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Recovering and monitoring the thickness and elastic properties of sea ice from one month of seismic noise in Svalbard

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The decline of Arctic sea ice extent is one of the most spectacular signatures of global warming, and studies converge to show that this decline has been accelerating over the last four decades, with a rate that was not anticipated by climate models. To improve these models, relying on comprehensive and accurate sea ice thickness and mechanical properties is essential. However, there is a trade-off between accuracy comprehensiveness. On the one hand, estimations from in situ acquisitions such as ice drillings or SONAR surveys are very accurate, but they remain rare and at a local scale. On the other hand, satellite observations allow an average ice thickness estimation at the global scale from the measurement of freeboard, but it remains of poor accuracy. Seismic methods have been known to provide very accurate estimations of both sea ice thickness and mechanical properties since the 1950s, but due to the hostile environment and complicated logistics in the Arctic, such methods have not been given much interest. However, thanks to the rapid technological and methodological progresses of the last 10 years, they have known a regain of interest. In particular, passive seismology has proved very promising for the continuous and autonomous monitoring of sea ice.

This paper introduces a methodological approach for passive monitoring of both sea ice thickness and mechanical properties. To prove this concept, we use data from a seismic experiment where an array of 247 geophones was deployed on sea ice, in a fjord at Svalbard, between 1 and 26 March 2019. From the continuous recording of the ambient seismic field, the empirical Green's function of the seismic waves guided in the ice layer was recovered via the so-called noise correlation function (NCF). By comparing the NCF with recordings from active sources, we demonstrate that it converges towards the Green's function of the ice sheet with a temporal resolution of a few hours. Using specific array processing, the multimodal dispersion curves of the ice layer were calculated from the NCF, and then inverted for the thickness and elastic properties of sea ice via Bayesian inference. The evolution of sea ice properties was monitored for 26 days, and values are consistent with literature, as well as with measurements made directly in the field.