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**Large eddy simulation of turbulent pipe flows over surface roughness and their effects on the outer large structures** MAKOTO TSUBOKURA, JUN ETOH, SHIGEAKI KURODA, The University of Electro-Communications — Large Eddy Simulation (LES) of fully developed turbulent pipe flows with or without surface roughness were conducted using a very long streamwise analysis region to investigate the effects of surface roughness on the large-scale structures, which are typically observed in the logarithmic layer of wall turbulence. In a previous study we conducted an intensive grid resolution study to properly reproduce outer large-scale structures in plane channels and found that sufficiently fine grid resolutions of around  $h_x^+ \sim 30$  and  $h_z^+ \sim 20$  for streamwise and spanwise directions are required in the near wall region. Following this grid resolutions, our new pipe LES were carried out based on the fully conservative finite difference scheme in cylindrical coordinates along with the novel pole treatment developed recently by Morinishi et al. (2003). The roughness was made of ring-shaped slats with a square cross section, and modeled by the immersed boundary method. The effects are discussed in the context of the difference of the smooth and rough premultiplied spectra (both for streamwise and azimuthal) and related statistics at several roughness heights and longitudinal spacing as geometrical parameters.

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