Modeling the Impact of Power Plant Emissions to Regional Haze in Big Bend National Park With CMAQ-MADRID

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Summary

The Big Bend Regional Aerosol and Visibility Observational (BRAVO) study was designed to investigate the probable causes of visibility degradation in Big Bend National Park (BBNP), Texas. Gaseous inert tracers were released from several locations and their ambient concentrations were monitored at several sites including BBNP. In addition, measurements of aerosols and precursors were conducted at 40 sites within the study area.

We have applied an improved version of the Community Multiscale Air Quality (CMAQ) model to simulate tracers and PM chemical composition for a multi-day episode. The improvements consist primarily of the use of the Model for Aerosol Dynamics, Reaction, Ionization and Dissolution (MADRID) to simulate PM (Pun et al., 2001) and of the Carnegie-Mellon University (CMU) mechanism to simulate cloud chemistry.

Emission inventories were developed for an area that included Texas, the surrounding states, the Gulf of Mexico and northern Mexico (Kuhns et al., 2001). The emitted species included NO_x, VOC, CO, SO_2, NH_3 and PM. In addition, emissions of sea-salt (sodium chloride) from the Gulf of Mexico were taken into account (Zhang, 2001). Sea-salt emissions are a strong function of wind speed over the water.

The meteorological fields were simulated with the Mesoscale Model version 5 (MM5) by Professor Nelson Seaman at Pennsylvania State University.

The CMAQ simulations were conducted over the modeling domain using two nested grids with horizontal resolutions of 12 and 4 km, respectively. The domain extends about 1500 km in the east-west direction and 900 km in the north-south direction. Thirteen layers were used for the vertical resolution. The simulation period extends from 6 a.m. CST on 5 October 1999 to 6 p.m. CST on 15 October 1999. This period was selected because it corresponds to a regional haze episode in BBNP with prevailing winds from the northeast to the southeast.

Simulations with CMAQ were first conducted to simulate tracer concentrations. These simulations clearly showed that the Mexican Carbon power plant led to higher tracer concentrations (normalized to their emission rates) than the Texas power plants because of the proximity of the former to BBNP (Seigneur et al., 2001).

Next, a simulation was conducted with atmospheric chemistry to simulate regional haze for this 11-day period. The results indicate that both the model and the measurements show the highest PM concentrations toward the end of the episode. A statistically significant correlation between simulated and measured sulfate concentrations is obtained at BBNP. Both the measurements (Malm et al., 2001) and the model simulation results show that particulate nitrate is present in the coarse particles, primarily as sodium nitrate, following reaction of HNO_3 with sea salt. This result could not have been obtained with the original version of CMAQ because it does not treat sea-salt particles whereas CMAQ-MADRID provides a comprehensive treatment of the chemical interactions between HNO_3 and coarse sea-salt particles. Simulated concentrations of particulate organic compounds (OC) are commensurate with the available measurements. CMAQ-MADRID predicts that secondary OC are more important than primary OC, which is consistent with the available data at BBNP (Brown et al., 2002).

Future work will focus on the application of this model to investigate the effect of various emission management options on PM concentrations at BBNP.

References

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