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A Shape-Hessian based analysis of roughness effects on turbulence SHAN YANG, GEORG STADLER, ROBERT MOSER, UT-Austin, ICES, OMAR GHATTAS, UT-Austin — One of the difficulties with evaluating the effects of roughness on wall-bounded flows is that the commonly used metric for roughness effects, the equivalent sand-grain roughness height, is determined not from the topography of the roughness, but from the measured effect of the roughness on the flow. It would be much more useful if the effects of roughness could be predicted directly from the roughness topography. To do this, we characterize the mapping from roughness topography to fluid dynamics impact (in this case the drag) by examining its shape gradient and shape Hessian. The eigenfunctions and eigenvalues of the shape Hessian are studied as they describe how the fluid dynamics impact changes with the roughness. For flat boundaries, the Fourier modes can be proven to be the eigenfunctions of the shape Hessian. Further, the flat boundary is a stationary point (a minimum) of this mapping and the eigenvalues depend on the wavenumber and the Reynolds number. A priori knowledge of the eigenfunctions allows the entire shape Hessian operator to be determined from a single solution of state, incremental state, adjoint and incremental adjoint equations, making determination of the adjoint feasible, even for turbulent flows. For transient Navier Stokes flow (i.e. turbulence), DNS will be used to find the Hessian in this way. The adjoint equations are solved backwards in time, requiring the complete time history of the state solution. The algorithmic and computational challenges of these calculations are discussed.

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