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Optical distortions by compressible turbulence: distortion measures and importance of small-scale structures

ALI MANI, Stanford University

This study is focused on aero-optics, which investigates optical distortions due to the compressibility mechanism, rather than entropy fluctuations. In particular, distortion effects by separated shear layers and turbulent wakes are considered. Typically, wavefront aberrations by these flows are larger than the optical wavelength; therefore, traditional measures (i.e. the Strehl ratio) would be inaccurate if used for quantifying optical distortions. Through statistical analysis of highly aberrated waves we introduce alternative measures with provable scaling properties. These norms, provide explicit relations between far-field optical statistics and statistics of the distorting media. We also present results of our study on the optical importance of small-scale flow structures. Using Kolmogorov hypothesis, a relation is derived to estimate the smallest optically-important length scale in a general aero-optical framework. This length is typically in the inertial range and the developed criterion is shown to reasonably predict the resolution requirements for simulations. This analysis can also be used to estimate frequency requirements for adaptive-optics.