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Coherent vortical structures in turbulent flows over gravity and gravity-capillary surface waves

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We study the structures and distribution of coherent vortices within turbulent boundary layer over the wavy air-water interface with a focus on revealing the impact of parasitic capillary wavelets. Identification of the vortical structures is based on local analysis of the velocity gradient tensor, and the mathematical criterion upon which the structure is defined. Four identification criteria were tested; they all educe similar vortical structures and distribution patterns indicating unambiguity of the schemes. The analyzing results reveal three types of characteristic vortical structures in the layer in proximity to the interface: forward (head points downstream) and reversed horseshoe vortices, and quasi-streamwise vortices. Quasi-streamwise elongated vortex, however, is the dominant structure. More forward horseshoe vortices are observed than the reversed horseshoe vortices; most reversed horseshoe vortices appear near the leeward face. The population and distribution pattern of coherent vortices are similar in both air flows over gravity and gravity-capillary surface waves, suggesting an insignificant impact of parasitic capillary ripples on governing turbulence dynamics and transport of air boundary layer. This is contrasted to the aqueous boundary layer, in which the formation of parasitic capillary waves induces vortex shedding and significantly enhances viscous dissipation.
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