Investigating the effect of anisotropic mesh adaptation on resolving aerodynamic force coefficients for atmospheric entry simulations.

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Abstract:
The aim here is to improve the prediction of the dynamic stability of atmospheric entry capsule geometries by determining what the effect is of improving the mesh resolution in critical parts of the computational domain. We use the recently developed metric-based mesh adaptation capability [1] in the context of Detached Eddy Simulations (DES) carried out using the advanced compressible flow solver US3D [2]. The metric-based mesh adaptation capability [1] enables us to improve both the resolution of small-scale turbulent eddies in the wake, and highly anisotropic features like the strong bow shock and the shear layers. As a test case we consider the Mars 2020 aeroshell that landed on Mars in July of 2020. We intend to compare our simulation results at different mesh refinement levels with the available pressure data that was collected using Mars Entry, Descent, and Landing Instrumentation 2 (MEDLI2).

Keywords: Anisotropic mesh adaptation, Computational Fluid Dynamics, Atmospheric entry simulations.

1 Problem statement

Atmospheric entry capsules experience a wide range of flow conditions during their entry trajectory moving from hypersonic velocities down to low transonic and subsonic velocities when the probe lands on the planets' surface. These entry capsules tend to become dynamically unstable in the low supersonic regime ($Ma < 2.5$) towards the end of the atmospheric entry trajectory. In this work, we use the advanced compressible flow solver US3D [2] to simulate the aerodynamics that drive this unstable behavior during the vehicles free-flying descent phase.

The recently developed metric-based mesh adaptation capability [1] allows the US3D user to apply both anisotropic and isotropic mesh refinement to improve the resolution in the vicinity of anisotropic flow features like shock waves and shear layers and isotropic flow phenomena like small-scale turbulent eddies in the wake. The anisotropic error indicator depends on the Hessian of a derived flow quantity, in this case we use the Mach number [3]. In order to incorporate isotropic wake refinement we compute the Turbulent Kinetic Energy (TKE) and use this quantity to blend in an isotropic contribution to the total metric tensor field [1]. In Figure 1 two examples