Generation and propagation of acoustic waves in the atmosphere

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Acoustic wave propagation in the atmosphere can be modeled by solving the linearized Euler equations of compressible fluid flow. Here, the acoustic waves are small perturbations on top of a background flow field, characterized by its velocity, density, and pressure, which may all vary in space and time. Acoustic waves are advected by the wind, which can cause significant bias in sound propagation and modify the refraction of energy compared to a calm atmosphere. Due to the advective terms, it is natural to solve the linearized Euler equations as a first order hyperbolic system (i.e. containing up to first derivatives in space and time). After this system has been written on symmetric form, a summation by parts finite difference discretization technique leads to a stable high order numerical method, allowing effects of realistic topography and heterogeneous background flow properties to be accurately accounted for.

An important aspect of our acoustic modeling methodology is the generation of sound in the atmosphere. In this talk we develop discretizations of singular sources for hyperbolic wave propagation problems in first order formulation, in conjunction with a high order accurate finite difference scheme. By studying the Fourier transform of the source discretization, we derive sufficient conditions for achieving design accuracy in the numerical solution. Only half of the conditions in Fourier space can be satisfied through moment conditions on the source discretization, and we develop smoothness conditions for satisfying the remaining accuracy constraints. The resulting source discretization has compact support in physical space, and performs well on bounded domains as long as the source discretization is separated from the boundaries. To also allow modeling of sources near physical boundaries, we generalize the smoothness conditions based on numerically computed null vectors of the summation-by-parts operator. In numerical experiments we demonstrate high order of accuracy in numerical solutions of the 1-D advection equation and the 3-D linearized Euler equations.

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