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Estimates of wave attenuation from ICESat-2 observations

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Introduction

"So, where do we go from here as far as building a waves-in-ice model that can reliably predict the dispersion and attenuation over the entire wave spectrum? The answer is universal in any field of research: we need more observations and we need to improve the theories." [Shen, 2019]

Satellite remote sensing provides opportunities in assessing wave field characteristics which may be used to estimating wave attenuation in sea ice [e.g., Horvat et al. (2020, GRL); Collard et al. (2022, JGR); Stopa et al. (2018, PNAS); Ardhuin et al. (2017, RSE)].

Here, we aim to estimate wave attenuation rates across the MIZ from ICESat-2 derived wave observations.

Methods

- Quality controlled ICESat-2 transects taken from Brouwer et al. (2022)
- 320 transects covering February, May, September, December 2019
- MIZ defined by linear fit to H_s estimate along transect (Brouwer et al., 2022))

- Surface elevation resolution 8 m, spectral density estimated using 8192 m sections.
- Attenuation rate estimated assuming exponential decay, $\Delta x = 16$ km:

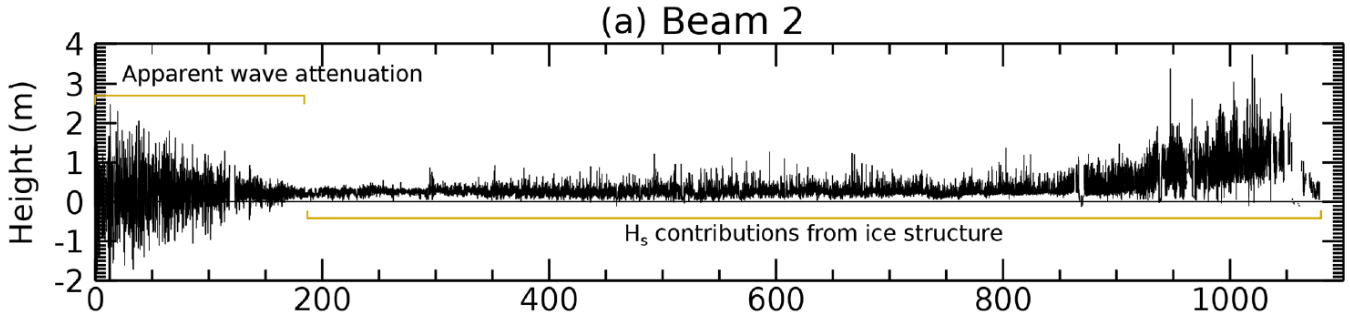
$$E(x_2, f) = E(x_1, f)\exp(-\alpha\Delta x)$$

- Further QC measures include cutoff based on SNR, and absolute minima in wave energy transects.

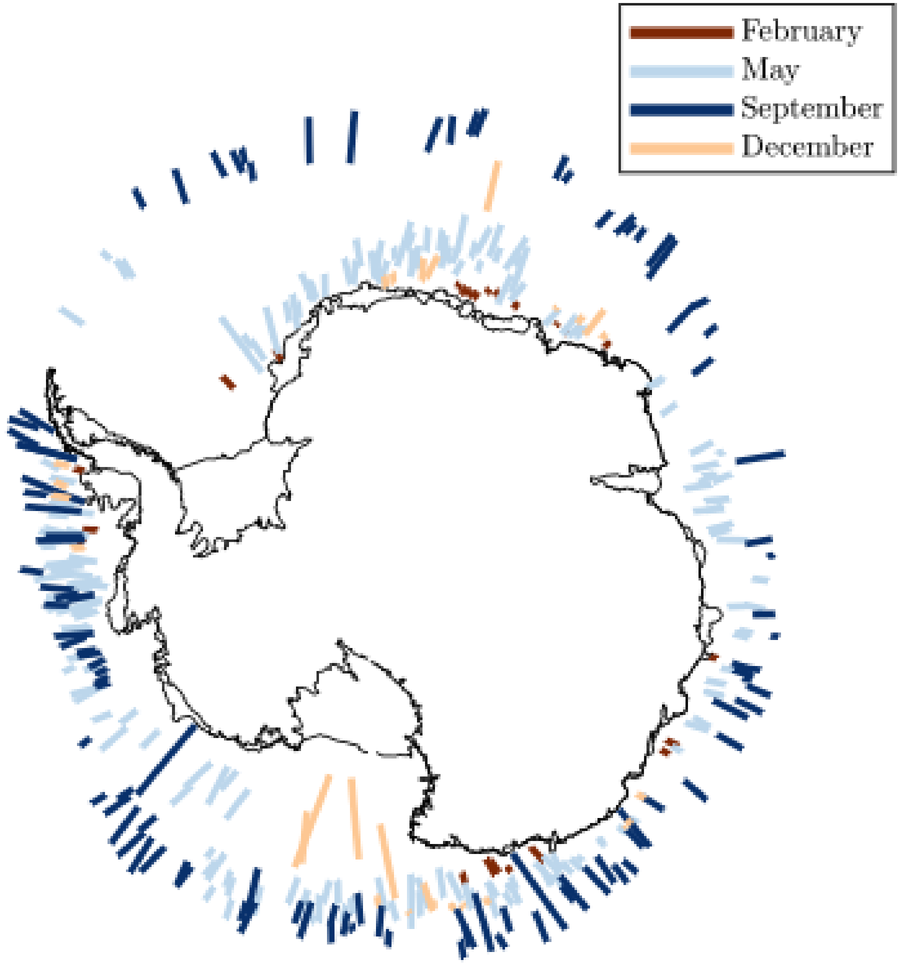
ICESat-2 Transects

- After QC, we are left with 304 transects:
  - February: 23
  - May: 161
  - September: 98
  - December: 22

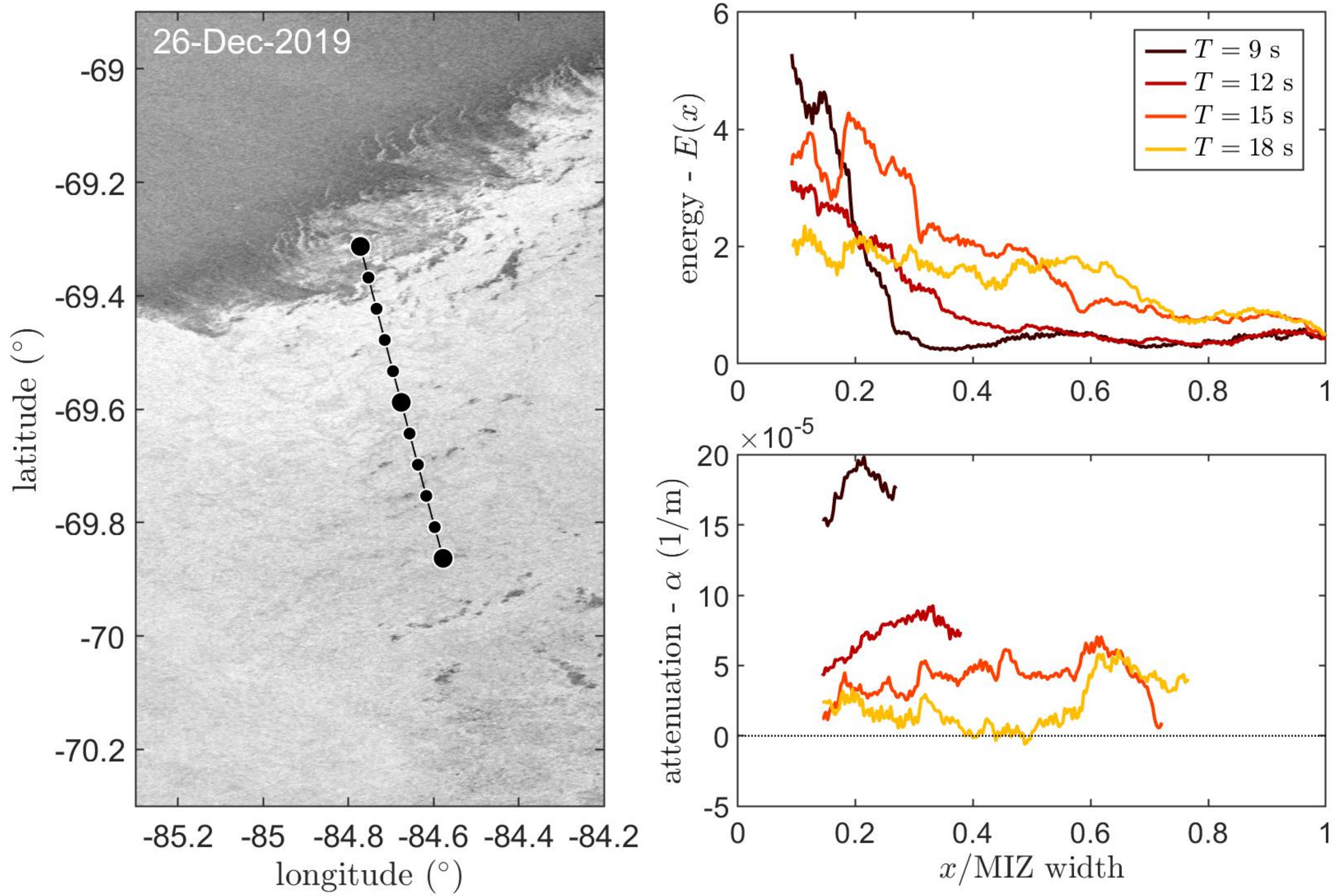
Example transect:



[Brouwer et al. (2022, TC)]

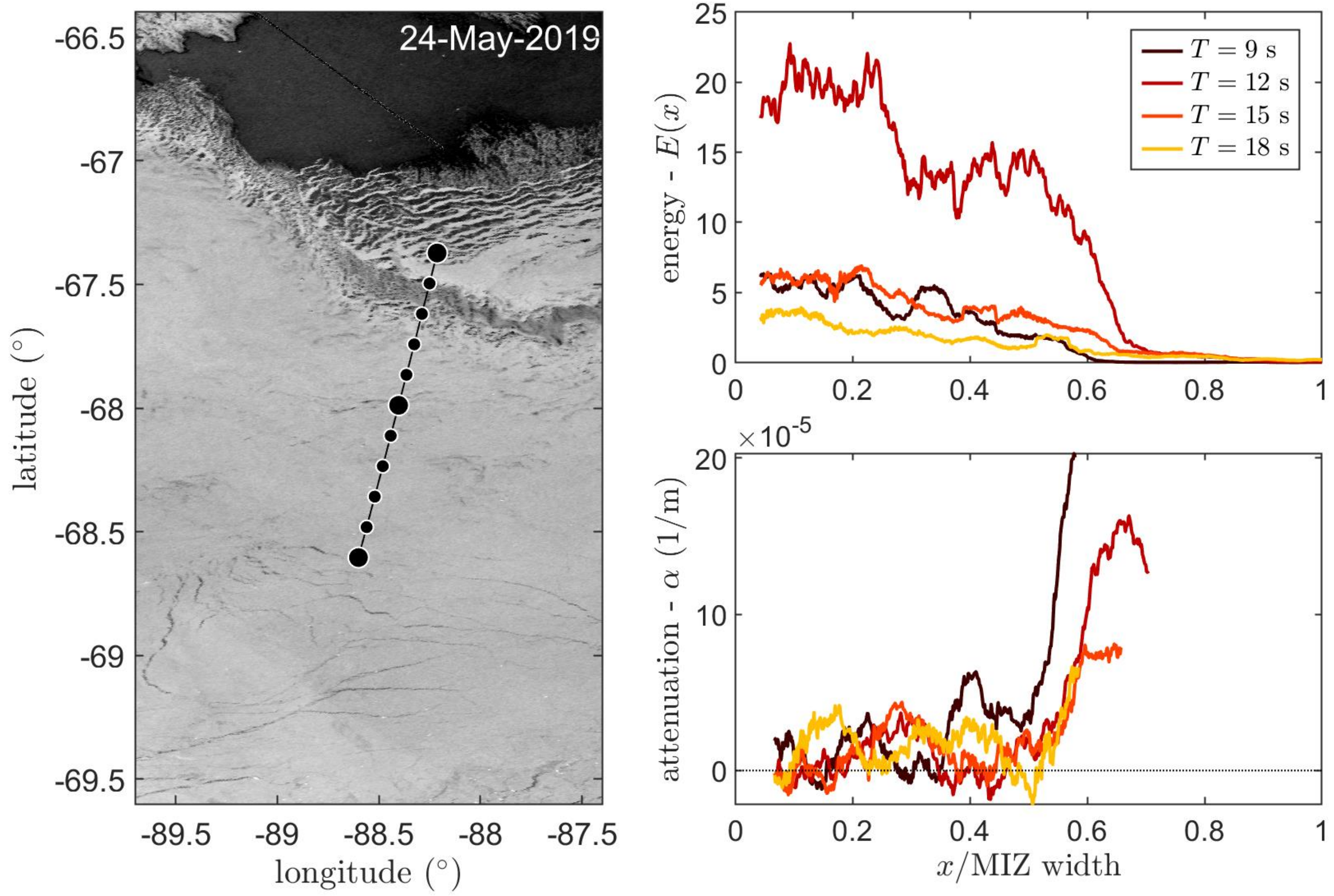


Results - attenuation



α is well sorted with wave frequency, with a tendency to increase with distance into the MIZ - x

Results - attenuation

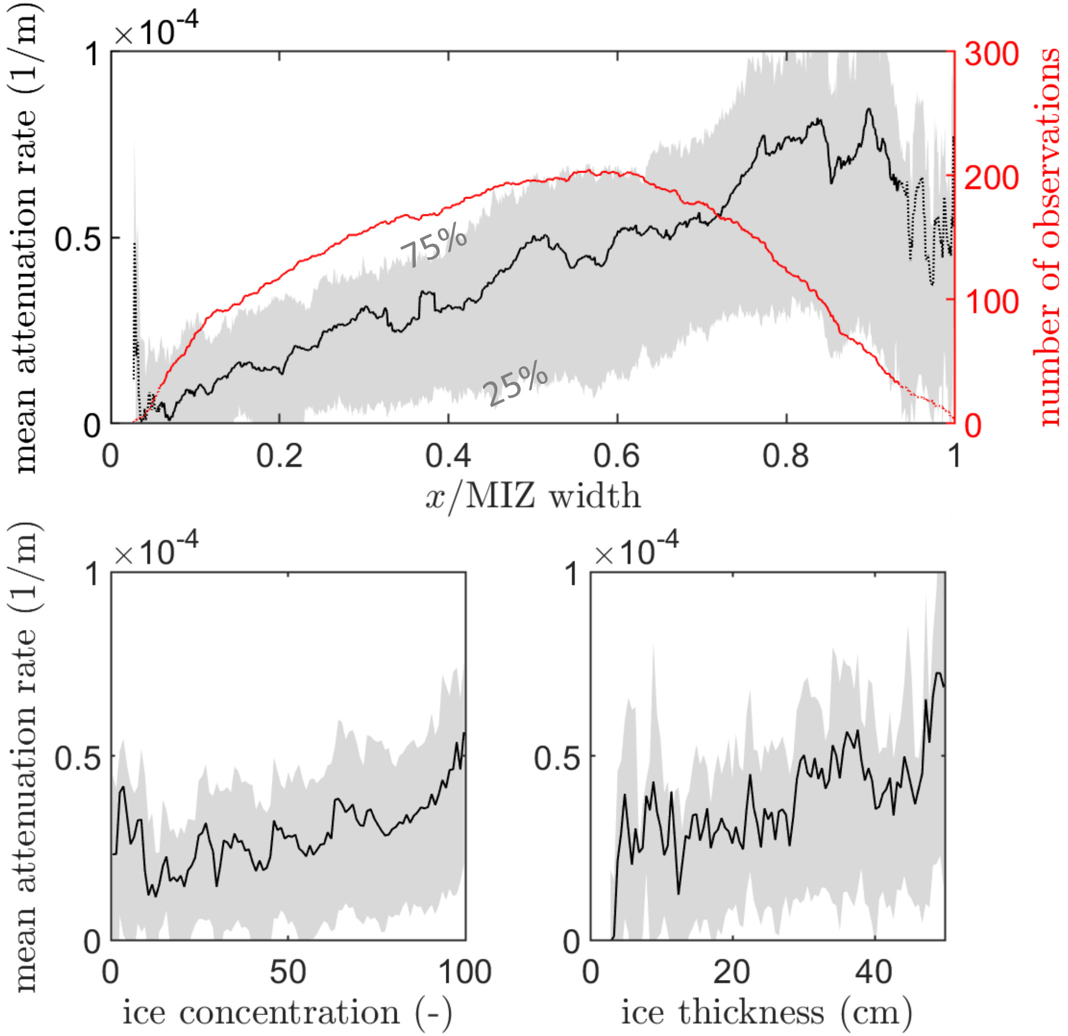


Initially, no clear trends or sorting of α, though this changes well into the MIZ. Estimates of wave energy along the transect may lead to apparent negative α.

Results – attenuation

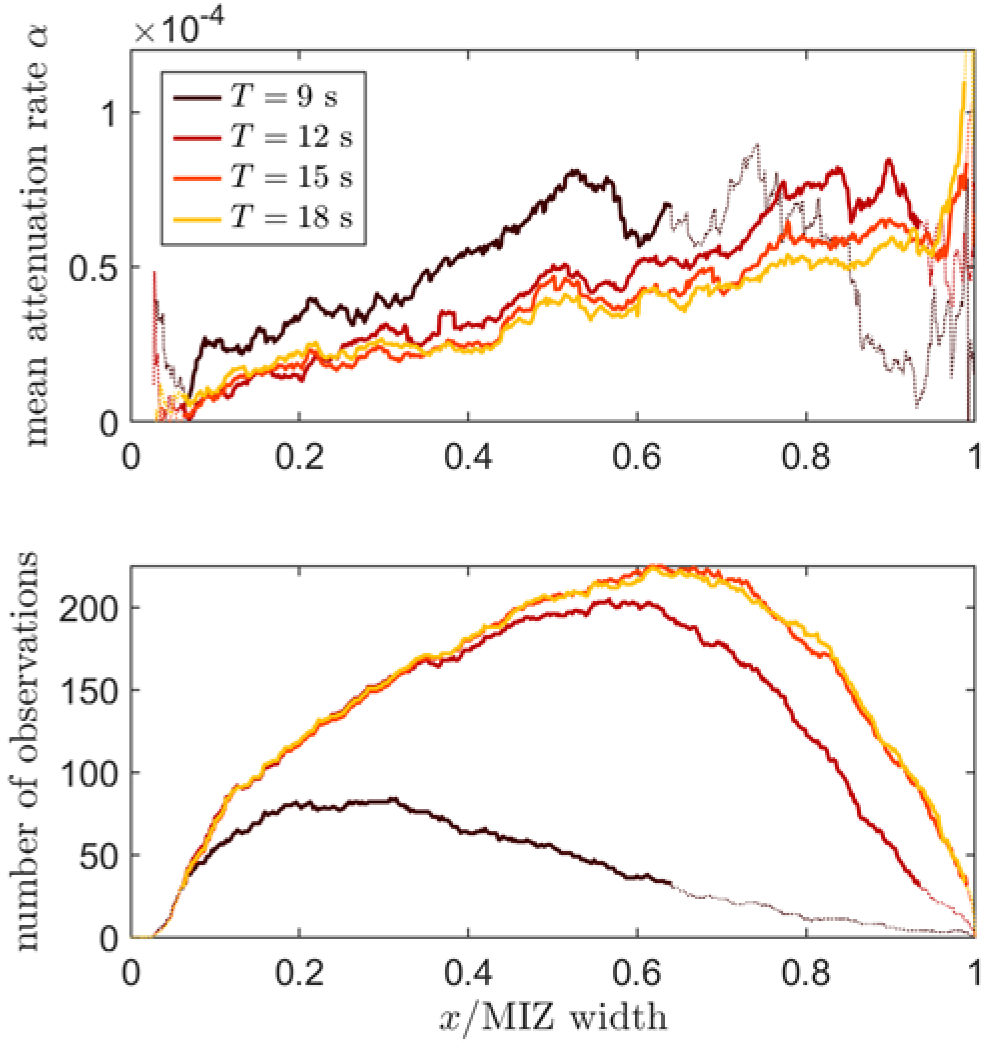
Average attenuation rate across the MIZ for a $T = 12$ s wave suggests a linear increase of α with x.

A relatively weak trend is observed with ice concentration (ASMR2) and sea ice thickness (SMOS, only up to 50 cm thick).



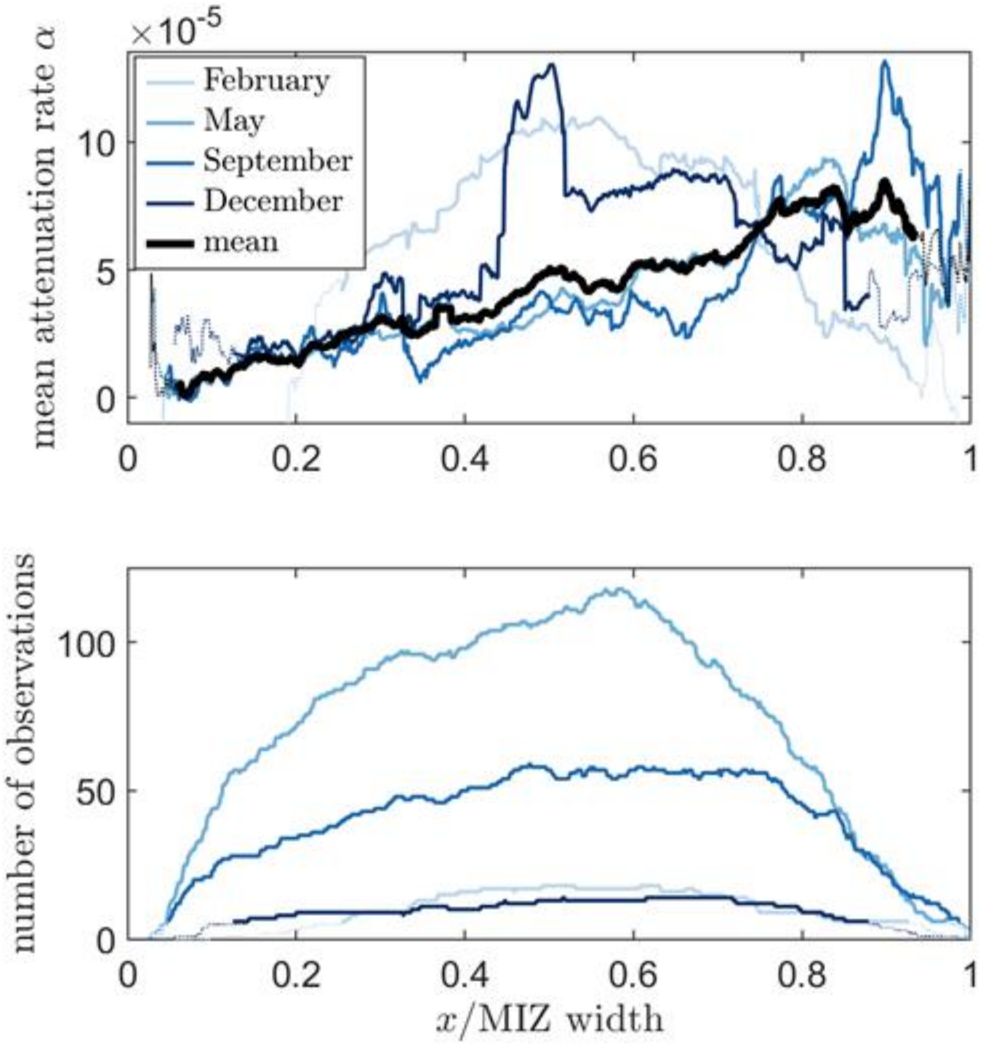
Results – attenuation (frequency)

While individual transects may vary greatly, on average, the attenuation rate appears to be well sorted with wave frequency and increases linearly with x.



Results – attenuation (seasonally)

Attenuation rates in February and December may be larger than in May and September, although the number of observations in these two months is too small to be significant.



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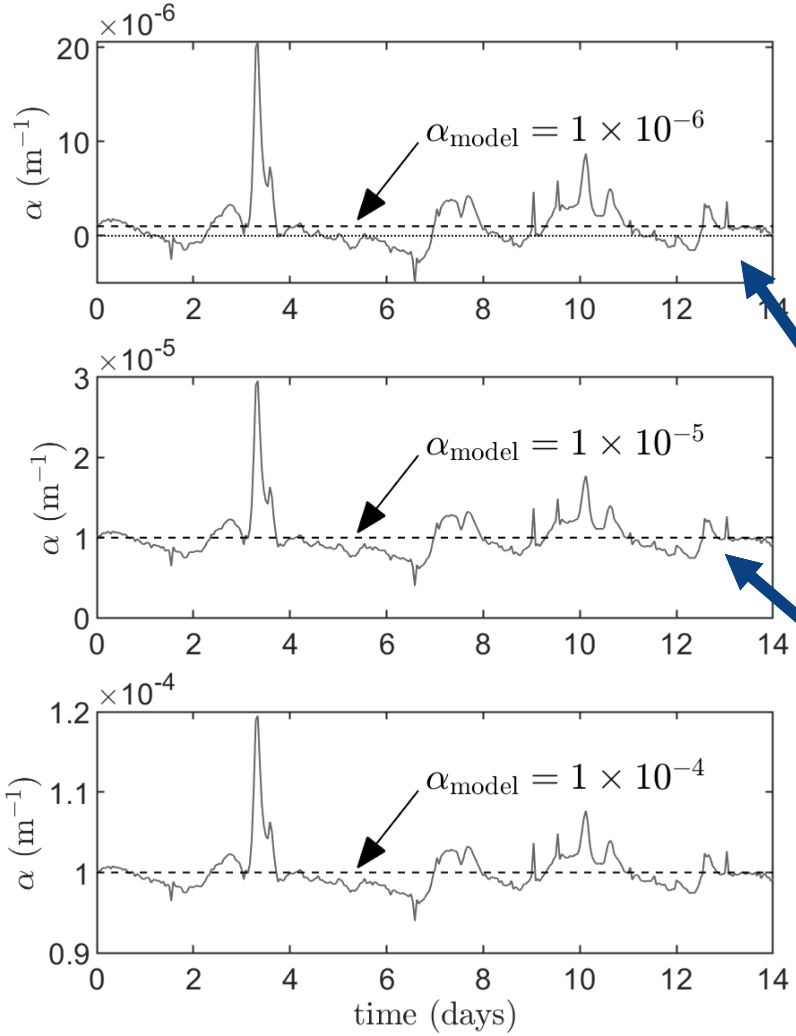
Negative attenuation rates



[Voermans et al. (2022, JoG)]

Negative attenuation rates may be physically explained by wind-input, non-linear interactions and/or methodological artifacts.

Non-stationarity of wave energy entering the MIZ may lead to:

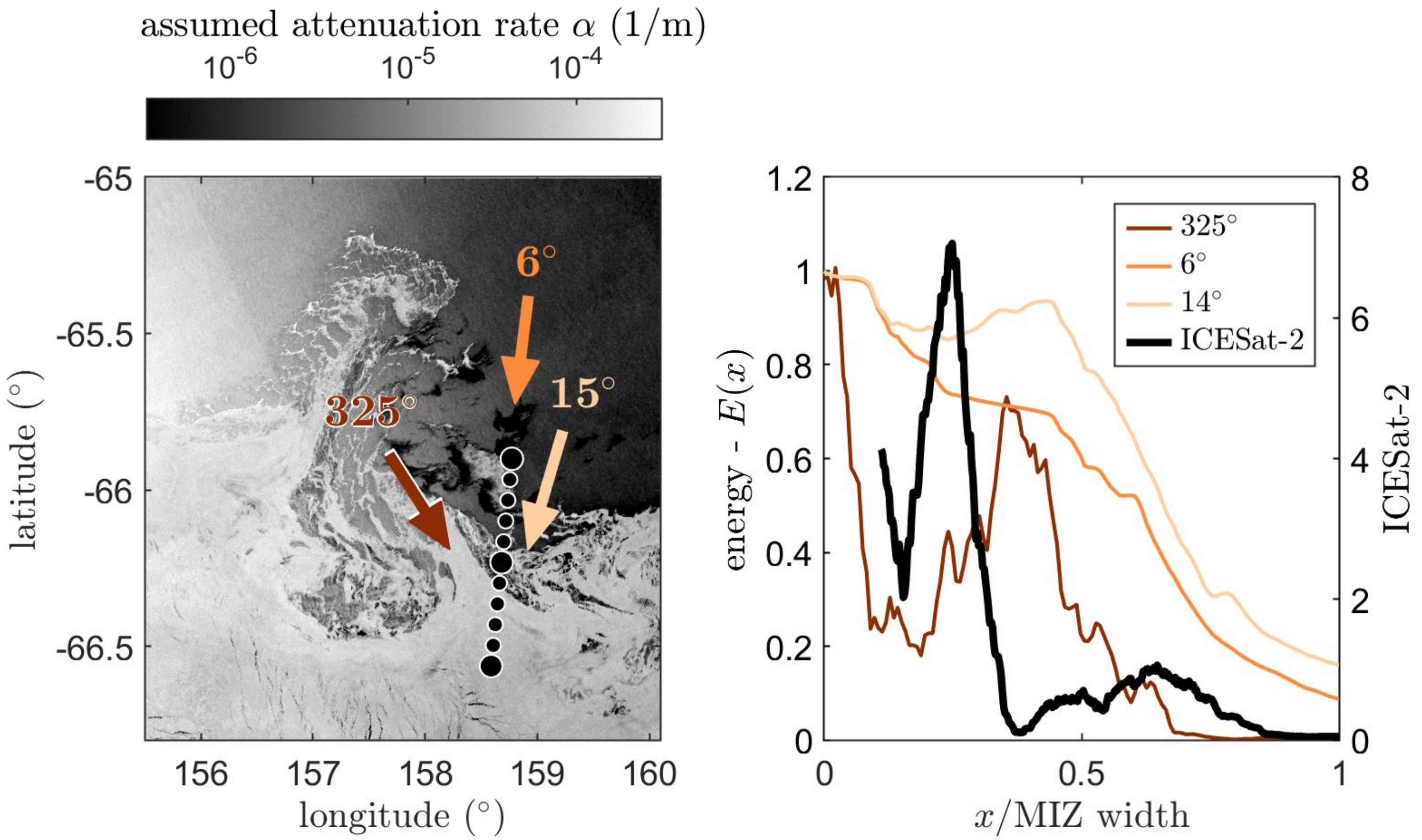
- perceived negative attenuation rates for low α
- significant fluctuations for medium α.

Negative attenuation rates – wave direction

Waves typically come from NW-direction (Antarctic MIZ)

Take backscatter as a proxy for α to evaluate impact of misalignment between wave direction and transect on α.*

Waves arriving at different positions along the transect do not experience the same ice conditions. This may lead to strong fluctuations of energy along the transect.



*This is by no means an accurate representation of the true attenuation rate, but merely intended to illustrate the impact of wave direction.

Conclusions

- ICESat-2 wave observations may be used to estimate wave attenuation rates, and are in quantitative agreement with in-situ observations
- While local attenuation rates may vary greatly, on average, α appears to increase linearly with distance into the MIZ.
- As per current understanding, attenuation rates of short waves are larger than long waves.

- Further validation of ICESat-2 attenuation observations are required
- More observations are required to identify variability and trend based on seasons and along the longitudes.