Modeling Estimates of Emission-Influenced Background Ozone and its Relationship to Trends in the Western United States

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With Contributions from

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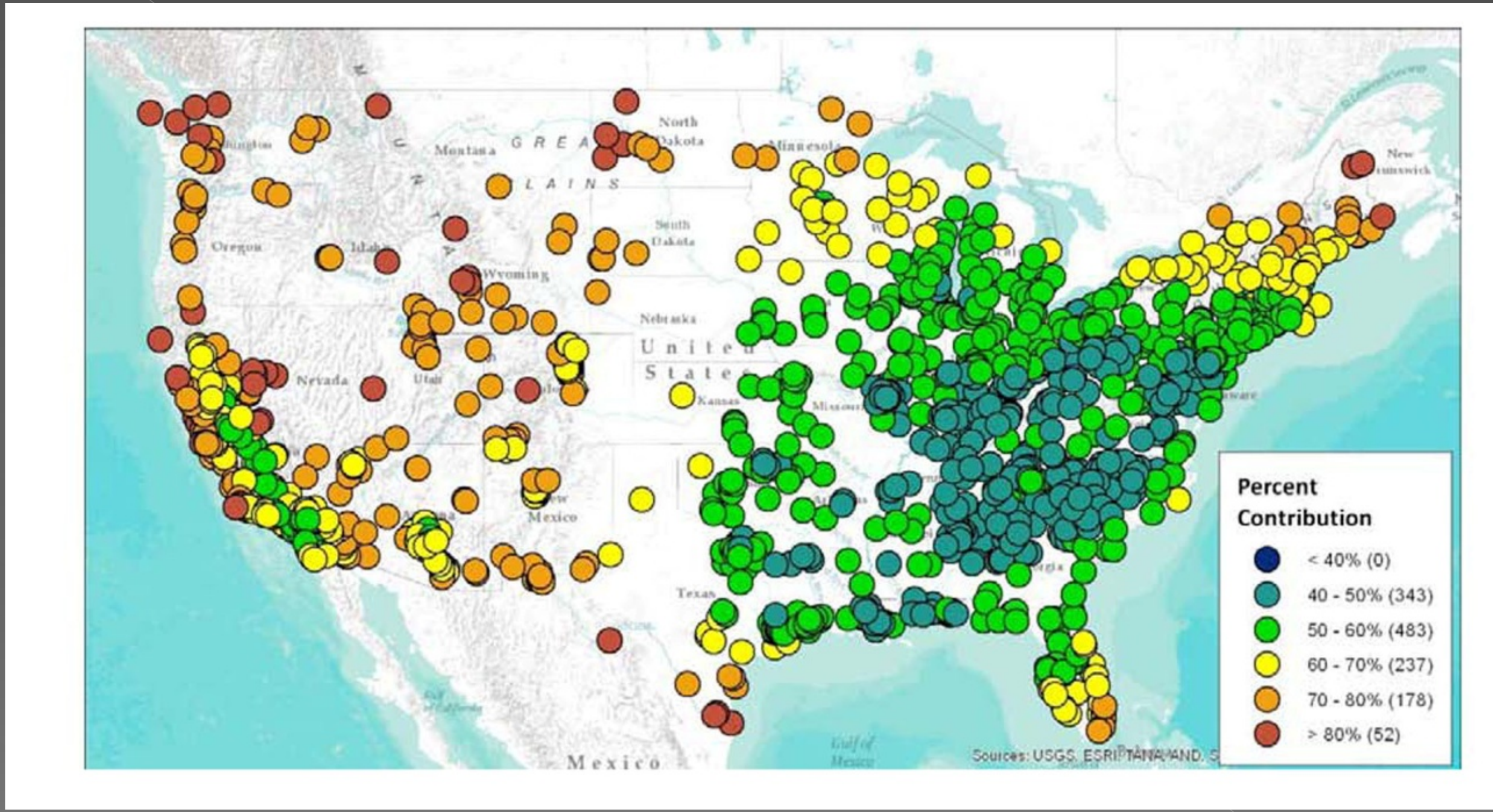
- Heini Wernli, Institute for Atmospheric and Climate Science, ETH Zurich, Switzerland
- Chris Emery, ENVIRON International, Novato, California
- U.S. Environmental Protection Agency, Research Triangle Park, NC (2007 Observed/USB_{ab} Data Provided)

Why is Background Ozone Important?

- At some sites, background O_3 directly leads to exceedances of the O_3 standard and at other sites it is an enhancement to the anthropogenic contribution leading to exceedances;
- Background concentrations associated with stratospheric intrusions are an important contributor to observed O_3 concentrations; and
- Background O_3 plays an important role in the EPA's risk assessments.

How Important is Background O_3 on a Seasonal Basis?



Map of apportionment-based U.S. background percent contribution to seasonal (April-October) 8-h mean O_3 based on 2007 CAMx source apportionment modeling. (Source: EPA, 2014).

EIB O_3 and USB_{ab} O_3

- Lefohn et al. (2014) defined Emission-influenced background (EIB) O_3 to include contributions from natural sources throughout the globe and from anthropogenic sources outside of North America. EIB O_3 includes chemical interactions with North American anthropogenic emissions, is usually less than NAB/USB, and represents North American background O_3 under current conditions.

- EPA (2014) defined source-apportionment based U.S. Background (USB_{ab}) in a similar manner as EIB O_3, except that USB_{ab} includes anthropogenic sources from Canada and Mexico. USB_{ab} includes chemical interactions with U.S. anthropogenic emissions and represents U.S. background O_3 under current conditions.

Findings from Lefohn et al. (2014)

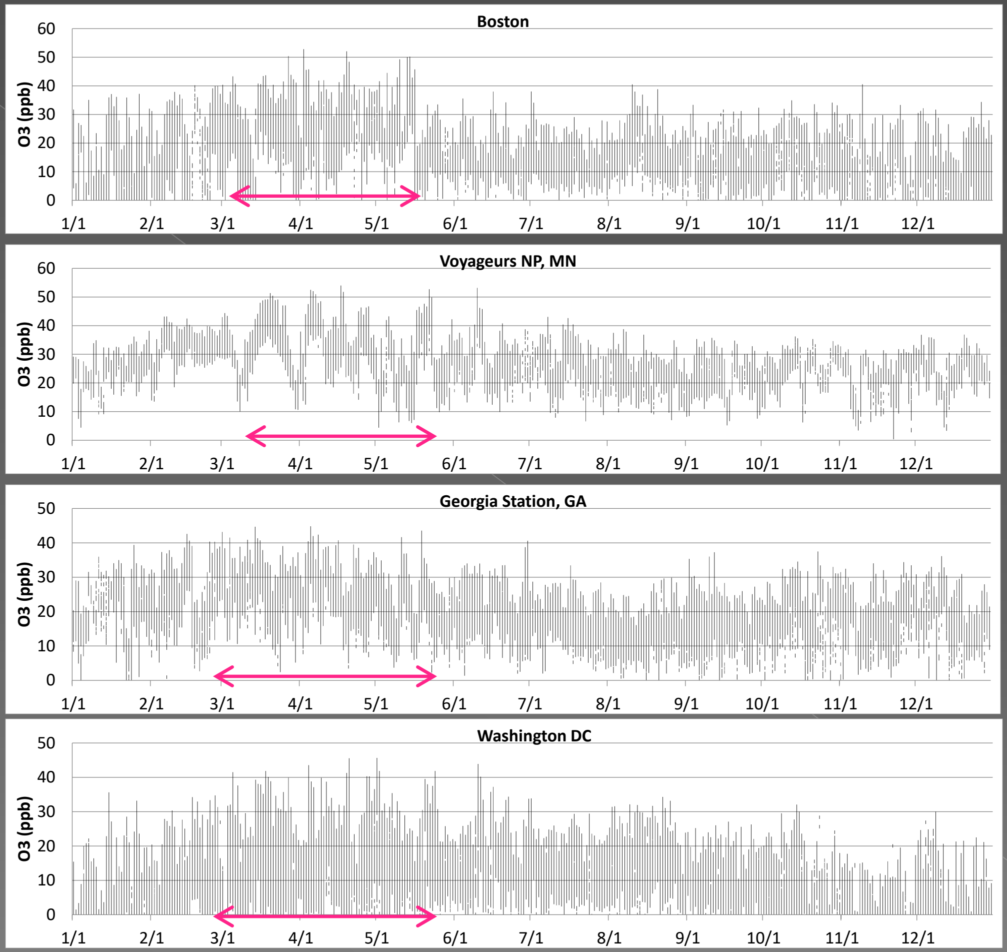
- Using coupled GEOS-Chem/CAMx models, we estimated background surface O_3 concentrations across the U.S. at high- and low-elevation, rural and urban locations;

- At many of the sites across the U.S. during the spring, fall, and winter months, higher background was associated with frequent stratosphere-to-troposphere transport to the surface (STT-S) based on the trajectories calculated using 3-dimensional wind fields from operational ECMWF analyses with 1 deg horizontal resolution and 91 vertical levels ;

- Patterns of higher spring EIB O_3 are followed by lower values during the summer, which are then followed by rising EIB O_3 during the fall and winter months;

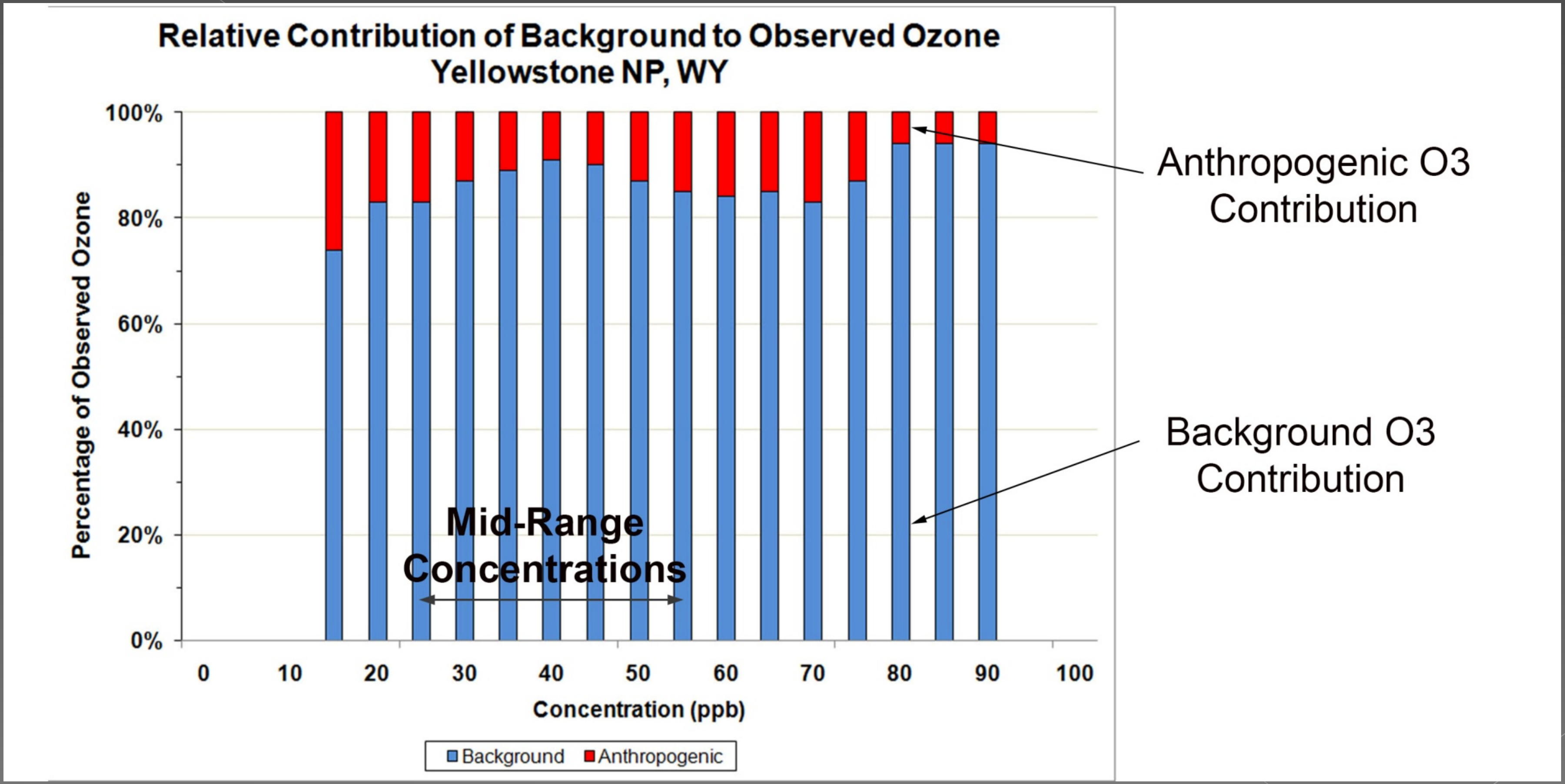
- For some high-elevation western U.S. sites, this seasonal pattern is less discernible due to relatively small anthropogenic contributions and high EIB O_3 estimated throughout the year.

Background Ozone is Higher During the Spring Throughout U.S. and Appears to be Related at Times to STT-S Processes



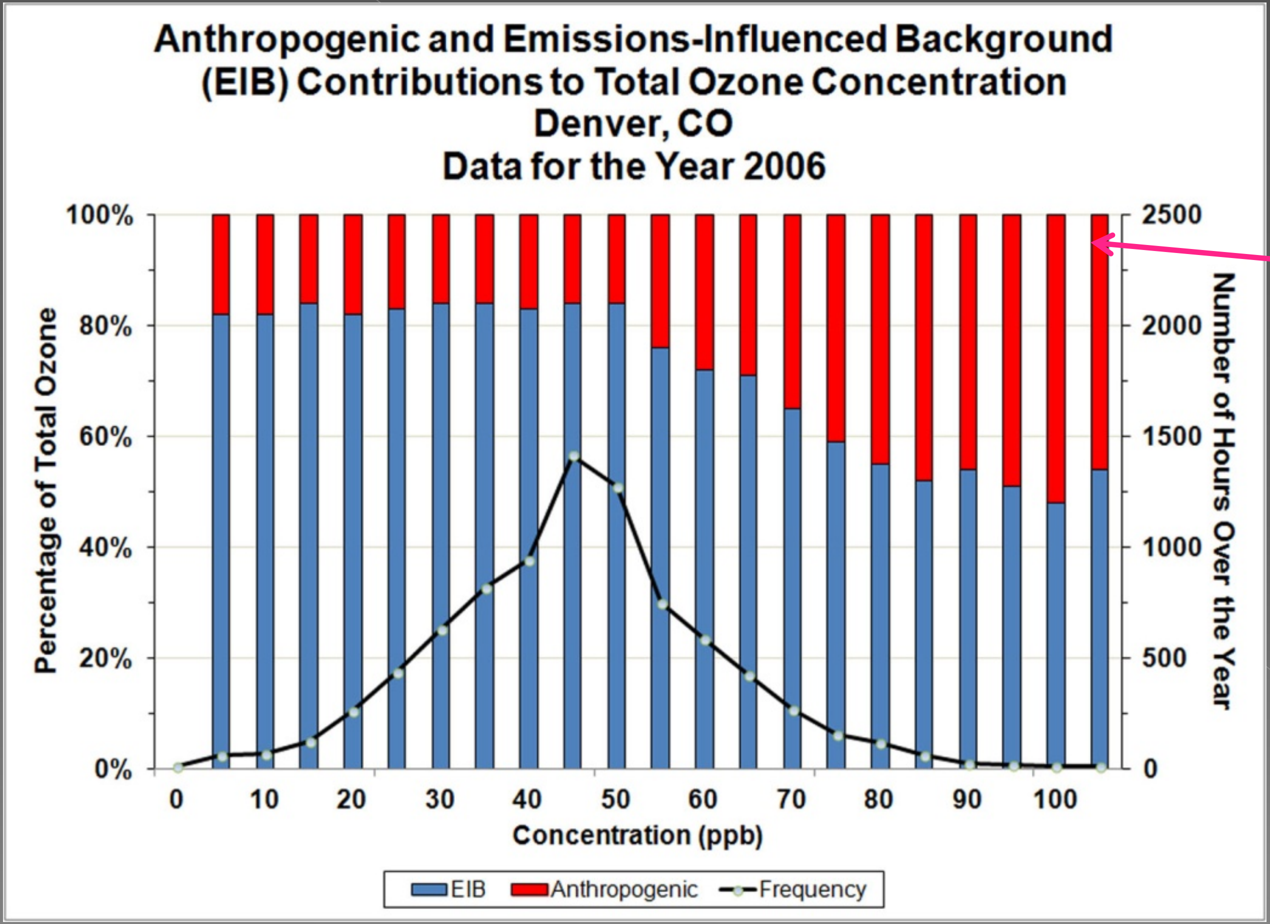
Source: Lefohn, A.S., Emery, C., Shadwick, D., Wernli, H., Jung, J., Oltmans, S.J., 2014. Estimates of Background Surface Ozone Concentrations in the United States Based on Model-Derived Source Apportionment. Atmospheric Environment, 84:275-288.

Relative Contribution of Anthropogenic and Background Ozone – Yellowstone NP (2006)



Source: Lefohn, A.S., Emery, C., Shadwick, D., Wernli, H., Jung, J., Oltmans, S.J., 2014. Estimates of Background Surface Ozone Concentrations in the United States Based on Model-Derived Source Apportionment. Atmospheric Environment, 84:275-288.

Relative Contribution of Anthropogenic and Background Ozone - Denver



Substantial Reductions Possible in Anthropogenic Contributions at the Higher Concentrations In Relation to Lower Concentrations

Source: Lefohn et al. (2014)

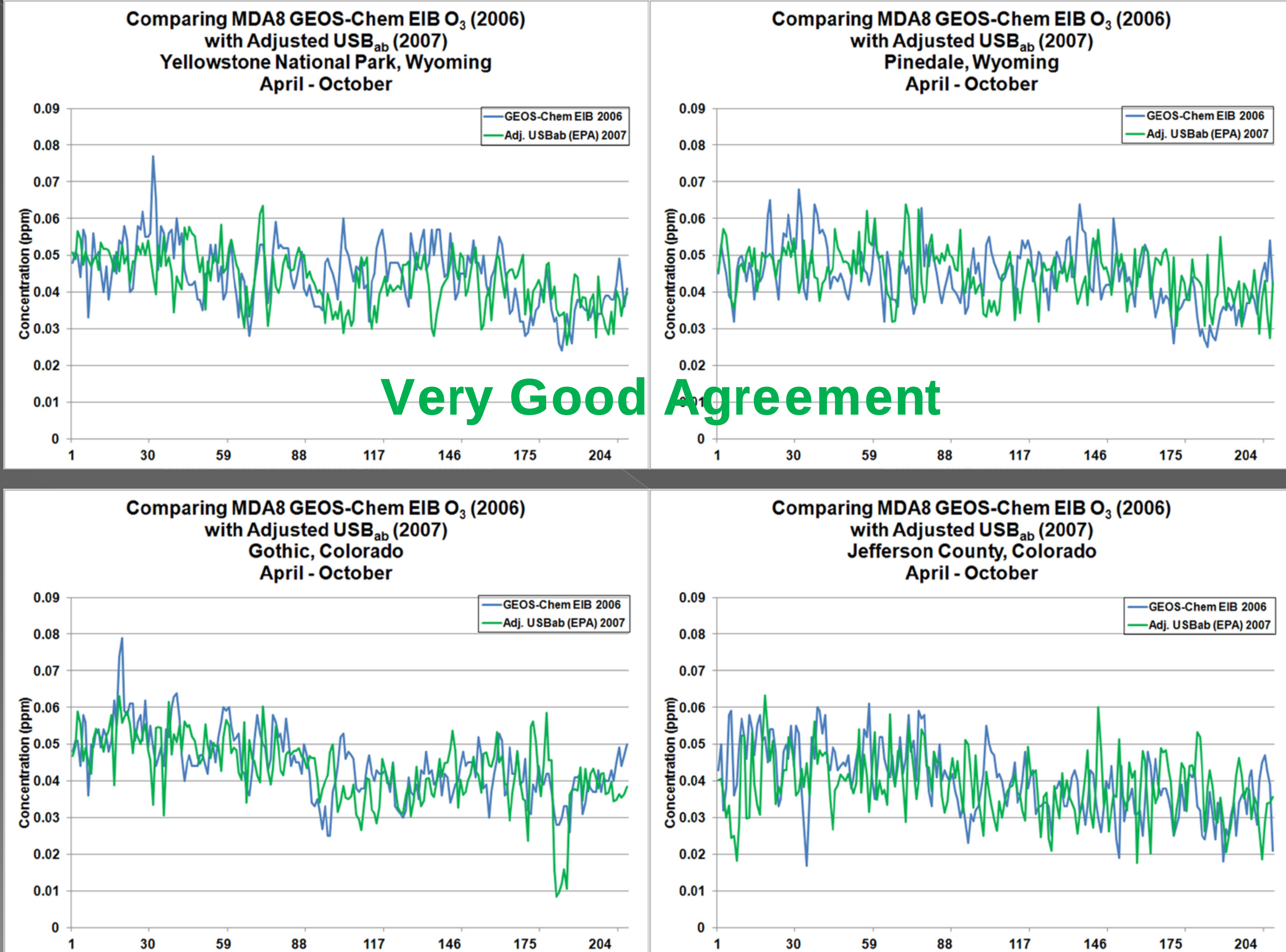
How does EIB O_3 (2006) compare to USB_{ab} (2007)?

Comparison of bias-adjusted EIB with bias-adjusted USB_{ab} MDA8 O_3 Seasonal Means

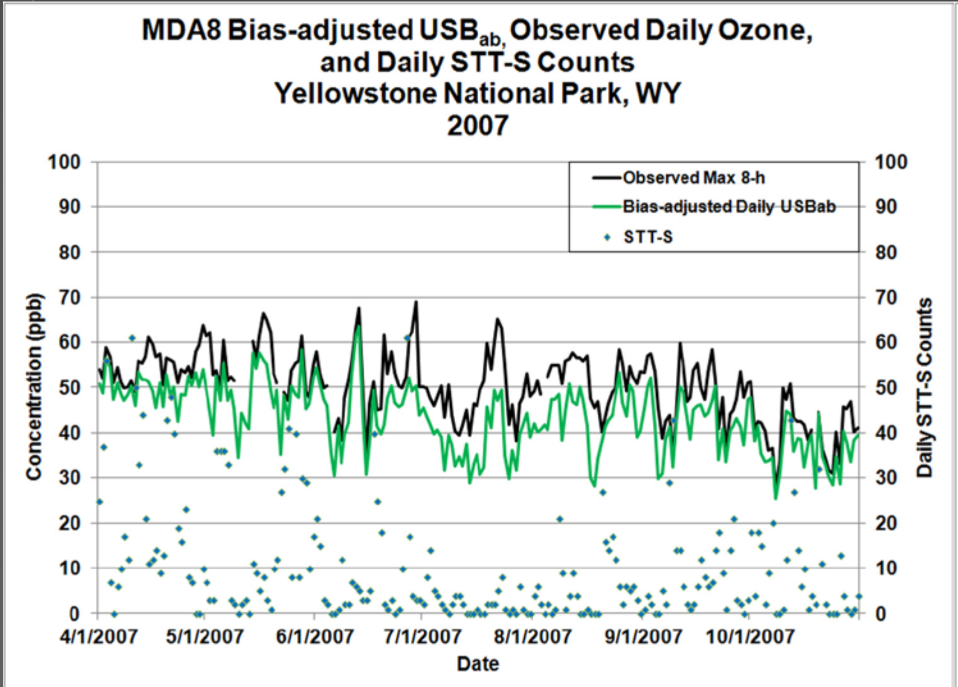
Comparison of April-October mean bias-adjusted EIB (2006) with USB_{AB} MDA8 ozone (ppm) as estimated by a 2007 CAMx source apportionment simulation.

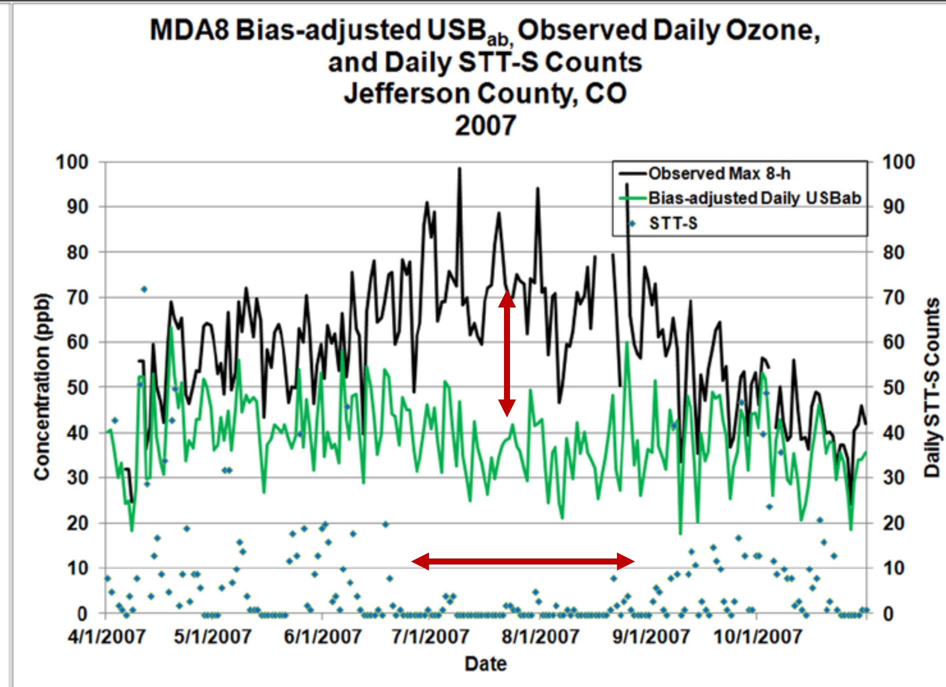
Site	Lefohn et al. (2014) 2006	Values from Data Provided by EPA 2007
Denver	0.040	0.039
Sacramento	0.033	0.033
Yellowstone NP	0.045	0.043
Yosemite NP	0.048	0.049
Gothic	0.045	0.043
Pinedale	0.044	0.045

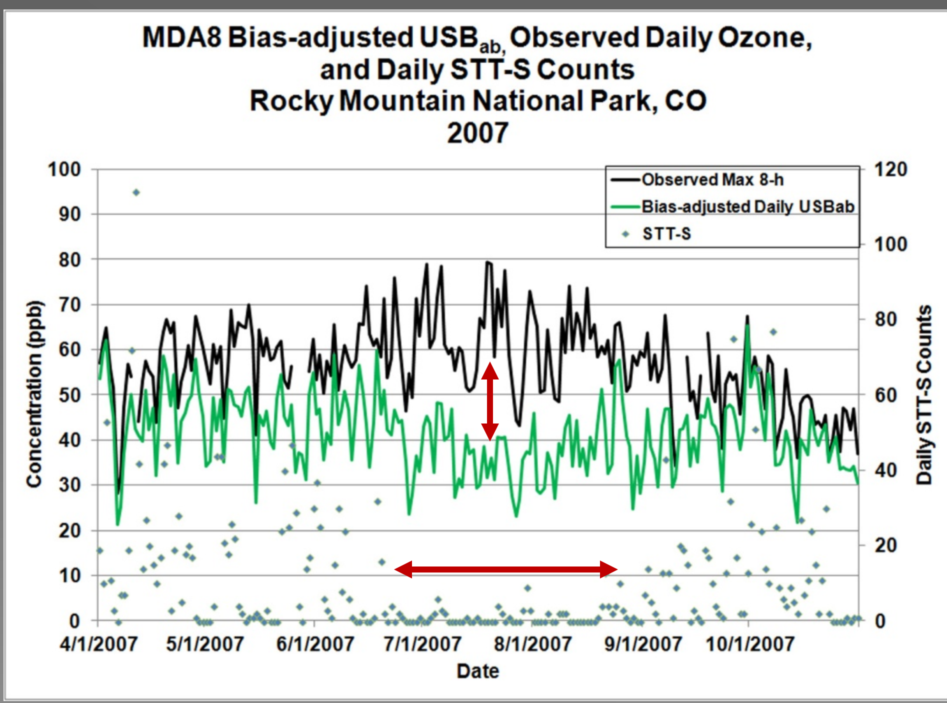
The seasonal mean comparison shows very good agreement. How do daily values compare using 2006 (EIB) and 2007 (USB_{ab})data?

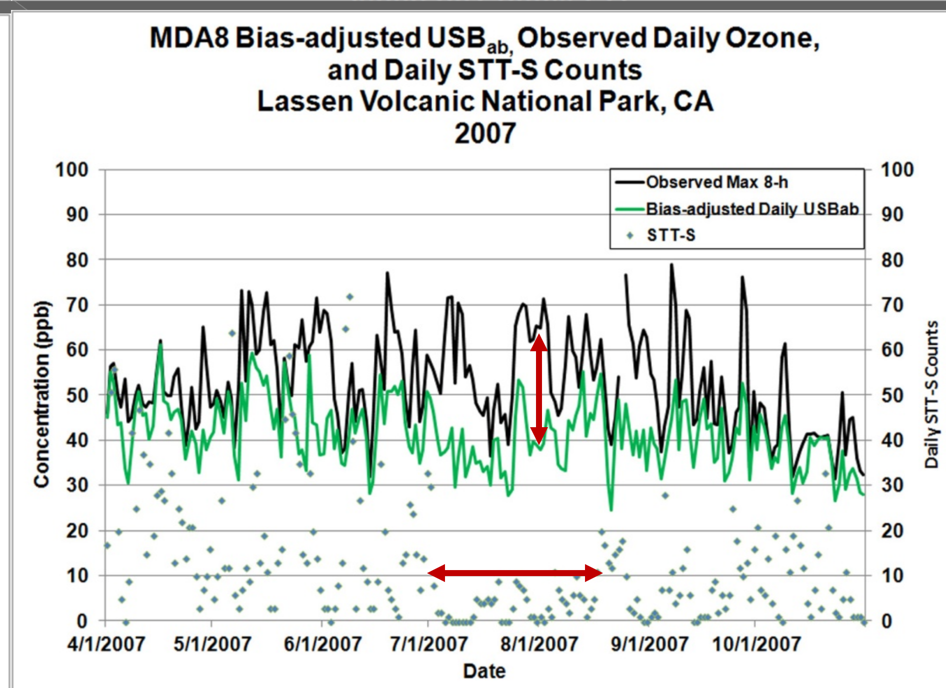

Comparing MDA8 GEOS-Chem EIB O_3 (2006)
with Adjusted USB_{ab} (2007)
Yellowstone National Park, Wyoming
April - October
Concentration (ppm)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1
30
59
88
117
146
175
204
GEOS-Chem EIB 2006
Adj. USBab (EPA) 2007
Comparing MDA8 GEOS-Chem EIB O_3 (2006)
with Adjusted USB_{ab} (2007)
Pinedale, Wyoming
April - October
Very Good Agreement
Comparing MDA8 GEOS-Chem EIB O_3 (2006)
with Adjusted USB_{ab} (2007)
Gothic, Colorado
April - October
Comparing MDA8 GEOS-Chem EIB O_3 (2006)
with Adjusted USB_{ab} (2007)
Jefferson County, Colorado
April - October

How does overlaying the daily STT-S (stratospheric) counts compare with daily MDA8 bias-adjusted USB_{ab} (2007) and observed daily O_3?


MDA8 Bias-adjusted $USB_{ab,}$ Observed Daily Ozone,
and Daily STT-S Counts
Yellowstone National Park, WY
2007
Observed Max 8-h
Bias-adjusted Daily USBab
STT-S
Concentration (ppb)
Daily STT-S Counts
Date
4/1/2007
5/1/2007
6/1/2007
7/1/2007
8/1/2007
9/1/2007
10/1/2007


MDA8 Bias-adjusted $USB_{ab,}$ Observed Daily Ozone,
and Daily STT-S Counts
Jefferson County, CO
2007
Observed Max 8-h
Bias-adjusted Daily USBab
STT-S
Concentration (ppb)
Daily STT-S Counts
Date
4/1/2007
5/1/2007
6/1/2007
7/1/2007
8/1/2007
9/1/2007
10/1/2007


MDA8 Bias-adjusted $USB_{ab,}$ Observed Daily Ozone,
and Daily STT-S Counts
Rocky Mountain National Park, CO
2007
Observed Max 8-h
Bias-adjusted Daily USBab
STT-S
Concentration (ppb)
Daily STT-S Counts
Date
4/1/2007
5/1/2007
6/1/2007
7/1/2007
8/1/2007
9/1/2007
10/1/2007


MDA8 Bias-adjusted $USB_{ab,}$ Observed Daily Ozone,
and Daily STT-S Counts
Lassen Volcanic National Park, CA
2007
Observed Max 8-h
Bias-adjusted Daily USBab
STT-S
Concentration (ppb)
Daily STT-S Counts
Date
4/1/2007
5/1/2007
6/1/2007
7/1/2007
8/1/2007
9/1/2007
10/1/2007

Observations

- During summer, when STT-S is strongly reduced, USB_{ab} is slightly reduced in Jefferson and RMNP and therefore periods occur with "gaps" between observed values and USB_{ab}, likely attributable to anthropogenic sources;

- The amplitude of the "gap" varies strongly between sites: during rare events of STT-S > 0 in summer (e.g., Lassen, end of July and end of August), the two curves approach one another, indicating that STT-S episodes can also occur in summer with the result there is a close agreement between observed values and USB_{ab}; and

- Outside of summer, during periods of STT-S = 0 (e.g., Jefferson mid May, RMNP early May, Lassen end of October) the "gap" occurs, indicating that anthropogenic sources play a larger role in non-summer periods preferentially when meteorological conditions are such that STT-S does not occur.

For sites illustrating important influences by EIB and USB_{ab} during the spring, is the low-end (i.e., 5^{th} percentile) in the spring shifting toward the mid-level concentrations?

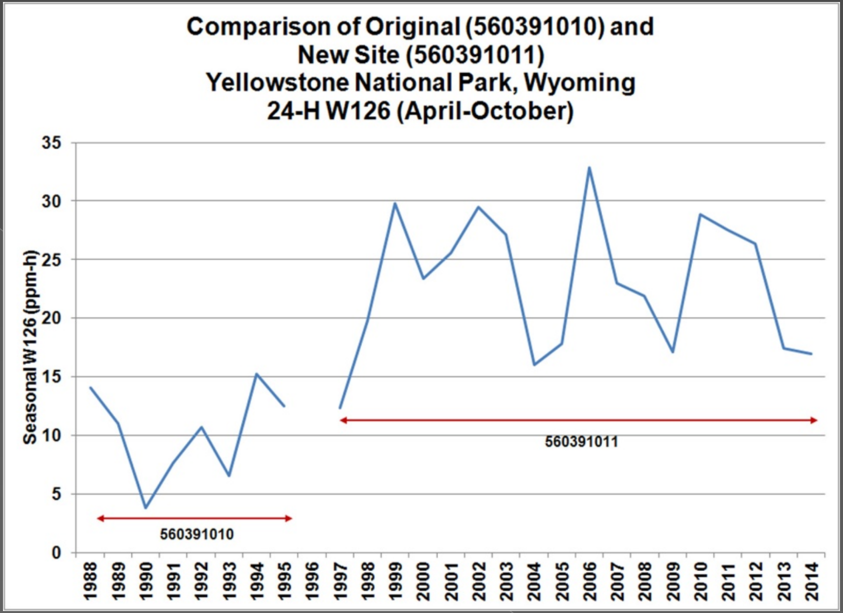
15-Year Trending Patterns for Sites Influenced by STT-S Processes Using LAGRANTO Trajectories
(1998-2012)
Spring

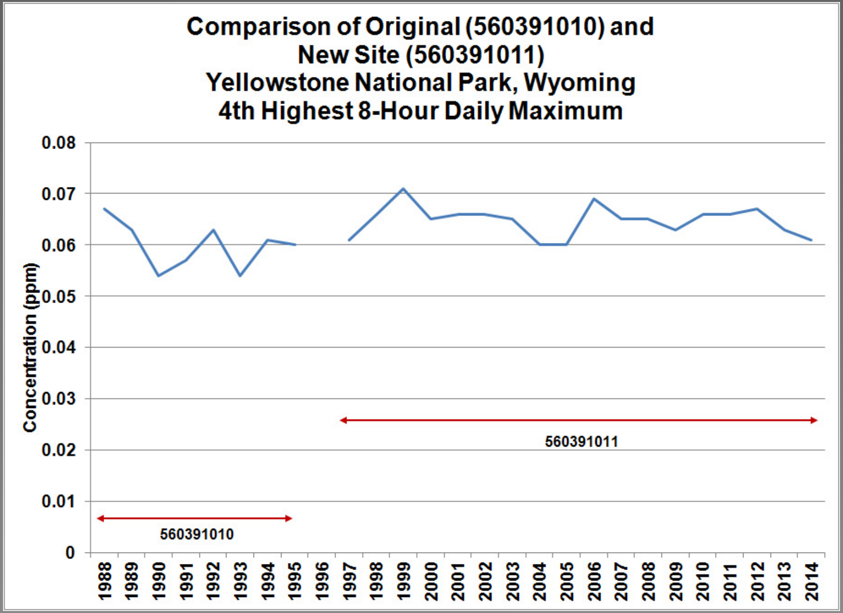
	5^{th} Percentile Lefohn et al.	50^{th} Percentile Lefohn et al.	95^{th} Percentile Lefohn et al.
Denali NP	NS	NS	NS
Yellowstone NP	NS	NS	NS
Pinedale	NS	NS	NS
Centennial	NS	NS	NS
Rocky Mountain NP	NS	Significant (+)	NS
Gothic (1997-2011)	NS	Significant (-)	Significant (-)

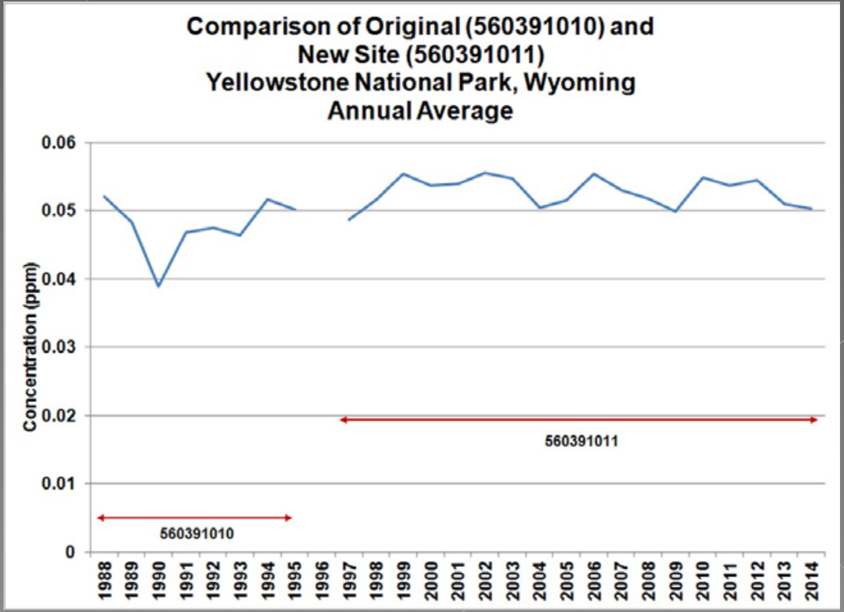
NS = Non-Significant Trending

Source: Lefohn et al. (In Preparation)

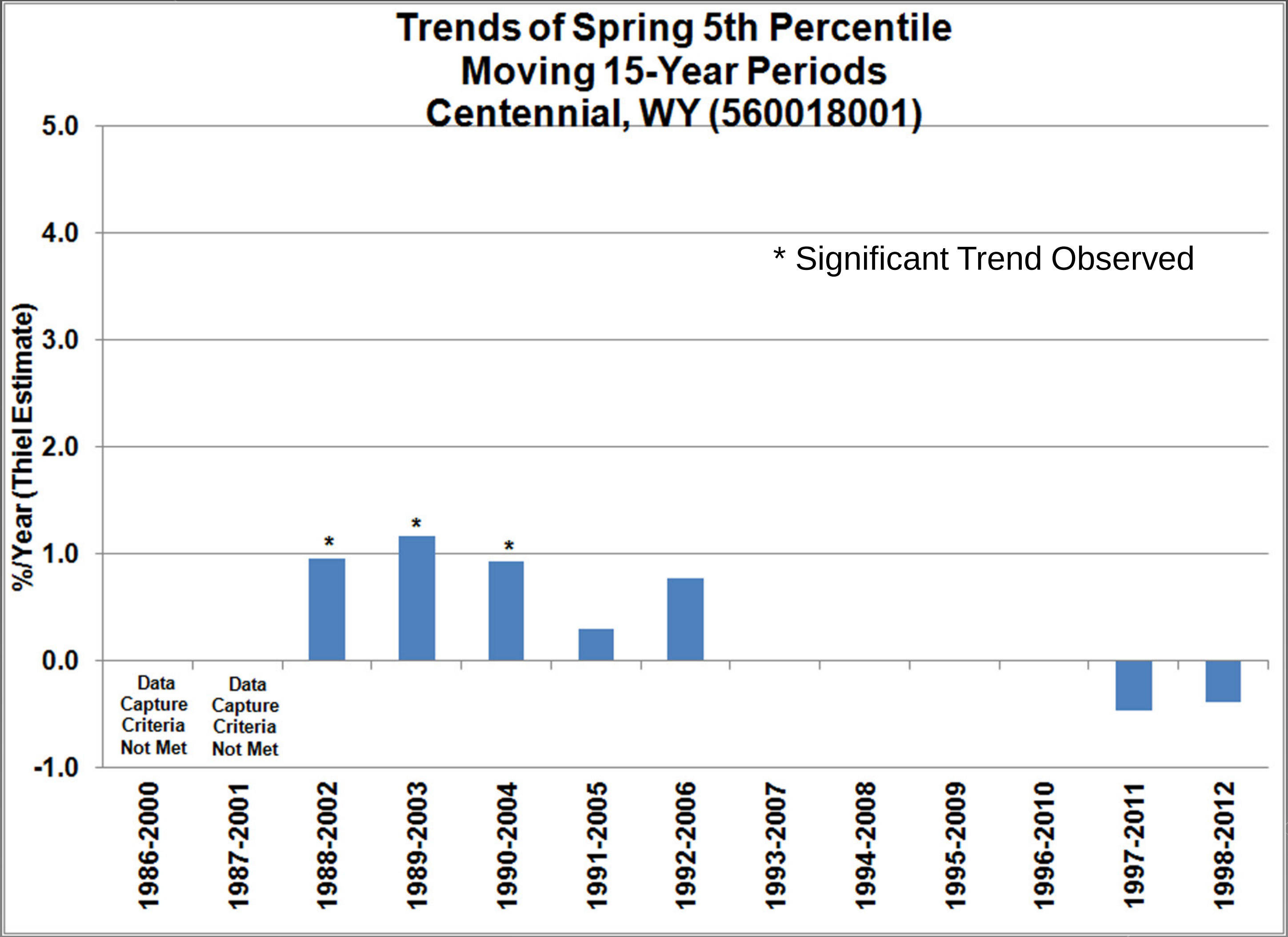
Time Series for Yellowstone NP 1988-2014



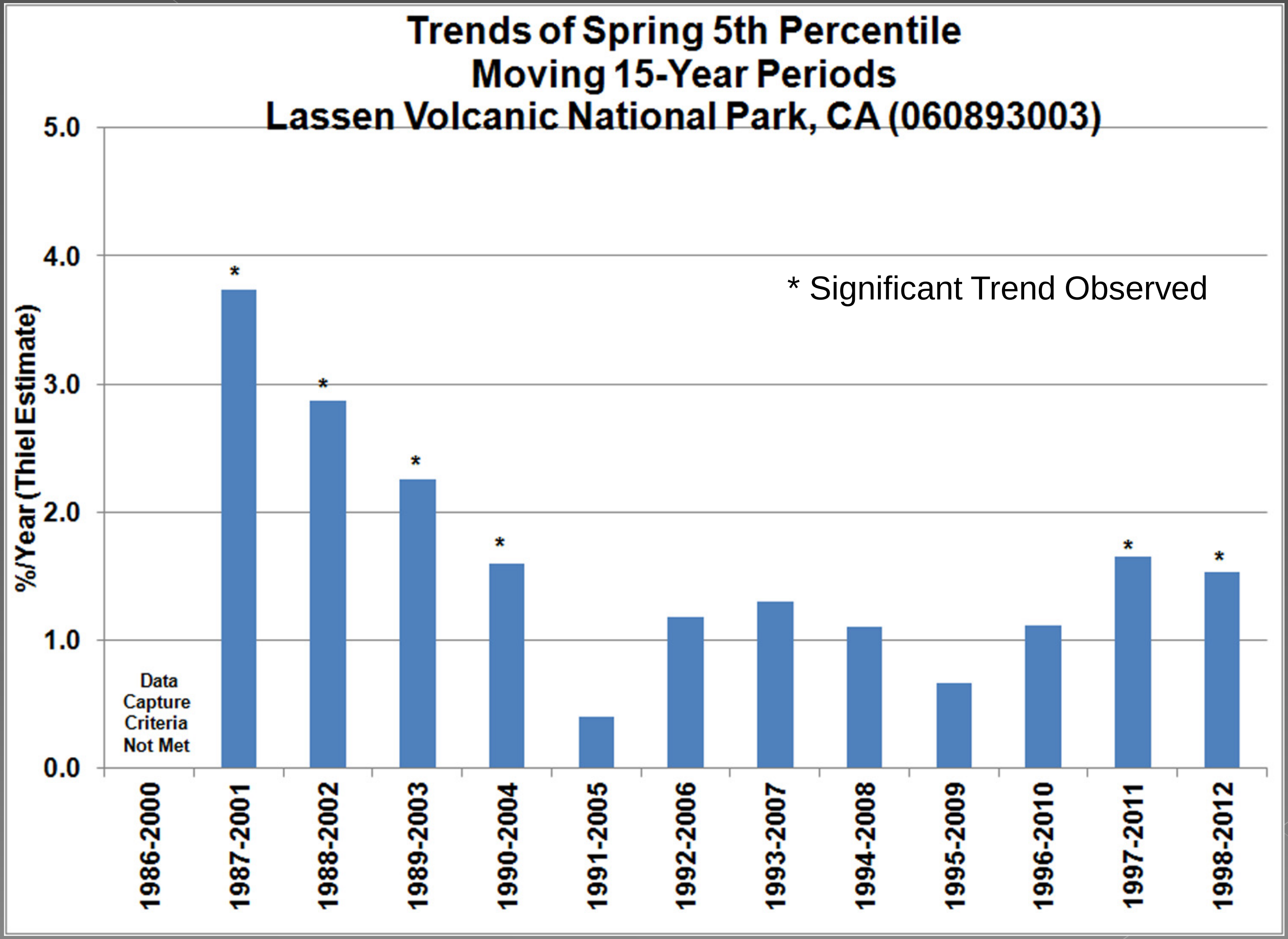




Rate of Change in Trending Rate for Low-End Shifting Upward or Downward During the Spring



Rate of Change in Trending Rate for Low-End Shifting Upward During the Spring



Conclusions for the West

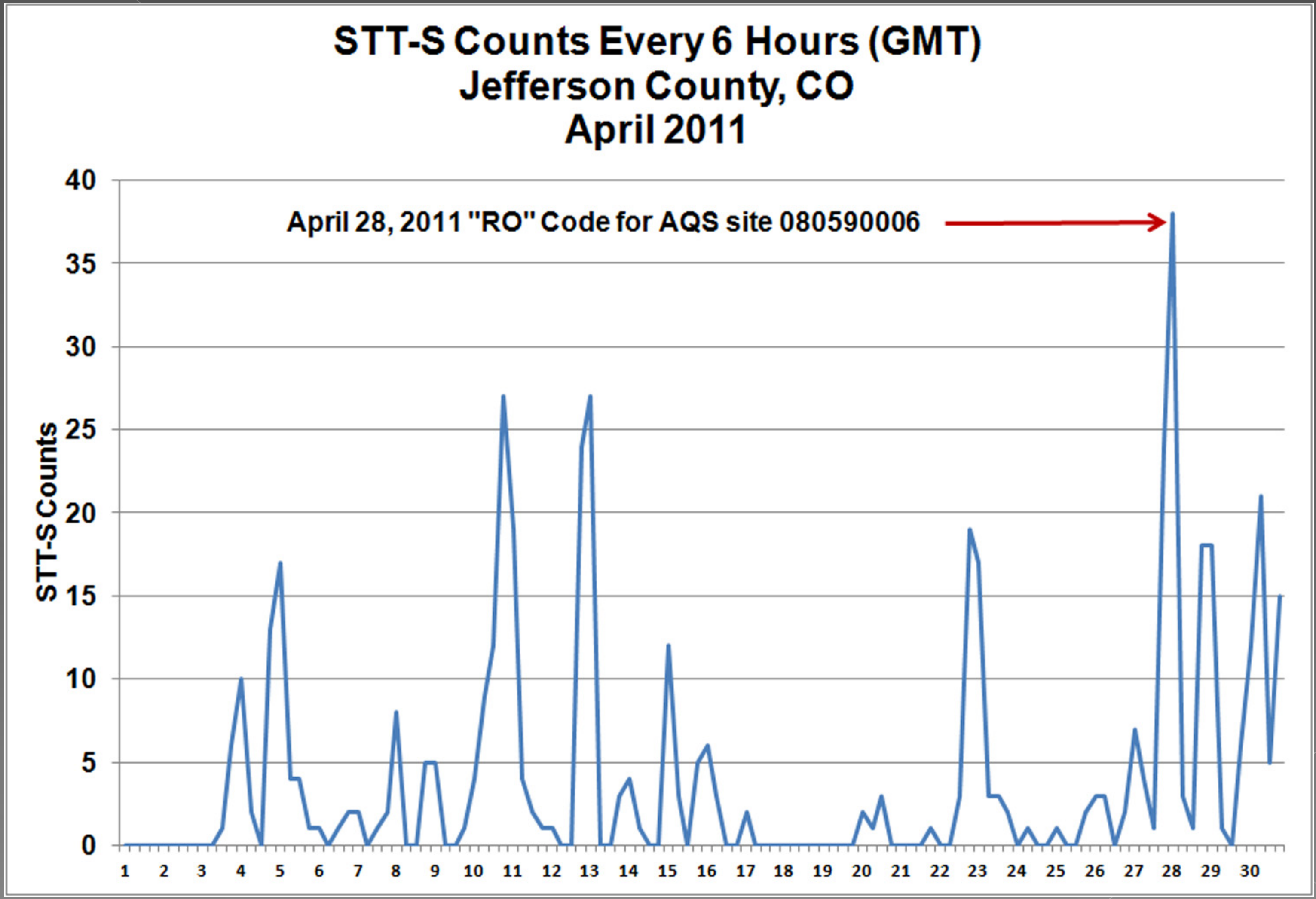
- In the West and Intermountain West, EIB and USB_{ab} O_3 contributes an important amount to observed O_3 and the stratosphere is an important contributor;
- On a seasonal and daily basis, EIB O_3 (2006) and USB_{ab} (2007) are in very good agreement across years;
- The pattern of daily STT-S trajectories appear to relate to EIB O_3, USB_{ab}, and observed O_3 concentrations;
- During the spring in the Intermountain West, we find that most sites influenced by STT-S processes are not exhibiting shifts from the low end of the distribution to the mid-level concentrations; and
- Additional research is needed to quantify the relative importance of long-range versus stratosphere-to-troposphere transport in influencing surface O3 levels (Lefohn and Cooper, 2015).

Extra Slides

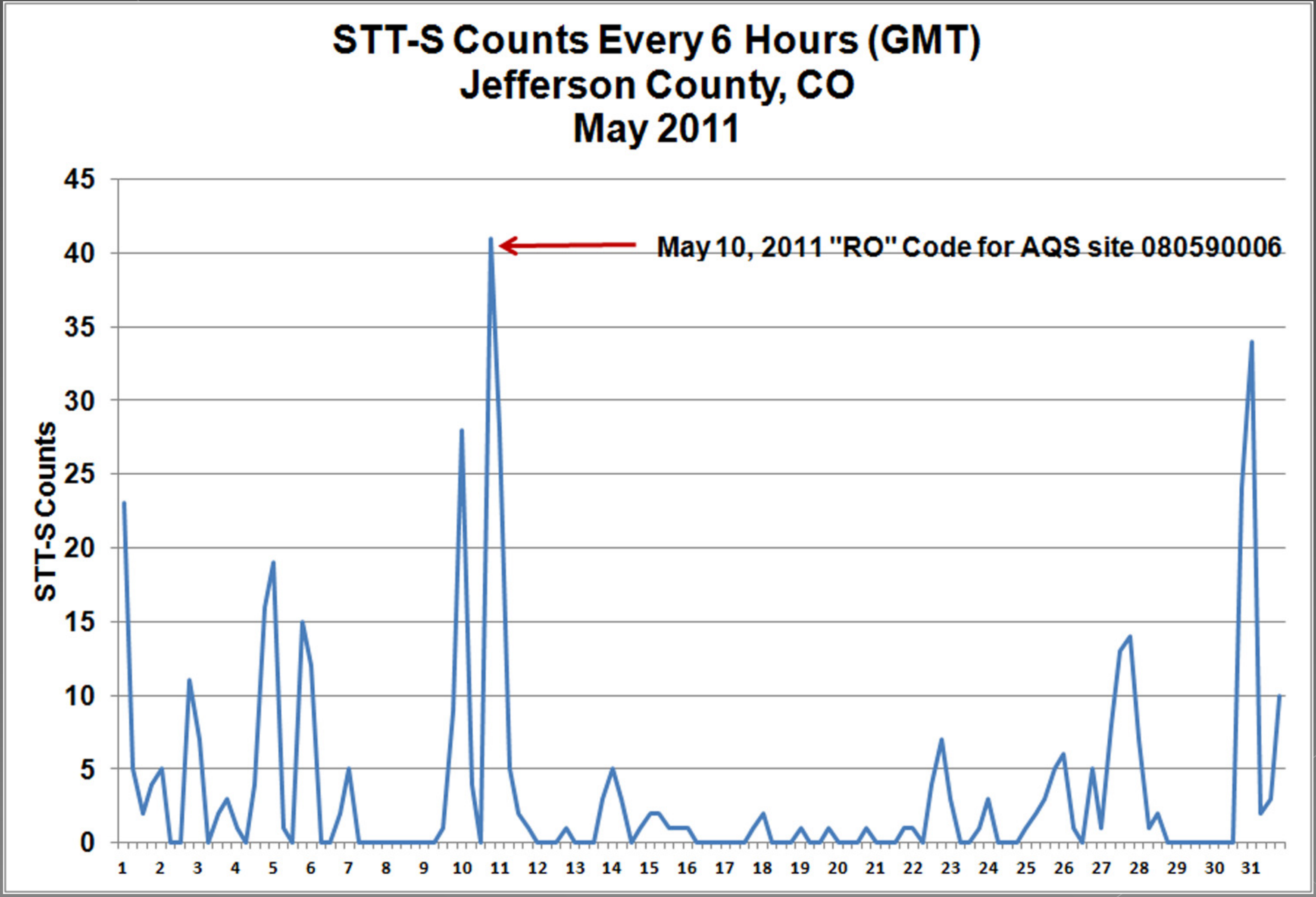
"RO" Designation in EPA AQS Database

- The "O" in "RO" stands for ozone intrusion.
- The "R" stands for "requesting exclusion" meaning that when the state flagged this data, it plans to submit a demonstration that this value should be excluded from NAAQS calculations.

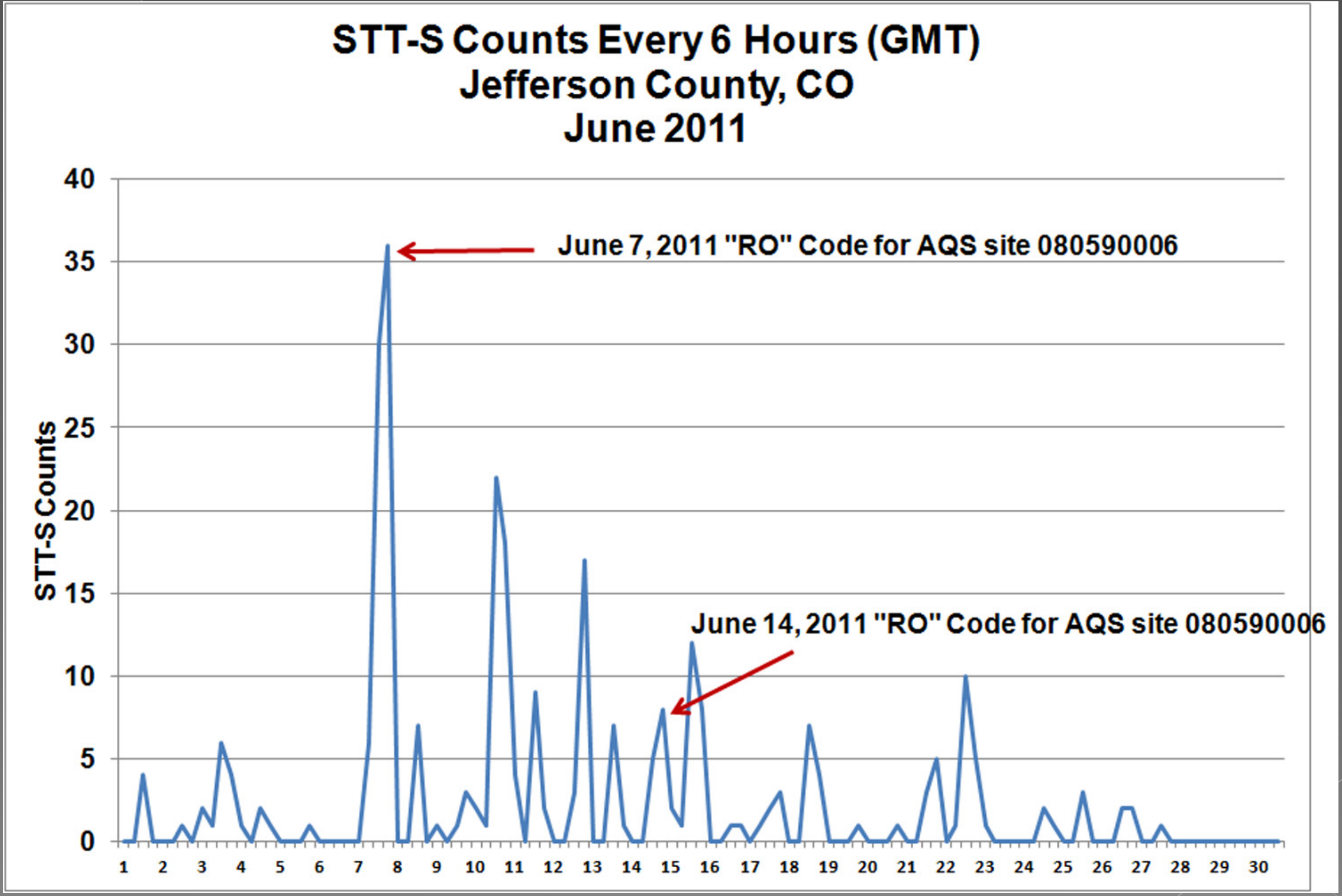
STT-S Counts and "RO" Designations



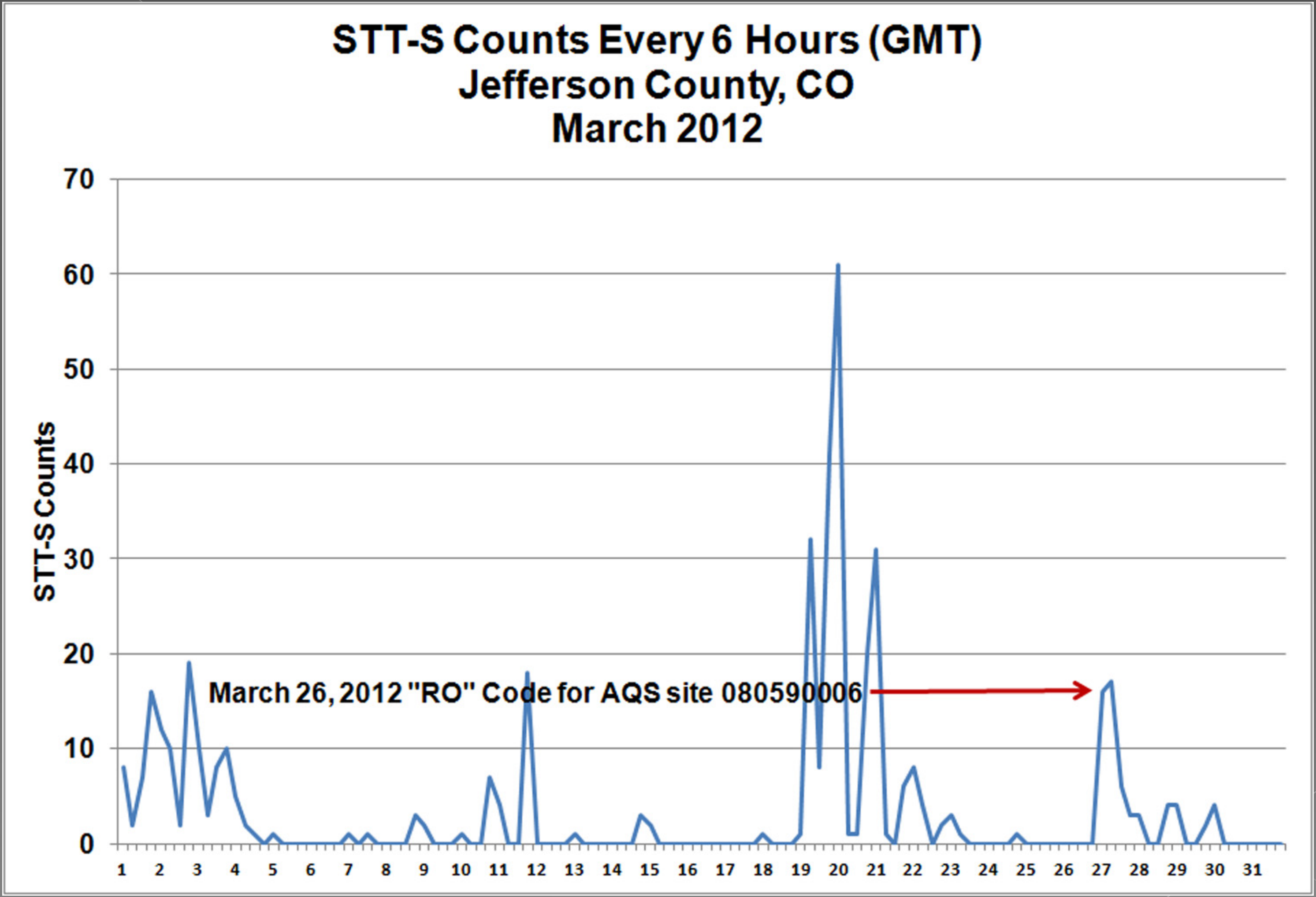
STT-S Counts and “RO” Designations



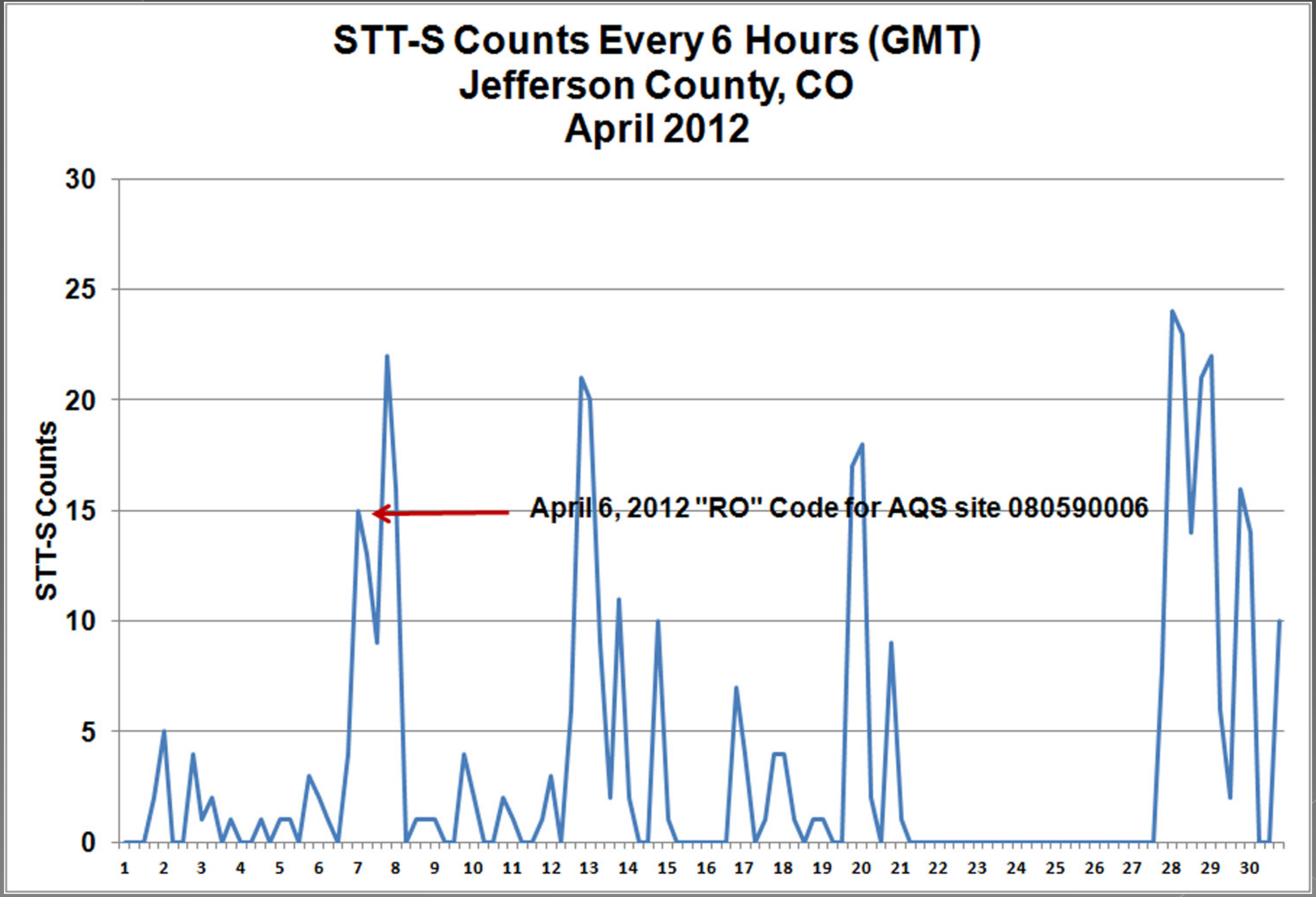
STT-S Counts and "RO" Designations



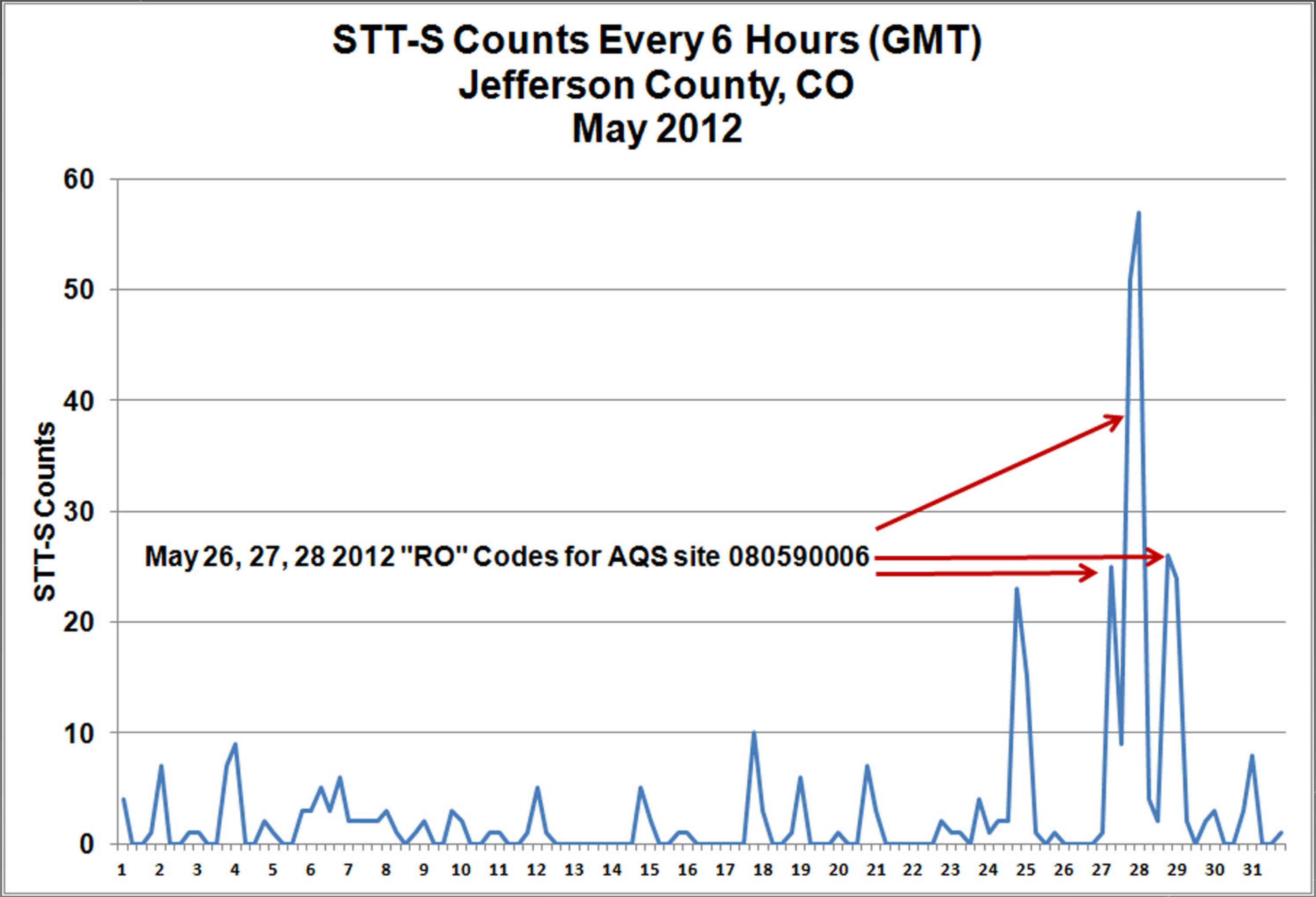
STT-S Counts and "RO" Designations



STT-S Counts and "RO" Designations



STT-S Counts and "RO" Designations



STT-S Counts and "RO" Designations