# *Background Ozone: Recent Research in the US and Texas*

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**Southeast Texas Photochemical Modeling Technical Committee Meeting**

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# Outline

- Definitions of background ozone
- Background ozone studies in Texas
- Background ozone studies in the US
- Future background ozone studies for Texas

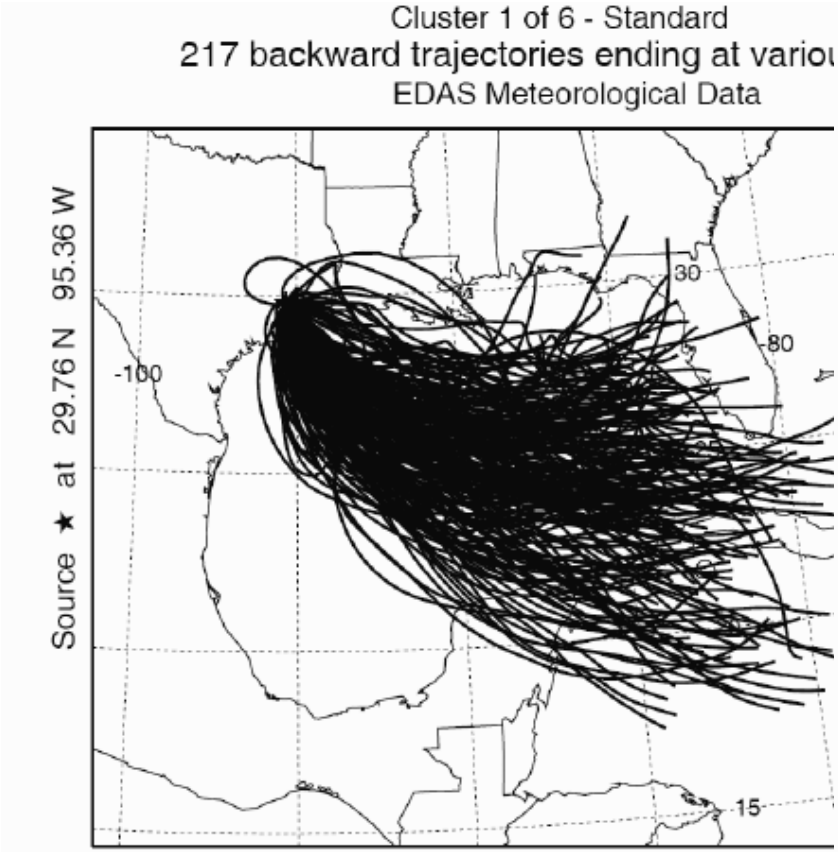
# Definitions of background ozone

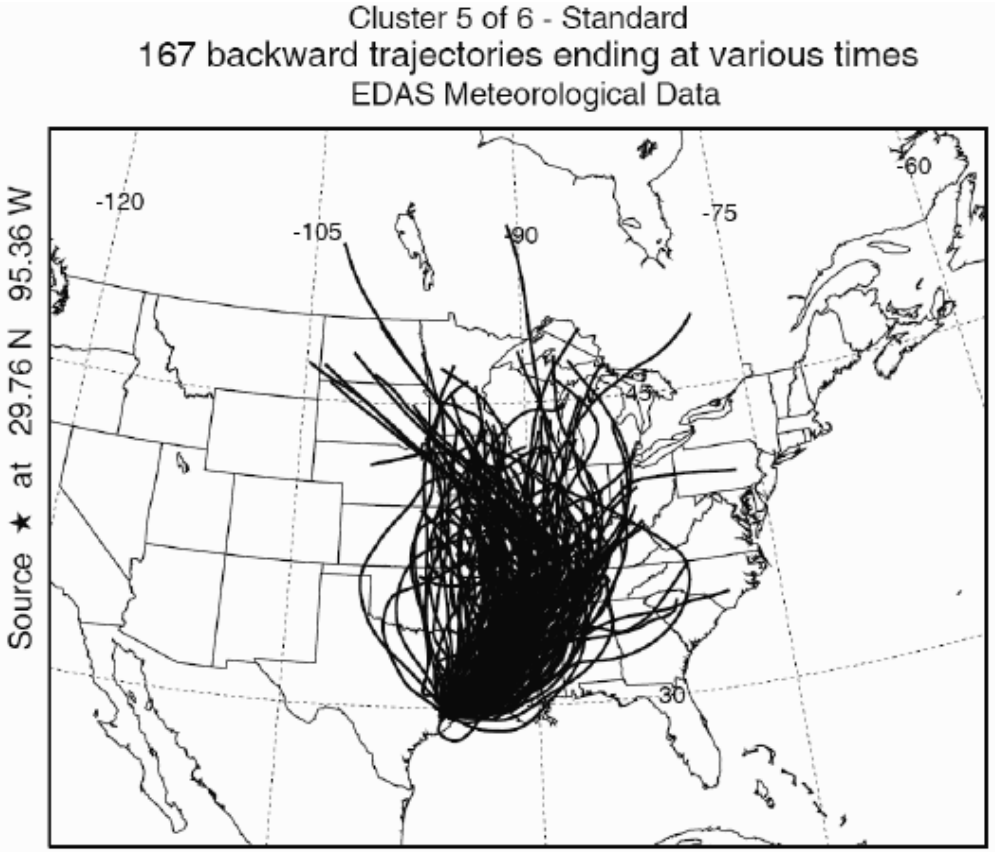
- Natural background:  ozone concentrations that would be present with only natural emissions.
- Regional background:  ozone in an air mass that enters a city from outside, which has not been affected by the city of interest.
- EPA policy-relevant background:  ozone concentrations that would be present if there were no anthropogenic emissions in North America.
- Natural background < policy-relevant background < regional background.

# Background ozone in Texas

- How high is the background?  It depends:

- Varies by transport pattern
  - Continental vs. Gulf vs. stagnation
- Varies by season
  - Spring and late summer peaks, midsummer minimum
- Observed trends
  - No trend detected, but not all studies agree

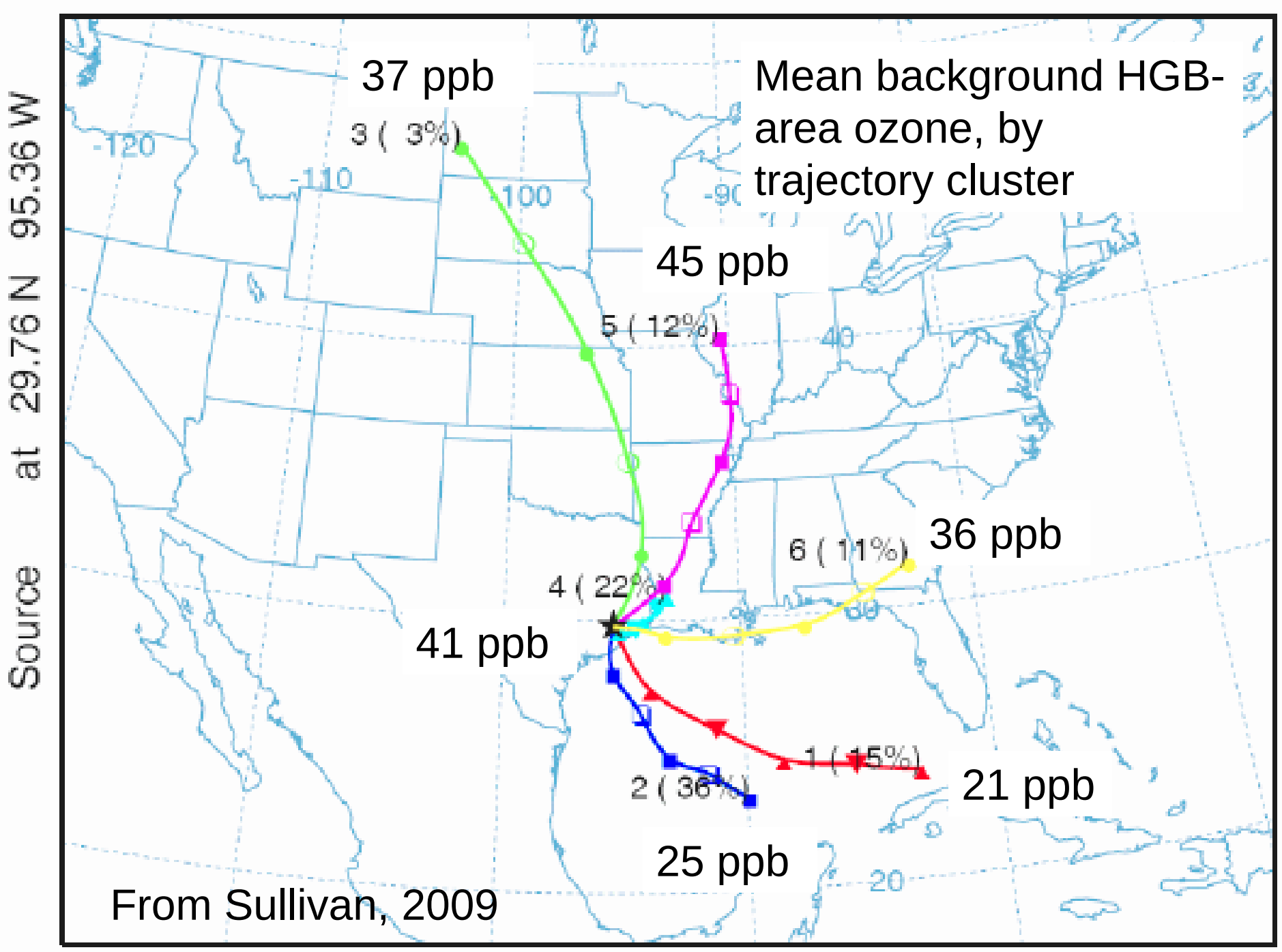


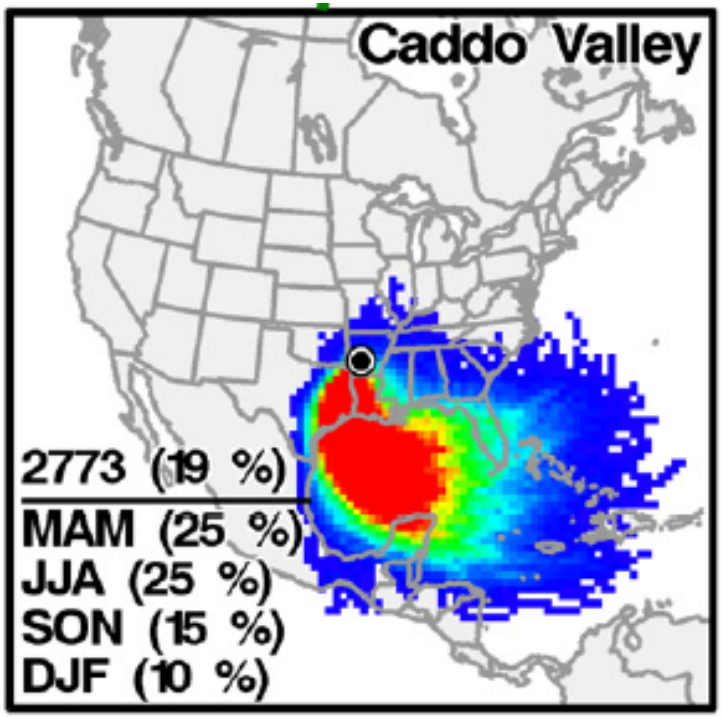




Cleanest 72-hour back trajectory cluster for Houston

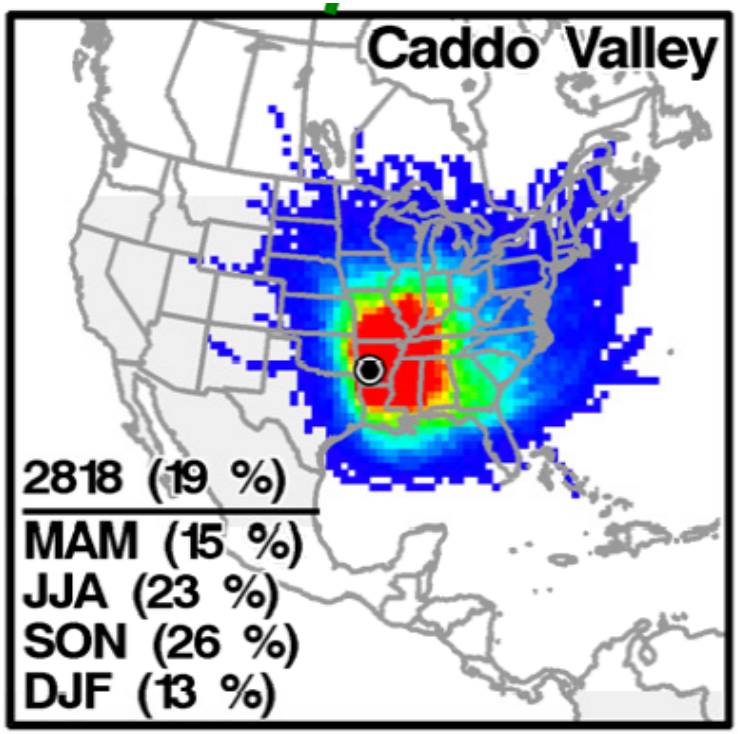
Dirtiest 72-hour back trajectory cluster for Houston

Continental transport is closely associated with higher regional background ozone than Gulf transport. From Sullivan, 2009.


Source at 29.76 N 95.36 W
37 ppb
3 ( 3%)
Mean background HGB-area ozone, by trajectory cluster
45 ppb
5 ( 12%)
36 ppb
6 ( 11%)
4 ( 22%)
41 ppb
1 ( 15%)
21 ppb
2 ( 36%)
25 ppb
From Sullivan, 2009



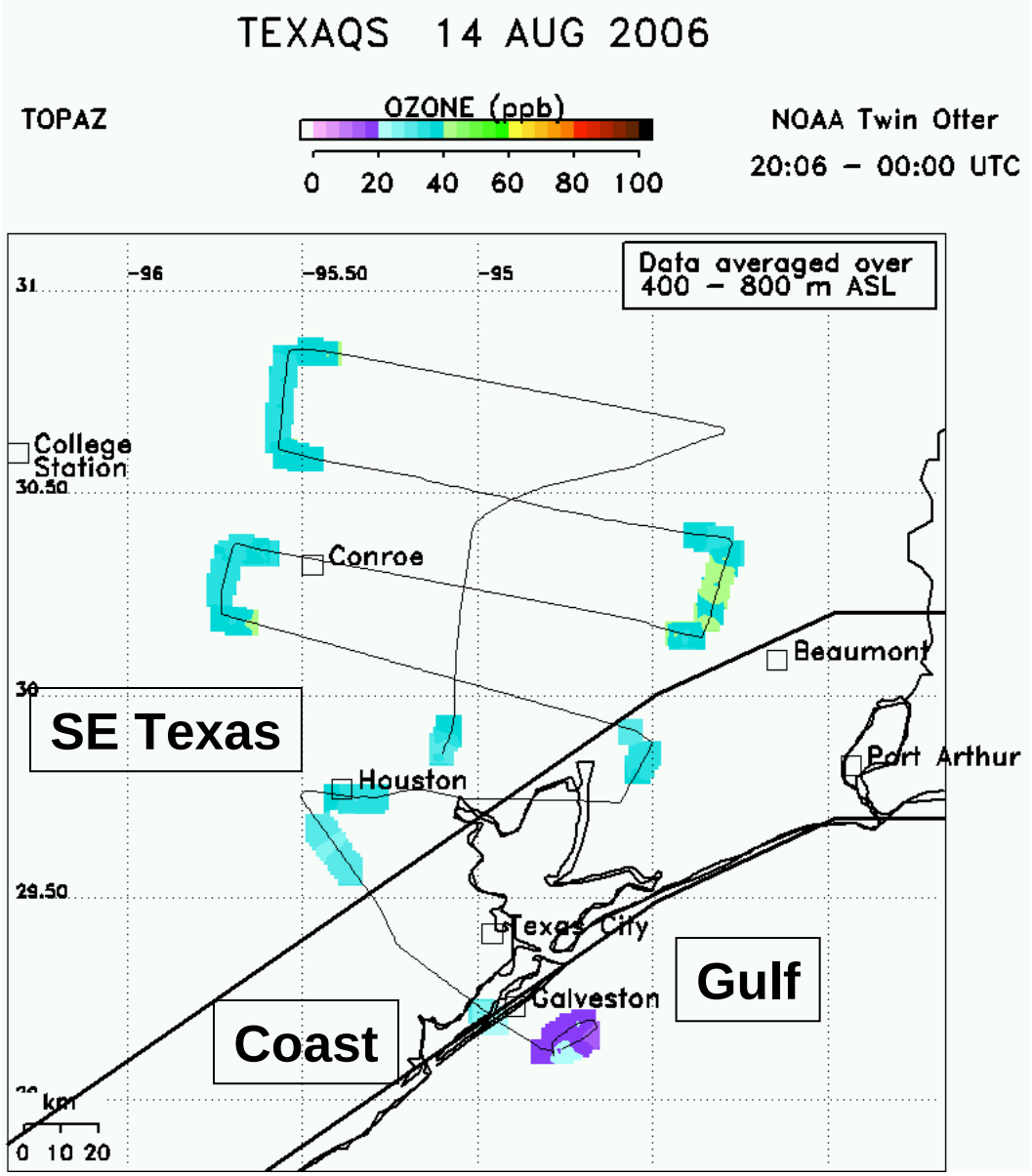

Cleanest trajectory cluster for Caddo Valley, AR




Dirtiest trajectory cluster for Caddo Valley, AR

Continental vs. Gulf relationship holds for other nearby locations. From Chan and Vet, 2009

# Background ozone measurements from lidar

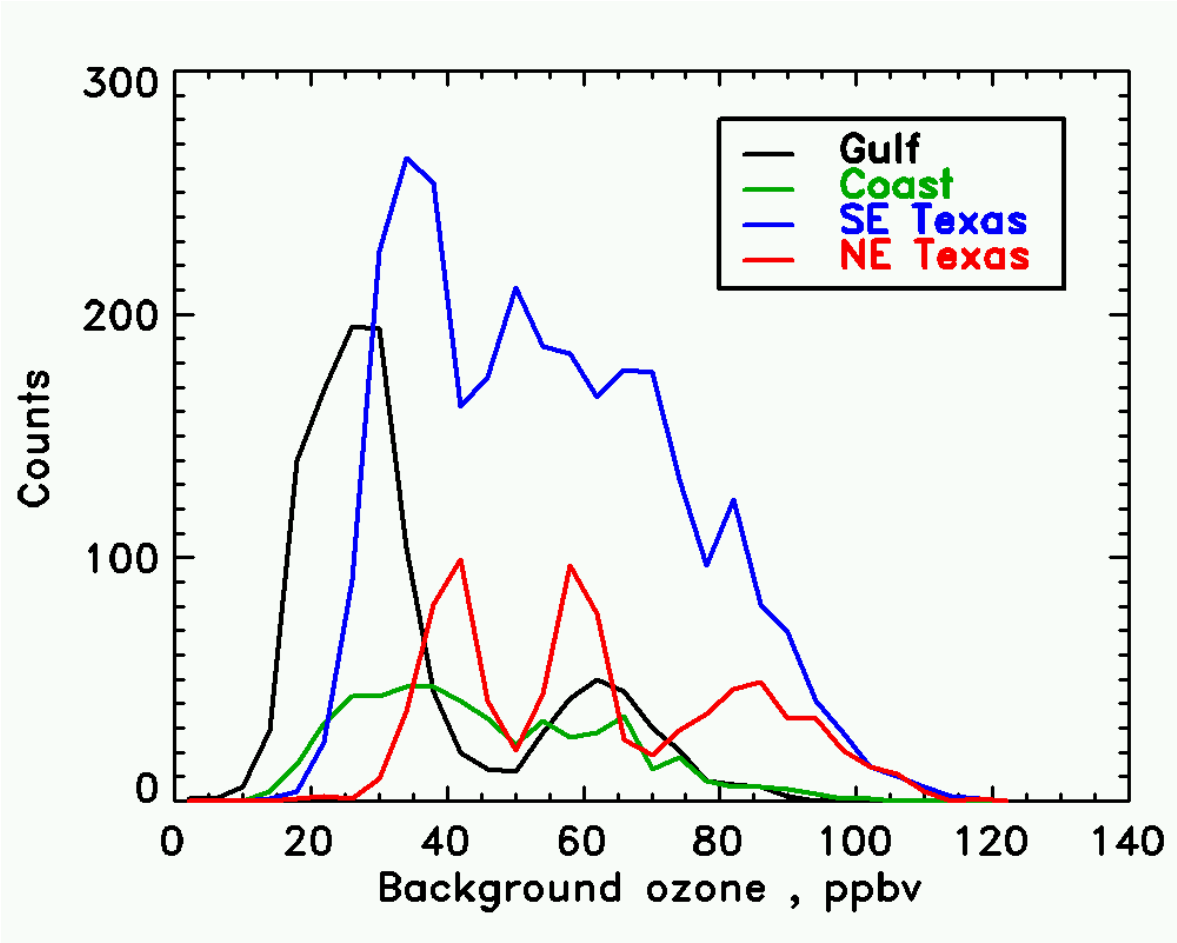



1) Average $O_3$ data between 400 and 800 m ASL

2) Remove $O_3$ plume data

3) Sort by region

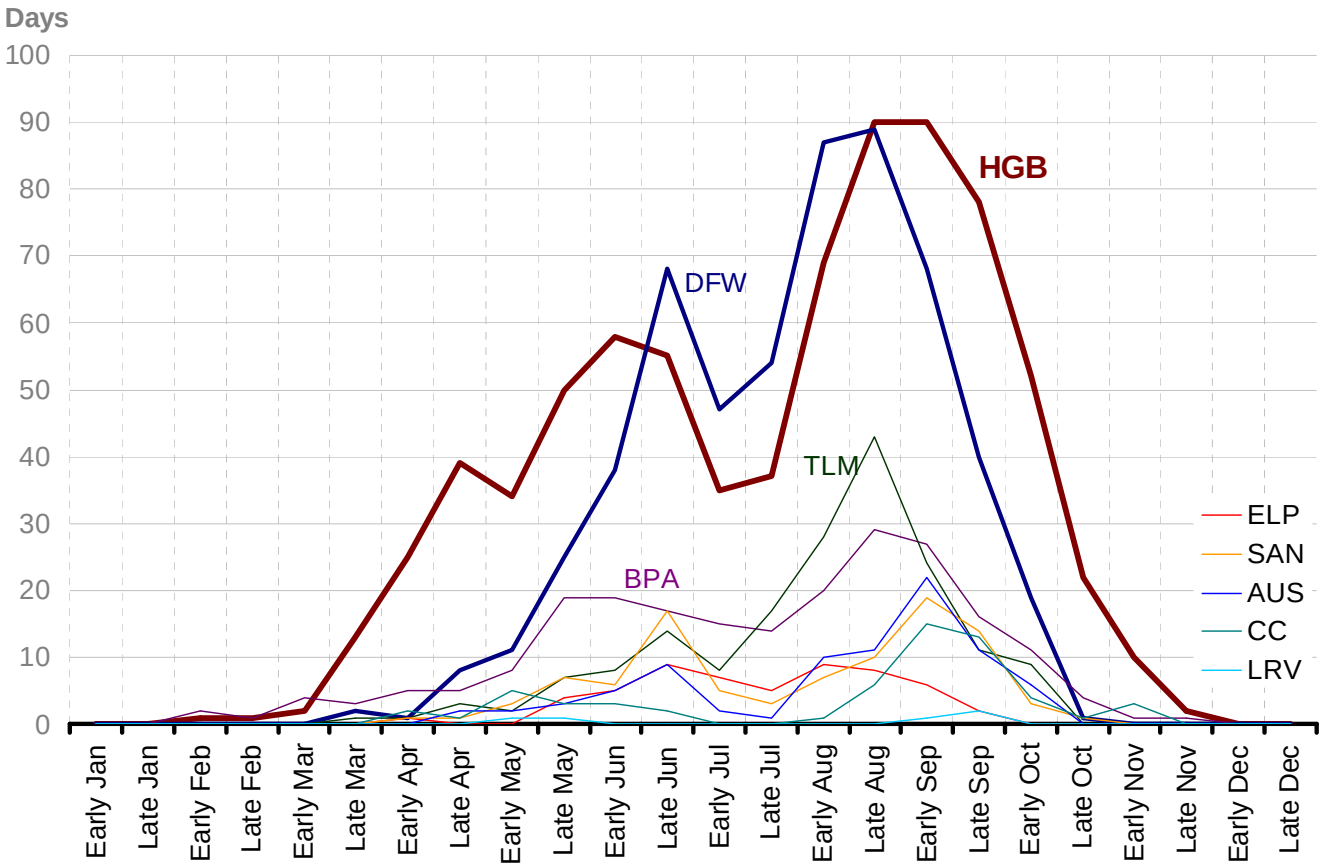
# Background ozone by region




| Region | Background $O_3$, ppbv |
|---|---|
| Gulf | 39 |
| Coast | 46 |
| SE TX | 51 |
| NE TX | 61 |

Data from all 21 TOPAZ flights

# Seasonal ozone in Texas
# Exceedance days from 1991-2008



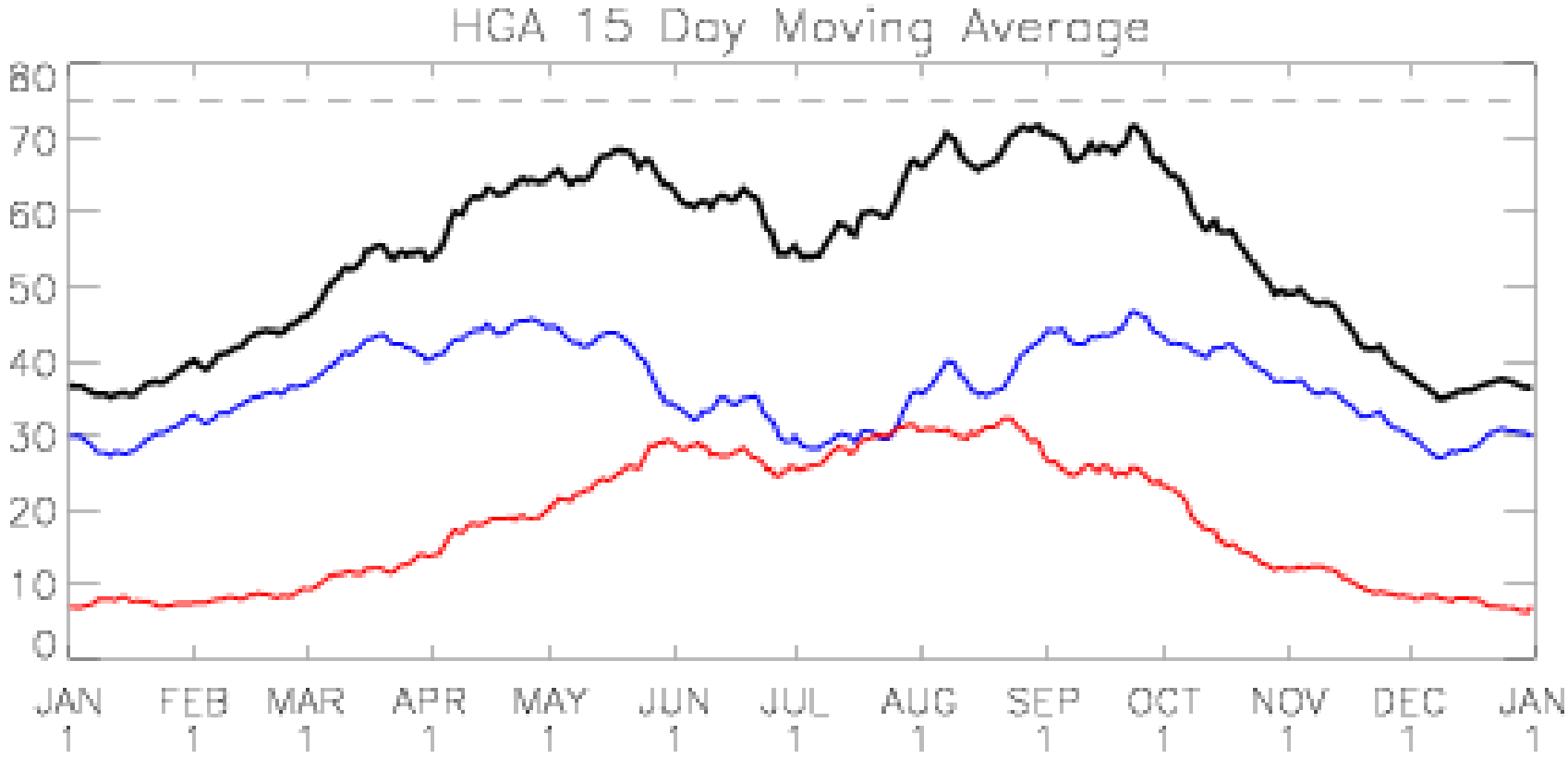

The number of days that ozone exceeds the NAAQS peaks in early June, followed by a higher, longer peak in late August and early September.

July tends to observe fewer exceedance days compared to the two peaks.

Other areas follow similar patterns, but with fewer exceedances.

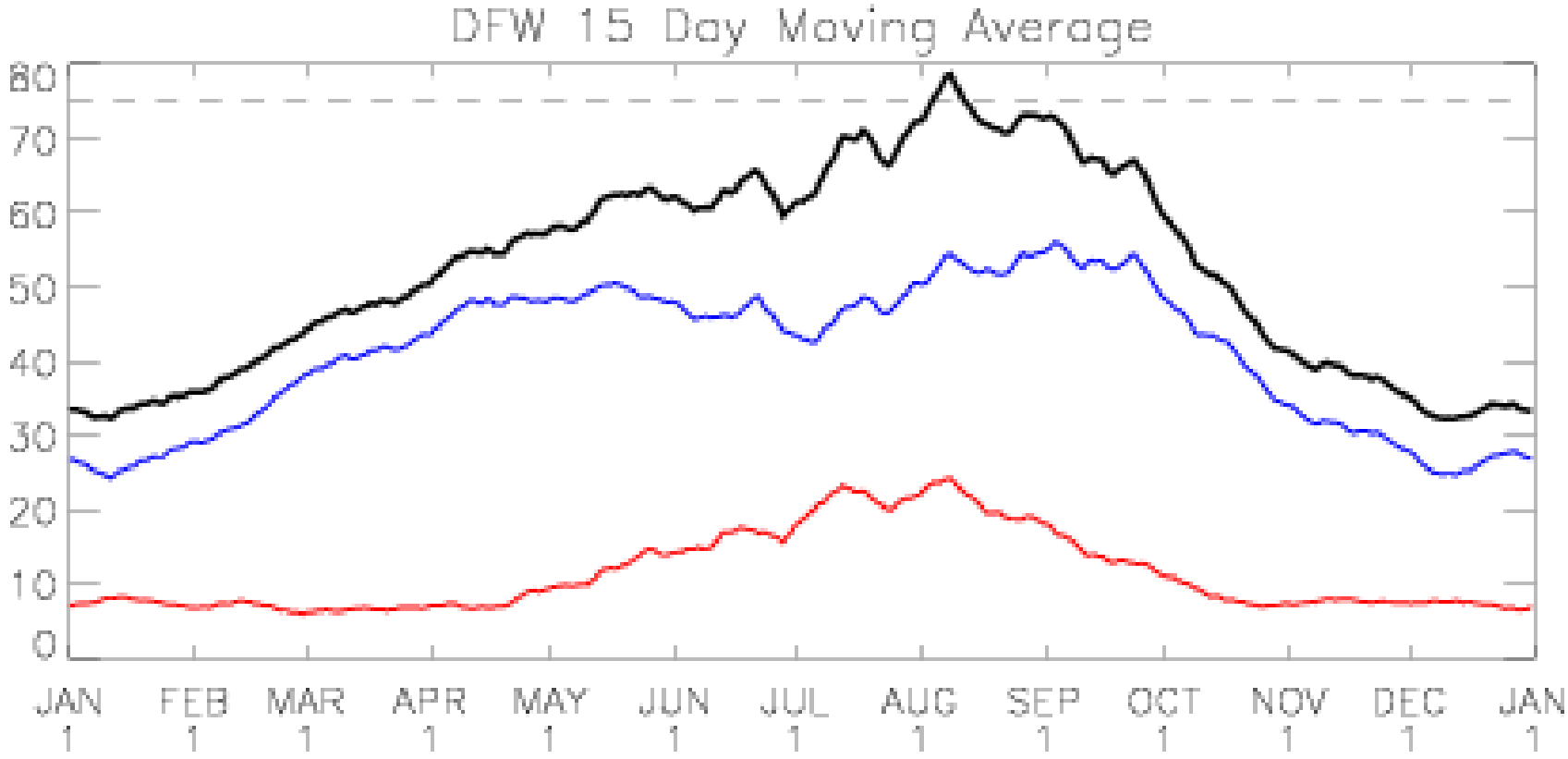
TCEQ Data Analysis Team

# Seasonal variations in background ozone in Houston



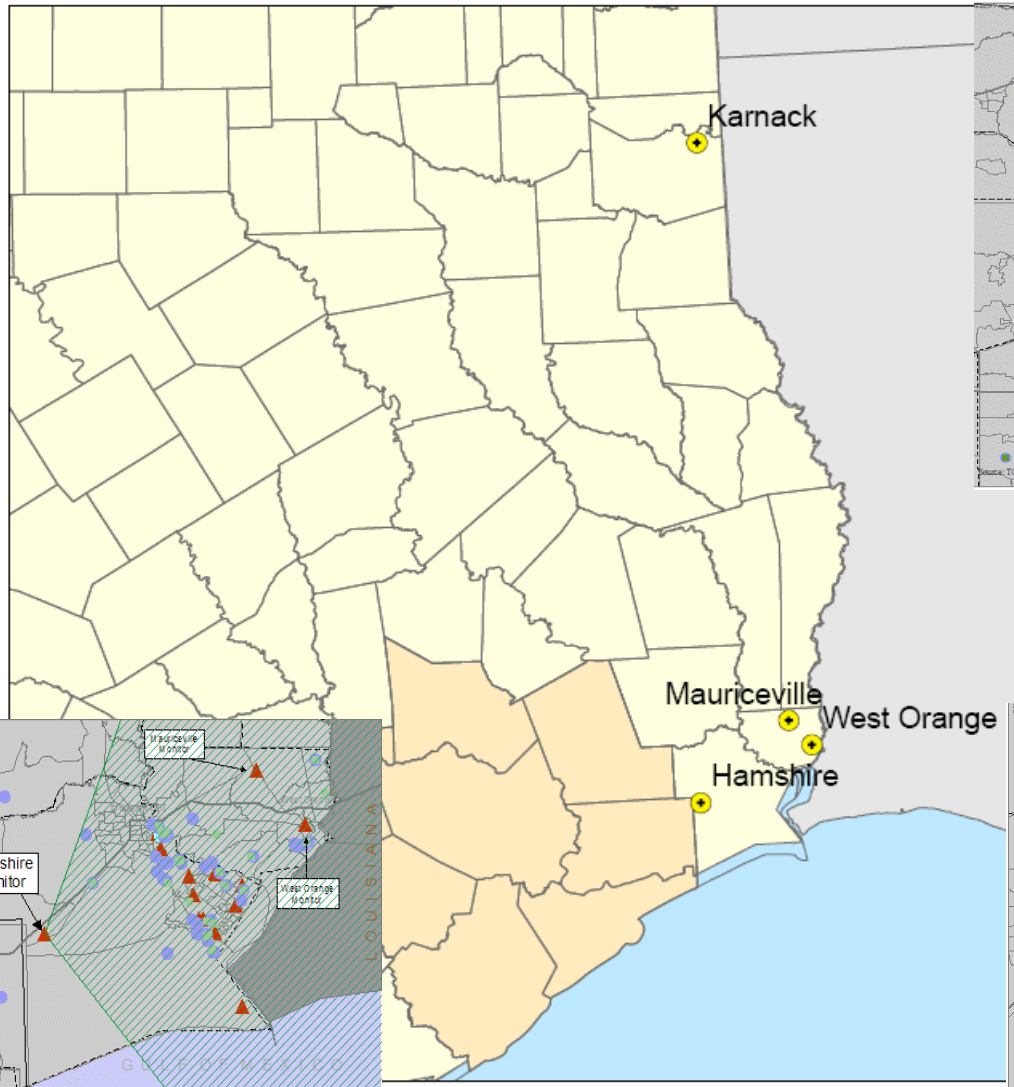

Tobin and Nielsen-Gammon (2010) have shown that background ozone (blue) in Houston peaks in May and again in September, but local contribution (red) peaks from June to September. The mid-summer dip may be related to flow from the Gulf, which is often strong during July.

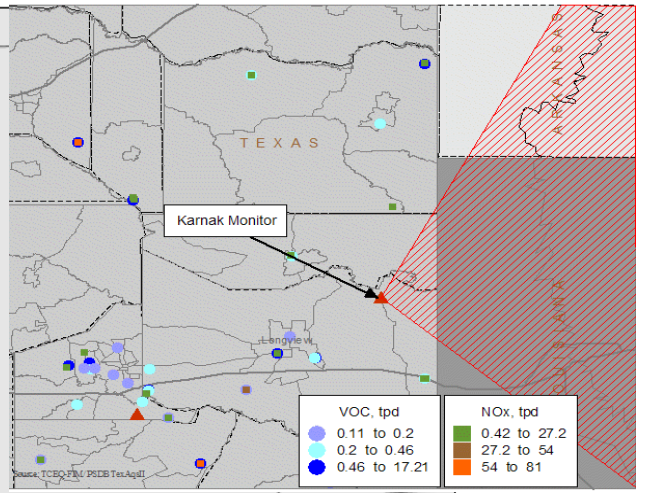
# Seasonal variations in background ozone in Dallas-Fort Worth

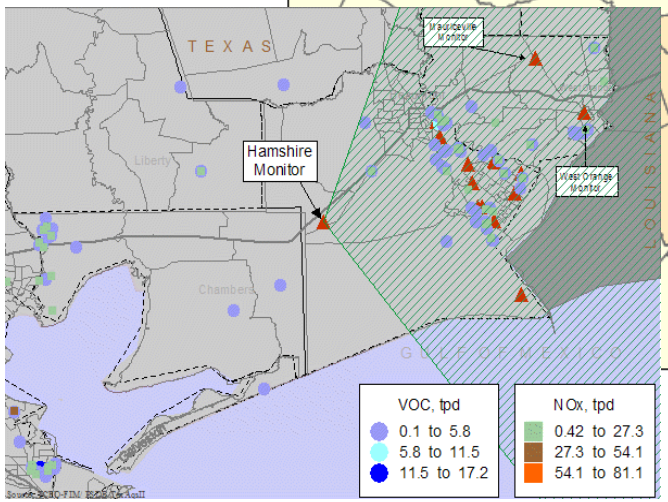


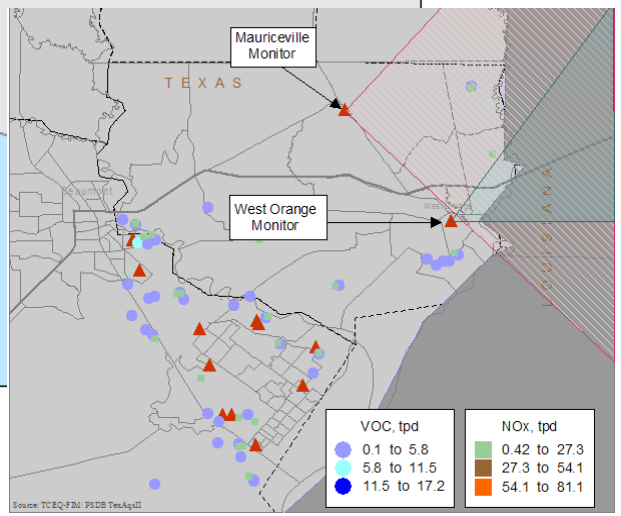

Tobin and Nielsen-Gammon (2010) have shown that background ozone (blue) in Dallas rises to about 50 ppb in April, and stays there until October, but local contribution (red) peaks from July to September.

# Map of background ozone sites for eastern Texas

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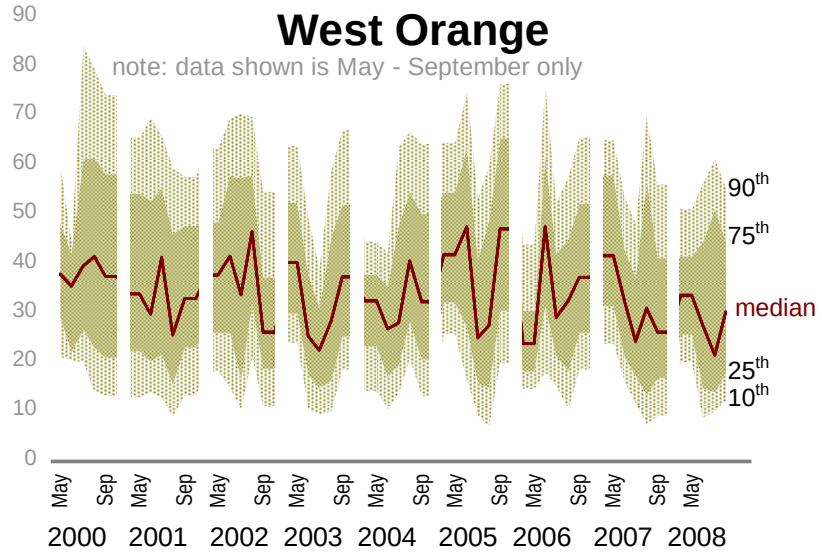
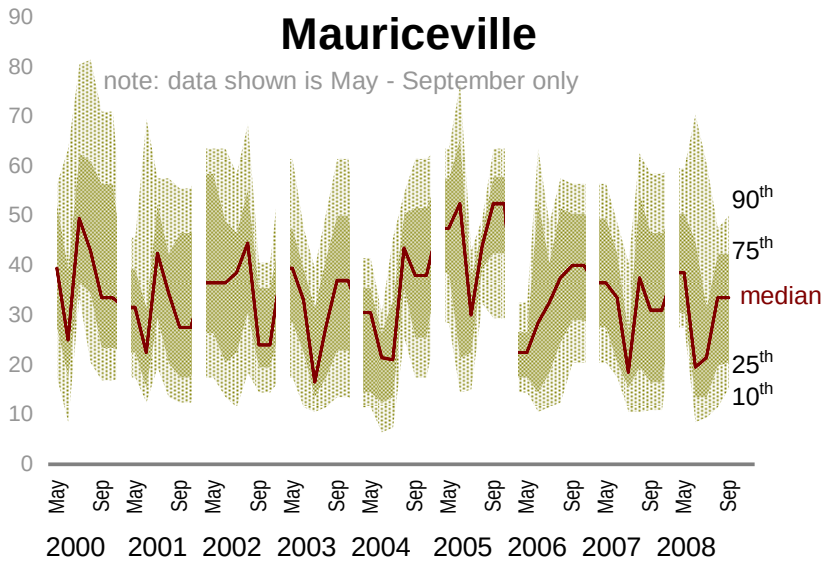
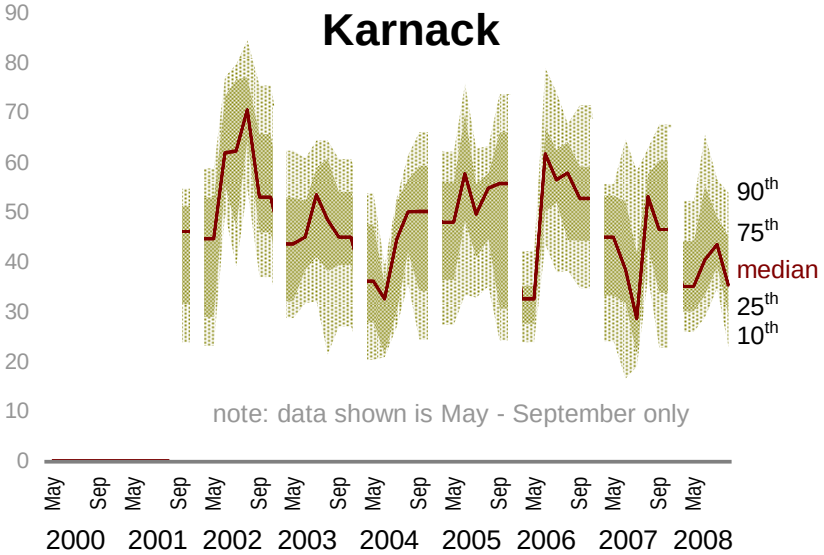
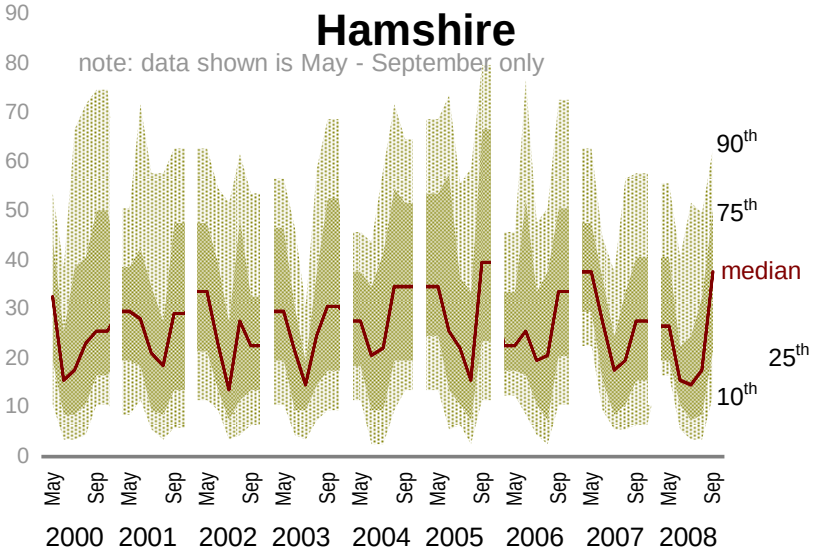
# Background Ozone Trends (TCEQ Data Analysis Team)



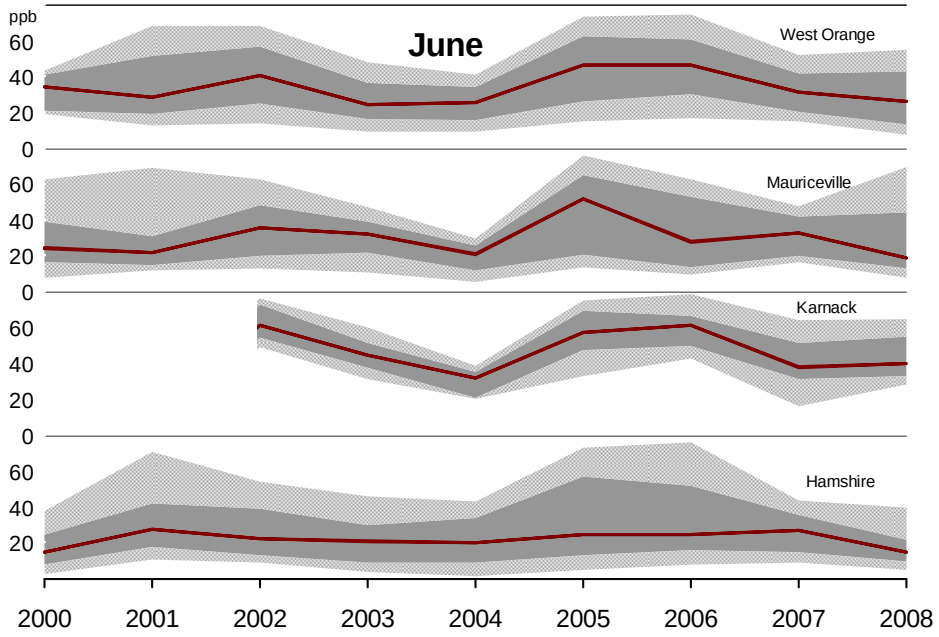



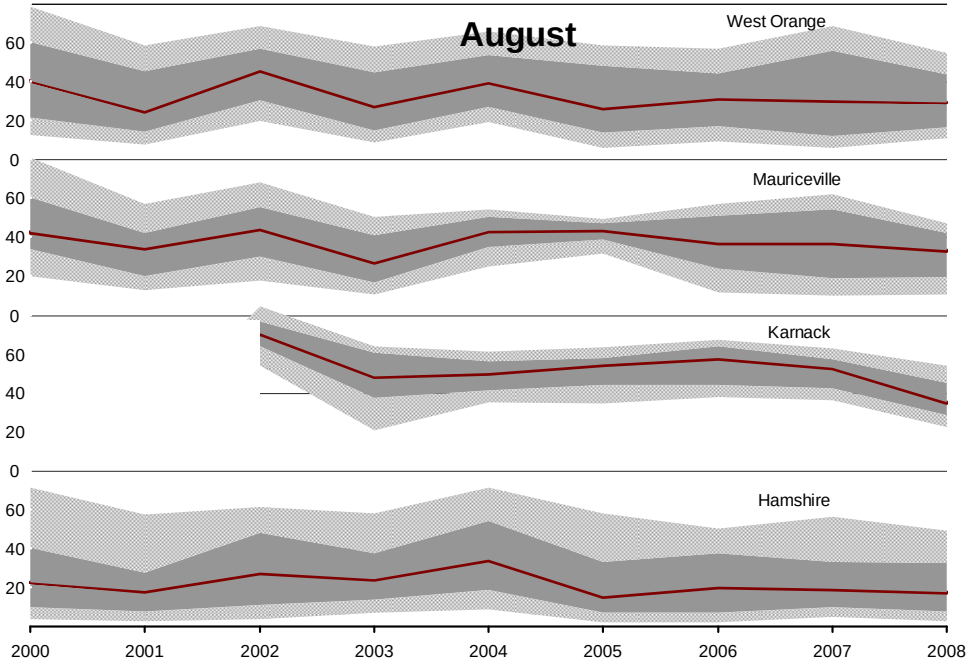



# Background Ozone Trends

Examining background ozone for individual months enables us to eliminate seasonal fluctuations.

Neither visual inspection nor statistical analysis of the data was able to confirm any trends.



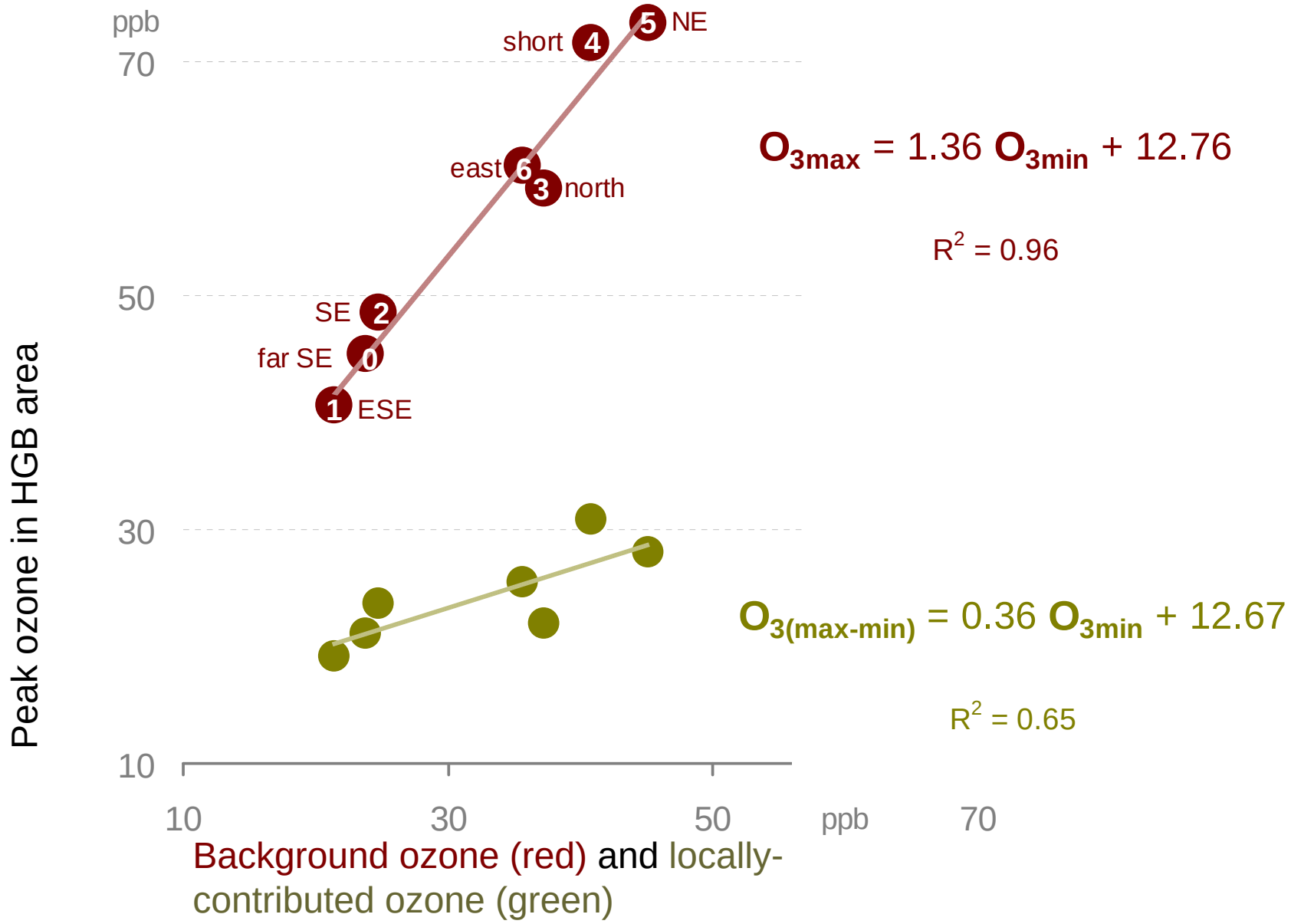




Thus, we conclude, there is no discernible trend in background ozone entering the HGB area.

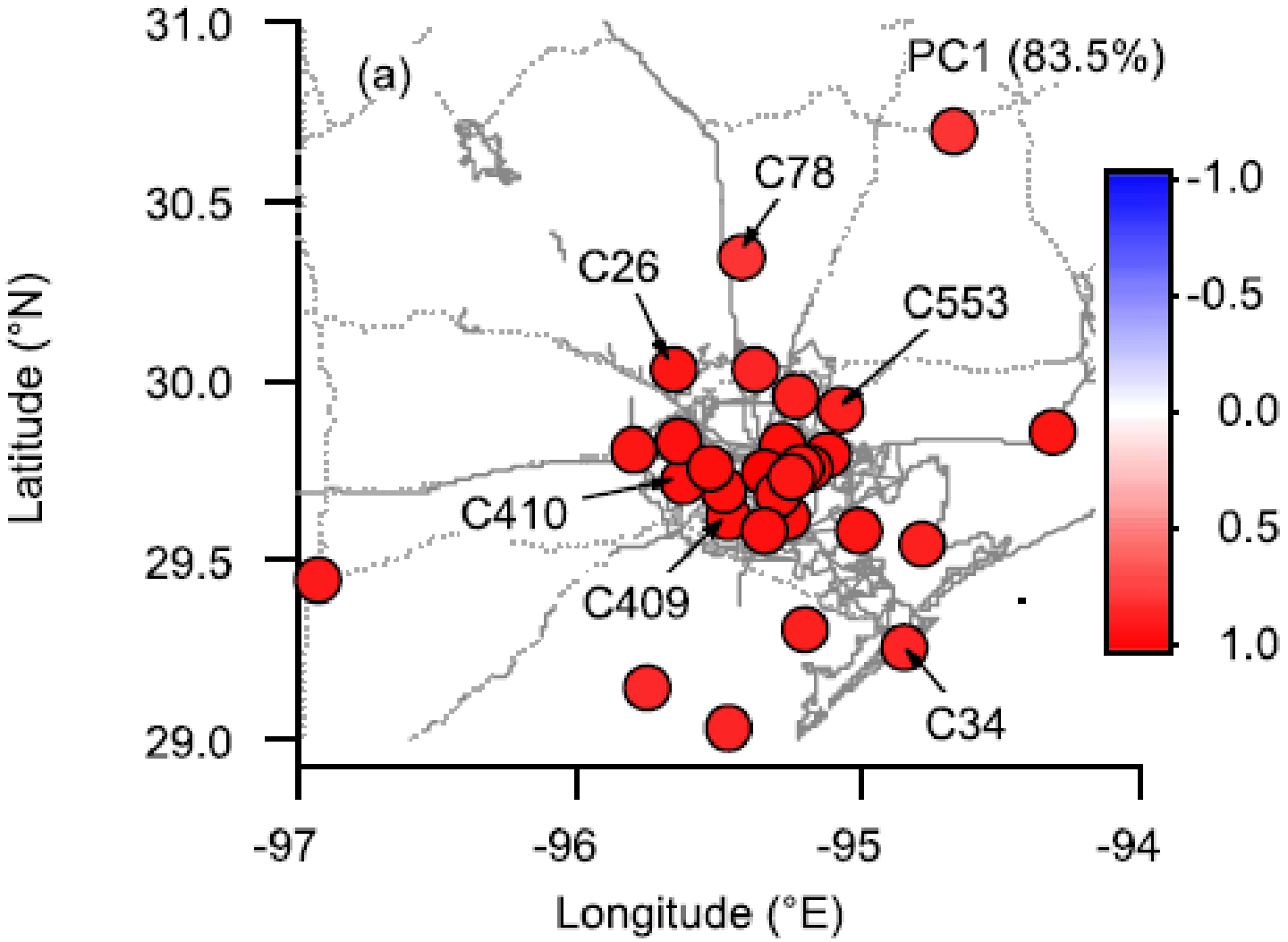
(TCEQ Data Analysis Team, 2009)

# Relationship between high ozone in cities and background ozone

- Sullivan (2009), Tobin and Nielsen-Gammon (2010), and Langford et al. (2009) all concluded that background ozone and high ozone in Houston are correlated.
- The reason for this correlation is not yet clear. Possible causes:
  - High background + constant local contribution pushes peak above NAAQS.
  - Transport pattern that brings high background interacts with bay/Gulf breeze, creating greater local production on top of greater background.

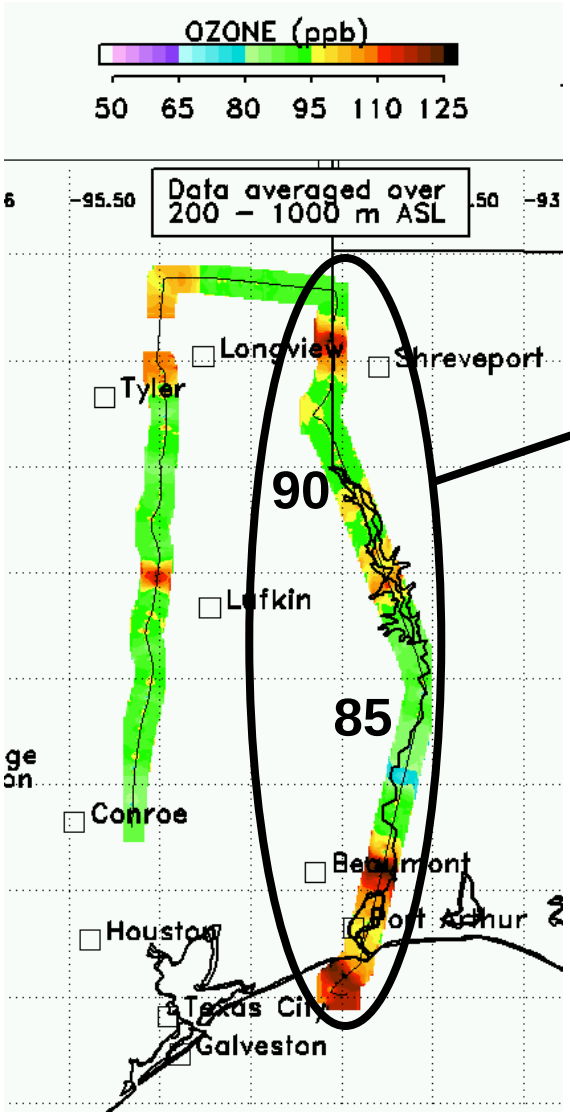


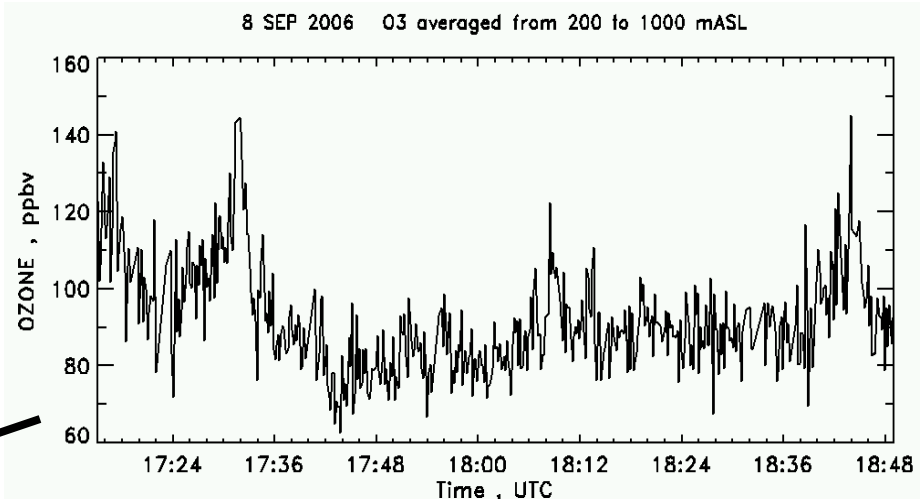

Both background and local contribution are affected by transport direction. Adapted from Sullivan, 2009.

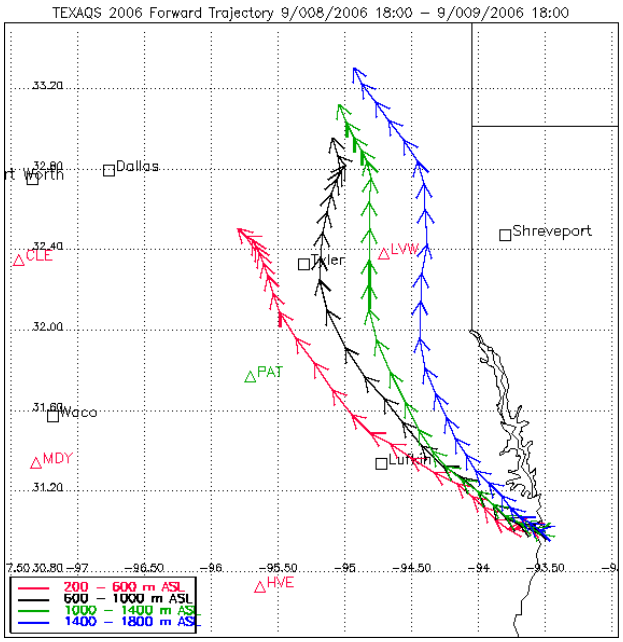



The result of an analysis of the patterns in measured ozone concentrations in Houston for Aug – Oct 2006. The largest principal component, explaining 83.5% of the variance in ozone concentrations, raises concentrations at all monitors at once, suggesting it is associated with regional background ozone. From Langford et al., 2009.

# An extreme example of high background ozone, September 8, 2006 (from Hardesty et al., 2007)



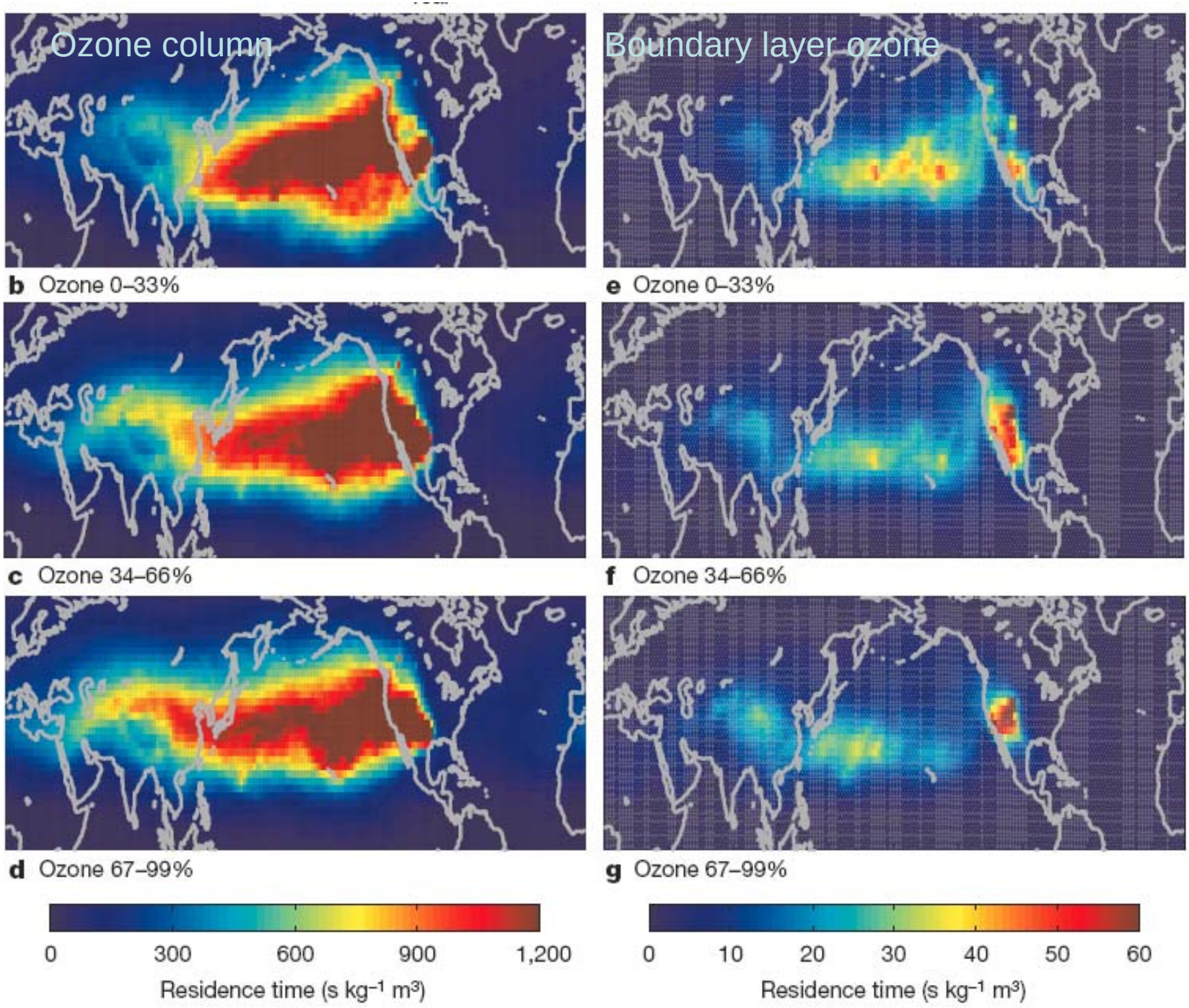



# Background ozone in Texas

- Background ozone varies greatly by transport pattern and by season.
- Background ozone affects ozone concentrations in eastern Texas cities.
- Background ozone entering the state from the Gulf is much lower than continental background.
- TCEQ analyses so far show no apparent trends in summertime background ozone.
- In Houston, the transport pattern affects both background ozone and the local contribution.

# Background ozone in the US

- Background ozone entering western North America has been increasing significantly.
- The most recent study (Cooper et al., 2010, *Nature*, 463, doi:10.1038/nature08708) found an upward trend of $0.63 \pm 0.34$ ppbv/year. This trend has been linked to transport from east and south Asia, across the Pacific.
- Trans-Pacific transport peaks in spring.
- Lightning NOx and biomass burning plumes can affect surface ozone, but not frequently in the eastern US.




From Cooper et al., 2010

**Table 3.** A comparison of the statistical methods used and the background ozone trend estimates focusing on Western Canada and US from three recent papers and this paper.

| Authors | Period | Location | Average metrics | Data screening method | Statistical method | Season | Trend estimate (ppb/year) |
|---|---|---|---|---|---|---|---|
| Oltmans et al. (2008) | 1988–2007, 1999–2007 | Western US | Daytime averages | Backward trajectory | Autoregressive model – a cubic polynomial for trend | Winter<br>Spring<br>Summer<br>Fall | No significant changes |
| Jaffe et al. (2007) | 1987–2004 | Western US (Rocky Mt., Yellowstone, Lasseon) | Daytime monthly means | N/A | Linear regression | Winter<br>Spring<br>Summer<br>Fall | +0.21 to +0.62<br>+0.33 to +0.59<br>+0.43 to +0.50<br>+0.28 to +0.56 |
| Parrish et al. (2009) | Various length covering (1974–2007) | West coast of the US | Monthly means | Local wind data | Linear regression | Winter<br>Spring<br>Summer<br>Fall | +0.43±0.17<br>+0.46±0.13<br>+0.24±0.16<br>+0.12±0.14 |
| This paper | 1997–2006 | Western Canada and the US | Daytime averages | Backward trajectory | Regional trend analysis using GLMM – long-term sinusoidal cycles (3 to 5 years) for trend | DJF (PC7)<br>MAM (PC10)<br>JJA (PC10)<br>SON (PC9) | +0.93±0.41<br>+0.28±0.26<br>+0.72±0.55<br>No significant changes |

Table from Chan and Vet shows several studies that indicate significant upward trends in background ozone along west coast of North America, with the highest trends generally in the winter and spring.

# Some remaining questions about background ozone in Texas

- Is there a trend in the background ozone transported from the Gulf of Mexico into Texas?
- What are the relative roles of background ozone and local contribution during ozone episodes in Texas cities?
- What is the regional background ozone in Texas cities relevant to design values and attainment status?  How does it differ from EPA-defined “policy relevant background?” How does it vary by season and transport pattern?