

From: Will Ollison  
Sent: Friday, May 30, 2014 11:29 AM  
To: Hanlon, Edward  
Subject: RE: CASAC public comment

Please post the following item to your website as public comment to inform CASAC-AMMS deliberations scheduled for June 12, 2014: May 20 API comments that were submitted to Holly Stallworth.

All the best...

## Consideration of Altitude Effects in CASAC's 5-12-14 Draft Letter to the Environmental Protection Agency (EPA) on the February, 2014 Health Risk and Exposure Assessment (HREA) for the O<sub>3</sub> National Ambient Air Quality Standard (NAAQS)

**Synopsis:** CASAC should recommend that EPA adjust for the altitude effect on the HREA-estimated inhaled O<sub>3</sub> exposure and estimated population response. Without the adjustment, the exposure-related health effects for people living at elevated locations are overestimated. This issue was raised in public comment at the CASAC-AMMS April 3, 2014 teleconference and deferred for further discussion at the May 28, 2014 CASAC teleconference by the AMMS chair.

**Introduction:** In contrast to the O<sub>3</sub> NAAQS, EPA has long recognized and accounted for altitude effects on inhaled PM<sub>2.5</sub> dose.<sup>1,2</sup> This is accomplished by permitting volumes (m<sup>3</sup>) used in computing particle microgram per cubic meter (ug/m<sup>3</sup>) concentrations for risk assessment and compliance purposes to be measured at *local* barometric pressures.<sup>3</sup> The altitude effect occurs because people respond to a gaseous pollutant *concentration* (i.e., molecules/cm<sup>3</sup>; ug/m<sup>3</sup>) inhaled at a given ventilation rather than to a parts per million (ppm) *mixing ratio* metric where inhaled mass at a given breathing rate changes with barometric pressure. However, the Agency has failed to account for this effect since changing the form of the gaseous O<sub>3</sub> NAAQS to a mixing ratio (ppm) from its original ug/m<sup>3</sup> form.

The O<sub>3</sub> altitude effect has been mentioned repeatedly over the past several years. Although raised from the floor at the 2012 EPA Monitoring Conference held in Denver, convening EPA staff maintained that it was not a monitoring issue, but did promise to pursue it with Agency health researchers. The attached poster presentation at the 2013 Society of Risk Analysis meeting attended by EPA staff and CASAC panelists in Baltimore provided an O<sub>3</sub> HREA approach to addressing this issue. The effect was again discussed during the April 3, 2014 CASAC-AMMS teleconference on a proposed new O<sub>3</sub> federal reference method where the AMMS chair advised that it be raised for CASAC consideration at their May 28, 2014 teleconference. Accordingly, the following information is submitted in support of an altitude effect discussion at the May 28, 2014 CASAC teleconference.

**O<sub>3</sub> HREA Analyses:** Since mixing ratios are pressure invariant, monitoring data at high altitude and response functions determined at low altitude will overestimate HREA resident inhaled dose and modeled responses in the higher elevation cities. Computed mixing ratio exposure levels are tabulated in Table 1 over a U.S. municipality elevation range, listing the O<sub>3</sub> ppm levels needed to maintain an equivalent inhaled dose comparable to a 75 ppm exposure at sea level. For example, Denver populations residing at the 5700 foot average elevation of the 14 HREA O<sub>3</sub> monitors (Figure 1) would need to be exposed to about 90 ppb O<sub>3</sub> to inhale the same O<sub>3</sub> mass at a given breathing rate as inhaled by sea level residents exposed to 75 ppb. Altitude-adjusting each monitor for its individual elevation would provide a more sophisticated analysis where inhaled exposure equivalents to the sea level NAAQS would range from 87 to 95 ppb (4800-9000 feet).

Coastal city monitors also vary in elevation. For example, monitors deployed in the Los Angeles South Coast Air Quality Management District (SCAQMD) range from about -15 to 4600 feet. Monitor-specific inhaled exposures, equivalent to the sea level NAAQS would range between 75 and 87 ppb.

Most exposure chamber studies under CASAC consideration were conducted at the low altitudes of the UC-Davis (50 feet) and UNC-Chapel Hill (500 feet) chambers and the 2012 MSS FEV<sub>1</sub> response model used in the HREA was fit to these data. A revised 2013 MSS FEV<sub>1</sub> proportional variance model<sup>4</sup> provided a better fit to these data and CASAC should ask that EPA apply this improved MSS model in the final O<sub>3</sub> HREA.

CASAC should also ask that the Agency weigh the impact of two available hypobaric O<sub>3</sub> chamber studies,<sup>5,6</sup> that simulate multi-hour airline cabin occupant exposures to 200-300 ppb O<sub>3</sub> with intermittent exercise at 6000 foot cabin pressures, if they have not been considered by EPA or CASAC in previous O<sub>3</sub> rulemakings. If they have been excluded, CASAC should ask EPA to retrieve the Individual subject response data from FAA archives and use it to validate prospective HREA altitude corrections in the time available for HREA revision and development of a revised O<sub>3</sub> NAAQS proposal.

**O<sub>3</sub> NAAQS Compliance Determinations:** Finally, CASAC should ask EPA to correct the O<sub>3</sub> NAAQS noncompliance penalty currently imposed by the altitude effect on elevated cities. EPA should (1) adjust the individual monitor mixing ratios used in the HREA at elevated monitor locations and (2) change the form of gaseous NAAQS back to a concentration (ug/m<sup>3</sup>) metric that can be implemented similarly to the PM NAAQS. Figures 3 and 4 illustrate how such monitor-specific O<sub>3</sub> mixing ratio adjustments might be made in HREA analyses and implemented in NAAQS compliance determinations.

Altitude meters	Altitude feet	Inhaled O3 Equivalent ppb
0	0	75
110	361	76
220	722	77
340	1115	78
460	1509	79
580	1903	80
700	2297	81
830	2723	82
960	3150	83
1090	3576	84
1220	4003	85
1350	4429	86
1490	4888	87
1630	5348	88
1770	5807	89
1920	6299	90
2070	6791	91
2220	7283	92
2370	7776	93
2530	8301	94
2690	8825	95
2850	9350	96
3020	9908	97

Table 1: Equivalent O<sub>3</sub> mixing ratio levels required to maintain a sea level 75 ppb NAAQS equivalent inhaled dose at a given breathing rate over the altitude range of U.S. municipalities.

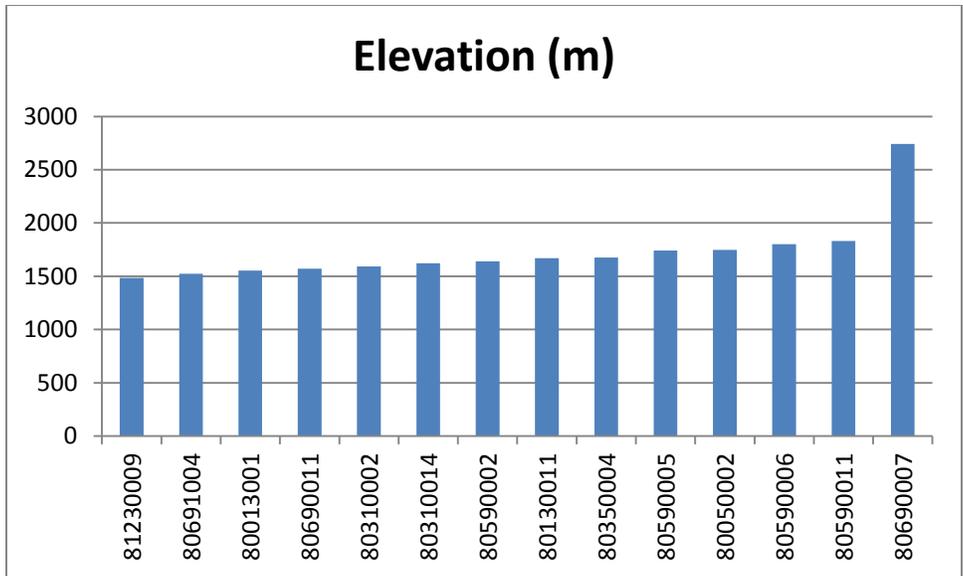


Figure 1: Nominal elevations of O<sub>3</sub> monitors used in the Denver, CO HREA analysis.

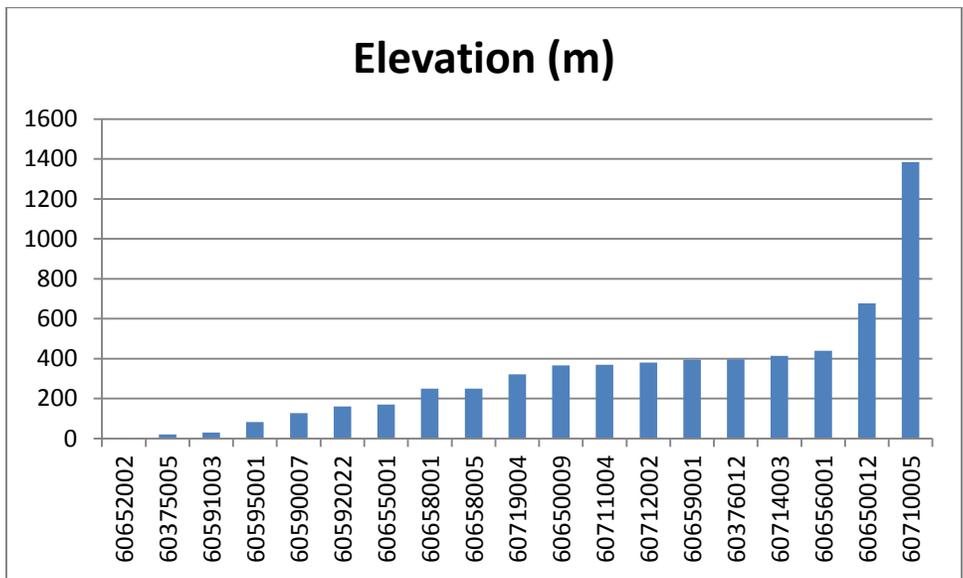


Figure 2: Nominal elevations of Los Angeles, CA SCAQMD O<sub>3</sub> monitors.

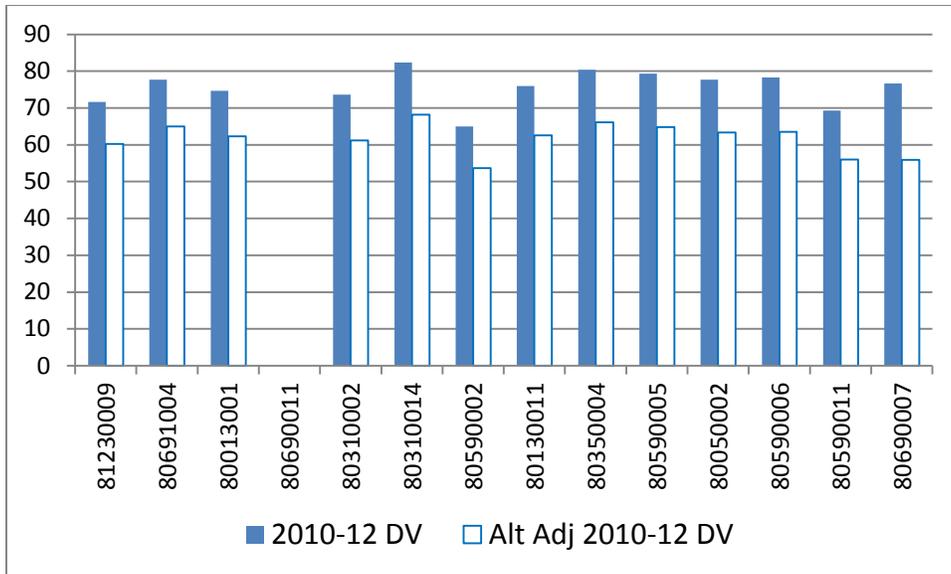


Figure 3: Unadjusted and altitude-adjusted HREA Denver 2010-2012 O<sub>3</sub> design values (ppb).

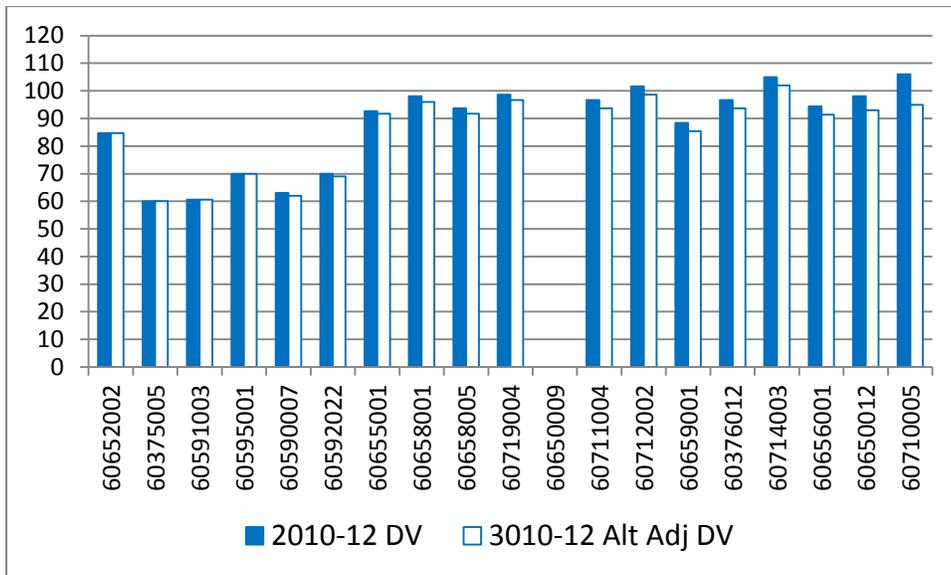


Figure 4: Unadjusted and altitude-adjusted Los Angeles SCAQMD 2010-2012 O<sub>3</sub> design values (ppb).

<sup>1</sup> Wedding, J.B., Weigand, M.A., Kim, Y.J., Swift, D.L., Lodge, J.P. (1987). A critical flow device for accurate PM<sub>10</sub> sampling and correct indication of PM<sub>10</sub> dosage to the thoracic region of the respiratory tract. JAPCA 37: 254-258.

<sup>2</sup>Lillquist, D.R., Lee, J.S., Wallace, D.O. (1996). Pressure correction is not required for particulate matter sampling. JAWMA 46: 172-173.

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<sup>3</sup> 40 CFR Part 50, Appendices J & L, 2.2. PM<sub>2.5</sub>/PM<sub>10</sub> measurements based on the measured flow rates at actual ambient temperature and pressure.

<sup>4</sup> McDonnell, W.F., Stewart, P., Smith, M.V. (2013). Ozone exposure-response model for lung function changes: an alternate variability structure. *Inhalation Toxicology* 25: 348–353.

<sup>5</sup> Lategola, M.T., Melton, C.E., Higgins, E.A. (1980). Effects of ozone on symptoms and cardiopulmonary function in a flight attendant surrogate population. *Aviation, Space, and Environmental Medicine* 51: 237-246.

<sup>6</sup> Lategola, M.T., Melton, C.E., Higgins, E.A. (1980). Pulmonary and symptom threshold effects of ozone in airline passenger and cockpit crew surrogates. *Aviation, Space, and environmental Medicine* 51: 873-884.

# O3 Risk Sensitivity to Better Exposure/Response Models



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## Implications

- New FEV<sub>1</sub> response models that better fit the clinical data should be used in EPA risk & benefit assessments.
- O<sub>3</sub> assessments adjusted for ME O<sub>3</sub> monitoring error, altitude, and urban NO titration substantially reduce assessed exposure & risk.
- O<sub>3</sub> network photometer upgrades are cheap & needed to lower monitor bias - [http://www.twobtech.com/model\\_GPT.htm](http://www.twobtech.com/model_GPT.htm)

## Abstract

We evaluate the sensitivity of EPA's current ozone (O<sub>3</sub>) exposure model (APEX) to (1) alternative pulmonary function response models, (2) attainment AQ rollback approach, (3) altitude effects, (4) newly measured O<sub>3</sub> penetration rates, and (5) microenvironmental (ME) factors, corrected for O<sub>3</sub> measurement error. Results are provided for Denver AQ scenarios representing 2006 conditions and the attainment of the 75 ppb O<sub>3</sub> standard. We test recently published 1-sec forced expiratory volume (FEV<sub>1</sub>) pulmonary function models<sup>1-3</sup> that incorporate O<sub>3</sub> response thresholds and response variability proportional to response level. A CAMx rollback model adjusts 2006 Denver AQ and accounts for NOx control-related increases in urban and background O<sub>3</sub> levels resulting from reduced NO-O<sub>3</sub> titration that is not addressed by EPA's quadratic rollback approach. Inhaled O<sub>3</sub> mass was adjusted to account for reduced O<sub>3</sub> inhalation<sup>4-6</sup> in acclimated Denver residents. Newly measured<sup>7-8</sup> indoor O<sub>3</sub> penetration rate effects on modeled responses are compared to current APEX model values. APEX ME factors are adjusted to recent values<sup>6</sup> from new interference-free O<sub>3</sub> photometers<sup>9-11</sup>. Impacts of these upgraded APEX components are compared to those of the current APEX model.

## APEX Simulations

Pilot APEX sensitivity testing runs simulated daily behaviors for 120 people (aged 12-88) over a 204 day O<sub>3</sub> season (24,480 person-days). The same pseudo-random number seed was used to minimize Monte Carlo stochastic error. APEX outputs include four median personal maximum 1h/8h daily exposure & dose metrics, a daily average dose, a block-hour daily dose (BH), and four response metrics, a median maximum daily event-level forced 1-second expiratory volume (FEV<sub>1</sub>) decrement (dFEV<sub>1</sub>), and the percent of responses (%dFEV<sub>1</sub>) above 5%, 10%, & 15% decrements. The tested exposure model parameters (Figure 1) include an altitude adjustment, alternative quadratic/CAMx AQ model rollback approaches, and humidity control (2B 205 monitor)/interference minimization (2B 211 monitor) corrections using re-measured O<sub>3</sub> ME & indoor penetration factors. The tested O<sub>3</sub> FEV<sub>1</sub> response models (Figure 2) include comparisons of the original<sup>3</sup>, threshold<sup>2</sup>, and a new threshold-proportional variance FEV<sub>1</sub> model<sup>1</sup> (T/PV) that best fits the clinical data.

## Results

- 10-25% drop in exposure/dose (E/D) metrics from altitude & quadratic rollback adjustments; small CAMx rollback changes likely stem from reduced urban NO titration following requisite NOx emission controls.
- 10-40% drop in E/D metrics from re-measured ME factor corrections; 8-h metrics are the most affected.
- 5-30% drop in E/D metrics from re-measured indoor mass-balance model penetration factor corrections; 8-h metrics are the most affected.
- 5% E/D metric drop for newly measured detached home penetration factors<sup>7</sup>; 10-30% E/D metric drop for apartments<sup>8</sup> (preliminary data), likely from relatively smaller external surface areas.
- Minimal change in median pulmonary function event-level decrement values for original & threshold FEV response models but a 35% drop for the T/PV model.
- 10-15% drop in %dFEV<sub>1</sub> > 10%; 80% rise in %dFEV<sub>1</sub> > 15% for the T/PV FEV model, likely due to its larger variances at higher exposures.
- 85% altitude & 65% quadratic rollback drops in %dFEV<sub>1</sub> > 10% by threshold FEV model; 70% altitude & 45% quadratic rollback drops for T/PV model.

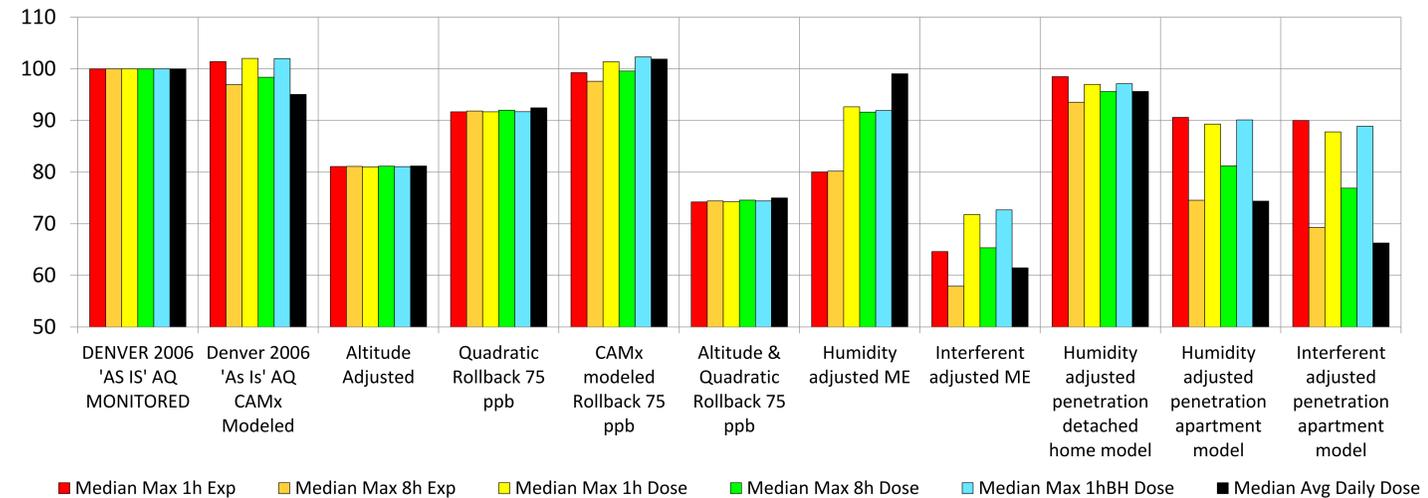


Figure 1. Exposure Impacts - Normalized effects on 2006 Denver population exposure & dose metrics of tested APEX model assumptions concerning altitude adjustment, quadratic/CAMx standard attainment rollbacks, and ME/indoor-penetration factor corrections for O<sub>3</sub> monitoring interferences.

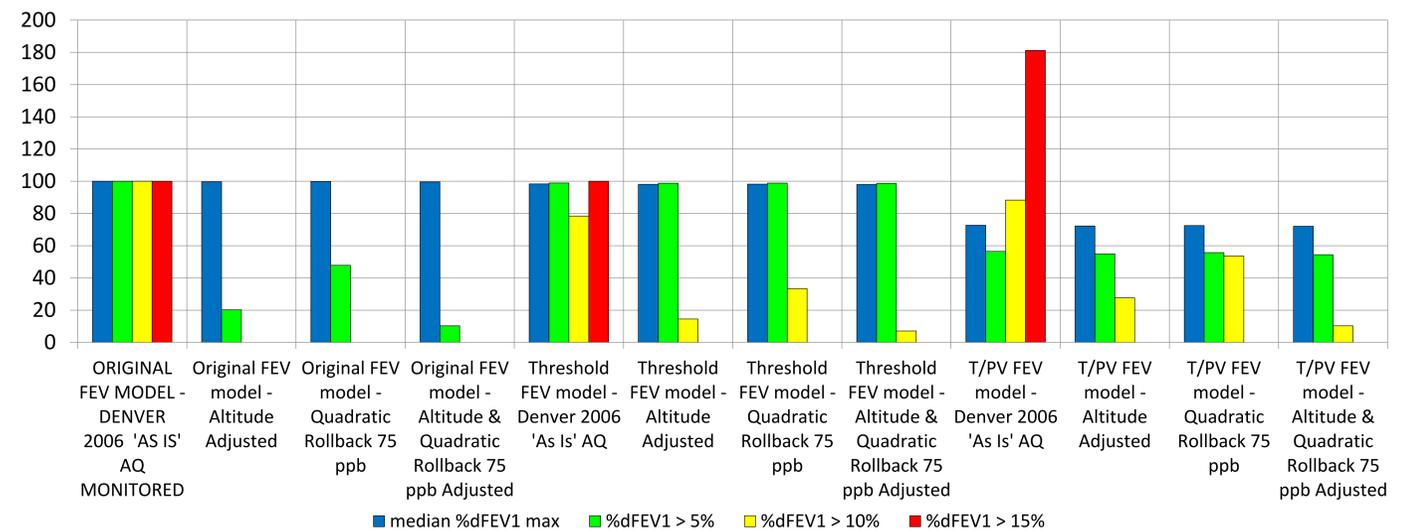


Figure 2. Health (dFEV1) Impacts - Normalized effects on 2006 Denver population pulmonary function decrements (dFEV<sub>1</sub>) of APEX FEV model choice, altitude, and quadratic rollback adjustments.

## Definitions

Max1hExp - Daily maximum event-averaged hourly exposure  
 Max8hExp - Daily maximum event-averaged 8-hour exposure  
 Max1hDose - Daily maximum event-averaged hourly dose  
 Max8hDose - Daily maximum event-averaged 8-hour dose  
 Max1hBH Dose - Daily maximum event-averaged hourly dose  
 AveDailyDose - Daily 24-hour average dose  
 %dFEV<sub>1</sub>Max - Daily maximum event-level %dFEV<sub>1</sub> calculation

## References

1. McDonnell et al. (2013) *Inhal Toxicol* 25: 348-353.
2. McDonnell et al. (2012) *Inhal Toxicol* 24: 619-633.
3. McDonnell et al. (2010) *Inhal Toxicol* 22: 160-168.
4. US EPA 452/R-08-004 (p. 69) 2008.
5. Wedding et al. (1987) *JAPCA* 37: 254-258.
6. Lillquist et al. (1996) *JAWMA* 46: 172-173.
7. Stephens et al. (2012) *ES&T* 46: 929-936
8. Stephens et al. (2013) *personal communication*
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10. Ollison et al. (2013) *JAWMA* 63: 855-863
11. Spicer et al. (2010) *JAWMA* 60: 1353-1364