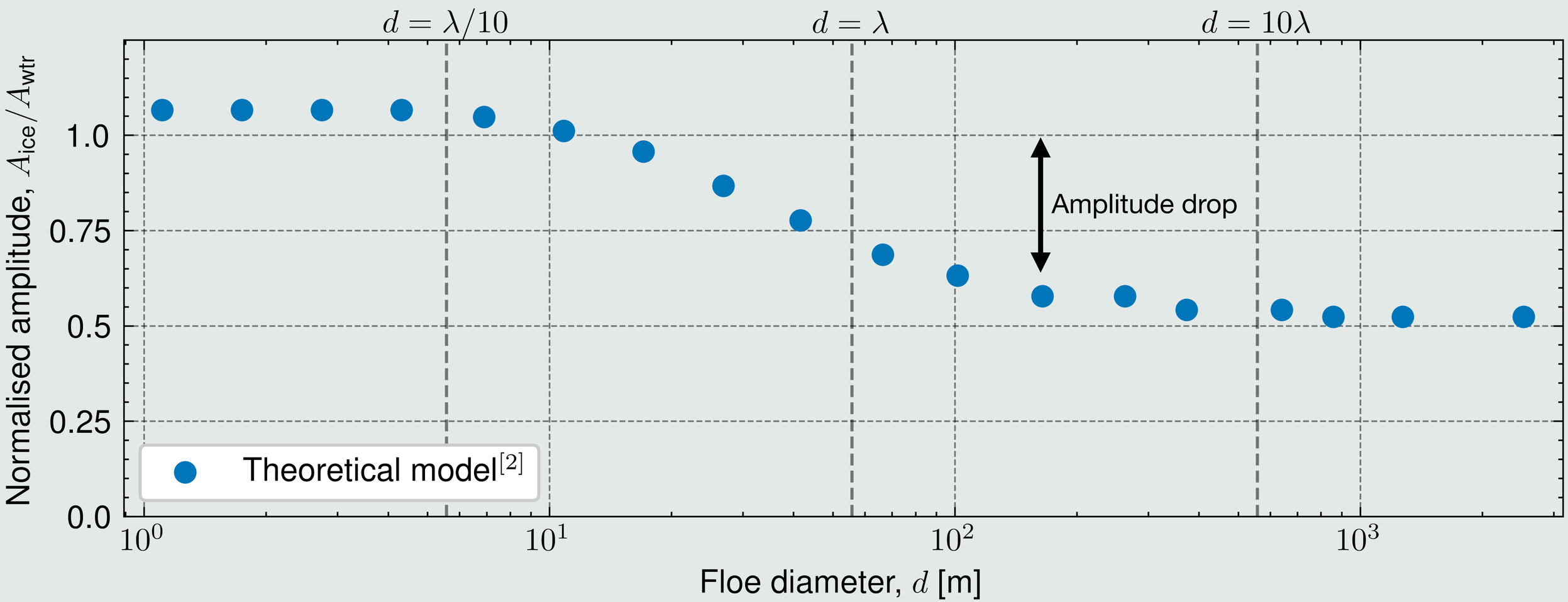




As waves enter consolidated ice, wave energy suddenly drops <u>and</u> the rate of attenuation decreases

[1] Passerotti et al., *JPO*, 2022

Parameterising a theoretical model



[2] Pitt & Bennetts [Preprint], arXiv:2311.13886, 2023

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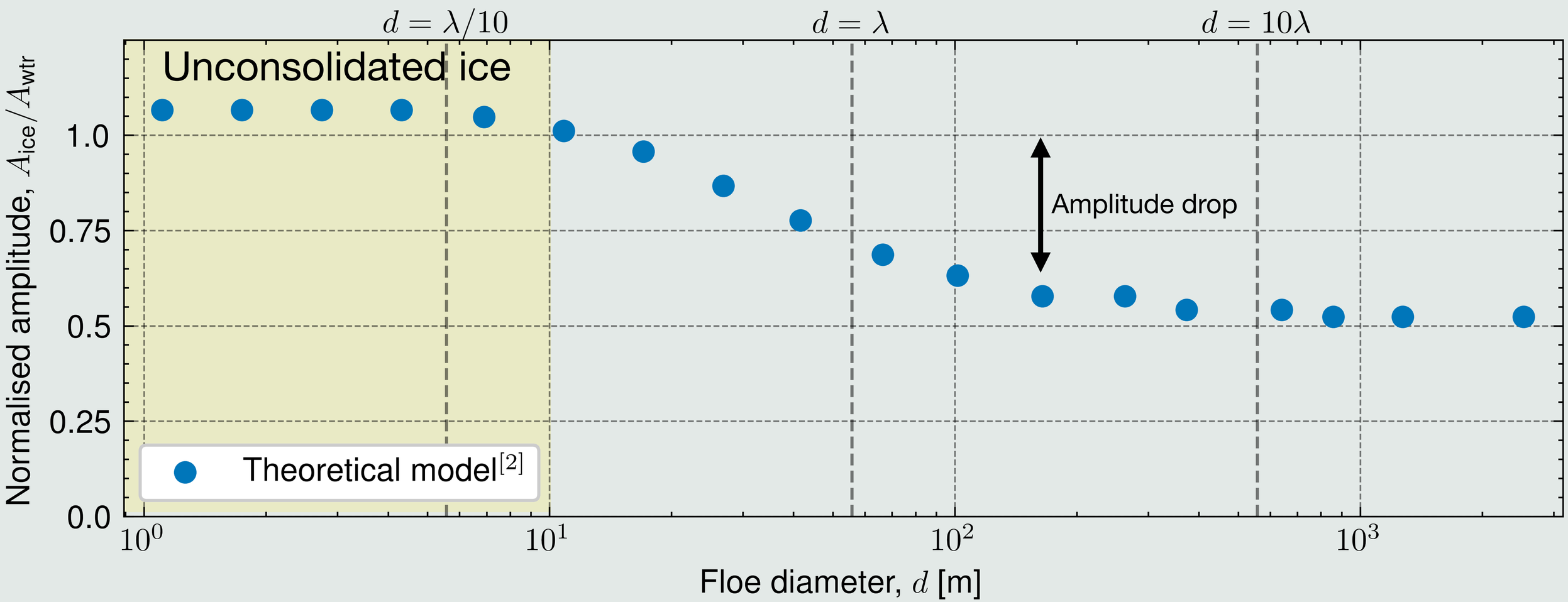

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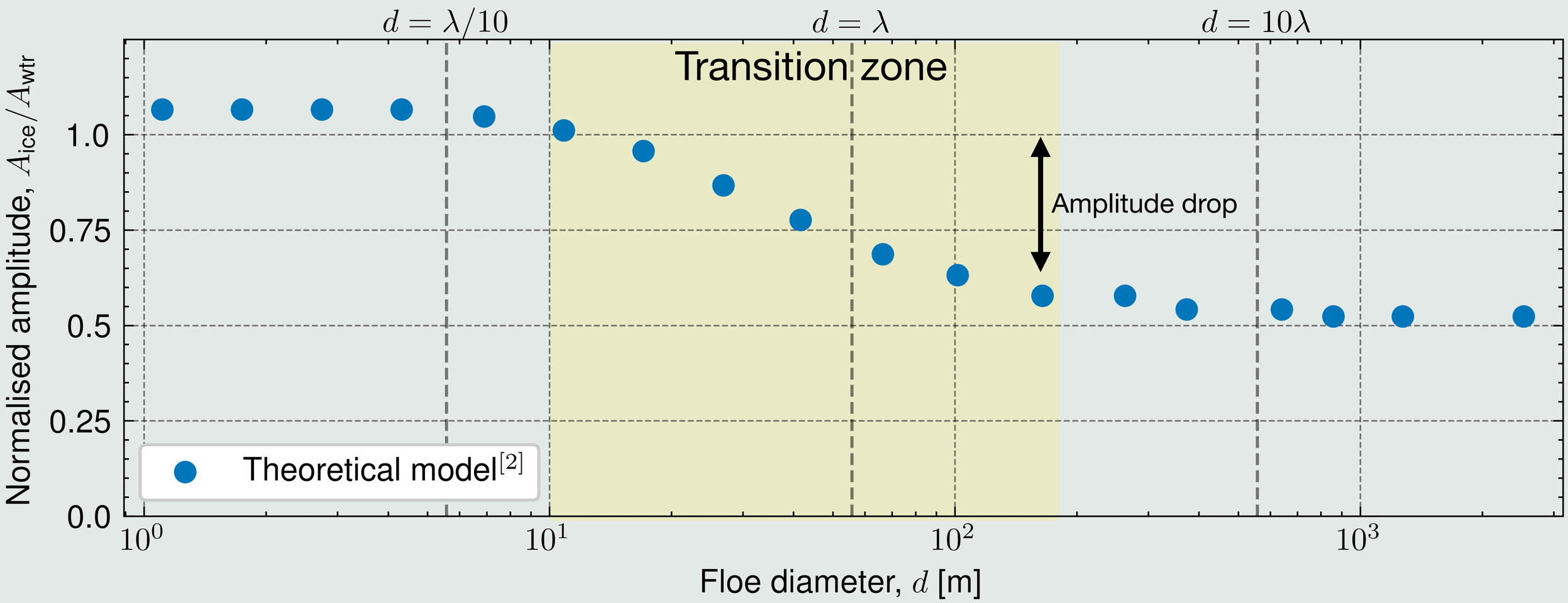

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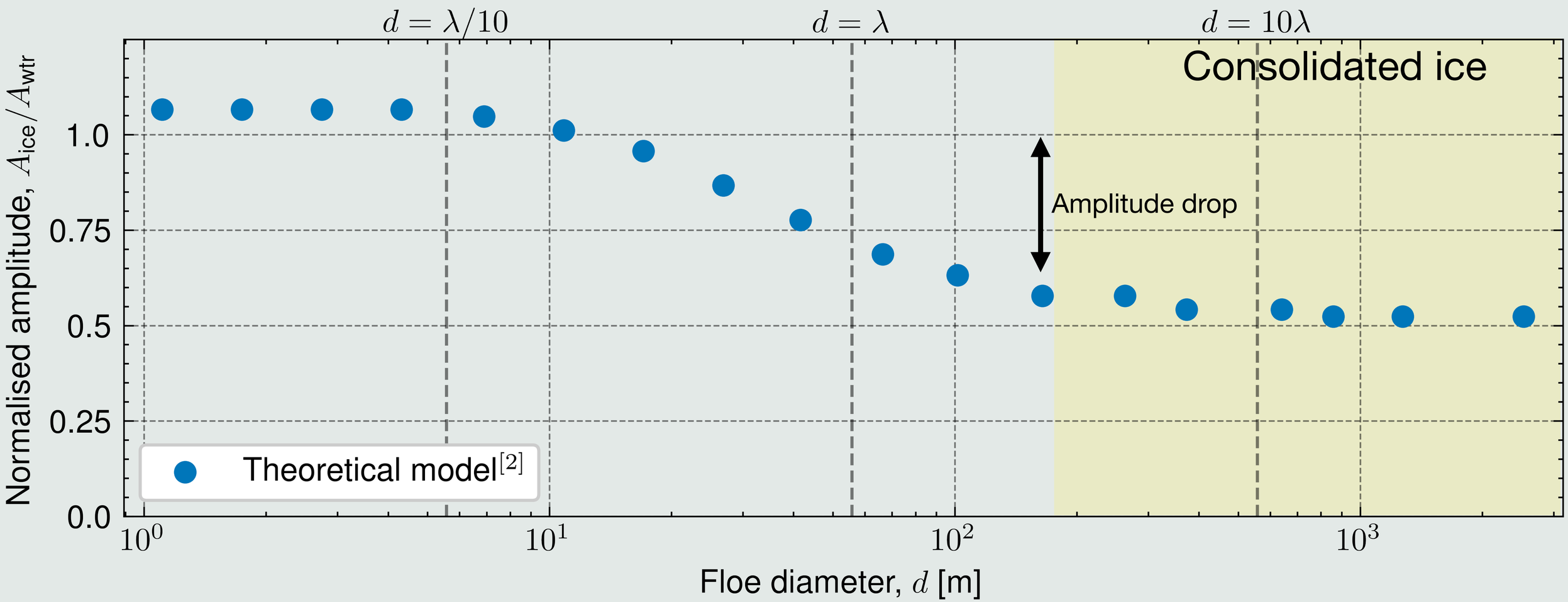

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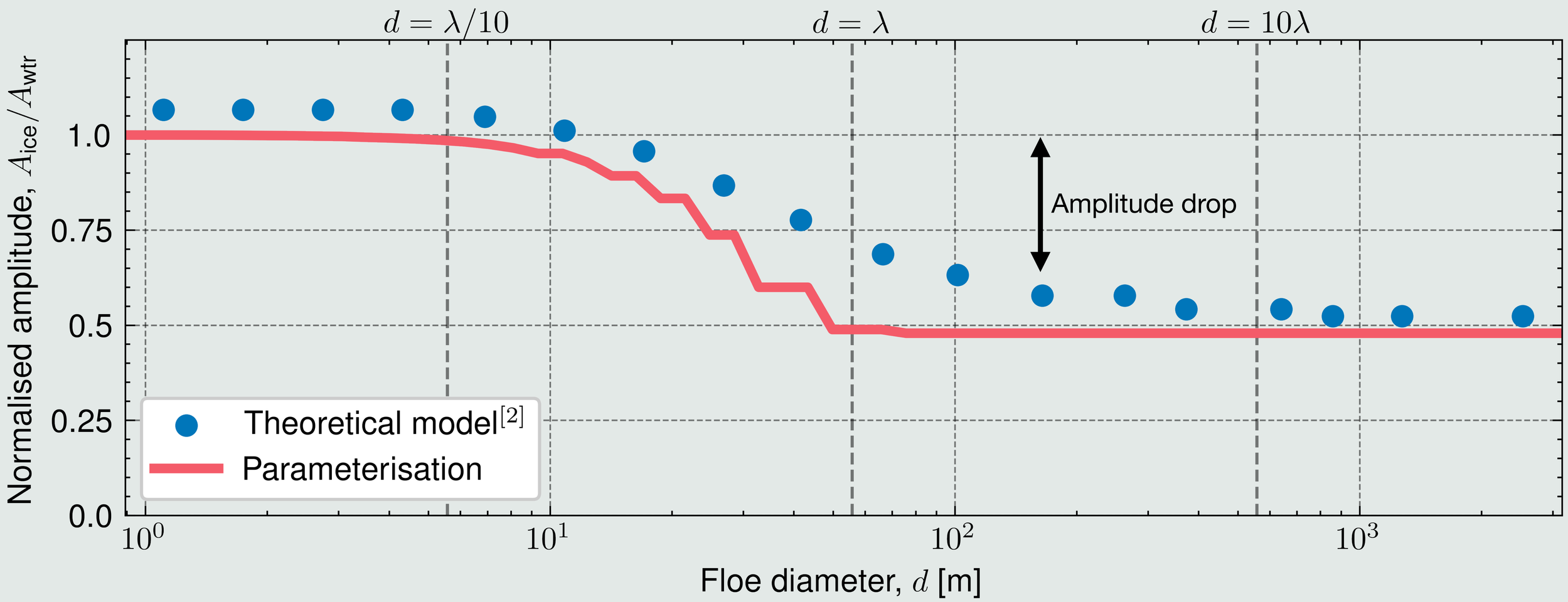

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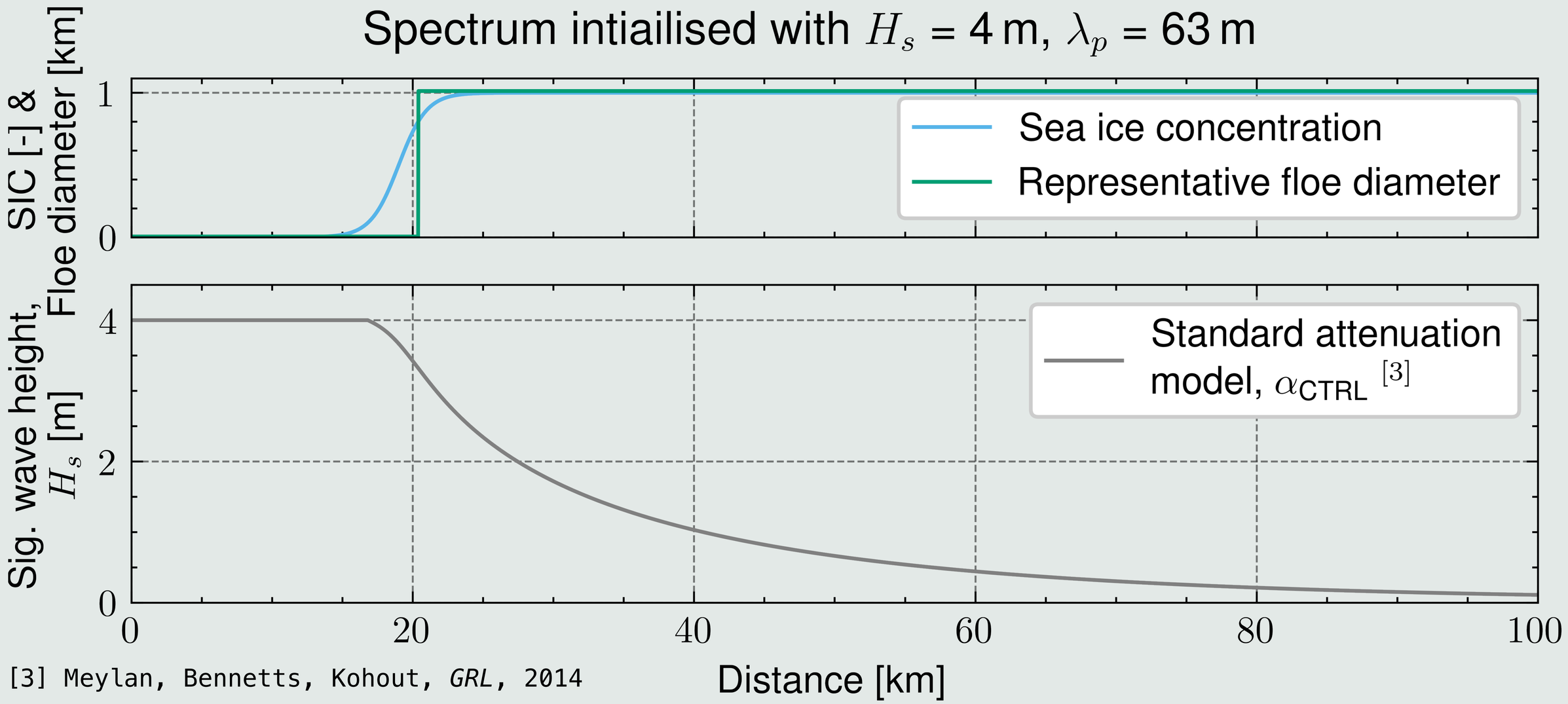
An idealised example

A jump in floe diameter from $10\,\mathrm{m} \rightarrow 1000\,\mathrm{m}$



[3] Meylan, Bennetts, Kohout, *GRL*, 2014

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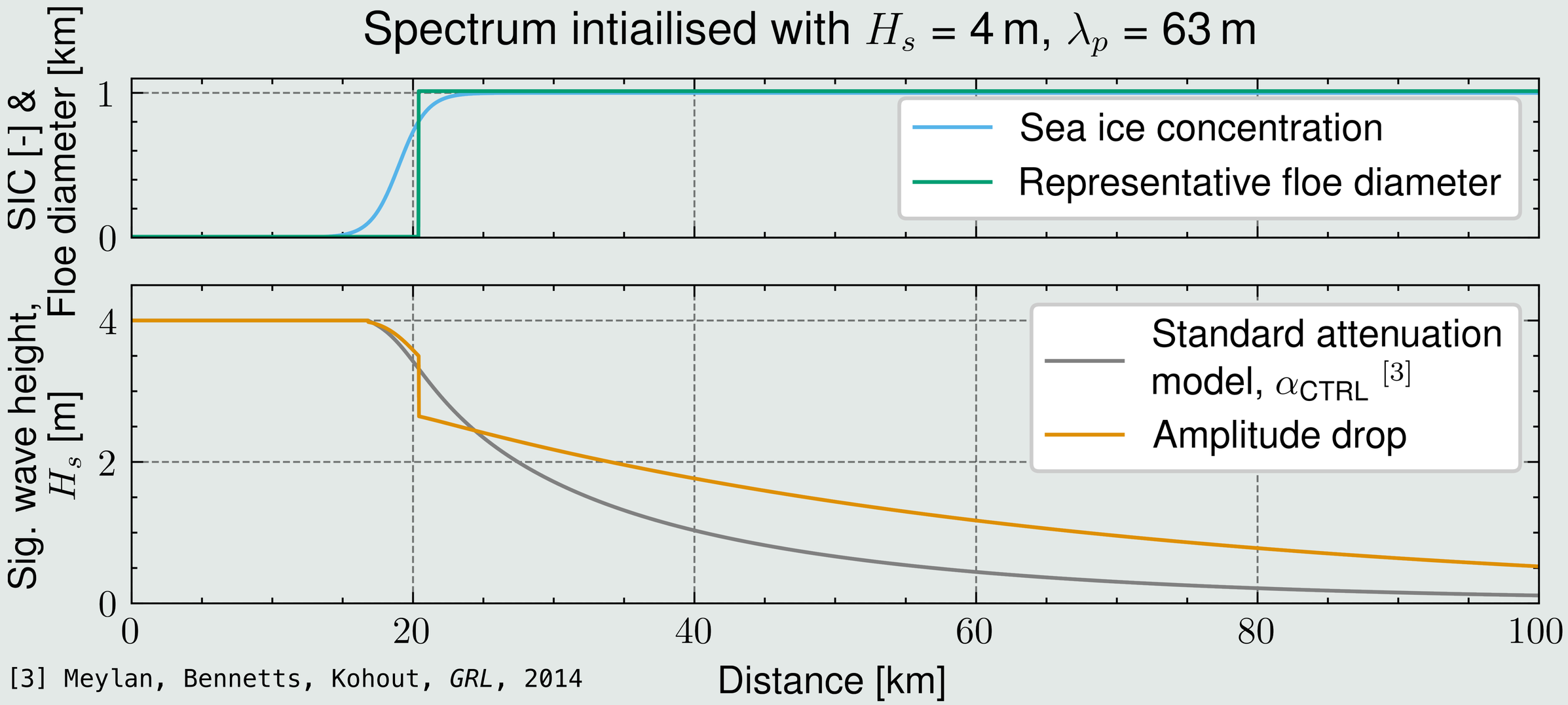

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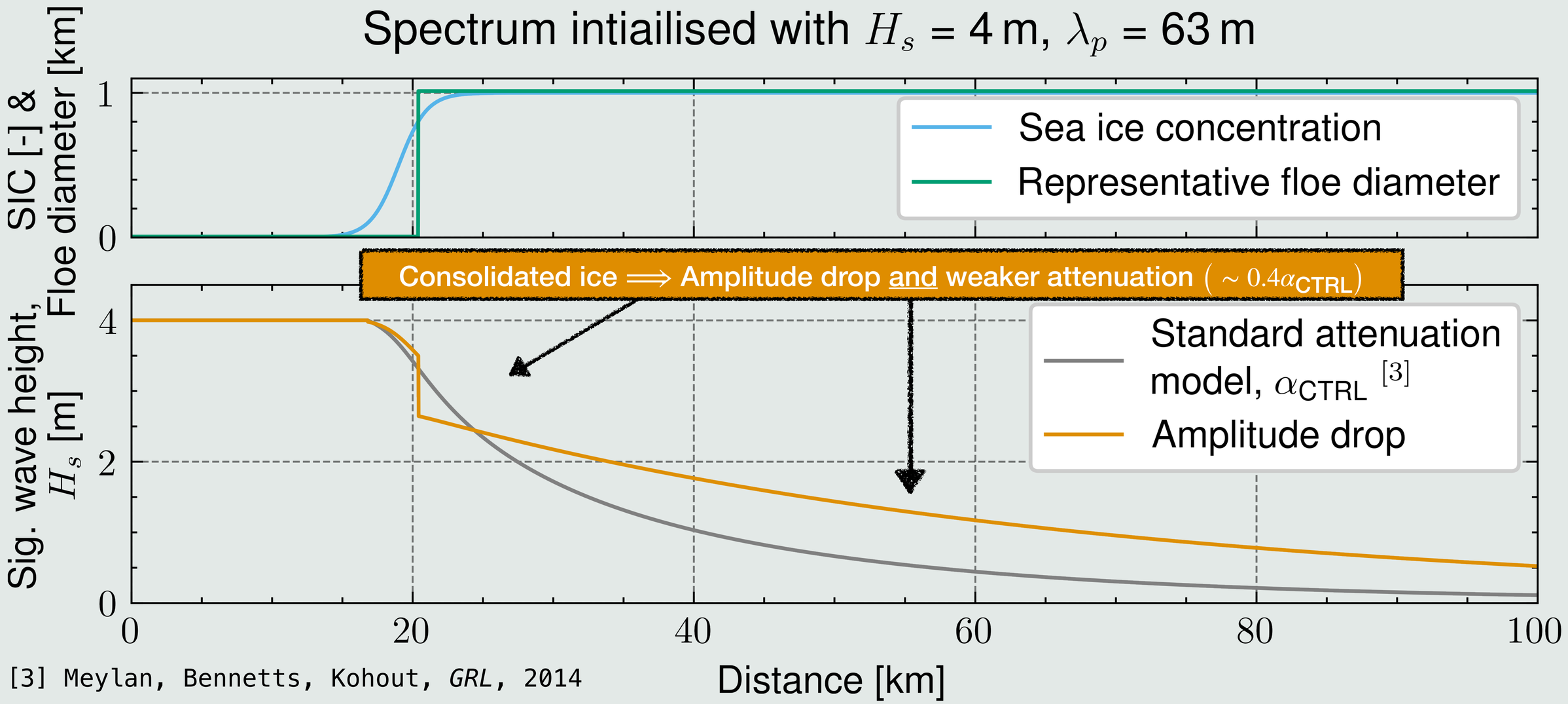

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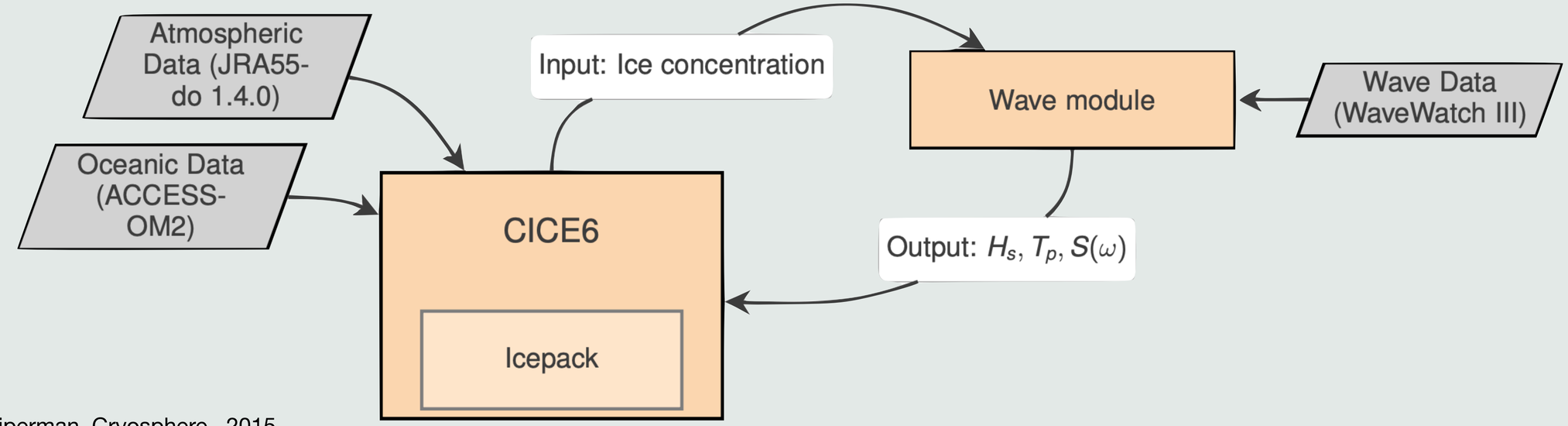
Numerical sea ice model with waves

- The floe size and ice thickness distribution (FSTD), $f(r, h; \mathbf{x}, t)$, evolves according to

$$\frac{\partial f(r,h)}{\partial t} = -\nabla \cdot (f(r,h)\mathbf{v}) + \mathscr{L}_{\text{thermodynamics}} + \mathscr{L}_{\text{mechanical redistribution}} + \mathscr{L}_{\text{wave fracturing}}$$

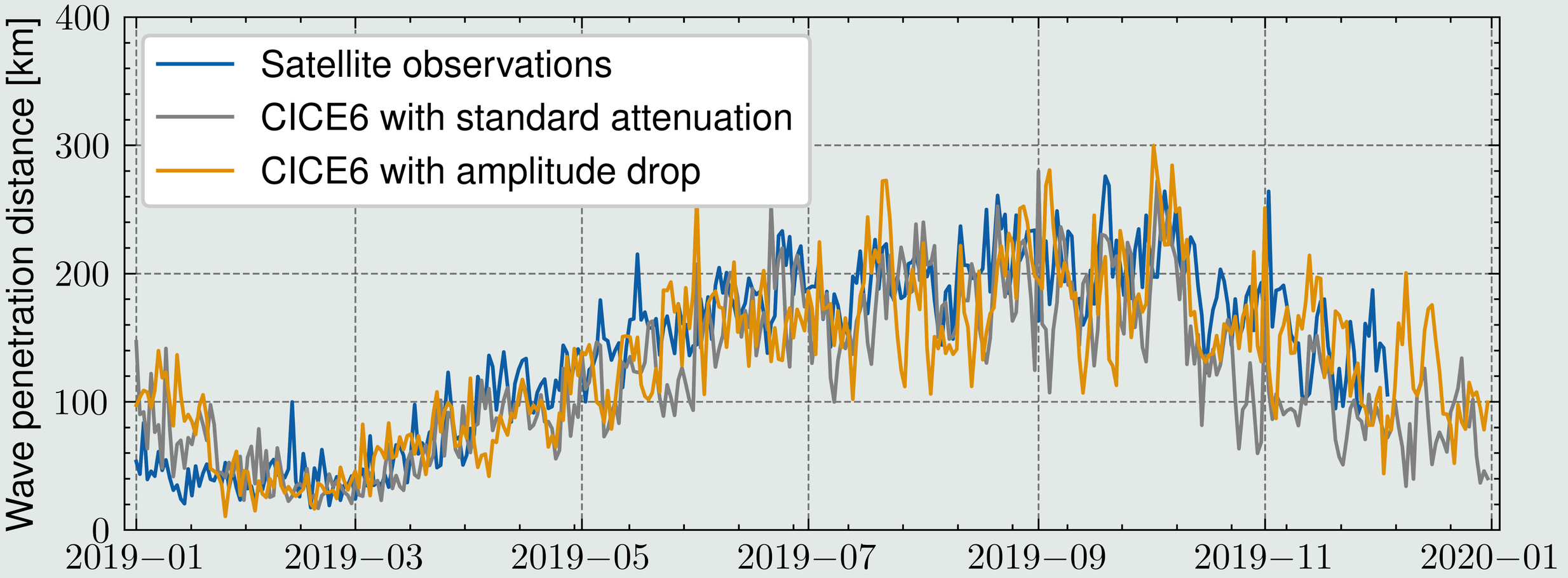
- Waves breakup floes [8] and determine the size of new floes [9] using the FSTD [10]



[8] Horvat and Tziperman, Cryosphere , 2015
[9] Shen et al., Annals, 2001
[10] Roach et al., JAMES, 2019

Model configuration of standalone CICE6 at 0.25 degree resolution with a waves-in-ice module (CICE6-WIM).

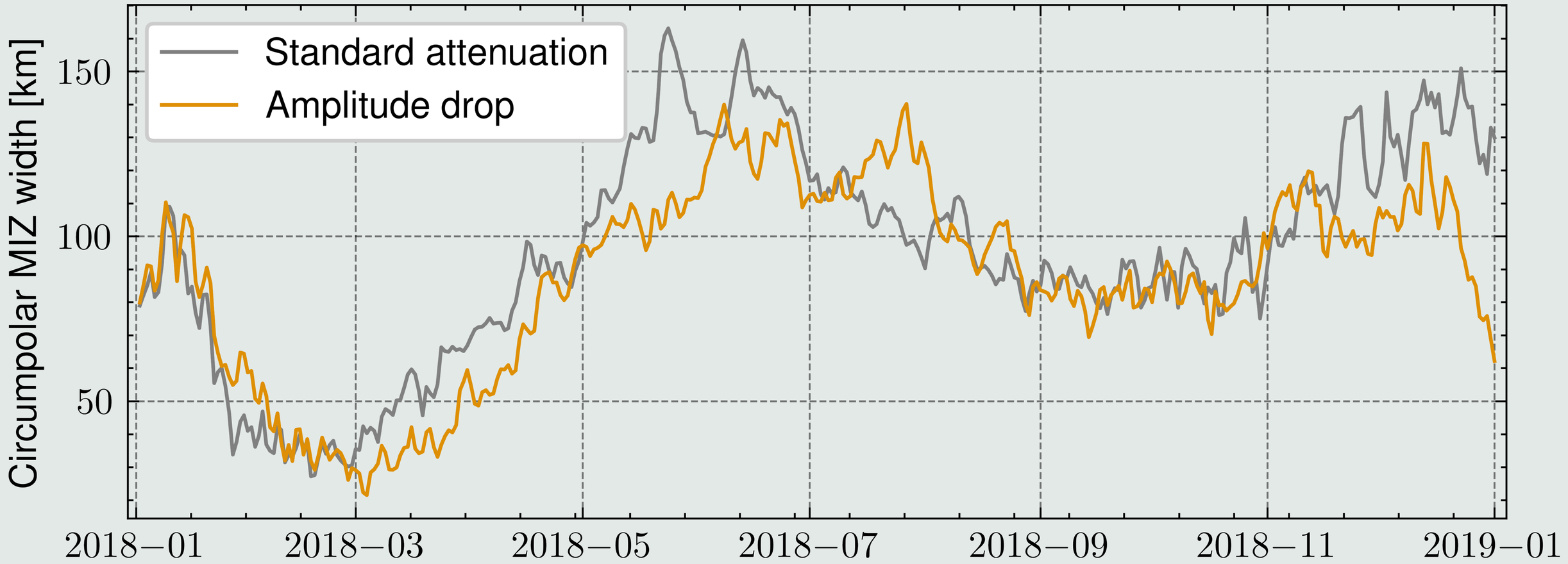
Comparison of circumpolar wave penetration



Satellite-derived observations of wave heights retrieved from Alex Fraser and others.
Amplitude drop simulation was completed over 2018.

Effect on the Antarctic marginal ice zone

- Antarctic marginal ice zone (MIZ) is defined as when floe diameters < 40 m [4] (and SIC > 15%)



[4] Day, Bennetts, Alberello, O'Farrell, and Montiel [Preprint], *Authorea*, 2023

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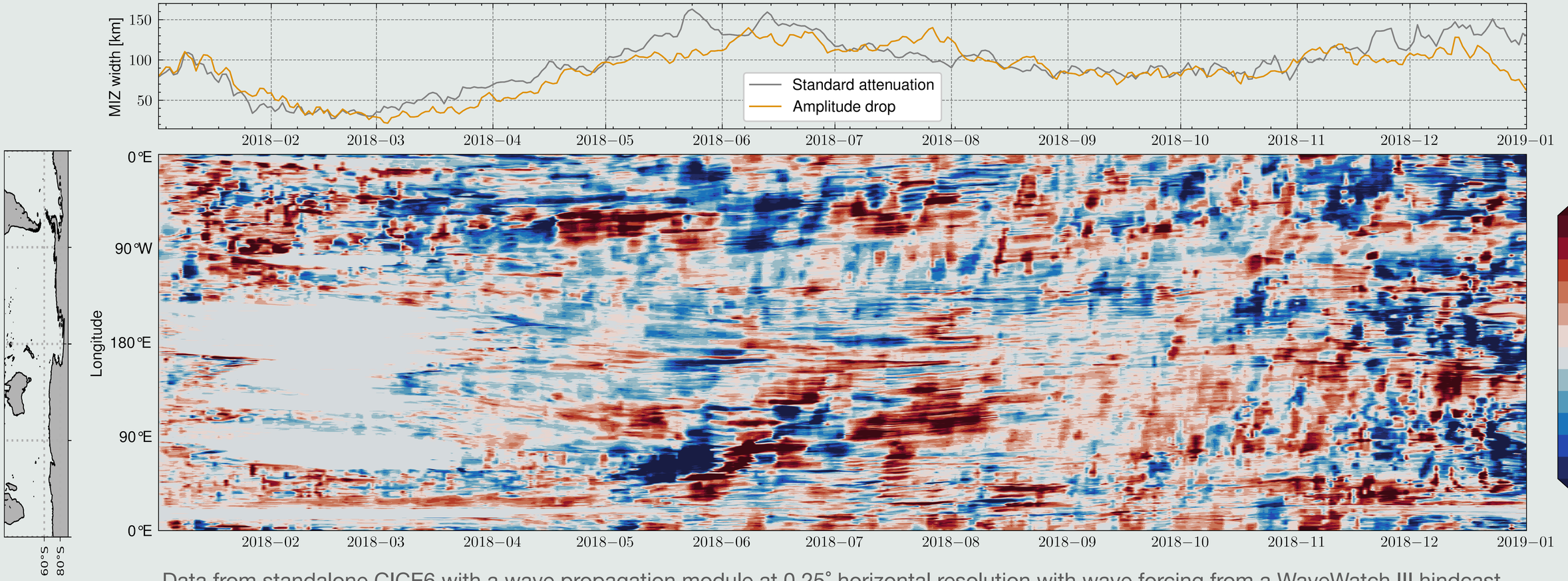


Data from standalone CICE6 with a wave propagation module at 0.25˚ horizontal resolution with wave forcing from a WaveWatch III hindcast.

[4] Day, Bennetts, Alberello, O'Farrell, and Montiel [Preprint], *Authorea*, 2023

Conclusions

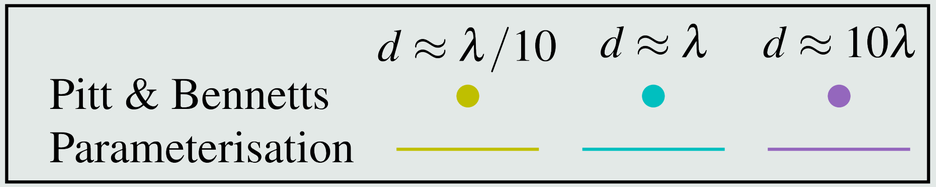
- Consolidated or large ice floes can produce a sudden drop in wave energy (wave-amplitude drops), as well as impacting the rate of wave attenuation
- The circumpolar-average width of the Antarctic MIZ was found to comparable to a standard attenuation model and satellite-derived observations (seasonal maximum of 150—200 km)
- However, the choice in wave attenuation model can vary the MIZ width by hundreds of kilometres, highlighting the complex and coupled interactions waves have on the evolution of sea ice

Thank you!

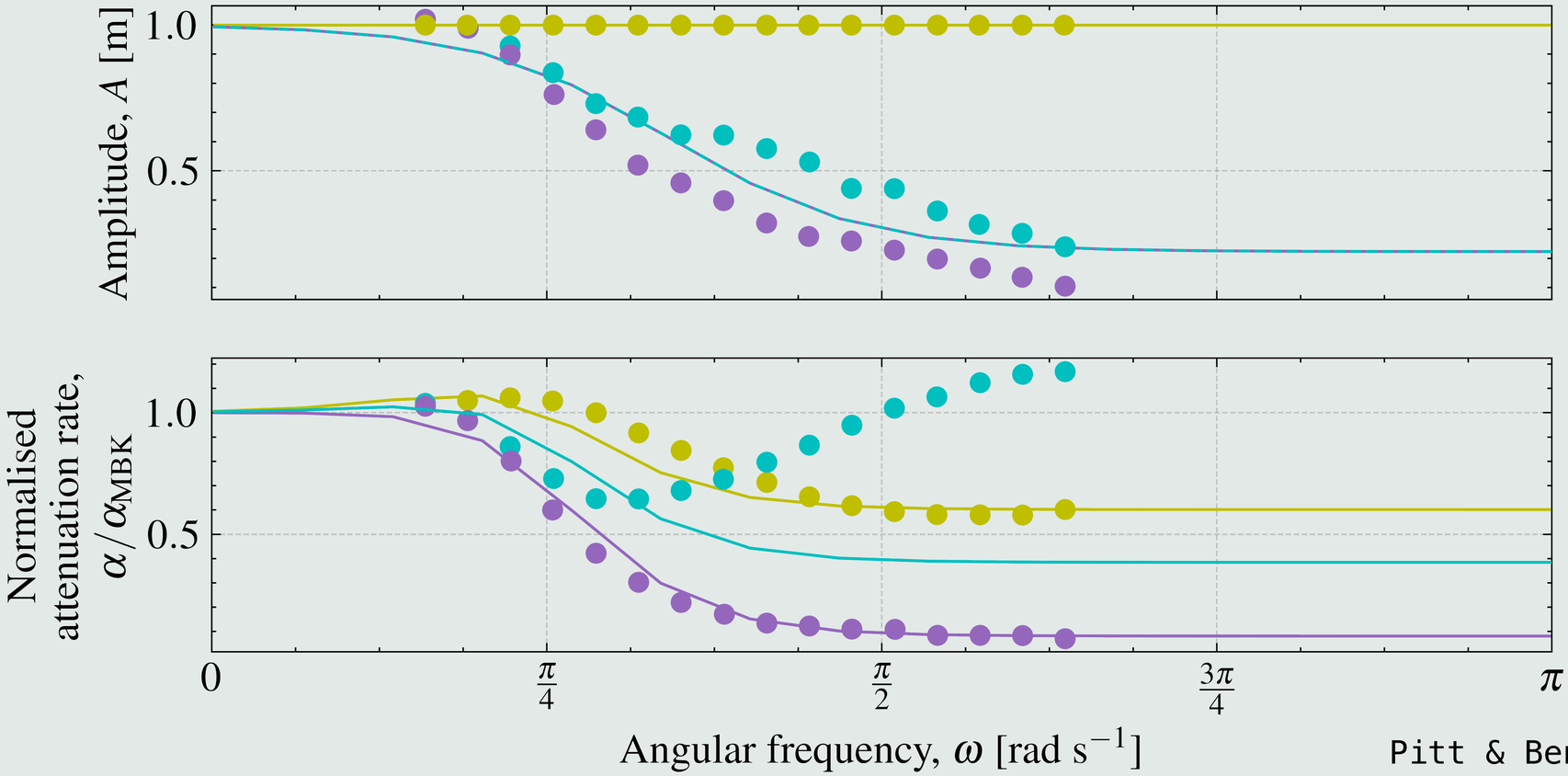
noah.day@adelaide.edu.au

Supporting slide

Further details on the parameterisation



(Assuming a deep water dispersion relation)



Relatively long waves — weaker attenuation

Relatively short waves — stronger attenuation

- α_{MBK} = standard attenuation model [3] and is independent of floe size!

[3] Meylan, Bennetts, Kohout, *GRL*, 2014
Pitt & Bennetts [Preprint], arXiv:2311.13886, 2023