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Modeling rough-wall turbulent channel flow with principal component analysis enhanced amplitude modulation SICONG WU, University of Illinois at Urbana-Champaign, KENNETH CHRISTENSEN, Univeristy of Notre Dame, CARLOS PANTANO, University of Illinois at Urbana-Champaign — Direct numerical simulation of turbulent channel flows over rough surfaces, formed from hexagonally-packed arrays of hemispheres on both walls, were performed at friction Reynolds numbers $Re_\tau = 200$, 400, and 600. The inner normalized roughness height $k^+ = 20$ was maintained for all Reynolds numbers while the spacing between hemispheres was varied from $d/k = 2 - 4$. The interactions between the near-wall small-scale fluctuations and outer layer large-scale turbulence were studied by amplitude modulation (AM) analysis that has been modified to include principal component analysis (PCA). Based on these interactions, a PCA-adapted predictive inner–outer model was developed to address the modeling of anisotropic effects near the roughness and effectively predict the near-wall statistics up to 4^{th} order moments of all velocity fluctuations, including cross terms. The predictions based on the PCA-adapted model were shown to agree excellently with the original statistics from the DNS with better predictions of the statistics of v compared to model without the PCA.

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