Estimating Control Impacts Based on Prior Modeling, Including Particulate Source Apportionment Technology (PSAT) Modeling

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If results of two or more sets of modeling runs are available, but an estimate of the results of a different set of parameters is needed, such as a different set of controls, and it is not possible to obtain a new set of modeling runs (for instance due to time or budgetary constraints), then some other means of obtaining an estimate of these results is needed. Since Regional Haze modeling (like many other air quality modeling applications) is principally applied via calculation and application of Relative Response Factors (RRFs), it would be natural to interpolate RRFs from prior modeling to estimate RRFs that would be obtained by modeling a given set of controls that are similar to the control sets used in earlier runs.

Within this document we present a reasonable method for estimating impacts of controls that have not actually been modeled, based upon a linear interpolation over RRFs of two available modeling runs. This method is reasonable provided the two interpolated model runs have the same baseline conditions as the unmodeled run, and are sufficiently similar to each other and to the unmodeled run, to justify a linear approximation. The interpolation coefficient used in this method takes advantage of a Source Apportionment Technology (in this case, Particulate Source Apportionment Technology or PSAT) future case run to provide a receptor and/or monitor[1] specific interpolation, provided this run is sufficiently similar to the conditions of the future cases of the prior modeled runs.

Consider one of the two modeled runs to be a "base" control run. The difference in emissions between the "second" control run and this "base" control run are the emission reductions of the "second" control set. Further, the difference in emissions between the unmodeled, or, "target" control run and this "base" control run are the emission reductions of the "target" control set. Since this approach is a linear approximation, emission species such as sulfur dioxide and nitrogen oxides, will be associated with measured species that are most closely related, such as ammonium sulfate and ammonium nitrate, respectively.

The **emissions reduction ratio** associated with a given species will be the ratio of the emission reductions of the "target" control set associated with that species over the emissions reductions of the "second" control set associated with the same species. These ratios are computed on an emission apportionment category basis (such as source region and emitter category) using the same emission apportionment categories in the PSAT future case run. The **apportionment fraction**, for each species and receptor, is the fraction of the average PSAT modeled future case concentration apportioned to a given

[1] Henceforth, the term *receptor* shall be used in place of receptor and/or monitor.

emission apportionment category, for that species and receptor, over all emission apportionment categories that differ between the "base" and "second" control runs. This ensures the sum of the apportionment fractions, over all the emission apportionment categories that differ between the "base" and "second" control runs, will yield one.

The interpolation coefficient, for each species and receptor, equals the sum, over all the emission apportionment categories that differ between the "base" and "second" control runs, of the product of the emissions reduction ratio associated with that species, and the apportionment fraction, for the category, species, and receptor.

This interpolation factor, for each species and receptor, is then multiplied by the difference in the RRFs of the "second" control run and the "base" control run (with the "base" being subtracted from the "second"). This product is added to the RRF of the "base" control run to obtain the estimate of the RRF of the "target" control run, for the given species and receptor.

What follows is a mathematical derivation of this method.

Derivation of the Method

Equation 10-4-1 below shows the method of linear interpolation to a new "target" RRF (RRF_T) from RRFs obtained from "base" (RRF_B) and "second" (RRF_S) modeling runs, as above:

$$\begin{aligned} RRF_{Trs} &= \left(1 - f_{Trs}\right) RRF_{Brs} + f_{Trs} RRF_{Srs} \\ &= RRF_{Brs} + f_{Trs}\left(RRF_{Srs} - RRF_{Brs}\right) \end{aligned} \qquad \text{(eq. 10-4-1)}$$

where f_{Trs} is the interpolation coefficient, RRF_{xrs} is the RRF for modeling run x, (where $x \in \{B, S, T\}$), with B and S representing the two modeled runs and T representing the interpolated "target" estimate desired, for each receptor (r)and species (s).

If the new control set is simply an interpolated set of emissions between those used in the "base" and "second" modeling, and emissions in these modeling runs are not too different (so a linear approximation is reasonable), then the interpolation coefficient is given by

$$f_{Trs} = f_{Ts} = \frac{E_{Tr} - E_{Bs}}{E_{Ss} - E_{Bs}} = \frac{\Delta E_{Ts}}{\Delta E_{Ss}} \qquad \text{(eq. 10-4-2)}$$

where the E_{xs} are the emissions for modeling run x ($x \in \{A, B, I\}$) associated with species s.

If emissions are not simply a scaled interpolation between "base" and "second" model runs, then determination of a proper interpolation coefficient becomes much less straight forward. In this case, the above interpolation is likely to misappropriate the impacts of

changes, since it applies the same interpolation for all receptors (r), for a given species (s).

However, if apportioned RRFs from ”base” and ”second” modeling runs were available, then interpolation of apportioned RRFs would be possible and a more representative set of emissions could be obtained. For instance, if the equivalent of RRFs for each run, species, receptor, and apportionment category (such as source region and emitter category, like electric generating units, etc.) were available, it would be possible to obtain RRFs apportioned by such categories.

Given $RRF_{B\,rs} = \sum_t RRF^t_{B\,rs}$ and $RRF_{S\,rs} = \sum_t RRF^t_{S\,rs}$, where the “tag” ($t$) runs over all apportionment categories (such as source region and emitter category) that differ between the runs, an interpolated “target” $RRF_{T\,rs} = \sum_t RRF^t_{T\,rs}$ is obtained:

$$RRF^t_{T\,rs} = RRF^t_{B\,rs} + f^t_{T\,rs}\left(RRF^t_{S\,rs} - RRF^t_{B\,rs}\right) \qquad \text{(eq. 10-4-3)}$$

where

$$f^t_{T\,rs} = f^t_{T\,s} = \frac{E^t_{T\,s} - E^t_{B\,s}}{E^t_{S\,s} - E^t_{B\,s}} = \frac{\Delta E^t_{T\,s}}{\Delta E^t_{S\,s}} \qquad \text{(eq. 10-4-4)}$$

If the baselines for the two “base” and “second” modeling runs and for the “target” modeling run are identical, then interpolation between RRFs is equivalent to interpolation between averaged modeled concentrations. Thus, if a Source Apportionment Technology (like PSAT) run for the future case is available that involves emissions that are not too different from the future “base”, “second”, and “target” cases, then an apportioned RRFs may be estimated as:

$$RRF^t_{x\,rs} \approx RRF_{x\,rs}\left(\frac{\left\langle C^t{}_{rs}\right\rangle}{\sum_t \left\langle C^t{}_{rs}\right\rangle}\right) = RRF_{x\,rs}\,\frac{\left\langle C^t{}_{rs}\right\rangle}{\left\langle C_{rs}\right\rangle} \qquad \text{(eq. 10-4-5)}$$

where $\left\langle C^t{}_{rs}\right\rangle$ is the averaged modeled future case concentration apportioned to tag (t) for receptor (r), and species (s). $\left\langle C_{rs}\right\rangle$ is defined as $\left\langle C_{rs}\right\rangle = \sum_t \left\langle C^t{}_{rs}\right\rangle$.

Therefore, a better interpolation is thus obtained as:

$$\begin{aligned} RRF_{T\,rs} &= \sum_t RRF^t_{T\,rs} \\ &= \sum_t RRF^t_{B\,rs} + \sum_t f^t_{T\,s}\left(RRF^t_{S\,rs} - RRF^t_{B\,rs}\right) \\ &\approx RRF_{B\,rs} + \left(RRF_{S\,rs} - RRF_{B\,rs}\right)\sum_t f^t_{T\,s}\frac{\left\langle C^t{}_{rs}\right\rangle}{\left\langle C_{rs}\right\rangle} \\ &= RRF_{B\,rs} + f_{T\,rs}\left(RRF_{S\,rs} - RRF_{B\,rs}\right) \end{aligned} \qquad \text{(eq. 10-4-6)}$$

The interpolation coefficient, $f_{T\,rs}$, now depends upon the receptor (r), and is given by

$$f_{T\,rs} = \sum_t f^t_{T\,s}\frac{\left\langle C^t{}_{rs}\right\rangle}{\left\langle C_{rs}\right\rangle} = \sum_t \frac{\Delta E^t_{T\,s}}{\Delta E^t_{S\,s}}\frac{\left\langle C^t{}_{rs}\right\rangle}{\left\langle C_{rs}\right\rangle} \qquad \text{(eq. 10-4-7)}$$

The foregoing is a reasonable method for estimating impacts of controls that have not actually been modeled, based upon interpolation over two available modeling runs, provided, of course, the two runs over which we are interpolating have identical baseline conditions as would be used for the "target" run to be estimated, and are sufficiently similar to each other and to the "target" run. The interpolation coefficient, thereof, takes advantage of a Source Apportionment Technology (like PSAT) future case run to provide a receptor-specific interpolation, provided this run is sufficiently similar to the conditions of the future cases of the other available runs.

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