Regional to global source contributions to Eastern U.S. high-O$_3$ episodes

Arlene M. Fiore

Acknowledgments.
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H. Rieder (U Graz), G. Correa, M. Previdi (LDEO),
V. Naik, L. Horowitz (GFDL), P. Dolwick (EPA OAQPS), T. Keating
(EPA/OAR/OPAR), J. Pinto (EPA NCEA), G. Tonnesen (EPA Region 8)
Designing effective SIPs requires knowledge of source contributions to \( \text{O}_3 \) and \( \text{PM}_{2.5} \) pollution episodes

Observed pollution levels are the summation of in-state, out-of-state, international and natural sources

AQAST EUS Episodes TT is helping quantify these components
- Framework for continued communication with stakeholders (AQMIs)
- Short consulting-style reports on individual episodes (on team website)

**AQAST TT Members**
- U WI, Columbia/LDEO, CU-Boulder, Harvard,
- NASA GSFC, NCAR
- NRL, Rice U, U IA, U MD

**Air Agencies**
- CT DEEP, MDE, ME DEP, MO DNR, NH DES,
- NYSDEC, TX/TCEQ, WI DNR/LADCO, VT DEC,
- OTC, MARAMA, NESCAUM, US EPA…
  …your agency??

Our request for priority high-\( \text{O}_3 \) and high-\( \text{PM}_{2.5} \) episodes from AQMs identified late June-early July 2012 heat wave as problematic for multiple EUS agencies
Estimated anthropogenic contributions
MDA8 O₃ From Source / MDA8 O₃ in Base
GEOS-Chem 2°x2.5° v9.02 MERRA winds

OBSERVED (AQS)
MDA8 O₃ (ppb)

U.S. ANTHRO.  
1-STATE ANTHRO.  
CANADA+MEXICO

NOTE COLOR SCALE DIFFERENCES!

O. Clifton, L. Murray, M. Seto
OBSERVED (AQS)
MDA8 O₃ (ppb)

ESTIMATED BACKGROUND CONTRIBUTIONS
MDA8 O₃ From Source / MDA8 O₃ in Base
GEOS-Chem 2°x2.5° v. 9.02 MERRA winds

U.S. Background  Soil NOₓ  Biogenic NMVOC

NOTE COLOR SCALE DIFFERENCES!

O. Clifton, L. Murray, M. Seto

Seto, AGU poster, Thurs morning
Might daily NO$_2$ columns be useful for understanding EUS ozone episodes?

Excerpt from AQAST7 talk: June 12, 2007 episode

→ Rough mapping with spatial pattern of O$_3$ enhancement, but not perfect
→ Regional NO$_2$ transport?
→ Proxy for local O$_3$ production?
Suggestion of local relationship between ozone and tropospheric NO$_2$ column:
Suggestion of local relationship between ozone and tropospheric NO$_2$ column:
Potential to quantify local ozone production from tropospheric NO$_2$ columns over EUS in summer

South, Central, and Eastern U.S.A. (~28-44°N, 75-102°W)
May 21-July 19 2012 1pm CST

$y = 2.3 \times 10^{-15} x - 0.5 \text{ppb}$
$R^2 = 0.784$

WRF-Chem model
12km averaged to 48km
(for NO$_2$ columns < $5 \times 10^5$ mol. cm$^{-2}$)

→ NO$_x$-sensitive, linear O$_3$ production regime
  (consistent with He et al., 2013)

→ Map O$_3$ production rate from NO$_2$ anomalies?

→ Include NO$_2$-based O$_3$ source term in re-analysis model to quantify cross-state O$_3$ transport?
Increase in warmest days projected throughout 21st Century: Implications for EUS high-ozone events?

Change in warm days above 90th percentile temperature (2071-2100) – (2006-2035)

GFDL CM3 chemistry-climate model, RCP8.5 (extreme) scenario

X = outside range of variability (95%) of differences between 30-year intervals in preind. control simulation Tx90p, see e.g., Sillman et al., JGR 2013ab; reference period 1961-1990

Role of declining aerosols: air pollutants → regional weather events → extreme pollution?

N. Mascioli, AGU
Wed 2:55 West 3001
Projected changes in high-ozone events: 1-year return levels (probability of MDA8 O₃ occurrence on 1/92 summer days, as estimated by CM3 chemistry-climate model (bias-corrected))

2006-2015 1-year return levels

Climate change only (RCP4.5)

1-year return levels remain above 75 ppb for ~50% of the region throughout 21st C

Rieder et al., in review at JGR
Projected changes in high-ozone events: 1-year return levels
(probability of MDA8 O₃ occurrence on 1/92 summer days, as estimated
by CM3 chemistry-climate model (bias-corrected)

2006-2015 1-year return levels

Climate + Air pollutants change (RCP4.5)

1-year return levels over entire region fall during 21st C:
• below 70 ppb by 2030s
• below 60 ppb by 2060s

Rieder et al., in review at JGR
Simple relationship between changes in regional NO\textsubscript{x} emissions and in regional average summer 1-year return levels

GFDL CM3 Chemistry-Climate Model, RCP4.5

R=0.99

Rieder et al., in review at JGR
Site-level Projections: Apply changes from chem-climate model at each percentile of the regional O$_3$ distribution to each site’s distribution

Average number of summer (JJA) days with MDA8 O$_3$ > 75 ppb at CASTNET sites

2001-2005

2046-2055, RCP8.5 from GFDL CM3

By mid-century under RCP8.5 scenario:
→ regional NO$_x$ emissions decrease by ~70%
→ 3 or fewer JJA days with MDA8 O$_3$>75 ppb

... but global methane doubles

H. Rieder, AGU
Thurs morning poster
Summertime decreases at least partially offset by winter-spring increases (from methane [Clifton et al., GRL, 2014])

Change in 90th percentile MDA8 O₃ over Eastern U.S.A. in RCP8.5

H. Rieder, AGU
Thurs morning poster
Summary: Regional to global source contributions to Eastern U.S. high-O_3 episodes  (See Tracey or me to join Tiger Team)

- 2012 heat wave: attribution to U.S. anthropogenic vs. international vs. biogenic influence
  - sensitivity simulations available 2004-2012

Space-based info on local ozone production?
- Model results suggest this may be possible

Continued NO_x emission controls offset ‘climate penalty’ in summer; could incur a winter-spring penalty from rising background (methane)
  - Simple relationship between emissions (NO_x) and extreme EUS O_3 events (1-year return levels)

AQAST-related talks & posters at AGU Fall Meeting:
Mon 4:00: Meiyun Lin (WUS background ozone): Moscone West 3001
Wed 2:55: Nora Mascioli (GHG vs. aerosols on extreme T over USA): Moscone West 3001
Wed afternoon: Luke Valin Poster (mapping OH+VOC from column NO_2 and CH_2O): MSouth
Thurs morning: Melissa Seto & Harald Rieder Posters (O_3 episodes, current & future): MWest
Offsetting impacts on extreme temperature events from greenhouse gases vs. aerosol over historical period

-4.0 -2.0 0.0 2.0 4.0
Change in Hottest Days (°C)

Greenhouse Gas Only
Aerosol Only

Consistent (?) patterns (spatial correlation $r = 0.56$)
Pollutants $\rightarrow$ regional weather events $\rightarrow$ extreme pollution?

N. Mascioli
### Compiling spreadsheet with $O_3$ and $PM_{2.5}$ episodes requested from air agencies

**2012**

<table>
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<th>Notes</th>
<th>$O_3$</th>
<th>$PM_{2.5}$</th>
<th>other</th>
<th>identified by</th>
<th>MARA</th>
<th>MA</th>
<th>MDE</th>
<th>MO</th>
<th>NY</th>
<th>TCEQ</th>
<th>WDNR</th>
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MD, MO, TCEQ, WDNR all identified high-$O_3$ events during the 2012 heat wave beginning late June into mid-July

→ Animation of EUS MDA8 $O_3$ (J. Guo, Columbia)
→ Also $PM_{2.5}$ available