Turbulent and Wave-Induced velocity fields over Wind-driven Surface Waves

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In recent years, the exchange of momentum and scalars between the atmosphere and the ocean has been the subject of several investigations. Although the role of surface waves on the air-sea momentum flux is now well established, detailed quantitative measurements of the turbulent and wave-induced fields in the airflow over surface waves remain scarce. The current incomplete physical understanding of the airflow dynamics impedes further progress in developing physically based parameterizations for improved weather and sea state predictions, particularly in high winds and extreme conditions.
Using a combined Particle Image Velocimetry (PIV) and Laser Induced Fluorescence (LIF) system, we obtained laboratory measurements of the airflow velocity above surface waves for wind speeds ranging from 0.86 to 16.63 m/s. The mean, turbulent, and wave-coherent velocity fields and then extracted from instantaneous measurements.
In strongly forced cases in high wind speeds, Individual airflow separation events generate turbulence and vorticity in the bulk flow. There, phase averaged turbulent Reynolds stress forms a negative-positive pattern along the wave crest with a separation-induced maximum above the downwind side of the wave. Concurrently, the wave-induced stress near the surface is a significant fraction of the total stress. At lower wind speeds and larger wave ages, the wave-induced stress is positive very close to the surface, below the critical height and decreases to a negative value further above the critical height. This indicates a shift in the direction of the wave-coherent momentum flux across the critical layer. Our measurements will be discussed in the context of available previous experimental, theoretical and numerical results.