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Response of dominant wind wave fields to abrupt wind increase

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Over the last decades, significant progress has been made in modelling wave field development by wind observed at sea, based on more elaborated numerical schemes and refined parametrizations of wind energy input and wave dissipation. In such models, the wind wave growth in space or time is generally governed by the average wind speed evaluated at one reference level and the natural wind speed variability is neglected. However, the impact of this assumption is not really known, mainly because of the lack of appropriate observations. To revisit this question, we report a detailed laboratory investigation aimed at describing the dominant wave field evolution resulting from an abrupt local wind speed increase.
The experiments were conducted in the large Marseille-Luminy wind wave tank for moderate to high wind conditions. At 23 m fetch, a contraction of the wind tunnel section by a convergent profile created a spatial wind speed acceleration over a distance of about 2 m. Downwind, the wind speed, enhanced by a factor 1.4, was kept constant up to the end of the water tank. The wind wave field development induced by such a "wind gust" was investigated at successive fetches by wave probes and compared to those observed at similar fetches for homogeneous wind conditions. When wind increases, these observations first revealed no dramatic change in the evolution of the dominant spectral peak with fetch. The dominant wave energy which increases slowly for constant wind conditions, follows the wind speed but with a significant space lag. For well-established gravity wave fields, the space relaxation scales which describe this evolution do not depend noticeably on wind, all the curves collapse into a single one when wave quantities are normalized by their value observed just upstream the convergent profile. The wave growth rate observed for the new equilibrium state can be described by the Hasselman et al. (1973) relationship but with an “equivalent” shorter fetch since, in such conditions, the dominant wave age decreases drastically. The evolution of the dominant spectral peak frequency has two more distinctive stages. First, there is a marked slowdown of the downshift immediately after the wind increase. This stage is then followed by a fast adjustment to the uniform wind regime corresponding to the new wind speed. A detailed analysis of the shape of the dominant peak however shows significant differences in the spectral energy distribution compared to those observed in homogeneous wind conditions. This finding suggests a deep change in the intrinsic features of wave groups. To characterize it quantitatively, the evolution of a number of statistical wave field properties as wave field skewness and kurtosis or the dominant wave breaking rate is examined and discussed within the framework of nonlinear wave theories.