Prediction of Optical Scale Atmospheric Turbulence with a Typical NWP Code: Lessons Learned Projected to Petascale Computing

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Resolution of the scales required for accurate prediction of optical turbulence in the atmosphere presents a daunting task for current numerical weather prediction codes, the majority of which have been developed and subsequently optimized for execution at typical mesoscale mesh spacings of 1km to 5km horizontally and 300m to 1km vertically. In order to improve the present capability of these codes, a project is in progress at NCSU Aerospace Engineering to develop an adaptively high resolution version of WRF-ARW with the goal of achieving more accurate optical turbulence predictions with little resource increase as compared to the unmodified code. The code modifications planned originally included installing a version of the NCSU dynamic solution adaptive grid algorithm, DSAGA, and a new physically based LES/RANS turbulence model developed at NCSU by Hassan and collaborators. These modifications were to be guided by experience gained in developing an adaptive MM5 using the same algorithms.

However, execution of the adaptive MM5 in both normal and adaptive mesh modes revealed a number of code features that tend to reduce or eliminate the anticipated advantage of increased resolution where accurate prediction is needed. The MM5 solutions tend to be overdamped/excessively filtered in normal mode, with this solution characteristic also identifiable in higher resolution regions in adaptive mode. MM5 contains multiple sources of algorithmic and artificially added dissipation, with the latter usually included for stability and solution conditioning. Some of the added dissipation terms are used with constant coefficients independent of time or mesh interval, with values apparently chosen to give desired damping levels for mesoscale mesh spacing. This approach is continued, for example, in the RK3 filters used in WRF-ARW. At best, this may produce a damping with variation unrelated to the damping due to numerical approximation error terms. At worst, mathematical inconsistency with the original PDE's may occur if the resolution is increased to levels made possible by petascale computing resources.

The oral presentation will first review briefly typical results obtained with the standard and adaptive MM5 to illustrate what has been achieved to date and to open discussion of the above points. The effect of dissipation will be examined as resolution changes, and other resolution-dependent influences on solution accuracy will be addressed, such as absorbing, lateral and nest boundary implementations. The interaction of dissipation with turbulence models will be discussed in support of the related talk by Hassan. Examples will be provided where available and the need for further analyses and numerical experimentation will be discussed. Changes in algorithms and usage will be suggested where possible in order to increase benefit from petascale computing resources.