2.6 EXAMINING THE SENSITIVITY OF METEOROLOGICAL AND CHEMICAL PREDICTIONSTO EXPLICIT MICROPHYSICS SCHEMES

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1. INTRODUCTION

Because of the inherent interactions of meteorology and chemistry within the atmosphere, the accurate representation of meteorological conditions is essential for skilled predictions by an air quality model (AQM). This study evaluates the performance and sensitivity of the model predictions of meteorological (i.e., precipitation) and chemical (i.e., atmospheric concentrations and wet deposition amounts of ammonium (NH_4^+), nitrate (NO_3^-), and sulfate (SO_4^{2-})) parameters to different cloud microphysics schemes.

In this work, the Fifth Generation National Center for Atmospheric Research/Pennsylvania State University (NCAR/PSU) Mesoscale Model (MM5)/Community Multiscale Air Quality (CMAQ) modeling system is applied on a 4-km horizontal resolution domain containing most of North Carolina and small portions of neighboring states. The simulations are for two one-month periods, August and December 2002. Different meteorological inputs are generated by changing the explicit microphysics scheme option within MM5. This physics option is chosen because of its impacts on both clouds and precipitation processes, which can influence the wet deposition processes simulated in CMAQ. Additionally, the clouds/precipitation processes simulated within the explicit microphysics scheme have impacts on the tendencies of simulated temperature, moisture, and non-convective rainfall. It is also noted that because of the fine horizontal resolution (4-km), the MM5 cumulus parameterization is turned off, since all clouds and convective-type precipitation are assumed to be resolved by the explicit microphysics scheme (Roselle and Binkowski, 1999). Results from three pairs (August and December) of MM5/CMAQ simulations are evaluated and compared to gain insight on the overall skills and sensitivity of predictions of parameters related to wet deposition to the explicit microphysics scheme chosen. The baseline MM5 simulation is based on Wu et al. (2005), which uses the Reisner 1 (mixed-phase) (Reisner et al., 1993) explicit microphysics scheme (hereafter referred to as R1). Two additional MM5 simulations are completed using the Reisner 2 (mixed-phase with graupel) (Reisner et al., 1993, 1998) and the Dudhia (simple ice) (Dudhia, 1989) schemes, hereafter referred to as R2 and SI, respectively.

In this work, the previously mentioned simulation pairs are evaluated with respect to performance and sensitivity based on statistical, spatial, and temporal comparisons. To determine overall model performance, a model evaluation is completed by comparing simulated values of precipitation, particulate matter (PM) species concentration, and wet deposition amounts with observed values from the following networks: the NC Automated Surface Observation Systems (ASOS), the Automated Weather Observing System (AWOS), the National Acid Deposition Program (NADP), the Clean Air Status and Trends Network (CASTNet), the Interagency Monitoring of Protected Visual Environments (IMPROVE), and the Speciated Trends Network (STN). The proposed protocol for all comparisons within this research includes domain-wide, as well as, geographic- and meteorological condition-specific evaluations.

2. SUMMARY

Preliminary evaluation results show better model performance by all three simulations for precipitation predictions during December, possibly due to the different meteorological forcings present during summer and winter. During August, mesoscale forced convection exists, including sandhills and sea-breeze front initiated, which are more difficult to simulate within the model, even at a fine grid-scale. December precipitation events generally result from synoptic-scale forcing, which is better represented by MM5. Overall, the simulated results from R1 and R2 are very similar for both precipitation and wet deposition amounts throughout the domain.

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However, the SI simulation differs from the R1 and R2 results with lower precipitation and wet deposition amounts simulated during August and higher values simulated during December. Spatially, the largest differences between the SI and both Reisner simulations occur within the coastal region during the summer and along the Appalachian Mountains during the winter, highlighting potential areas of increased sensitivity to the treatment of ice-phase processes. Statistically, the three simulations do not show significant differences in performance for concentrations of NH_4^+, NO_3^-, and SO_4^{2-} during August. However, December results show decreased skill in NO_3^- predictions for all three simulations. In addition, the winter predictions for SO_4^{2-} concentrations show increased sensitivity to microphysics scheme, especially at the rural and remote sites, where the SI simulation has noticeably higher predictions biases. A comparison of results for PM species concentrations shows an inverse relationship between precipitation amounts and the concentrations of these species. This relationship reflects the increased scavenging of pollutants with increased precipitation amounts. Even though the simulated precipitation and decreases in pollutant concentrations have similar timing, the magnitudes of the concentration changes are not directly proportional to the precipitation amounts. This nonlinear relationship suggests the impact of other atmospheric processes on the ambient concentrations of these species. These impacts may include, but are not limited to, dry deposition, transport, and transformation processes.

Because of the nonlinear relationship of the interactions present within the wet deposition process, further research is needed to examine why the noted differences occur. In addition, more spatial and temporal comparisons will be completed to determine the effects on a more location- and meteorological condition-specific basis to complement the completed domain-wide comparisons. The aforementioned seasonal trends of microphysics scheme sensitivity will also be examined further to determine the temporal influence of model performance and sensitivity. Finally, an additional sensitivity simulation for August and December using the Hsie (warm rain) (Hsie and Anthes, 1984) microphysics scheme, which does not include ice-phase processes, is proposed. The inclusion of this simulation pair along with the additional comparisons will give further information on the impacts of the explicit microphysics scheme on the meteorological and chemical predictions of MM5/CMAQ.

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