Variability & uncertainty in background ozone: Relevance to present & future O_3 NAAQS

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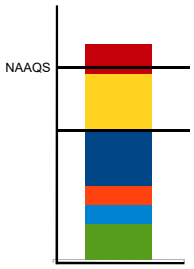
Air Quality-Background Ozone II
Washington, D.C.
May 11, 2016

Air Quality Management Requires Source Apportionment



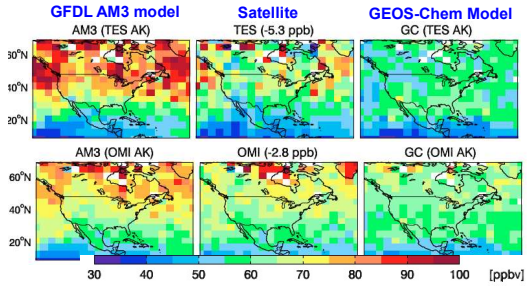
Clean Air Act Provisions

- Your State: •110 State Implementation Plans
- Upwind States: •110(a)(2)(d) Interstate Transport; •182(h) Rural Transport Areas
- International: •179(B) International Transport
- Stratospheric: •319 Exceptional Events

We need to be able to describe the sources that contribute to each exceedance day.

**slightly adapted from T. Keating, U.S. EPA*

Constraints on springtime background O_3 from mid-tropospheric satellite (OMI, TES) products (2006)

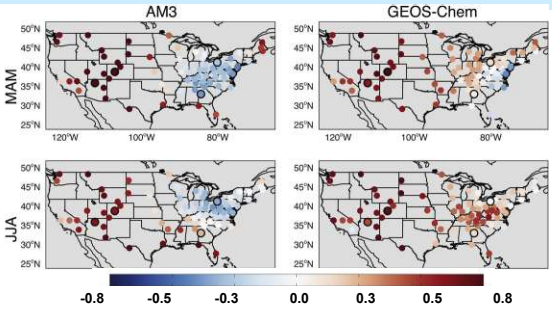


Bias vs sondes subtracted from retrievals as in Zhang et al., ACP, 2010

→ **Two different models bracket ozone "background" observed from space**

Fiore et al., Atm. Env., 2014; NASA AQAST Tiger Team

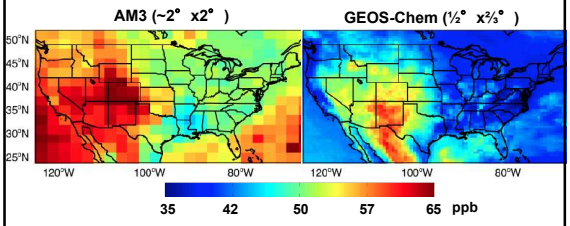
Background drives much of day-to-day variability in total surface ozone over high-altitude WUS in both models



Correlation coefficient (r) of total surface MDA8 ozone and North American background; models sampled at CASTNet sites for June 1 - Aug 31 2006

Fiore et al., Atm. Env., 2014

Spatial variability in estimates of 4th highest MDA8 North American background ozone in 2 models (Mar 1 to Aug 31, 2006)



Determined from simulations with N. American anthrop. emissions set to zero

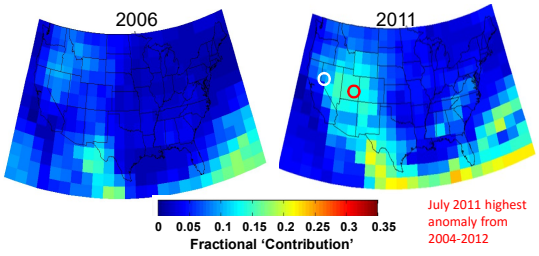
→ **Background higher at altitude in WUS**

→ **Differences/uncertainty associated with influences from lightning NO_x, fires, stratosphere, isoprene chemistry** (more than horizontal resolution)

Fiore et al., Atm. Env., 2014

Year-to-year variability in background from N. American lightning NO_x

Fractional 'contribution' from lightning NO_x on the top 10% of simulated total MDA8 surface ozone on summer days

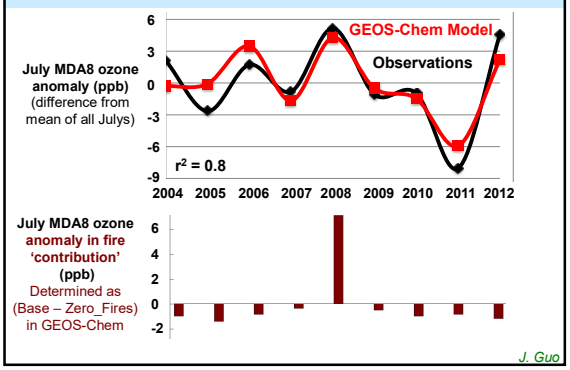


July 2011 highest anomaly from 2004-2012

Determined by GEOS-Chem simulations: (Base - Zero_LNO_x)/Base

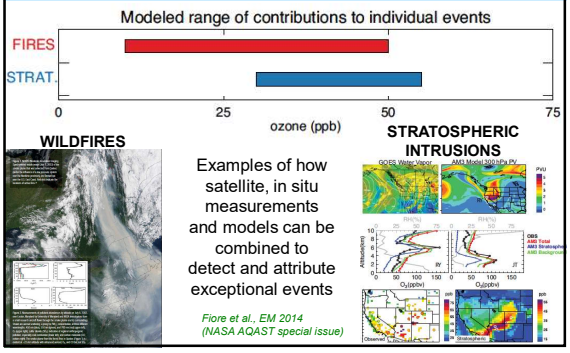
J. Guo; Murray, Curr Pollution Rep, 2016

GEOS-Chem model attributes July 2008 ozone anomaly over Reno, NV to fires



J. Guo

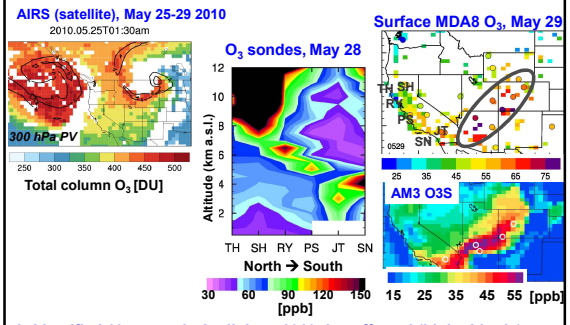
An Air Quality Management Challenge: NATURAL EVENTS How to detect and attribute accurately?



Examples of how satellite, in situ measurements and models can be combined to detect and attribute exceptional events

Fiore et al., EM 2014 (NASA AQAST special issue)

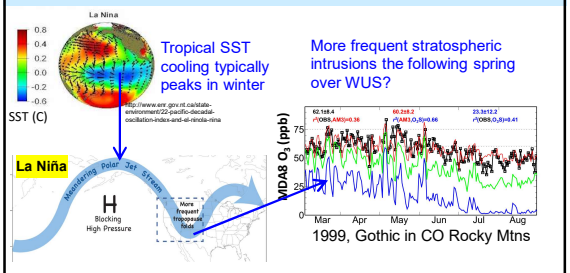
Stratosphere-to-troposphere (STT) O_3 transport influence on WUS high-O_3 events



→ **Identified 13 events in April-June 2010 that affected (high-altitude) surface sites over the WUS**

M. Lin et al., JGR, 2012b

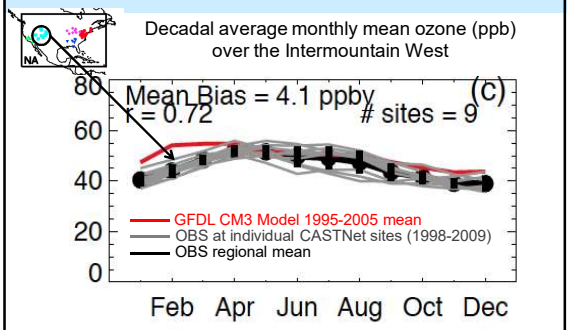
Climate variability can modulate WUS background ozone: Frequency of deep stratospheric intrusions over WUS tied to known mode of climate variability (La Niña)



→ **May offer a few months lead time to plan for an active stratospheric intrusion season (protect public health, identify exceptional events)**

M. Lin et al., Nature Communications, 2015

How might ozone (and background) change in the future?

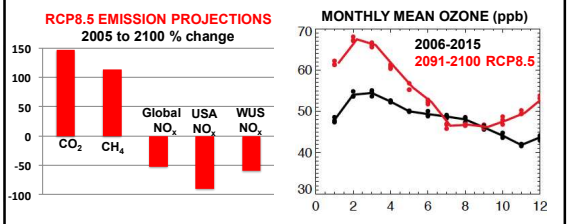


→ **GFDL CM3 chemistry-climate model roughly captures decadal mean seasonal cycle over the Intermountain West**

O. Clifton

Chemistry-climate model projects 21st Century WUS ozone increase in cooler months despite U.S. NO_x decreases

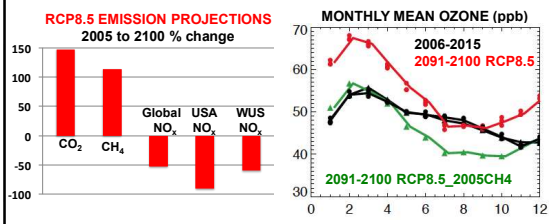
Transient **RCP8.5** simulations (climate + emissions change) with GFDL CM3 chemistry-climate model over the **high-altitude WUS** (36-46N, 105-115W)



Clifton et al., GRL, 2014

Chemistry-climate model projects increases from rising global methane: shift in balance of regional-v-global sources

Transient **RCP8.5** simulations (climate + emissions change) with GFDL CM3 chemistry-climate model over the **high-altitude WUS** (36-46N, 105-115W)

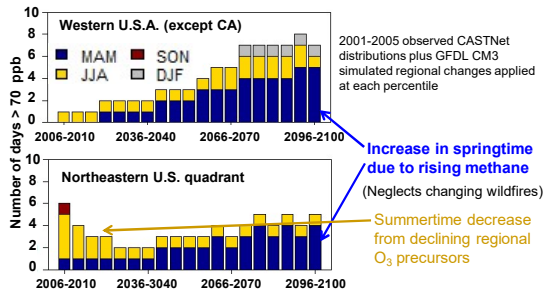


→ **More-than-doubling of global methane offsets NO_x-driven decreases**

Clifton et al., GRL, 2014

Rising methane may impose a 'penalty' on attaining current and more stringent, future ozone NAAQS

Average number of days > 70 ppb under RCP8.5 scenario



2001-2005 observed CASTNet distributions plus GFDL CM3 simulated regional changes applied at each percentile

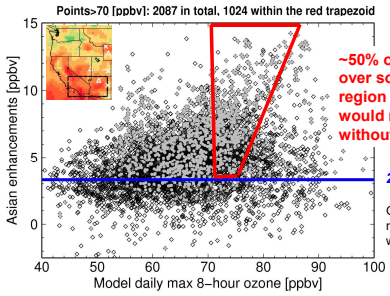
Increase in springtime due to rising methane

(Neglects changing wildfires)

Summertime decrease from declining regional O_3 precursors

H. Rieder et al., to be submitted to Atm. Env.

An AQM Challenge: INTERCONTINENTAL TRANSPORT How much pollution from afar?



~50% of MDA8 O_3 > 70 ppbv over southern CA/AZ region in May-June 2010 would not have occurred without Asian O_3

25th percentile

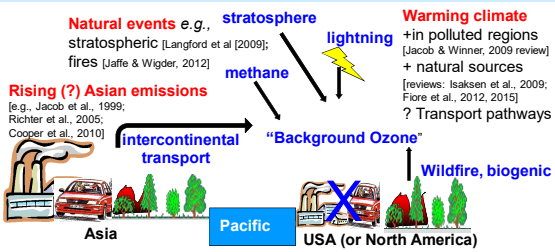
GFDL AM3 model (~50 km^2 resolution, nudged to NCEP winds)

→ Asian emissions contribute ≤ 20% of total O_3; **U.S. influence dominates**

→ **Highest Asian enhancements for total ozone in the 70-90 ppbv range**

Lin et al., JGR, 2012a

Some challenges for O_3 air quality management



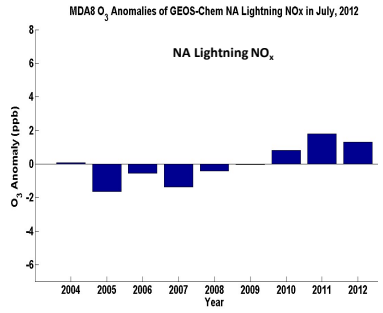
→ Need process-level understanding of each 'flavor' of background on daily to multi-decadal time scales

→ Multi-model approach in context of observational constraints can provide uncertainty / error estimates

→ Background poses largest challenge at high-altitude WUS sites

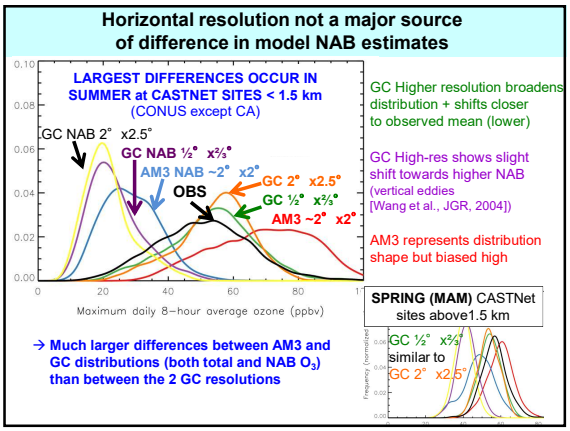
- Extras follow

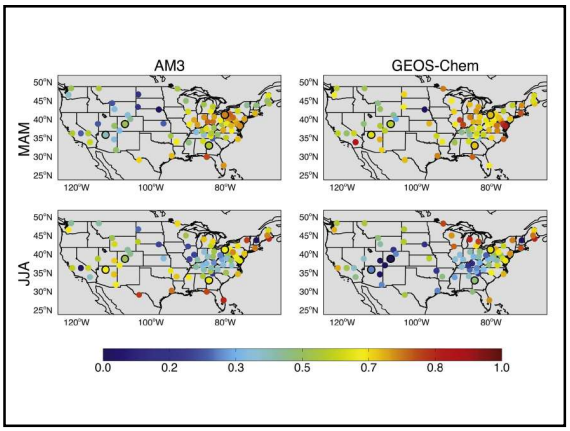
2004-2012 GEOS-Chem simulations indicate lightning NO_x influence strongest in 2011 (July, over Utah)



Determined by GEOS-Chem simulations: (Base - Zero_LNO_x)

J. Guo, L. Murray


Horizontal resolution not a major source of difference in model NAB estimates
LARGEST DIFFERENCES OCCUR IN SUMMER at CASTNET SITES < 1.5 km
(CONUS except CA)
GC NAB 2° x2.5°
GC NAB ½° x⅔°
AM3 NAB ~2° x2°
OBS
GC 2° x2.5°
GC ½° x⅔°
AM3 ~2° x2°
Maximum daily 8-hour average ozone (ppbv)
GC Higher resolution broadens distribution + shifts closer to observed mean (lower)
GC High-res shows slight shift towards higher NAB
(vertical eddies
[Wang et al., JGR, 2004])
AM3 represents distribution shape but biased high
SPRING (MAM) CASTNet sites above1.5 km
GC ½° x⅔°
similar to
GC 2° x2.5°
→ Much larger differences between AM3 and GC distributions (both total and NAB O3) than between the 2 GC resolutions


AM3
GEOS-Chem
MAM
JJA
0.0
0.2
0.3
0.5
0.7
0.8
1.0