Mechanical Engineering Doctoral Defense

Investigations of Environmental Effects on Freeway Acoustics

School for Engineering of Matter, Transport and Energy

Stephen R. Shaffer

Advisor: Mohamed Moustaoui

abstract

The role of environmental factors that influence atmospheric propagation of sound originating from freeway noise sources is studied with a combination of field experiments and numerical simulations. Acoustic propagation models are developed and adapted for refractive index depending upon meteorological conditions. A high-resolution multi-nested environmental forecasting model forced by coarse global analysis is applied to predict real meteorological profiles at fine scales. These profiles are then used as input for the acoustic models. Numerical methods for producing higher resolution acoustic refractive index fields are proposed. These include spatial and temporal nested meteorological simulations with vertical grid refinement. It is shown that vertical nesting can improve the prediction of finer structures in near-ground temperature and velocity profiles, such as morning temperature inversions and low level jet-like features. Accurate representation of these features is shown to be important for modeling sound refraction phenomena and for enabling accurate noise assessment. Comparisons are made using the acoustic model for predictions with profiles derived from meteorological simulations and from field experiment observations in Phoenix, Arizona. The challenges faced in simulating accurate meteorological profiles at high resolution for sound propagation applications are highlighted and areas for possible improvement are discussed.

A detailed evaluation of the environmental forecast is conducted by investigating the Surface Energy Balance (SEB) obtained from observations made with an eddy-covariance flux tower compared with SEB from simulations using several physical parameterizations of urban effects and planetary boundary layer schemes. Diurnal variation in SEB constituent fluxes are examined in relation to surface layer stability and modeled diagnostic variables. Improvement is found when adapting parameterizations for Phoenix with reduced errors in the SEB components. Finer model resolution (to 333 m) is seen to have insignificant ($<1\sigma$) influence on mean absolute percent difference of 30-minute diurnal mean SEB terms. A new method of representing inhomogeneous urban development density derived from observations of impervious surfaces with sub-grid scale resolution is then proposed for mesoscale applications. This method was implemented and evaluated within the environmental modeling framework.

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