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COMMENTS ON GLOBAL MODELING TO ESTIMATE POLICY RELEVANT BACKGROUND OZONE

EPA Clean Air Scientific Advisory Committee

Ozone Review Panel for the Reconsideration of 2008 NAAQS

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PRB Ozone

- EPA relied on a global model (GEOS-Chem) to establish PRB for the 2008 NAAQS (Fiore et al., 2003)
  - Modeled PRB range: 15-35 ppb
  - Minimal/infrequent stratospheric influence (<10 ppb)
  - Large uncertainties in total ozone and PRB estimates
- Observational research contradicts model results
  - Higher background ozone (often >50 ppb)
  - More natural short-term variability
  - More evidence of stratospheric events (winter – spring)
  - Ozone from Asia is increasing at ~3-5 ppb per decade (Parrish et al., 2009)

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GEOS-Chem as a PRB Tool

- PRB is not directly measureable: modeling is a useful tool
  - Integrate model estimates & observational evidence
  - Reflect seasonal, geographical, frequency distributions
- GEOS-Chem results circa 2000 are obsolete
  - Coarse resolution
  - Simplistic physical treatments
  - Older meteorological datasets
  - Global emission estimates are uncertain and outdated
- Latest GEOS-Chem increases PRB estimates
  - Higher resolution (grid nesting)
  - Better chemistry/physics (stratospheric treatment)
  - Updated inputs (emissions, meteorology)
  - Important to understand which new process is responsible

Refined Modeling of PRB

- New modeling
  - EPA: multi-year GEOS-Chem modeling (2006-2008)
    - Assess inter-annual variability and causes
  - ENVIRON/API: regional modeling at 12 km resolution
    - CMAQ and CAMx run for 2006
    - 2006 GEOS-Chem run providing boundary conditions
    - Addressing terrain influences on PRB in the west
- We recommend a targeted evaluation for model performance and processes
  - Evaluate performance consistent with use of results
  - Evaluate how well rural ozone events are simulated to test process representations
    - Compare to observation-based conceptual models
  - Assess uncertainties and consequences

Comments on
Global Modeling to Estimate Policy Relevant Background Ozone

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As part of the process of setting the 2008 ozone NAAQS, the US Environmental Protection Agency (EPA) relied on a global model (GEOS-Chem; Bey et al. [2001]) to establish the range of "policy relevant background ozone" (PRB). The EPA's 2006 ozone criteria document places emphasis on a particular GEOS-Chem PRB simulation for the year 2001, as documented by Fiore et al (2003). The resulting modeled PRB range was reported to be 15-35 ppb. Source attribution calculations were performed with the same model that split the contribution toward total simulated ozone into components for local (US) emissions, foreign emissions, and natural emissions. The source attribution results indicated a minimal and infrequent stratospheric influence (usually much less than 10 ppb), and a small (less than 10 ppb) contributions from anthropogenic emissions from outside North America during elevated ozone events in the US.

The GEOS-Chem performance evaluation documented by Fiore was conducted for total ozone against surface observations in rural areas across the US, and was therefore unable to discern whether compensating errors existed within different processes (especially important when considering PRB and source attribution). Disagreements between observed and simulated total ozone suggest uncertainty in model PRB estimates. While monthly means and unpaired (time/space) frequency distributions of daily maximum ozone were shown to be fairly well replicated in the western half of the US, observed ozone levels greater than 60 ppb were consistently under predicted. Model resolution was coarse, with grid box dimensions of 2 by 2.5 degrees (latitude/longitude), roughly 200 km on a side. Resolution strongly affects the accuracy of model chemistry and dispersion, especially in resolving stratospheric intrusion events and vertical circulations over complex terrain such as occur in the western US.

Observational research has contradicted the Fiore simulated PRB results (e.g., Lefohn et al. [2001] and Oltmans et al. [2008]). Such studies routinely report higher background ozone (often exceeding 50 ppb), with much more natural short-term variability, and more evidence of stratospheric events in the winter and spring seasons. There is evidence that ozone from Asia entering the US west coast is increasing at 3-5 ppb per decade (Parrish et al., 2009), which means that PRB is higher now than a decade ago, and will be higher in the future.

The EPA 2006 ozone criteria document contrasts these observational analyses of PRB with GEOS-Chem results, and repeats many conclusions reached by Fiore et al (2003). For example, in response to observational analyses that suggest winter/spring ozone peaks at elevated western rural sites are likely caused by stratospheric intrusion and continental transport, Fiore states that GEOS-Chem explains such high ozone as stemming from local emissions above a

much lower background level. Their results, however, clearly show that GEOS-Chem had difficulty replicating the highest ozone events in these areas and seasons.

PRB is not directly measureable and so modeling is a useful tool. It is important to avoid over reliance on one particular type of analysis, but to integrate model estimates and observational evidence to appropriately reflect seasonal, geographical, and frequency distributions of PRB throughout the US.

GEOS-Chem results from early in the previous decade are now obsolete due to continued model improvements. For example, the stratospheric chemistry algorithm was simplistic and has been consistently criticized. Meteorological analyses driving transport, stratosphere-troposphere exchange, and chemistry have since been revised. Global emissions of ozone precursors have been (and continue to be) difficult to estimate due to lack of data for much of Asia and third-world countries. According to satellite data, Asian NOx emissions used in GEOS-Chem through about 2005 were low by a factor of 2, and Asian NOx emissions have grown quickly over the past decade (Zhang et al., 2009). There are currently no corresponding analyses of uncertainty in Asian VOC emissions, so that component remains highly uncertain.

Newer GEOS-Chem versions currently being used predict higher PRB estimates than reported by Fiore et al. (2003). The latest version of the model includes higher resolution through the use of grid nesting (0.5 by 0.5 degrees, roughly 50 km), several improved chemistry and physics treatments (including stratospheric ozone chemistry), and updated inputs (emissions, meteorology). It will be very important to understand the degree to which each of these processes is responsible for the upward shift in PRB.

Current modeling using GEOS-Chem includes a multi-year (2006-2008) application sponsored by the EPA. The major advantage of multi-year applications is that it allows for an assessment of potential model biases caused by inter- and intra-annual variability and climatic anomalies (e.g., extreme fire seasons, hurricane activity, cool/wet vs. hot/dry ozone seasons). ENVIRON and the American Petroleum Institute are currently conducting US-wide modeling for the year 2006 using the CAMx and CMAQ regional transport models at 12 km resolution. A new 2006 GEOS-Chem global model run provides the boundary conditions for CAMx and CMAQ. Using 12 km resolution allows us to focus particular attention on vertical circulations over complex terrain and their influence on springtime PRB patterns throughout the west. Results of these modeling analyses are forthcoming and will be shared with the EPA.

I close with a recommended approach for a targeted evaluation of model performance and processes:

- Evaluate performance consistent with use of model results;
- Evaluate how well events are simulated to test process representations;
- Compare model predictions against observation-based conceptual models; and
- Assess uncertainties and consequences.

It is particularly important to perform an "event-oriented" modeling analysis for documented high ozone events in rural springtime west. These analyses will help to answer the following questions:

- How well does the model reproduce such events according to conceptual models derived from observational analyses?
- How well does modeling represent important processes (transport, stratospheric intrusion, chemistry, and removal)?
- How do model uncertainties impact total ozone, PRB, and source attribution estimates?

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