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Understanding and quantifying wall-turbulence: a new closure approach ZHEN-SU SHE, XI CHEN, YOU WU, Peking Univ., FAZLE HUSSAIN, Univ. of Houston — A new closure approach - structure ensemble dynamics (SED) - is proposed for integrating the flow dynamics into a rigorous, quantitative description of the mean flow of wall-bounded turbulence. Starting with the ensemble-averaged Navier-Stokes (EANS) equations, it expresses the unknown effects of fluctuation structures in terms of a set of order functions (a concept in statistical physics describing transitions between different statistical states). A multi-layer picture of wall turbulence naturally arises as a formal, quantitative extension of traditional views in terms of sublayer, buffer layer, log layer and wake. The order functions capture transitions between the layers. SED theory, applied to turbulent channel flow, reveals a surprisingly simple structure of $1 - z^4$ (where z is the distance from the channel center) for a turbulent eddy length function ℓ_ν in the bulk flow of the channel, where the traditional logarithmic layer near the wall is already included (without any matching): $\ell_\nu \propto y \equiv 1 - z$ as $z \to 1$. A quantitative multi-layer model for relevant order functions is shown to give accurate description of the mean quantities like the profiles of mean velocity, Reynolds stress, kinetic energy, turbulence production and energy dissipation. Finally, a systematic procedure for evaluating numerical simulations using the SED theory is outlined.

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