CRC Report No. A-112

Relative Reduction Factors Using Anthropogenic Ozone Increments

Executive Summary

October 2018

COORDINATING RESEARCH COUNCIL, INC.

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October 2018

EXECUTIVE SUMMARY

The objective of this study was to develop improved procedures for calculating and using Relative Reduction Factors (RRFs) that focus on the anthropogenic increments to ozone that are influenced by U.S. air quality management activities. The anthropogenic increment is the difference between the total ozone in an area of interest arising and the background ozone entering the area.

To develop State Implementation Plans (SIPs) for achieving the National Ambient Air Quality Standard (NAAQS) for ozone, the U.S. Environmental Protection Agency (EPA) recommends using model results in a relative sense. I.e., rather than comparing the absolute model predictions of ozone in a future year to the NAAQS, the model results for the future year are divided by corresponding results for the base year to develop an RRF. The ozone design value (DV) for a monitoring site in the base year, determined from measurements, is then multiplied by the RRF to predict the future-year design value (DVF) at the site, and this prediction is then compared to the NAAQS to determine if the emission reductions achieve attainment. Fig. ES-1 contains a description of this standard procedure for estimating DVFs.

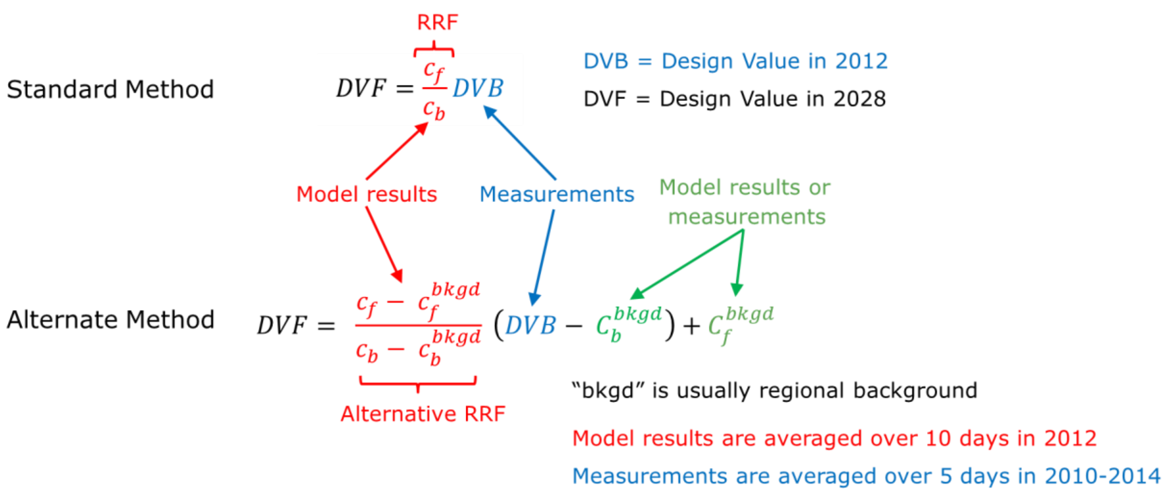

Figure ES-1. Description of the standard and alternative methods for estimating future design values (DVFs).

With the standard method, ozone increments from local and regional anthropogenic emissions are combined in the RRF (and the DVF) and therefore the contribution of each of these source categories to the RRF is obscured and errors in how either category is represented contaminate both the RRF and the predicted DVF. We developed the alternative method shown in Fig. ES-1 in which the RRF is the ratio of the anthropogenic increment in the future year to that in the base year, as determined from model results. The increment is determined by the difference between simulations with and without the local emissions. An advantage of the alternative method is that more measurements can be included. Specifically, though the RRF in the alternative method uses model results only, the other background concentrations (indicated in green font in Fig. Es-1) can be determined from either measurements or model results. Regional background measurements are available for the area we studied in this project, Houston-Galveston-Brazoria (HGB), and most of our work used measured or modeled regional background ozone. There are also estimates of U.S. background ozone derived from measurements, and the Appendix describes some additional work using these estimates and modeled U.S. background ozone.

We simulated ozone formation in the HGB area for May – September 2012 using the Comprehensive Air Quality Model with Extensions (CAMx) version 6.40 and the CB6r4 chemical mechanism. Input data sets were those developed by the Texas Commission on Environmental Quality (TCEQ) for the HGB 2012 SIP. The CAMx modeling domain consisted of a 36-km grid covering the continental U.S. and portions of Canada and Mexico, a 12-km grid covering entire Texas, and a 4-km grid focusing on the HGB area. We also simulated 2028 with emissions obtained by scaling the 2012 emissions using EPA's 2011 and 2028 national inventories. To estimate the regional background ozone concentrations for HGB, we simulated 2012 and 2028 with the HGB anthropogenic emissions removed. Six additional simulations focusing on the U.S. background (USB) ozone (no U.S. anthropogenic emissions), the sensitivity of results to the ozone boundary concentrations (BCs) and the sensitivity to regional emissions are discussed in the report.

We conducted an operational evaluation of model performance for hourly and MDA8 ozone during May-September 2012, and the performance is good for the larger concentrations (>60 ppb) in the HGB area and for other areas of Texas. However, the model over-predicts the smaller concentrations. We also evaluated the model performance for the concentration averages used in the RRFs. EPA recommends that the concentrations used in an RRF be averages over the 10 days with the largest maximum daily 8-h average (MDA8) ozone in the base-year (2012) simulation (T10Base days). We determined the model performance for total ozone, regional background ozone, and the HGB anthropogenic increment to ozone at the 20 monitoring sites in HGB for which DVs are calculated, and Fig. ES-2 shows the results of this evaluation. The T10Base days are a set of days on which the model significantly over-predicts the MDA8 regional background ozone for all the DV sites in HGB and under-predicts the anthropogenic ozone increment for most sites. The latter under-prediction is important because the anthropogenic increment provides the limit on how much local emission controls can impact the total ozone. Improving the model predictions for background ozone seems necessary to improving the accuracy of estimated DVFs.

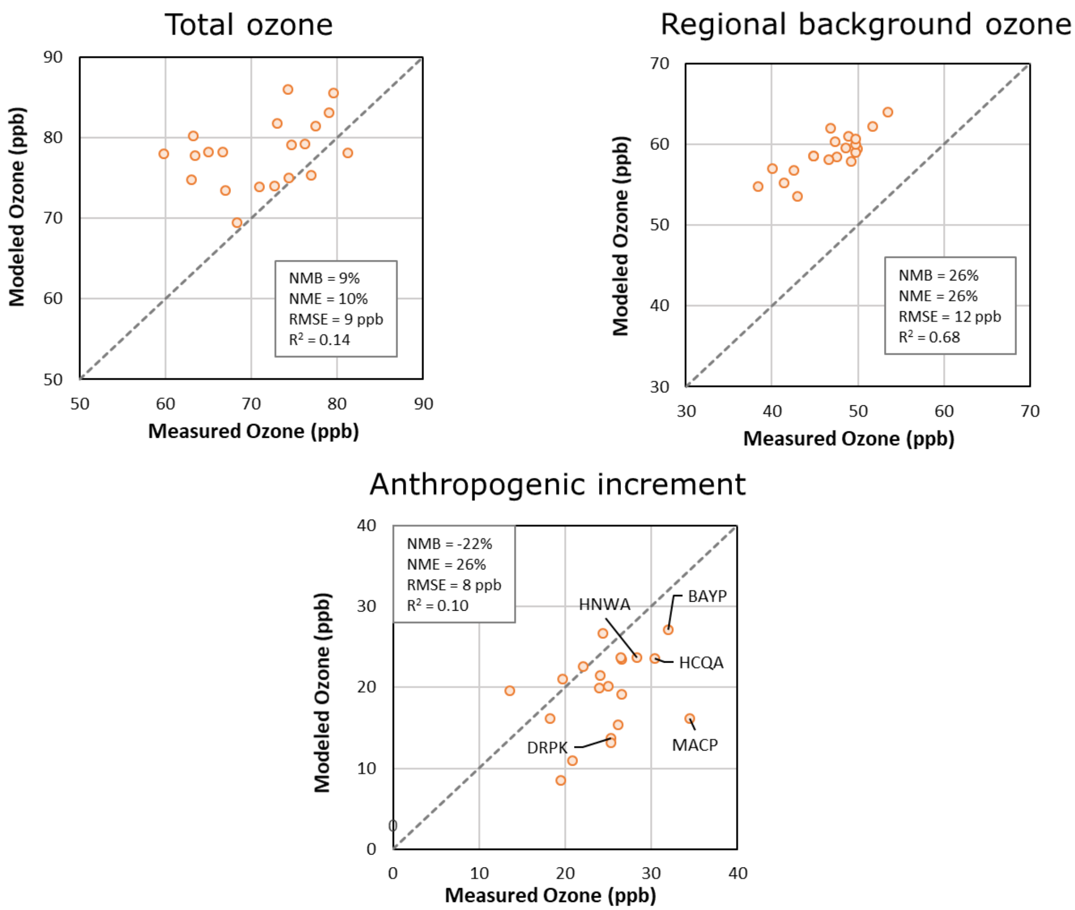

Figure ES-2. Comparison of modeled MDA8 ozone in 2012 averaged over the T10Base days vs. measurements averaged over those days. Each point corresponds to a site in HGB for which design values are calculated. Points for sites having the largest 2012 design values are labeled: Houston Deer Park (DRPK), Manvel Croix Park (MACP), Houston Bayland Park (BAYP), Northwest Harris County (HNWA), and Houston Croquet (HCQA).

We estimated DVFs by two alternative methods: Alt1 in which model results are used for all the regional background concentrations; Alt2 in which model results are used for the alternative RRF but measurements are used for the other background concentrations in the formula. The regional background concentrations were derived from monitoring site data by the TCEQ procedure. In this procedure, the minimum MDA8 ozone at the outlying monitoring sites on a given day is designated the background concentration for the day. We projected these 2012 measurements to 2028 using the wind direction at the background site and trends developed by Berlin et al. for different wind directions (Environ. Sci. Technol., 47, 13985-13992, 2013). Fig. ES-3 compares the alternative RRFs and the Alt1 and Alt2 DVFs to the standard RRFs and DVFs. (The RRFs are the same for the Alt1 and Alt2 methods.)

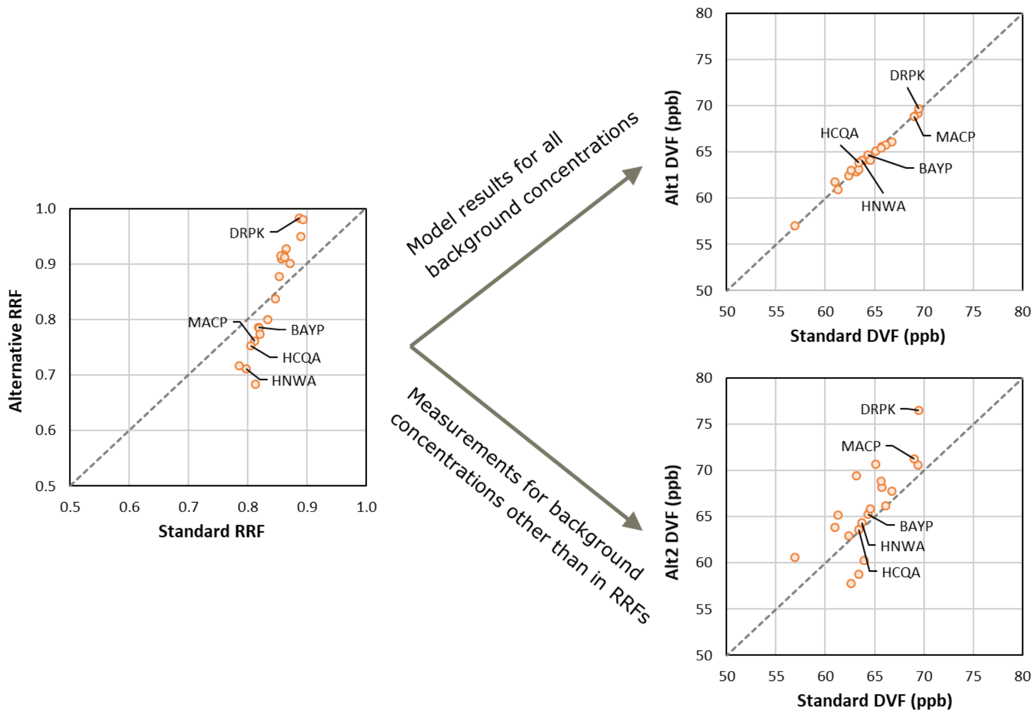

Figure ES-3. Comparison of the alternative RRFs to the standard RRFs and comparison of the Alt1 and Alt2 DVFs to the standard DVFs.

The Alt1 method gives DVFs that are close to those from EPA's standard procedure. This happens because the modeled ratio of the background to total MDA8 ozone at the sites is similar in 2012 and 2028 for HGB. However, this may not be true for other urban areas. The Alt2 method yields DVFs that are larger than the standard DVFs for about half the sites. The discrepancies occur because the estimated change in background MDA8 ozone from 2012 to 2018 derived from the measurements can differ by up to 8 ppb from the change derived from the model results. The differences between the changes in background ozone from the measurements and model results are due in part to differences in wind direction between the five days from 2010-2014 included in EPA's definition of a DV and the T10Base days used to average the model results for the RRF. We also estimated DVFs by four other alternative methods, but the results are similar to those of either the Alt1 or Alt2 methods.

A site of special interest is Deer Park, which has the largest 2028 DVF determined by the standard or any of the alternative methods for any of the sites. The DVF for Deer Park from the Alt2 method is greater than that from the standard method for two reasons. First, the modeled anthropogenic increment decreases little from 2012 to 2028, giving a large RRF. I.e., the model indicates that local controls have little effect on the ozone at this site, at least for the T10Base days in 2012. Second, the measured background averaged over the DV days is projected to decrease by only 1.3 ppb. This decrease is much smaller than the 8.3 ppb decrease obtained when the model results are averaged over the T10Base days, and thus the difference between the DV days and the T10Base days is important.

The alternative methods for estimating DVFs could be applied in some other urban areas. Model results can be used for all the regional background ozone concentrations, and the Alt1 DVFs could be compared to the standard DVFs to determine if they are very similar, as is the case for HGB, or different. The only requirement is to define an appropriate geographical separation of the urban area from the surrounding regional area. To use measurements to estimate the regional background ozone and calculate the Alt2 DVFs, there must be outlying monitors that are upwind of the urban area on those days when the ozone concentration is large. Wind directions may vary among the days with large ozone concentration, so multiple outlying monitors are needed. These background ozone measurements needed for the Alt2 DVF may not be available for all urban areas. If the future year is close to the base year, then it is reasonable to assume that the regional background ozone would be the same for both years when calculating the Alt2 DVFs. However, if the future year is >5 years beyond the base year, then analyzing historical trends in the regional background measurements (e.g., Berlin et al. 2013) seems necessary to project the future background used in the Alt2 DVFs.

The major conclusions of our study are:

- For the T10Base days, the model over-estimates the regional background ozone at the DV sites and under-estimates the local anthropogenic increment to MDA8 ozone.
- If model results are used for all the background ozone concentrations, the alternative and standard DVFs are similar (at least for HGB).
- If measurements are used for background concentrations other than those in the RRFs, the alternative DVFs are larger than the standard DVFs for about half the sites.
- The difference between the T10Base days used for an RRF and the 5 days used for a DVB causes different estimates of background changes from base to future years.
- Ozone BCs have little effect on the DVFs. Regional background emissions affect the standard and Alt1 DVFs; Alt2 DVFs are less sensitive to these emissions.
- The model predicts large ozone concentrations over the Gulf of Mexico that could contribute to background ozone in HGB, but measurements are unavailable to evaluate these predictions.
- Model results generally support the TCEQ procedure for estimating background ozone from measurements.