Background ozone in the U.S.

WESTAR Conference on Western Ozone Transport

10/11/2012

Introduction

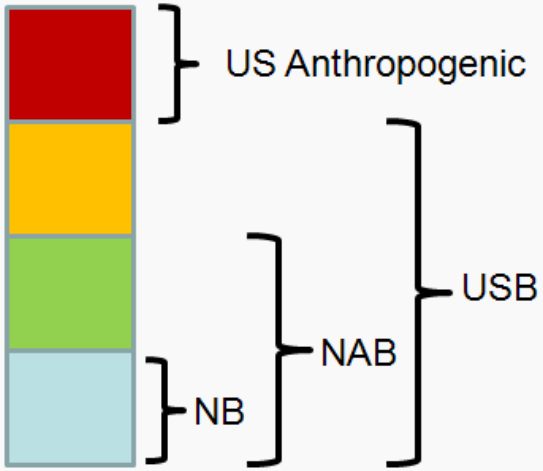
- The purpose of this presentation is to introduce key topics related to background ozone in the context of the NAAQS and the Western U.S.

- Outline:
  - Definitions , sources, and characteristics of background ozone
  - Use of background ozone in the establishment of the NAAQS
  - Estimates of background ozone in the U.S.
  - Consideration of background ozone in the implementation of the NAAQS

- Key question: What is the most efficient path to attainment of the new ozone standards in the western U.S.?
  - Developing a solid analytical understanding of natural background, international/regional transport, exceptional events, and other non-local contributions will be needed to design appropriate control programs.

Definitions of background

- Natural Background (NB)
  - Ozone formed from natural sources of ozone precursor emissions
- North American Background (NAB)
  - Ozone formed from natural sources in North America plus natural and anthropogenic sources in countries outside North America
- U.S. Background (USB)
  - Ozone formed from natural sources in the U.S. plus natural and anthropogenic sources in countries outside the U.S.
- Episodic background (EB)
  - Day-specific estimates of ozone produced by sources other than local sources.



Note: Figure not to scale. Schematic only provided for describing the ozone precursor emissions included in each background characterization.

Sources of background O_3

- Sources that mostly influence long-term (e.g. monthly / seasonal mean) background concentrations
  - Global methane (anthropogenic/natural)
  - International anthropogenic emissions (NOx, VOC, CO)
  - Biogenics (natural VOC and CO)
  - Lightning (natural NOx)
  - Soil (natural/anthropogenic NOx)
  - Stratospheric (routine low-level contribution)

- Sources that may produce locally high ground-level concentrations for short time periods (i.e., hours to days) and also influence long-term average concentrations
  - Stratospheric intrusions (natural O3)
  - Wildfires and prescribed fires (natural/anthropogenic NOx, VOC, CO)
  - Discrete transported plumes (natural/anthropogenic NOx, VOC, CO)

Characteristics of background O_3

- Background concentrations vary spatially and temporally
  - Different sources of background contribute differentially in space/time
- Mean NA background ozone concentrations are highest in the intermountain West (especially at higher altitude sites) in the spring.
- Mean NA background ozone concentrations are generally highest in spring, followed by summer; low in fall and winter
- The highest background concentrations are driven primarily by episodic events:
  - Wildfires: greatest frequency and impact in the summer over WUS
  - Stratospheric intrusions: most frequent in spring in WUS
  - International transport plumes: greatest effect in spring over WUS

Characteristics of background O_3

- Wildfires:
  - Emery et al. (2012) found that modeled day-specific fires in the West can increase 8-hour ozone concentrations by 10-50 ppb.
  - Jaffe et al. (2008) determined that WUS seasonal mean ozone concentrations increased by ~ 9 ppb in years with high wildfire activity.

- Stratospheric intrusions:
  - Lin et al. (2012) estimated that 8-hour ozone contributions from strong stratospheric intrusion events could range up to ~ 55 ppb in the WUS.
  - Langford et al. (2010) noted that strong intrusion events are relatively straightforward to identify, but harder to quantify.

- International transport:
  - Zhang et al. (2011) estimated that the worldwide anthropogenic methane plus intercontinental aNOX/aVOC contributions to 8-hour ozone is ~ 9 ppb at low-elevation sites and ~ 13 ppb at sites in the West. Also estimated mean contributions of 1-3 ppb from Canada and Mexico, with larger / more variable impacts in border regions.

Methods for estimating background O_3

- Few true measurements of background ozone
  - Most, if not all, rural / remote monitoring sites in the US are affected, at least to some extent, by ozone from US anthropogenic emissions

- Current scientific understanding of NA and U.S. background ozone is largely based on global / hemispheric photochemical models. These models have limitations:
  - Uncertainties in global emissions estimates
  - Uncertainties in chemistry important on global spatial and time scales
  - Uncertainty in mixing between the boundary layer and free troposphere
  - Limitations in capturing processes associated with episodic events

- Much of the modeling to estimate background has relied upon a "zero-out" approach which may not properly capture the contribution of background sources to ozone under current ambient conditions.
  - Zero out runs are designed to answer a specific question. What would ozone be in the absence of these emissions? (Not "in-situ" contribution.)

Use of background O_3 in NAAQS review (ISA)

- Integrated Science Assessment (ISA):
  - Provides a concise review, synthesis, and evaluation of the most policy-relevant science to establish a scientific foundation for the NAAQS review.
  - 3rd external review draft: June 2012

- ISA reviews several modeling studies to summarize the most recent estimates of ozone background concentrations.
  - Zhang et al. (2011) uses GEOS-Chem at 108 km with a 50 km grid over North America
  - Emery et al. (2012) uses GEOS-Chem at ~ 200 km w/CAMx at 12 km over North America
  - Lin et al. (2012) study which uses the AM3 model at 50 km resolution.

- ISA concluded that global models are capable of simulating measured seasonal / monthly mean 8-hour daily max ozone values to within a few ppb over most of the U.S.

Use of background O_3 in NAAQS review (REA)

- Risk and exposure assessment (REA):
  - Preliminary quantitative assessment of ozone-related risks to public health
  - 1st external review draft: July 2012

- REA estimated risk for the full range of ozone levels represented in the epidemiological studies (i.e., presented risk for current ozone concentrations down to both zero ppb and lowest measured level in each study).
  - This was in line with CASAC advice to look at total ozone risk and not just risk above background (as was done in last review).

- REA used modeled U.S. background concentrations as lowest values for "rollback" of spatial fields to simulate attainment of the current and alternative standard levels.
  - Second draft REA plans to use higher-order decoupled direct method (DDM) modeling information. As a result, specifying values for U.S. background concentrations is not necessary, as it is incorporated in the modeling directly.

Use of background O_3 in NAAQS review (PA)

- Policy Assessment (PA):
  - Intended to help bridge the gap between the relevant scientific information and assessments and the judgments required of the EPA Administrator that will determine if it is appropriate to revise the NAAQS for O_3
  - 1st external review draft: August 2012
  - Uses the ISA as a starting point for discussions involving background ozone

- PA refers to a technical memorandum that includes analyses of the regional and seasonal variability of background ozone, and the distribution of background contribution to simulated ozone from two existing model simulations cited in the ISA.

- PA concludes that GEOS-Chem and CAMx model results suggest that U.S. anthropogenic sources are largely responsible for 4th high 8-hour daily max ozone concentrations over most of the U.S.

Use of background O_3 in NAAQS review (RIA)

- Regulatory Impact Analysis (RIA):
  - Document that estimates the benefits and costs of meeting alternative air quality standards.
  - Draft RIA will be released with the proposed rule (targeted for Dec. 2013)
  - Final RIA will accompany the final rule (targeted for Sept. 2014)

- Nearly all sources of background ozone are explicitly included in the air quality modeling of illustrative control strategies designed to provide attainment of NAAQS
  - Ozone from anthropogenic and biogenic VOC sources outside the U.S.
  - Biogenic and soil (NO) emissions in the U.S.
  - Wild and prescribed fires (treated as time-averaged emissions)
  - Ozone transported into the domain from upper portion of the boundary
  - Ozone formed from reactions of methane

- For the purposes of projecting air quality to the future and for informing benefits calculations, episodic “events” are not included.

Estimates of background O_3 in the U.S.

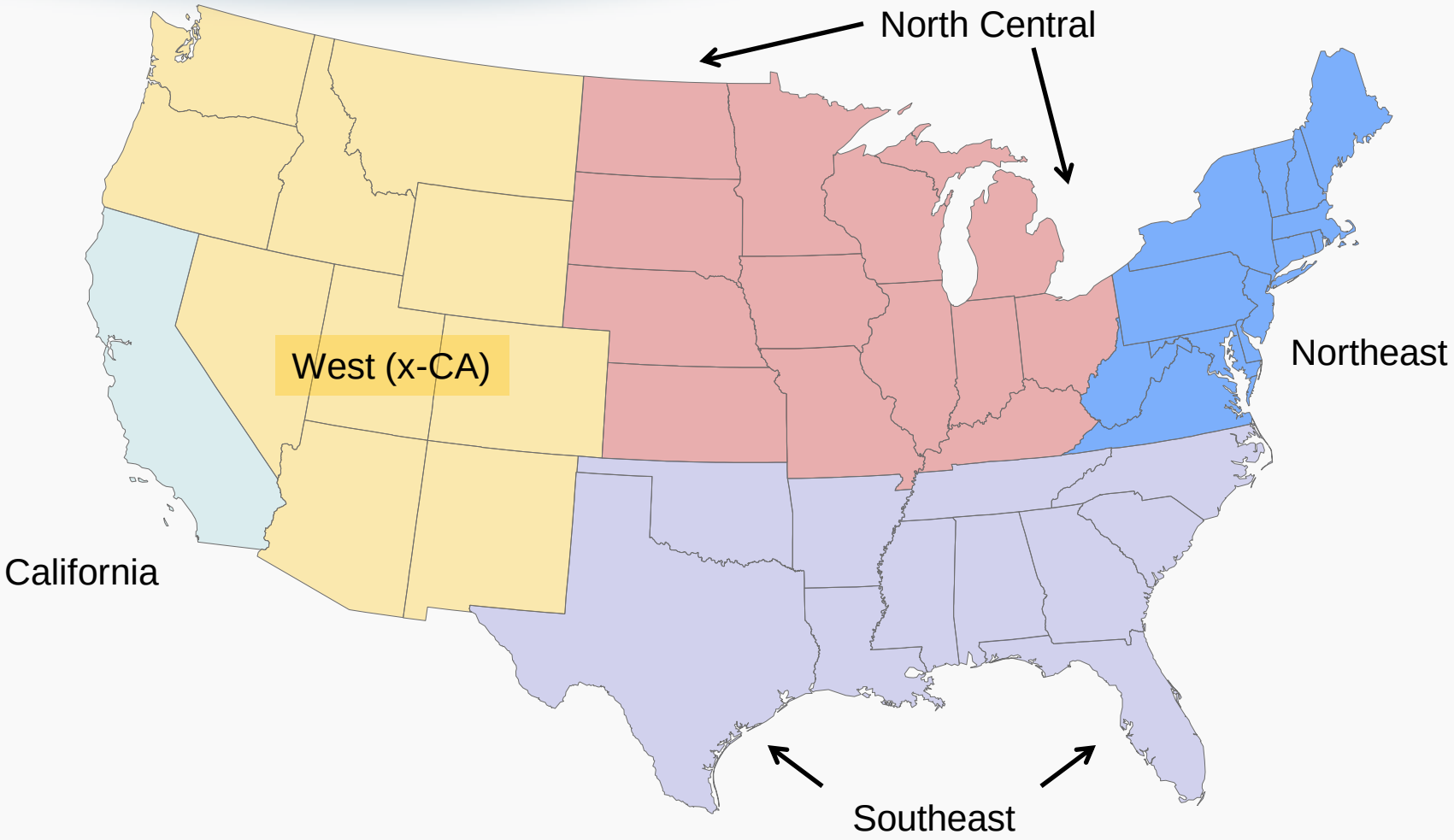
- To inform the PA document, EPA conducted additional analysis of two existing global model simulations, from two existing model simulations cited in the ISA.
  - GEOS-Chem (Zhang et al.) and CAMx (Emery et al.) zero-out runs of North American background (NAB)

- The purpose of the EPA analysis was to quantify the distribution of NAB as a function of ozone concentrations by region for spring and summer
  - MDA8 = maximum daily average 8-hour ozone

- Does background increase or decrease as total ozone increases – particularly at concentrations near and above the current NAAQS?

- Results of this analysis are summarized more completely in Henderson et al. (2012).

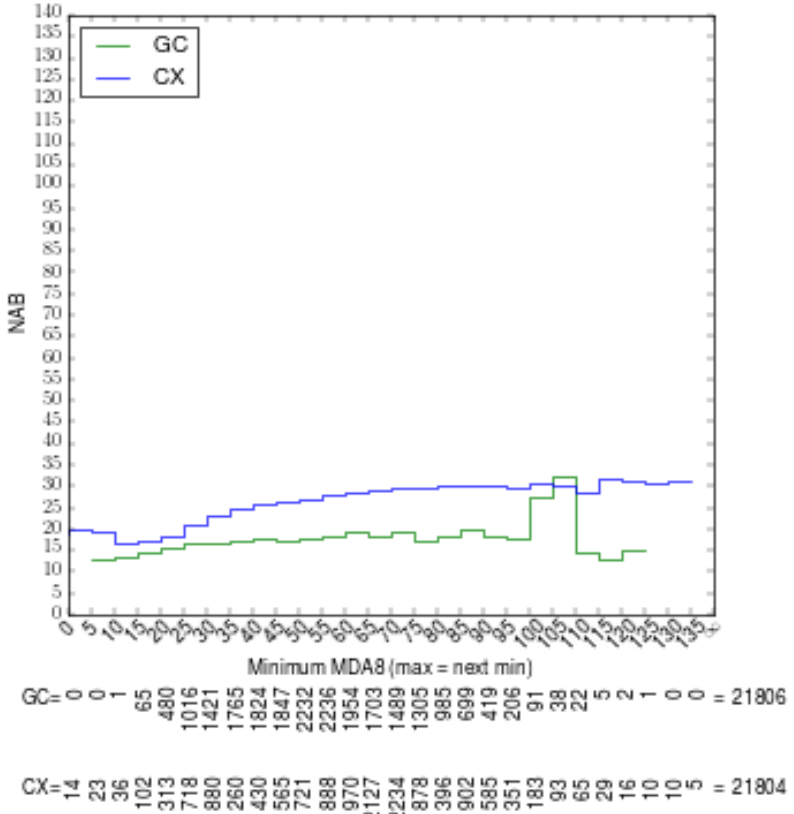
Estimates of background O_3 (analysis regions)



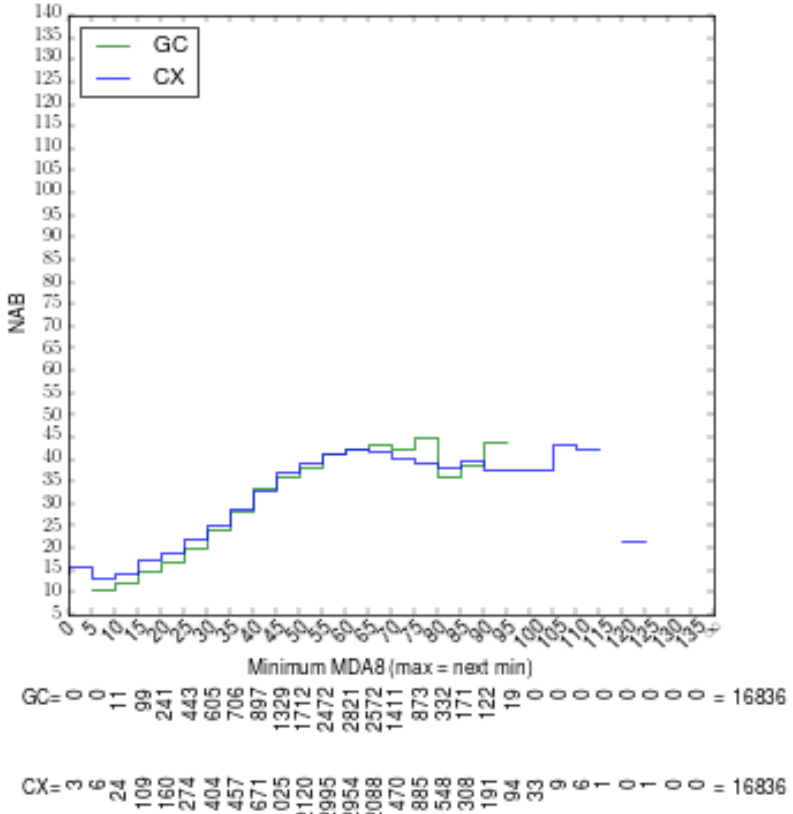
Estimates of background O_3 in the U.S.

Distributions of median summer NAB concentrations (y-axis) binned by surface MDA8 ozone intervals (x-axis)

Northeast



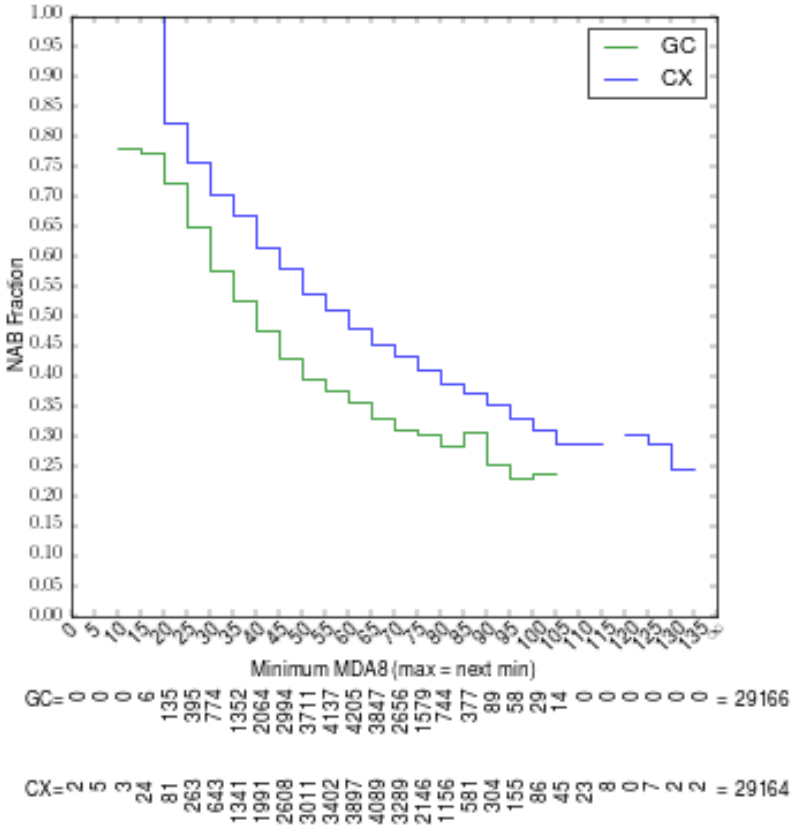
West (ex-CA)



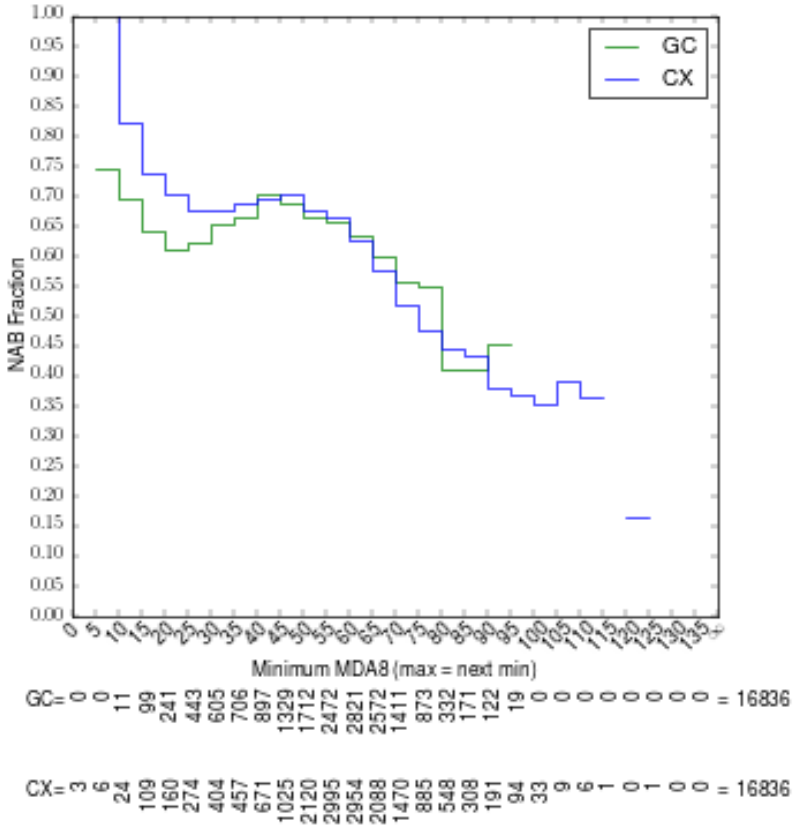
Estimates of background O_3 in the U.S.

Distributions of median summer NAB fractions (y-axis) binned by surface MDA8 ozone intervals (x-axis)

Northeast



West (ex-CA)



Estimates of background O_3 in the U.S.

Values are presented across the range of GEOS-Chem and CAMx results at all monitoring site locations with simulated MDA8 ozone concentrations above 55 ppb.

Region		Spring (GEOS-Chem/CAMx)			Summer (GEOS-Chem/CAMx)		
		Median (ppb)	75th percentile (ppb)	95th percentile (ppb)	Median (ppb)	75th percentile (ppb)	95th percentile (ppb)
California		34/35	40/40	48/48	30/36	36/40	45/47
North Central		28/33	33/37	40/42	24/33	28/36	39/41
Northeast		23/31	26/34	33/38	18/29	23/32	34/36
Southeast		30/34	34/38	41/45	29/31	36/34	44/41
West (x-CA)	*All sites*	44/43	47/48	52/55	41/41	46/46	54/52
	Low-elevation sites	43/41	46/44	51/51	40/39	45/44	52/52
	High-elevation sites	45/48	48/52	53/57	42/43	47/48	54/53

Median values provide a more robust indicator than higher values of the distribution for the purpose of examining and comparing the regional and seasonal variability in NAB. The NAB predictions toward the higher end of the distribution (e.g., 75th and 95th percentiles) are more reflective of infrequent or atypical events. Due to the overall uncertainties and assumptions in the inputs to the two modeling systems, the higher percentage NAB predictions are likely to have a greater degree of uncertainty than the median values. (Henderson et al., 2012)

Estimates of background O_3 in the U.S. (summary)

- Overall, NAB increases with increasing MDA8 up to ~ 55-60 ppb. At higher MDA8 values, median NAB contributions tend to be relatively flat.
  - Regional: median NAB is notably lower (~ 5-10 ppb) outside the "non-California" West
  - Seasonal: median NAB tends to be higher in the spring vs. the summer, mainly for MDA8 values below around 60 ppb
  - Elevation: median NAB contributions are higher at the high-elevation sites

- Results from the GEOS-Chem and CAMx applications indicate that anthropogenic sources are the dominant contributor to 8-hour daily maximum O3 concentrations on the days with the highest total O3 concentrations.
  - Where background O3 is highest, such as the western U.S. and at high-elevation sites, the sources contributing to high background concentrations include wildfires, stratospheric intrusions, and intercontinental transport.

Use of background O_3 in NAAQS Implementation

- Exceptional Events:
  - Existing rule establishes procedures and criteria by which air quality data affected by exceptional events can be excluded from regulatory decisions.
  - Among the criteria for defining an exceptional event is the determination that a violation would not have occurred “but for” the event.
  - Routine background contributions are not exceptional events.

- 179B/International Transport:
  - Allows special treatment if projected air quality or air quality on the attainment deadline date would meet the NAAQS “but for” emissions from another country

- Attainment demonstration guidance:
  - Consideration of boundary condition impacts on relative response factors?
  - Consideration of separate future-year boundary conditions?
  - Consideration of exceptional events in establishing baseline DV?
  - Will be an opportunity for State/Local review.

Summary

- As ozone standards have tightened over time, background ozone is becoming more important and will need to be carefully considered in our efforts to attain NAAQS.

- Recent modeling efforts have estimated that mean NAB contributions can range from 38-41 ppb in the intermountain Western U.S.
  - Background can be larger during episodic events associated with stratospheric intrusions, wildfires, or plumes of international emissions.

- Recent modeling suggests U.S. anthropogenic sources are the largest contributor to most days with high O_3 in most locations.

- EPA policy and eventual State efforts will need to carefully consider ozone background in developing efficient and effective attainment strategies.

References

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- EPA webpage on ozone standards:
  - http://www.epa.gov/ttn/naaqs/standards/ozone/s_o3_2008_td.html
- EPA webpage on ozone regulatory actions:
  - http://www.epa.gov/airquality/ozonepollution/actions.html
- EPA webpage on exceptional events:
  - http://www.epa.gov/ttn/analysis/exevents.htm