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Geoscientific Model Development Discussions

Interactive comment on "A method to represent ozone response to large changes in precursor emissions using high-order sensitivity analysis in photochemical models" *by* G. Yarwood et al.

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We thank Dr. Cohan for insightful and helpful comments on our draft manuscript. Below are his specific comments and our response to each.

1. A potential limitation of this approach is its use of concentrations and sensitivities only from runs with drastically reduced emissions. While this saves some computational time and helps target the low emissions cases where errors would otherwise be severe, it likely hinders accuracy near the base case by not using concentrations and sensitivities computed there. Response of ozone to modest reductions in emissions is often the most critical issue to address in policy applications such as attainment

demonstrations. The authors note the potential to improve accuracy for such cases by using coefficients from the base case (p. 2593 line 29 – p. 2594 line 2), but did not test that. This highlights that further refinement and evaluation of both the Simon and Yarwood methods will be a valuable next step, as the authors note at the end of Section 4. In the meantime, adopters of these methods are likely to be well served by the authors' recommendation (p. 2595, lines 20-21) to compute sensitivities at the midpoint of the range of interest, and adapt Eq. 3 accordingly. This may help lessen errors near the base case when modest emission reductions are the focus.

Response: We agree that results would be improved with an additional HDDM run at 100% emissions. Our study looked at performance over a wide range of emissions (zero to 100%) and found that greatest need for improved accuracy near zero emissions which we addressed by adding an HDDM run with 10% emissions.

2. While results are presented in terms of bias and error relative to brute force concentrations, was any testing done to quantify performance in representing the reduction in ozone resulting from a control measure? Accuracy of HDDM estimates of responsiveness, not just concentrations, is critical to some policy applications.

Response: We believe that comparisons with brute force are the most rigorous evaluation we can perform because the HDDM technique is a model result and therefore can perform no better than the model upon which it is based.

3. How common is the scenario in Figure 2, in which the second-order derivative actually reverses sign to become positive (concave up) at the high NOx levels? In the illustration, this drives the inaccuracy of the second-order Taylor expansion from point A.

Response: The example shown in Figure 2 is from box model simulations using a complete chemical mechanism which demonstrates that this type of response is at least theoretically possible, but we cannot quantify how frequently it arises in 3-D model simulations.

4. Equations 2 & 3: It may be helpful to subscript N and V, since they are calculated relative to the 10 or 50% sensitivity case.

Response: We prefer not to subscript the LHS of these equations as it indicates ozone as a function of N and V.

5. While Dallas is a good choice as a representative urban region, other cities such as Houston and Los Angeles are likely to have higher levels of precursor emissions and more highly nonlinear ozone photochemistry. Was either of those regions looked at? This could be of interest since the paper notes the greater challenge and weaker performance in urban areas.

Response: We have evaluated other cities and found generally similar results, but focused on one that is representative to keep the paper concise. We will add plots of HDDM vs. BF for Los Angeles and Houston in the supplement. We will be evaluating impacts of emission reductions via HDDM responses to meet current ozone standards in a variety of US cities in a follow on paper.

6. All of the cases focused upon in the performance evaluation involved equal percentage changes to NOx and VOCs. Was there any degradation in performance when these levels differed? This is worth checking, since the sub-cases in Eq 3 differ based on NOx but not VOC.

Response: Our tables in the manuscript and supplement include 25/100% NOx/VOC case. The original text was not very clear on this point and we will improve the way that we describe the 25/100% NOx/VOC case to make clear that we have evaluated an "off-diagonal" case.

Interactive comment on Geosci. Model Dev. Discuss., 6, 2585, 2013.