SENSITIVITY ANALYSIS OF MODELED OZONE IN A COASTAL URBAN AIRSHED

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1. INTRODUCTION

The Ozone Near Non-Attainment Areas (NNAs) Research and Planning Studies coupled the Comprehensive Air Quality Model with Extensions (CAMx) photochemical model and the Fifth-Generation NCAR/Penn State Mesoscale Model (MM5) prognostic meteorological model to evaluate the impact of various local and regional control strategies on ozone air quality within the South Texas NNAs region. Emission inputs were prepared using the Emissions Preprocessing System Version 2 (EPS2). Texas Commission on Environmental Quality (TCEQ) selected the September 1999 high ozone episode affected over the whole South Texas NNA region of Austin, San Antonio, Victoria, and Corpus Christi, during September 13-20, 1999. This study presents various model sensitivity runs conducted for the Corpus Christi urban airshed to provide a sound policy-making tool for the air quality planners in evaluating the effectiveness of ozone control strategies. The base case model was established by ENVIRON and Texas A&M University-Kingsville (TAMUK) performed further refinement of the base case for the Corpus Christi urban airshed. First, the model sensitivity to different types of advection schemes, advection time steps, haze turbidity values, and Plume-in-Grid (PiG) parameters was evaluated. The sensitivity of modeled ozone to various emission source categories was evaluated for the Corpus Christi urban airshed. Selected emission reductions in upwind areas to Corpus Christi were tested for evaluating the impact of inter-urban and long-range transport of ozone and its precursors.

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2. MODEL INPUT DATA

The MM5 mesoscale model was utilized to generate meteorological fields for the air quality simulations. Several meteorological sensitivity evaluations were performed for various parameterization schemes such as cloud parameterization, radiation, planetary boundary layer schemes, and the precipitation scheme. MM5 was configured to run with 28 vertical levels and a minimum surface layer depth of 20 m. This study used the following model configuration, such as a Medium-Range Forecast (MRF) model for planetary boundary layer (PBL) and Rapid Radiative Transfer Model (RRTM) for radiation scheme, with the initial schemes, such as Gayno-Seaman boundary layer turbulence scheme, simple-ice cloud microphysics, Kain-Fritsch cumulus parameterization, five-layer soil model, and cloud radiation scheme. Three levels of two-way horizontal grids were used with grid resolutions of 108, 36, and 12 km. Four dimensional data assimilation (FDDA) gridded analysis nudging was utilized to nudge horizontal wind field, temperature, and moisture for all domains, while observational nudging was employed to relax horizontal wind field, temperature, and moisture for the third domain (12 km). In addition, observational nudging for wind filed was utilized for the fourth domain (4 km) (Emery et al., 2001). The emission inventory was allocated temporally to account for seasonal, day of week, and hour of day variability, spatially to reflect the geographic distributions of emissions, and chemically to reflect the chemical composition of VOC and NOx emissions required for the Carbon Bond IV (CB4) chemical mechanism by the EPS2 system (Jimenez et al., 2002). EPS2 processed point and area sources with other types of anthropogenic source data prepared individually to provide total emission input for CAMx. Vehicle emissions were quantified by MOBILE5ah and a biogenic source data was provided by Global

Biosphere Emissions and Interactions System (GLOBEIS).

3. CAMx SIMULATION RESULTS

The CAMx model version 3.10 was utilized for air quality simulations using the CB4 chemical mechanism. A modeling domains based on a Lambert Conformal projection was developed with multiple nested subgrids (36-, 12-, and 4-km). The 4-km grid spacing was selected for the finest nested subgrid to allow evaluation of region-specific impacts and control strategies. The base case model prepared by ENVIRON used the Piecewise Parabolic Method (PPM) advection scheme, 30-minute advection time step, and 10- and 25-ton per day (tpd) of NOx emissions for PiG treatment in 4- and 12-km domains respectively.

3.1 Advection Schemes

The CAMx photochemical model provides three different options for advection schemes, such as Smolarkiewicz, Bott, and PPM (ENVIRON, 2002). It is obvious that there is no noticeably large disparity resulting from the use of the three different advection schemes on the simulation of base case ozone in Corpus Christi urban airshed. The Performance of Smolarkiewicz scheme seems to be a little better especially during peak ozone hour.

3.2 Advection Time Steps

TAMUK performed the CAMx sensitivity runs with two different advection time steps (30-minute and 60-minute). There is no difference in ozone simulation when these two different time steps are used. All statistical values, such as, unpaired peak accuracy, average paired peak accuracy, bias in peak timing, normalized bias and error are the same in both cases.

3.3 Haze Turbidity Values

TAMUK performed a sensitivity study related to haze turbidity. In the first case, turbidity values were reduced by 50%, in the second case, reduced by 100%, and in the third case increased by 100%. The differences, however, in ozone simulation with the three haze turbidity values are negligible.

3.4 PiG Parameters

Sensitivity analyses involving PiG options were examined to find out how different NOx cut-off emissions for PiG treatment of point source emissions affect ozone simulation in the 4-km domain. In the first case, PiG option was not selected, while in the second case point sources with 1 and 10 tons of NOx emissions were selected for PiG treatment in 4- and 12-km domains, respectively. It was noticeably apparent that the exclusion of the PiG option in the model had some noticeable effects in areas other than that of the four NNAs. Four near non-attainment areas showed differences in the range of 2 to 6 ppb. However, there were no differences during peak ozone hours with the selection of 1- and 10-tpd PiG option.

3.5 Selected Emission Reductions

A number of sensitivity studies were undertaken to find out effects of a variety of emissions reductions in Corpus Chrsiti area. Emissions sources examined for reduction scenarios are all anthropogenic sources, point sources, area sources, mobile sources, and selected upwind point sources.

For assessing the impact of all anthropogenic source emissions in Corpus Christi on both local and regional ozone levels, all point, area, and mobile sources were zeroed out from the two counties namely, Nueces and San Patricio. Maximum and minimum difference plots (Figure 1a-b) show that maximum decrease and increase in Nueces county ozone levels were 54 ppb and 22 ppb respectively.

When all point source emissions were taken out from the two counties, ozone levels increase during late evening through early morning hours. Maximum decrease and increase in Nueces county ozone levels were 8 ppb and 1.4 ppb respectively.

Emissions from all area sources were zeroed out from the two counties to evaluate the impact of all anthropogenic area sources combined together on both local and regional levels. Increase and decrease in ozone levels are observed in the same pattern of previous cases. Maximum decrease and increase in Nueces county ozone levels were 20 ppb and 8 ppb respectively.

Zeroing-out of mobile sources including both on-road and non-road mobile sources results in

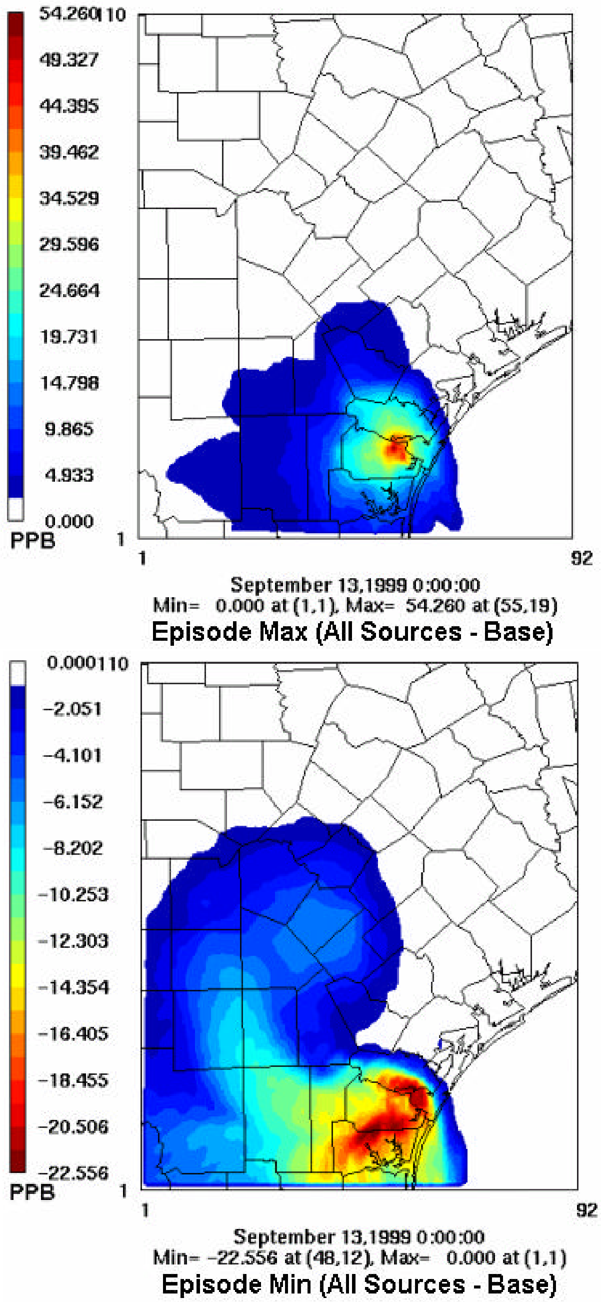

Figure 1. Spatial distribution of period (a) maximum and (b) minimum 1-hour ozone concentration difference between base and control case (without Corpus Christi anthropogenic sources) simulated in the 4-km grid on September 13-20, 1999.

the same diurnal pattern of increase and decrease in ozone levels as observed in previous cases. Ozone levels decrease during late evening and early morning, and increase during daylight hours. Maximum decrease and increase in Nueces county ozone levels were 20 ppb and 40 ppb respectively over the current modeling episode.

Selected emission reductions in upwind areas to Corpus Christi were tested for evaluating the impact of inter-urban and long-range transport of ozone and its precursors. Zero-out emission run conducted for upwind areas including the Houston-Galveston non-attainment area reveals that upwind areas contribute up to 12 ppb of ozone.

4. DISCUSSIONS

From the zero-out emissions sensitivity study, on-road mobile source calculated by MOBILE5a was the largest pollution contributor. It means calculation error of on-road mobile sources could affect total emissions significantly. Thus accurate mobile emissions inventory and modeling are required. MOBILE6, which requires more detailed input data and supports more various options, was recently presented to the public. It is expected that more precise on-road mobile source data would be acquired by applying MOBILE6 model.

Also the zero-out study showed area source emissions were the second-largest pollution contributor. Some of non-road mobile sources, however, was not collected and counted properly because it is collected using surveys. More precise non-road mobile source emissions data is required for better modeling result.

5. REFERENCES

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