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Water-waves frequency upshift of the spectral mean due to wind forcing

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The effect of wind forcing on monochromatic modulated water waves was investigated both numerically and experimentally in the context of the Modified Non-Linear Schrödinger (MNLS) equation framework. While wind is usually associated with a frequency downshift of the dominant spectral peak, we show that it may induce an upshift of the spectral mean due to an asymmetric amplification of the spectrum. Here the weighted average spectral mean is equal to the ratio of the momentum of the envelope to its norm and it detects any asymmetries in the spectrum (Segur et al. 2005).

Wind can however indirectly induce frequency downshifts, by promoting dissipative effects like wave breaking. We highlight that the definition of the up- and downshift in terms of peak frequency or average frequency is critical for a relevant discussion.

In our model, the wind input consists of a leading order forcing term that amplifies all frequencies equally and induces a broadening of the spectrum, and a higher order asymmetric term (Brunetti et al. 2014; Brunetti & Kasparian 2014) that amplifies higher frequencies more than lower ones and induces a permanent upshift of the spectral mean. The effect of MNLS + wind is exactly opposite to MNLS + viscosity, where the lower order viscosity terms damp the whole spectrum, while the higher order viscosity terms damp higher frequencies more than lower ones and thus causes a permanent downshift, as evidenced by Carter & Govan (2016).

We corroborated the model with wave tank experiments conducted in the IRPHE/Pytheas large wind-wave facility located in Marseille, France. Wave data analysis show the temporary downshift in the spectral peak sense caused by the wind, and the temporary upshift in the spectral mean sense characteristic of the MNLS. As the tank-length was limited, we used long-range simulations to obtain upshift in the spectral mean sense caused by the wind. The limit of the model is reached when breaking events occur.

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