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Francois Frenkiel Award Lecture: Low-Order Representations of Irregular Surface Roughness and Their Impact on a Turbulent Boundary Layer

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The relative impact of various topographical scales present within irregular surface roughness on a turbulent boundary layer is explored. Low-order representations of highly-irregular surface roughness replicated from a turbine blade damaged by deposition of foreign materials were generated using singular value decomposition (SVD) to decompose the complex topography into a set of topographical basis functions of decreasing importance to the original ("full") surface character. The low-order surface models were then formed by truncating the full set of basis functions at the first 5 and 16 modes (containing approximately 71% and 95% of the full surface content, respectively), so that only the most dominant, and large-scale, topographical features were included in the models. Physical replications of the full surface and the two low-order models were created using rapid prototyping methods and particle image velocimetry was used to acquire ensembles of instantaneous velocity fields in the streamwise-wall-normal plane and a streamwise-spanwise plane deep within the roughness sublayer at moderate Reynolds number. The efficacy of the low-order surface models in replicating the statistical and structural characteristics of the full-surface flow will be highlighted, particularly within the roughness sublayer where the flow behavior is tightly coupled to the roughness features.

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