Variability in surface ozone background over the United States:
Implications for air quality policy

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EPA O₃ air quality standard: 4th highest daily maximum 8-hour average O₃ concentration must be ≤ 84 ppbv (3-year avg)
Need to quantify U.S. surface background O$_3$ for current review of O$_3$ standard

"REGULATORY BACKGROUND" DEFINITION: O$_3$ concentrations that would exist in the absence of anthrop. emissions from N. Amer. [EPA, 2003]

i.e., background includes:

Natural O$_3$ from the stratosphere or produced from natural precursor emissions anywhere;

Anthropogenic O$_3$ produced from precursor emissions outside N. America

Range of background O$_3$ estimates in U.S. surface air

- Range considered by EPA during last revision of O$_3$ standard
- 84 ppbv: threshold for current U.S. O$_3$ standard
- 20 to 40 ppbv: frequent obs. attributed to natural background [Lefohn et al. 2001]
- 60 to 80 ppbv: range used by EPA to assess health risk from O$_3$
- 84 ppbv: threshold for current U.S. O$_3$ standard

What are appropriate background concentration(s) for assessing risk from O$_3$?
Is the standard set too close to background levels?
TOOL: GEOS-CHEM 3D Tropospheric Chemistry Model [Bey et al., 2001]
(uses assim. met.; 48 σ; 4ºx5º or 2ºx2.5º horiz. resn., 24 tracers)

Sensitivity Simulations for source attribution
Mar-Oct 2001

• **Standard simulation** ..... 2x2.5 GEOS-CHEM, 48 sigma levels 2001

• **Background** ............... no anthrop. NO\textsubscript{x}, CO, NMVOC emissions from N. America

• **Natural O\textsubscript{3} level** ............... no anthrop. NO\textsubscript{x}, CO, NMVOC emissions globally; CH\textsubscript{4} = 700 ppbv

• **Stratospheric** ............... tagged O\textsubscript{3} tracer simulation

Regional Pollution = Standard – Background

Hemispheric Pollution = Background – Natural O\textsubscript{3} level

Use 2001 CASTNet data in conjunction with GEOS-CHEM to
→ investigate how background O\textsubscript{3} varies with season and region
→ diagnose origin of springtime high-O\textsubscript{3} events at remote U.S. sites
Monthly mean afternoon (1-5 p.m.) surface O$_3$

- CASTNet sites
- Model at CASTNet
- Model entire region
- Background
+ Natural O$_3$ level
- Stratospheric

Regional pollution from N. Am. emis. (8-30 ppbv)

Hemispheric pollution enhancement (5-12 ppbv)

Mar-Oct 2001 U.S. daily mean afternoon surface O$_3$

Mean background: 20-35 ppbv
Mean natural level: 13-27 ppbv
Mean stratosphere: 2-7 ppbv

Background < 50 ppbv
Natural level < 40 ppbv
Stratosphere < 20 ppbv
High-O$_3$ "Haywood County" event in North Carolina

Model explains this event by regional pollution rather than a large stratospheric influence

CASTNet sites

- Model
- Background
- Natural O$_3$ level
- Stratospheric
- Continental lower troposphere

\[ \Delta = \text{Regional pollution} \]

\[ \Delta = \text{Hemispheric pollution} \]

Isentropic back-trajectory with the GEOS met fields capture previously reported strong subsidence (http://www.asl-associates.com/ncreport.htm)

Originates in free-troposphere

Model explains this event by regional pollution rather than a large stratospheric influence
Case study: Time series at Yellowstone NP, WY; frequent high-$O_3$ events previously attributed to natural, stratospheric source [Lefohn et al., 2001]

High-altitude site should receive free-tropospheric $O_3$ more frequently; Not necessarily representative of background contribution at surface sites
Background O\textsubscript{3} higher at elevated western sites

Background decreases with highest observed O\textsubscript{3} at SE sites

CASTNet sites

- * Model
- ◆ Background
- + Natural O\textsubscript{3} level
- ◆ Stratospheric

West (>1.5 km)

Southeast (<1.5 km)

Days in March 2001
Background $O_3$ for risk assessment = $f$ (season, altitude, total $O_3$ concentration)

Enhancement from N. Amer & hemis. pollution for high $O_3$ concentrations

Lower background; larger pollution influence in summer (& fall)

Lower background at surface sites; Maximum contribution at the center of the $O_3$ distribution

Using average background for pollution episodes underestimates risk to human health!
CONCLUSIONS ...and their implications for policy

1. Background O$_3$ varies with season, site elevation, and total surface O$_3$ concentrations
   -- highest at high-altitude western U.S. sites in spring
   -- lower at surface sites and in summer
   -- depleted during polluted conditions

→ health risk from O$_3$ underestimated in present EPA risk assessments

2. High-O$_3$ events at remote U.S. sites in spring previously attributed to a natural stratospheric source can be explained largely by regional pollution

→ these events should not be used to challenge legitimacy of O$_3$ NAAQS; measurements at these sites are not representative of background

3. Hemispheric pollution enhances U.S. background

→ international agreements to reduce hemispheric background would improve U.S. air quality & facilitate compliance w/ more stringent standards
Ozone (ppbv)

Health and Environmental Risk

Excess risk associated with observed O$_3$ concentration above background

Quantitative definition of background is critical for use in risk assessment

Risk from observed O$_3$

Risk from background O$_3$

Total risk from observed O$_3$

Ozone (ppbv)

40 observed