Hybrid Large Eddy Simulation/Reynolds Averaged Navier-Stokes Formulation for Numerical Weather Prediction

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An approach which couples Large Eddy Simulation and Reynolds Averaged Navier-Stokes Equations (LES/RANS) is formulated and used in the study of optical turbulence using MM5 as the mesoscale Numerical Weather Prediction (NWP) code. It became quickly evident that there are a number of problems associated with current mesoscale weather prediction codes when used to predict optical turbulence. First, the resolution is not adequate to resolve gravity waves or optical turbulence. Second, the present mesoscale turbulence parameterizations are based on those used for LES; problems have been noted due to the coarse mesoscale model resolution not resolving LES scales sufficiently. Third, the approximation used to calculate the index of refraction structure function is based on mixing length theory.

The index of refraction structure function depends on the dissipation rate of the turbulent kinetic energy (TKE) and the dissipation rate of the variance of potential temperature. In order to address the above problems, the Navier-Stokes in MM5 are supplemented by the TKE and an equation for its dissipation rate, $\varepsilon = \nu\zeta$ where ν is the kinematic viscosity and ζ is the variance of vorticity or enstrophy, and an equation for the variance of potential temperature and an equation for its dissipation rate. These four equations were derived directly from the Navier-Stokes equations and thus retain all relevant physics. Further, in order to account for scales that are not resolved by LES, a hybrid LES/RANS solver has been incorporated into MM5. The resulting turbulence model is tensorially consistent, Galilean invariant and coordinate-system independent.

The talk will focus on describing the approach developed for studying optical turbulence and on developing a systematic approach for introducing turbulence parameterization into NWP codes. The benefits expected from the use of the physically based model as NWP resolution is increased will be discussed as well as problems expected if the current code numerics are not modified for high resolution execution. A related talk by McRae will address these numerical issues in detail.