Comments to the CASAC Ozone Review Panel

CASAC Draft Review Letters on the ISA, HREA, and PA Documents

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I submit comments on two topics for the CASAC Ozone Review Panel's consideration. The first topic concerns the issue of background tropospheric ozone and the consistent theme to downplay the role of the stratosphere as a source. The second concerns the appropriate application and evaluation of CMAQ/HDDM as a methodology to replace the quadratic rollback technique for the health risk calculations.

Tropospheric Background Ozone

It is repetitively suggested throughout the review letters to downplay the role of the stratosphere as a source of tropospheric ozone. At numerous points the reviews state that elevated upper tropospheric ozone levels in the springtime are simply caused by lower decay rates and separation from terrestrial removal processes such as deposition. Such is true, but it reflects a purely chemical point of view and ignores the equally important perspective of atmospheric dynamics (a major driver for the source of that ozone).

If indeed stratospheric influences and intercontinental transport negligibly contribute to high springtime upper tropospheric ozone, then the CASAC Panel needs to cite published work that unambiguously and definitively supports that assertion. Conversely, there are numerous publications from respected researchers spanning decades that argue against this (other public commenters cite extensive lists of articles). The PA review letter cites two publications, but which scarcely support the Panel's assertion. In the first, Monks (2000) points out that "Most evidence suggests on average that there is not a strong seasonal variation in stratosphere-troposphere exchange frequency," but suggests that winter/spring storm intensity may play a role. Further, in considering outstanding issues, Monks (2000) states "the quantification of the input of stratospheric ozone into the troposphere during spring is crucial," but makes no statement concerning the irrelevance of the stratosphere. In the second, Li et al. (2002) describe older-generation GEOS-Chem modeling results for surface ozone at Bermuda, which indicates little contribution from the stratosphere. While I can conceptually believe such is true for a lower-latitude flat sea-level location, these results should not be extrapolated to the high elevation western US, much less the mid-latitude upper troposphere. Modern global modeling (Zhang et al., 2012; Lin et al., 2012) shows consistent springtime-average stratospheric contributions on the order of 10 ppb in the high surface elevations of the western US, with much larger contributions aloft.

In fact, the stratosphere is a dynamic contributor to upper tropospheric ozone in all seasons. Especially in the late winter and spring, the tropopause (the zone between the upper troposphere and lower stratosphere[1]) can sink to just 6-8 km above sea level depending on the intensity of upper atmosphere dynamics. At any given time, a half-dozen or more major low-pressure waves causing "tropopause folds" are distributed around the globe; these folds can be thought of as breaking waves that mix significant masses of stratospheric and tropospheric air through deep portions of the atmosphere (Holton, 1979). During the summer, mid-latitude systems are weaker and fewer, and the warmer atmosphere raises the tropopause to 9-12 km.

While tropopause folding events are discrete and episodic (separated in time and space), several other factors contribute to stratosphere-troposphere exchange via weaker but more continuous and widespread diffusive mechanisms. For example, the daily development of deep convection in thunderstorms is a very efficient vertical transport process that often extends into the lower stratosphere. Such activity is ubiquitous around the globe at mid-latitudes, especially in the spring and summer seasons. Other mechanisms include deep vertically propagating gravity waves induced by terrain or various meteorological features, and turbulence induced by smaller-scale breaking waves within shear zones along the mid-latitude jet stream. Global and regional models cannot generally resolve such mechanisms.

Model-Based Rollback Using HDDM

I am encouraged with the Panel's positive support to move away from the quadratic rollback and toward a photochemical model-based rollback using HDDM. However, Appendix B of the REA letter ("Assignment of Priorities") notes that EPA intends to employ NOx-only HDDM projections to observational data in each of the 16 risk assessment cities. Besides likely requiring deeper cuts to meet alternative standards, NOx-only vs. balanced NOx+VOC reductions will lead to different ozone responses, and thus potentially different ozone distributions and health risk impacts. This uncertainty must be quantified.

Furthermore, I must reiterate my concerns that I have previously expressed in comments to the CASAC in September and to the REA docket in October. The underlying modeling system should not be run blindly. The sample CMAQ evaluation documented by Simon et al. (2012) indicated particularly large error in replicating observations in Atlanta. A comprehensive model evaluation against observations must be conducted to ensure a reasonable chemical response in each of the 16 cities. Furthermore, simple statistical comparisons to just ozone observations may not reveal compensatory errors that may expose the model as predicting "right results for wrong reasons". This is particularly important since the goal is to simulate the chemical response as a function of time, space and chemical regime. An analysis on par with those calculated for GEOS-Chem (Zhang et al., 2011), CAMx (Emery et al., 2012), and the extended evaluation of background ozone referenced in the ISA (Henderson et al., 2012) should be undertaken for the 2007 CMAQ/HDDM simulation.

[1] It is important to disregard comments that refer to the troposphere as a "surface" (e.g., see ISA consensus letter, page 11, line 40). Rather, it is simply a zone of changing stability and wind gradients (shear) brought about by the warming of stratospheric air by the ozone photochemical process. Therefore, it is incorrect to visualize the tropopause in terms of a physical barrier to chemical exchange.

Finally, I note a tone in the HREA, and in the associated Panel review comments, suggesting that background concentrations can be ignored in the CMAQ/HDDM rollback technique. It is true that an external/artificial specification of background ozone is not needed when applying the HDDM-based rollback because CMAQ considers background contributions implicitly. That is, in the limit that controls approach zero anthropogenic emissions, CMAQ/HDDM projections should (if operating correctly) approach the simulated background ozone distribution according to the manner in which CMAQ treats boundary conditions (international transport), stratospheric contributions (again through boundary conditions), fires, lightning NOx, and especially biogenic emissions.

However, there are three pitfalls to avoid when considering CMAQ/HDDM estimates of background ozone:

1. Assuming the HDDM sensitivity projections to zero anthropogenic emissions faithfully reproduce the background distribution obtained with a "brute-force" simulation with zero anthropogenic emissions;

2. Assuming the simulated background distribution represents a correct distribution and reasonable contribution from various sources;

3. Assuming the background contribution cancels out when supplying risk models with ozone distributions reflective of current and "just meeting" an alternative standard.

With respect to (1), HDDM projections are second-order approximations for a particular emissions level, and therefore subject to higher-order inaccuracy. HDDM projections must be compared against explicit runs with zero anthropogenic emissions to assess their accuracy.

With respect to (2), CMAQ background estimates must be evaluated in a manner similarly performed for GEOS-Chem and CAMx with respect to their estimates of North American Background (NAB). It will be important to characterize the distribution of background and to assess its reasonableness and uncertainties. Errors and uncertainty in background estimates will translate to errors in the rollback technique (especially for cases requiring particularly deep reductions), and thus to errors in risk calculations (both optimistic and pessimistic).

With respect to (3), "background" contributions shift non-linearly between simulations with full and zero anthropogenic emissions. For example, in heavily polluted urban conditions, background ozone contributions are decayed by NOx titration and reactions with VOC (radicals). As controls are introduced, decay rates are reduced and the background distribution increases. It is therefore important not to assume that "background is background", and instead realize that it transforms with each control scenario. Changes in risk calculations, if performed properly with HDDM-projected observational data, should reflect the non-linear impact from a realistically evolving background ozone component.

References

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