An evaluation of the spatio-temporal characteristics of meteorologically-adjusted ozone trends in North Texas

A preliminary analysis
by

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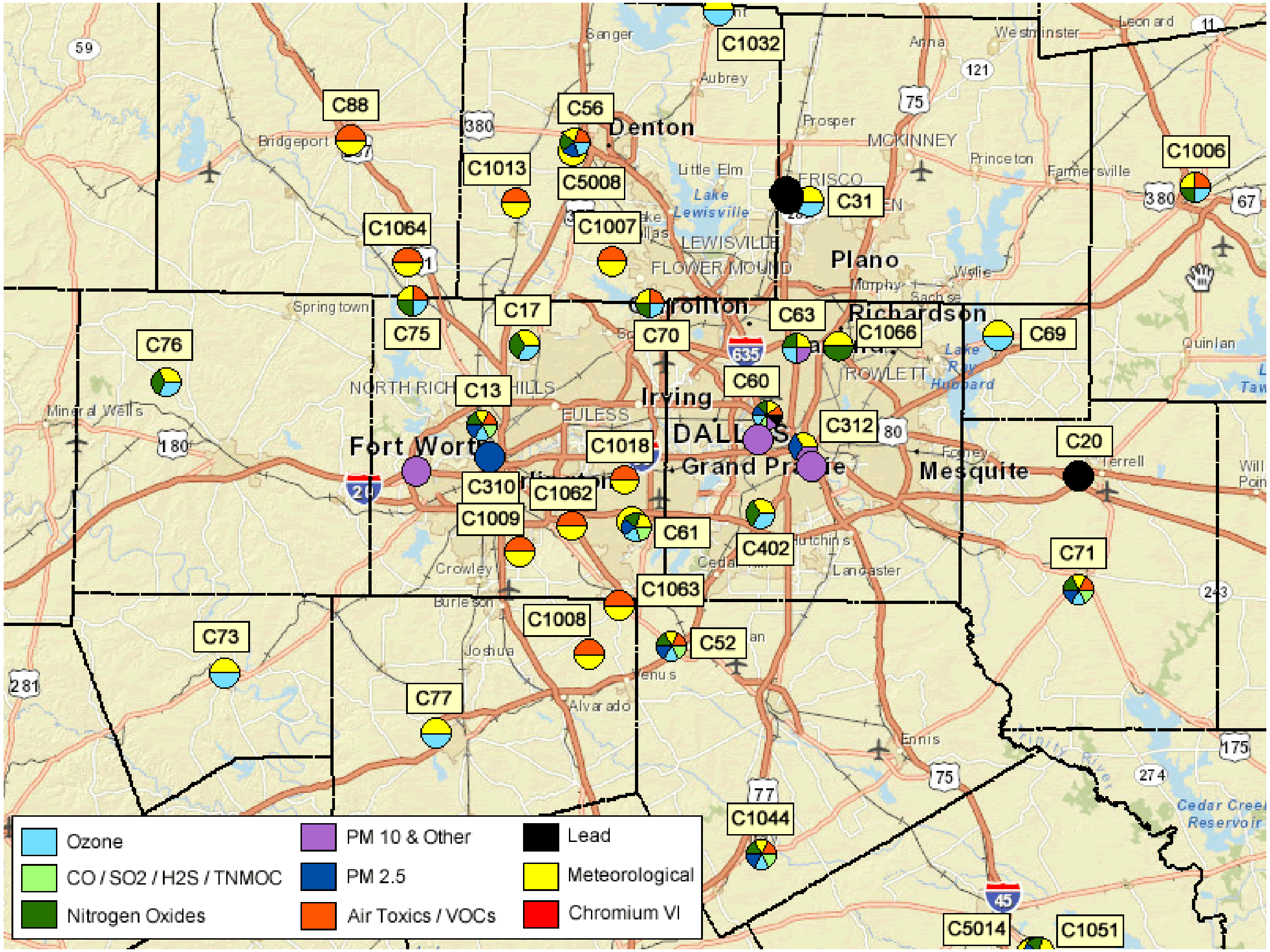
The Research

- Study objective: Evaluate the meteorologically adjusted trends in the measured ozone concentrations in north Texas
- Study area: North Texas region including DFW *metroplex*
- Study period: 1997-2014 (12-17 years worth of data)
- Air quality data: Ozone and meteorological parameters
- Number of air quality monitoring sites: 16 CAMS operated by TCEQ
- Method: Statistical analysis of raw ozone data (*part I*) and meteorologically adjusted ozone trend using KZ-filtering method (*part II*)

TCEQ CAMS : North Texas Sites

Current ozone level



Source: https://www.tceq.texas.gov

Data

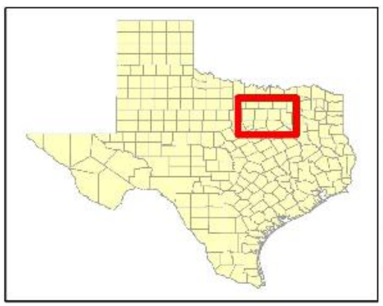
- Time series of 8-hr average ozone concentrations were extracted from TCEQ's Texas Air Monitoring Information System (TAMISWeb) for the 1997-2014 period (some of the monitoring stations were activated later than 1997) at sixteen state operated Continuous Ambient Monitoring Stations (CAMS).

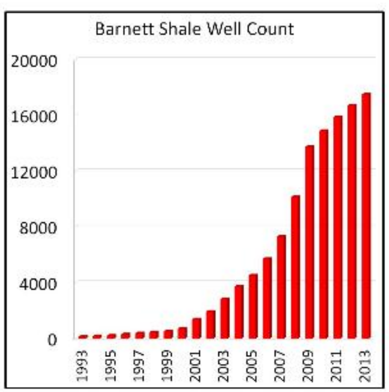
- In addition to the 8-hr ozone data, hourly and 8-hr averaged values of meteorological parameters for the same period were also acquired. Meteorological data include ambient temperature (T), solar radiation (SR), relative humidity (RH), and wind speed and direction (W).

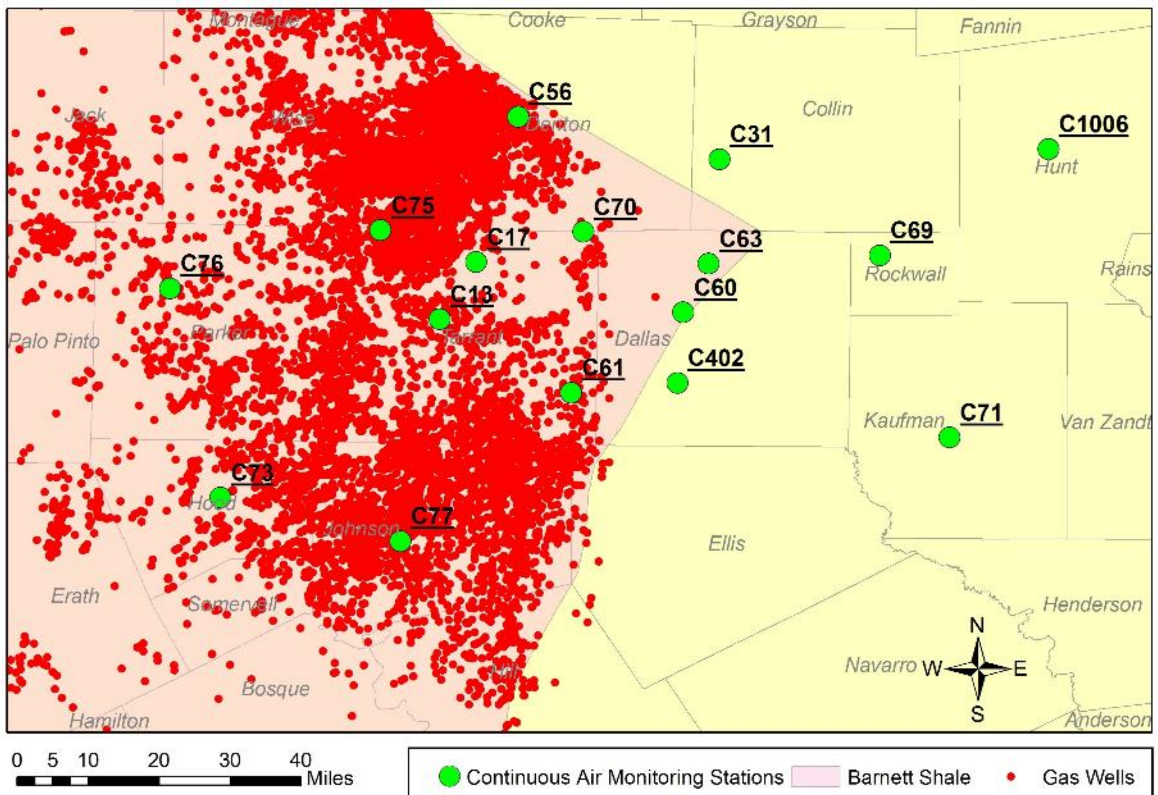
- Time series of the daily maxima of all parameters were compiled and used in this study to evaluate the meteorologically adjusted trends in the ozone concentrations over the north Texas region.

Study Area

- Total number of gas wells:
  - At the end of 2007: 5720 wells
  - At the end of 2013: 17,494 wells
- Rate: 713 wells/year (between 2000-2006), and 1682 wells/year (2007-2013)







Source: RRC and TCEQ

Monitoring Sites

CAMS #	Name	County	Parameters	No. of wells - 10 mi
C76	Parker County	Parker	O_3, SR, T, W	158
C73	Granbury	Hood	O_3, SR, T, W	428
C75	Eagle Mountain	Tarrant	O_3, SR, T, W	2723
C77	Cleburne Airport	Johnson	O_3, SR, T, W	1474
C13	Ft. Worth Northwest	Tarrant	O_3, SR, T, RH, W	1092
C17	Keller	Tarrant	O_3, SR, T, W	1364
C56	Denton Municipal Airport	Denton	O_3, SR, T, RH, W	1362
C61	Arlington Muni. Airport	Tarrant	O_3, SR, T, W	862
C70	Grapevine Fairway	Grapevine	O_3, SR, T, RH, W	299
C402	Dallas Executive Airport	Dallas	O_3, T, W	1
C60	Dallas Hinton St.	Dallas	O_3, SR, T, RH, W	2
C63	Dallas North No. 2	Dallas	O_3, SR, T, W	2
C31	Frisco	Collin	O_3, SR, T, W	0
C69	Rockwall Heat	Rockwall	O_3, SR, T, W	0
C71	Kaufman	Kaufman	O_3, SR, T, RH, W	0
C1006	Greenville	Hunt	O_3, SR, T, W	0

“Fracking region” (FR)

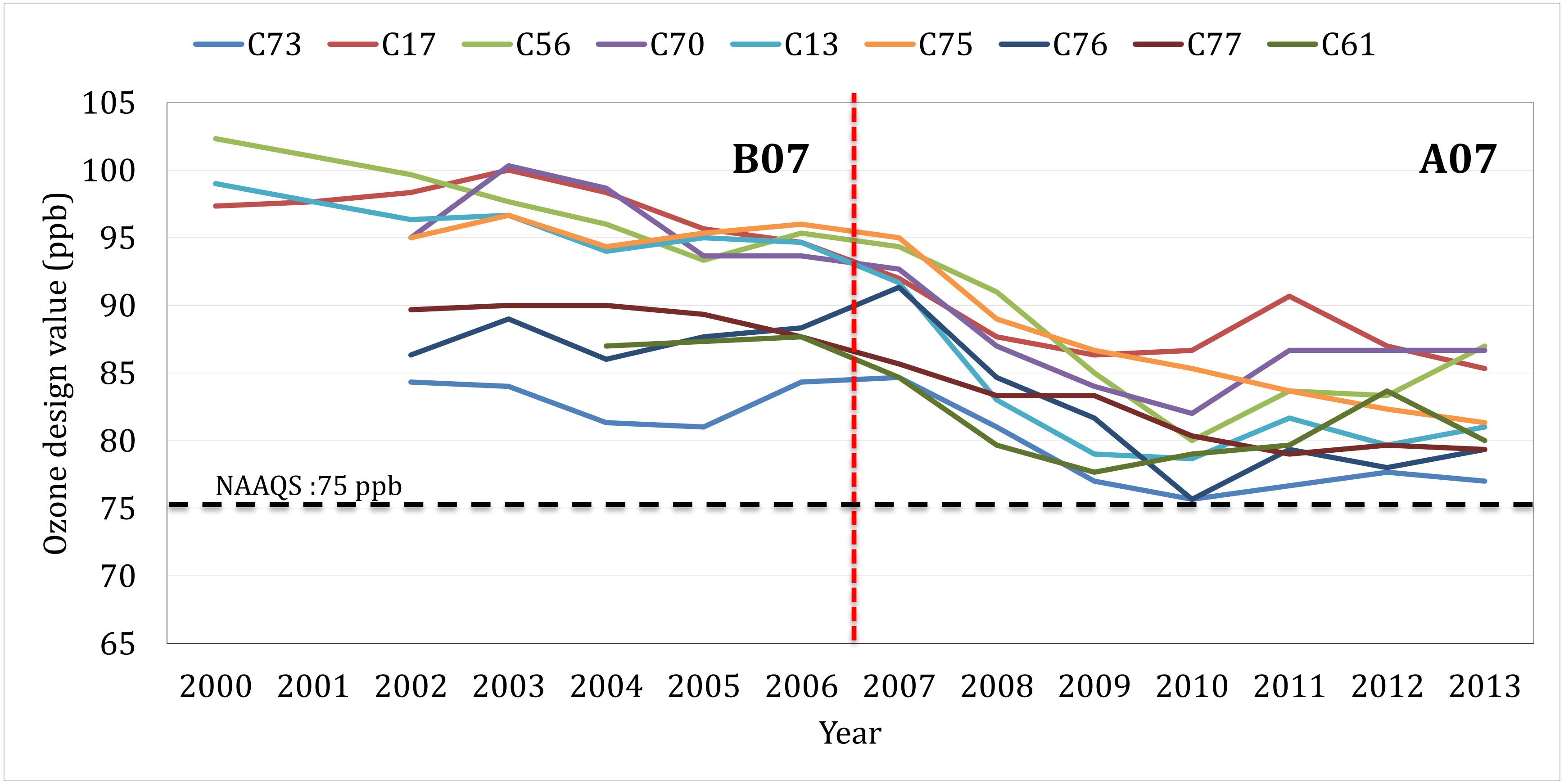
“Non-fracking region” (NFR)

Methods

- **Part I:** Statistical evaluation of trends in the raw ozone data
  - *Ozone design value*: "the 3-year average annual fourth-highest daily maximum 8-hour average ozone concentration"
  - *Ozone exceedances*: Number of days with maximum 8-hour ozone concentration exceeding NAAQS threshold (75 ppb)
- Evaluations performed for the **FR** and **NFR** regions over two contiguous periods: 2000-2006 (**B07**) and 2007-2013 (**A07**)

Results – Part I

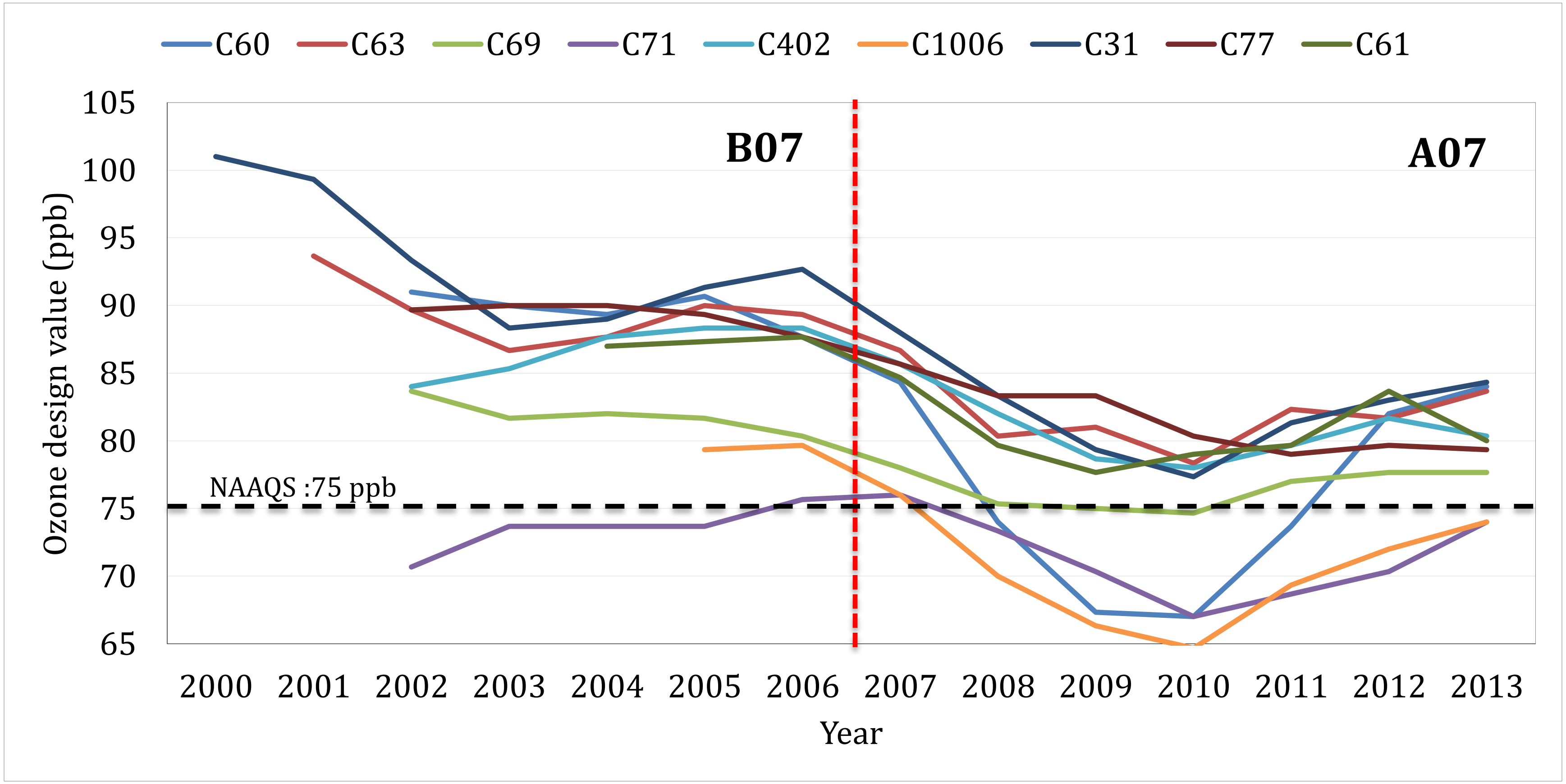
- Trend in the ozone design values within **FR**



- Average percent change from **B07** (2000-2006) to **A07** (2007-2013): **-10%**

Results – Part I

➢ Trend in the ozone design values within **NFR**



➢ Average percent change from **B07** (2000-2006) to **A07** (2007-2013): **-10%**

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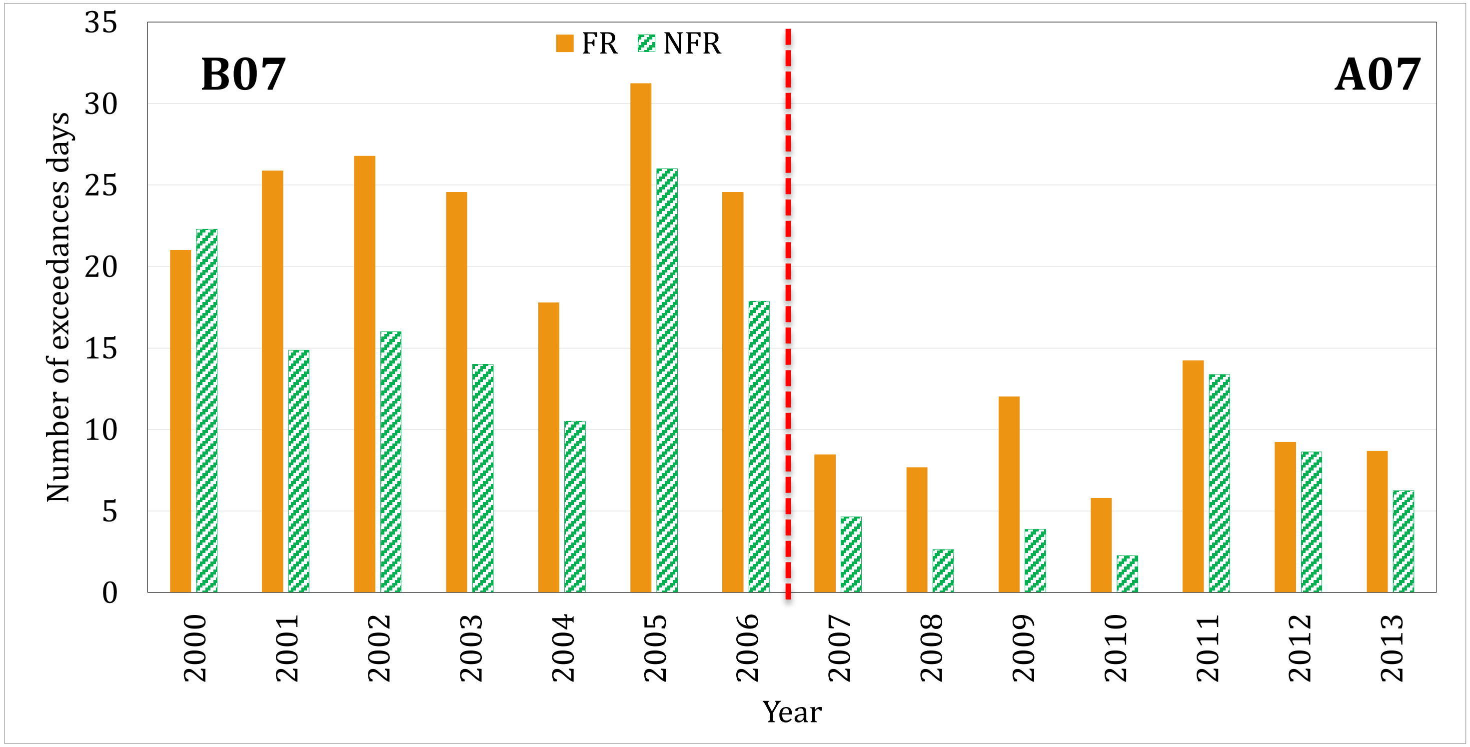
Results – Part I

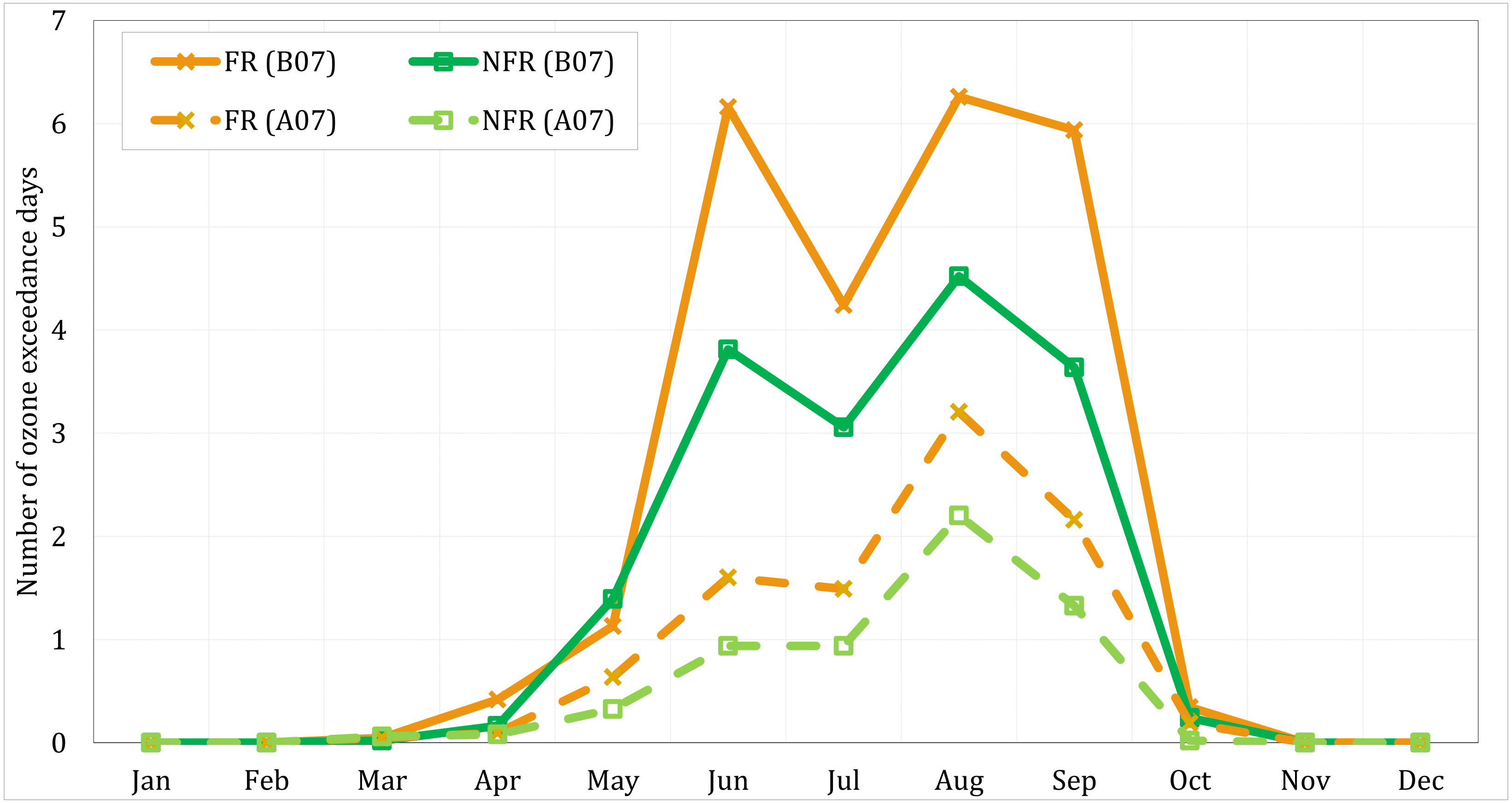
- Annual trend in the average number of exceedance days (> 75 ppb)



- Average percent change from **B07** (2000-2006) to **A07** (2007-2013):
  - Fracking region: **-61.6%**
  - Non-fracking region: **-65.7%**

Results – Part I

- Number of average ozone exceedance days by month (> 75 ppb)



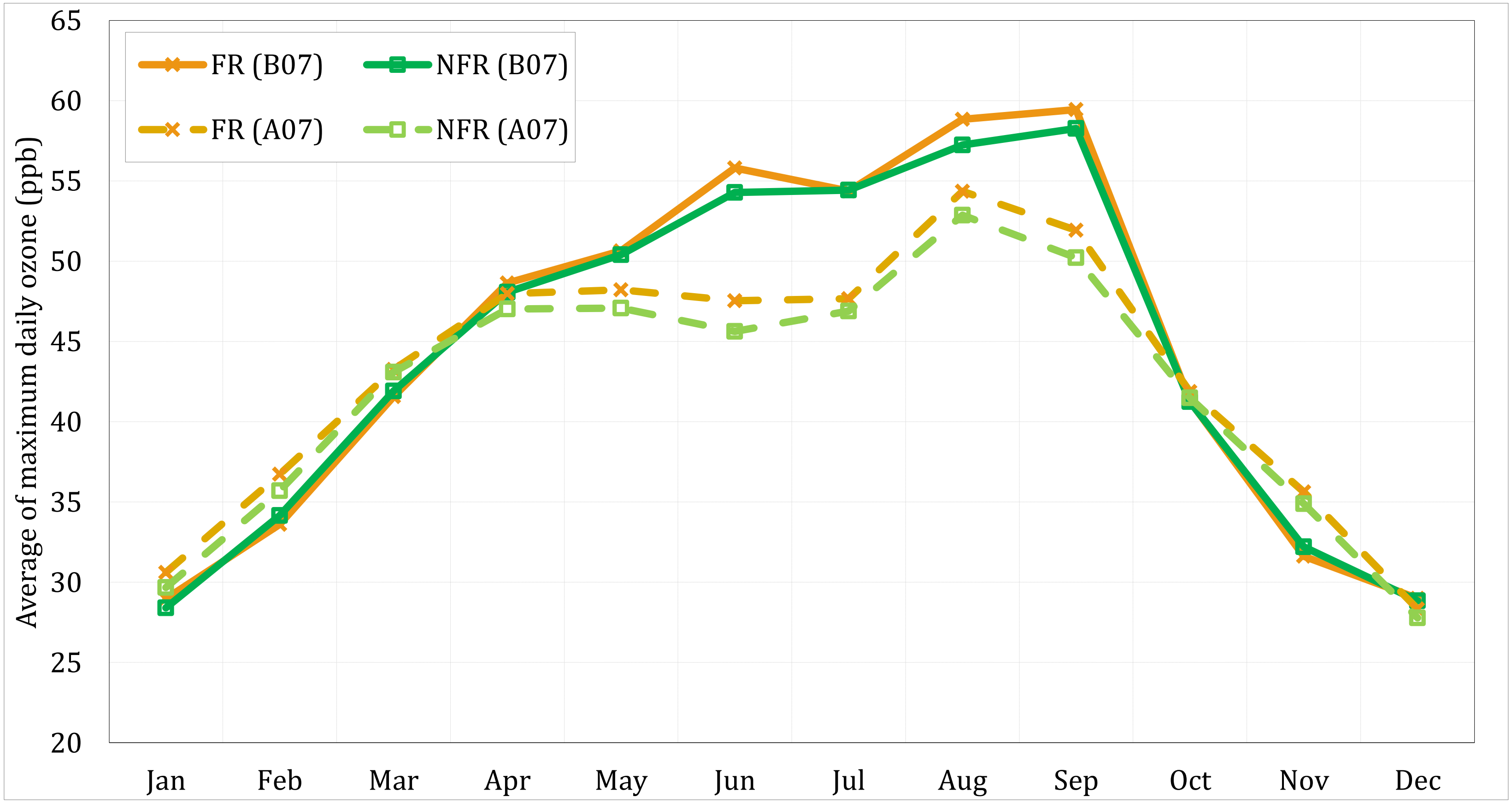
Results – Part I

- Average percent change of ozone exceedances between 2000-2006 (**B07**) and 2007-2013 (**A07**)

Time period	Ozone exceedances (75 ppb threshold)	
	FR	NFR
May	-47%	-78%
Jun	-74%	-76%
Jul	-66%	-72%
Aug	-49%	-54%
Sep	-64%	-64%
Whole year	-61.6%	-65.7%

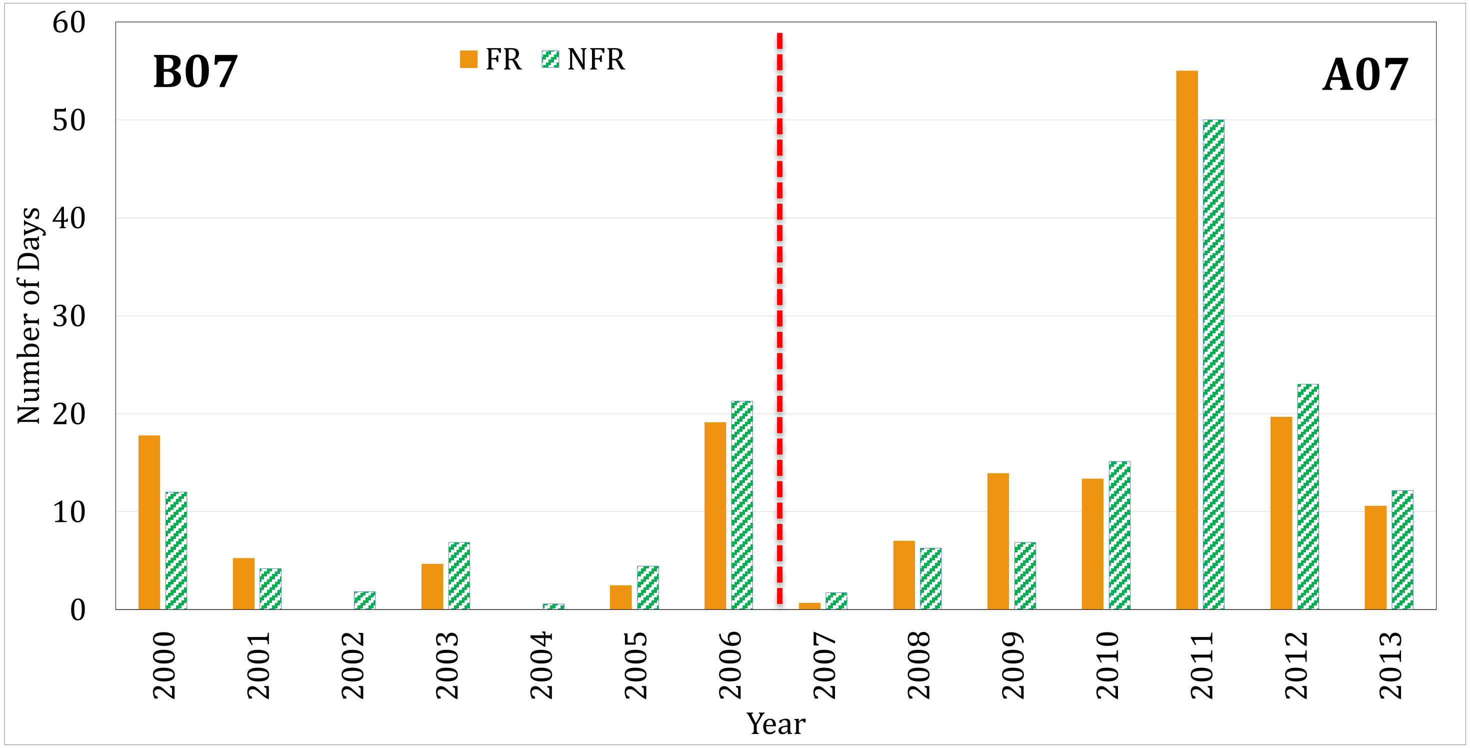
Results – Part I

➢ Trend of the average of maximum daily ozone values by month



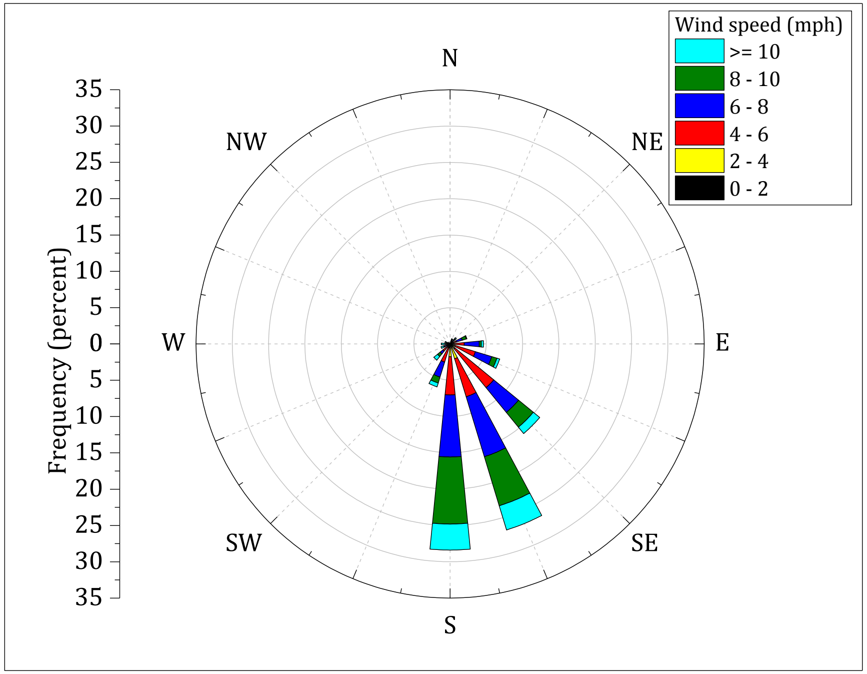
Results – Part I

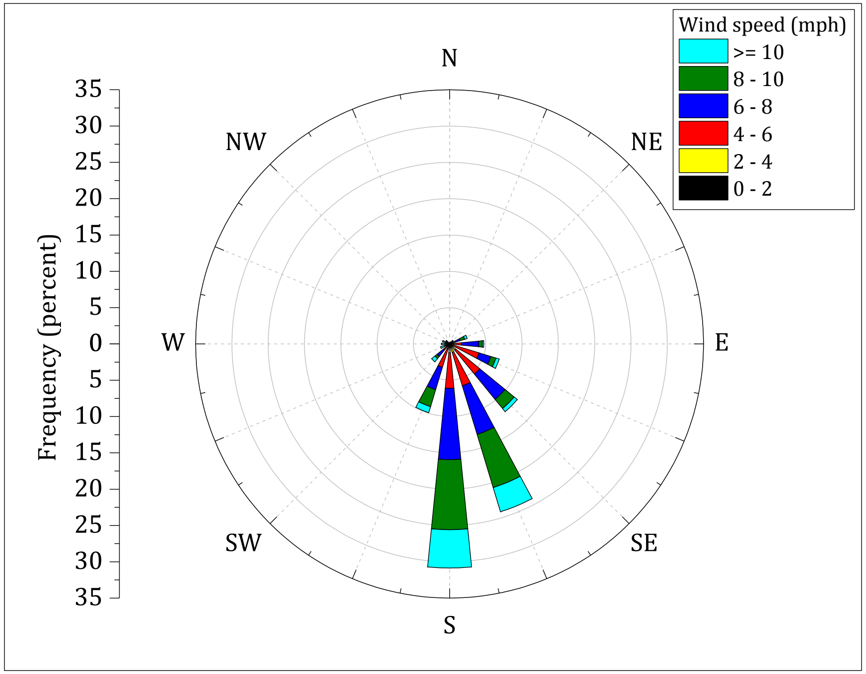
- Number of days with temperatures exceeding 100 F



Results – Part I

- Wind rose for **CAMS 13** (Ft. Worth Northwest) (May, Jun, Jul, Aug, Sep)

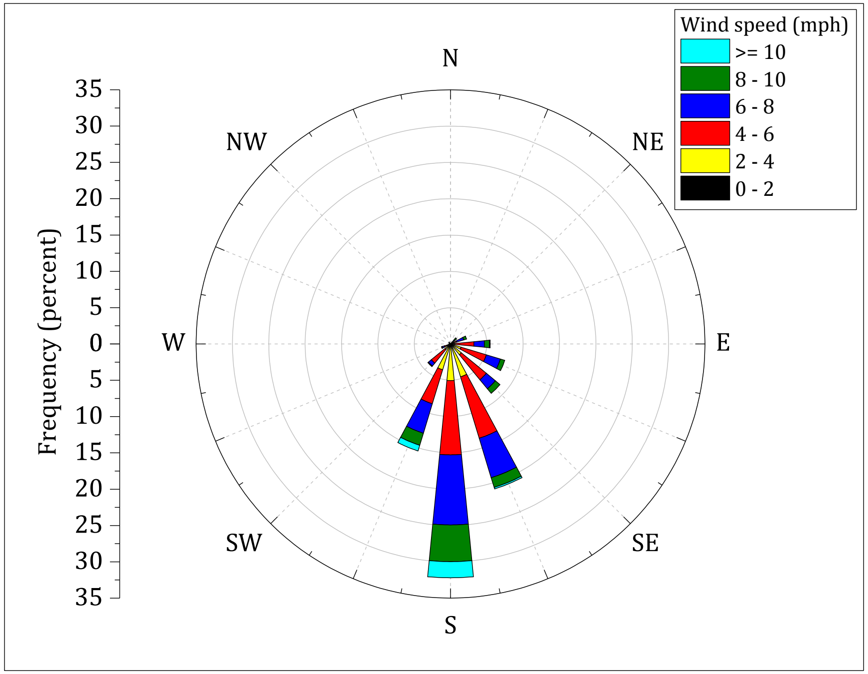


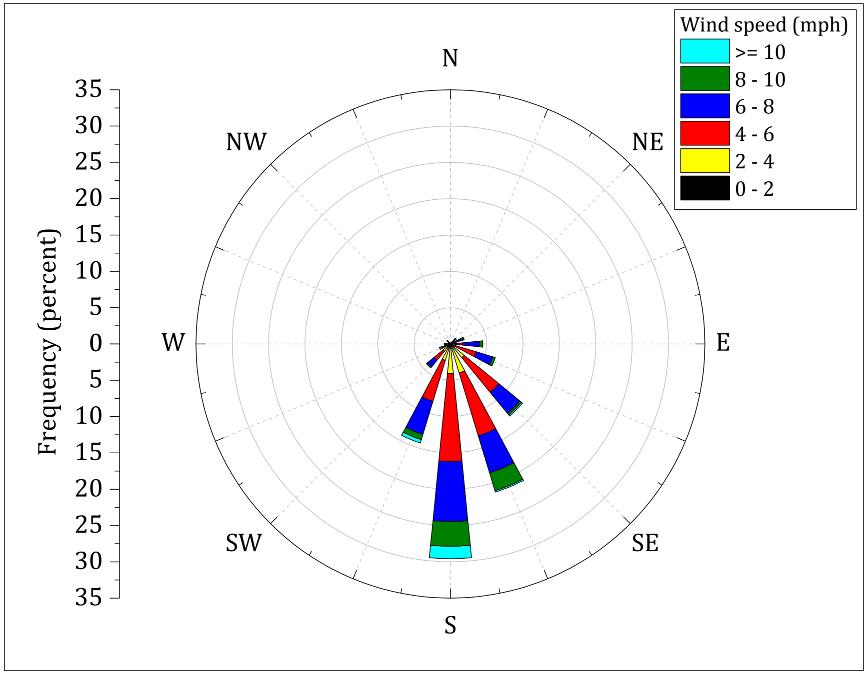


- **B07** (2000-2006)
- **A07** (2007-2013)

Results – Part I

- Wind rose at **CAMS 60** (Dallas, Hinton St.) (May, Jun, Jul, Aug, Sep)





- **B07** (2000-2006)
- **A07** (2007-2013)

Meteorologically Adjusted Ozone

- **Part II:** Statistical evaluation of trends of meteorologically adjusted (M.A.) ozone

  - *Construction of M.A. ozone:* application of Kolmogorov-Zurbenko (KZ) filter

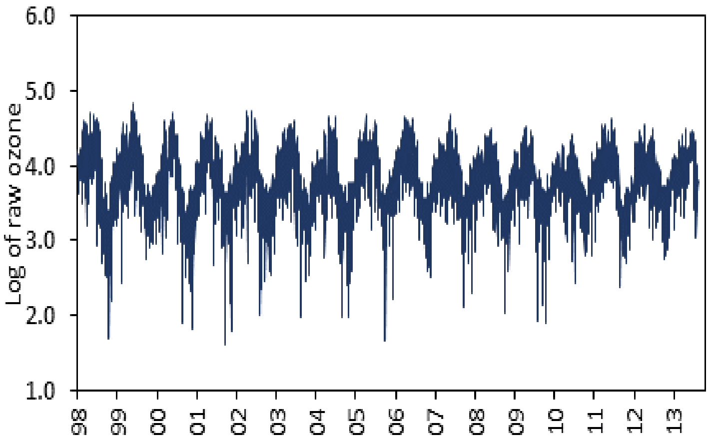
  - *M.A. ozone trends*: statistical evaluation of total, long-term, and baseline M.A. ozone

- Evaluations performed for the **FR** and **NFR** regions over two contiguous periods: 2000-2006 (**B07**) and 2007-2013 (**A07**)

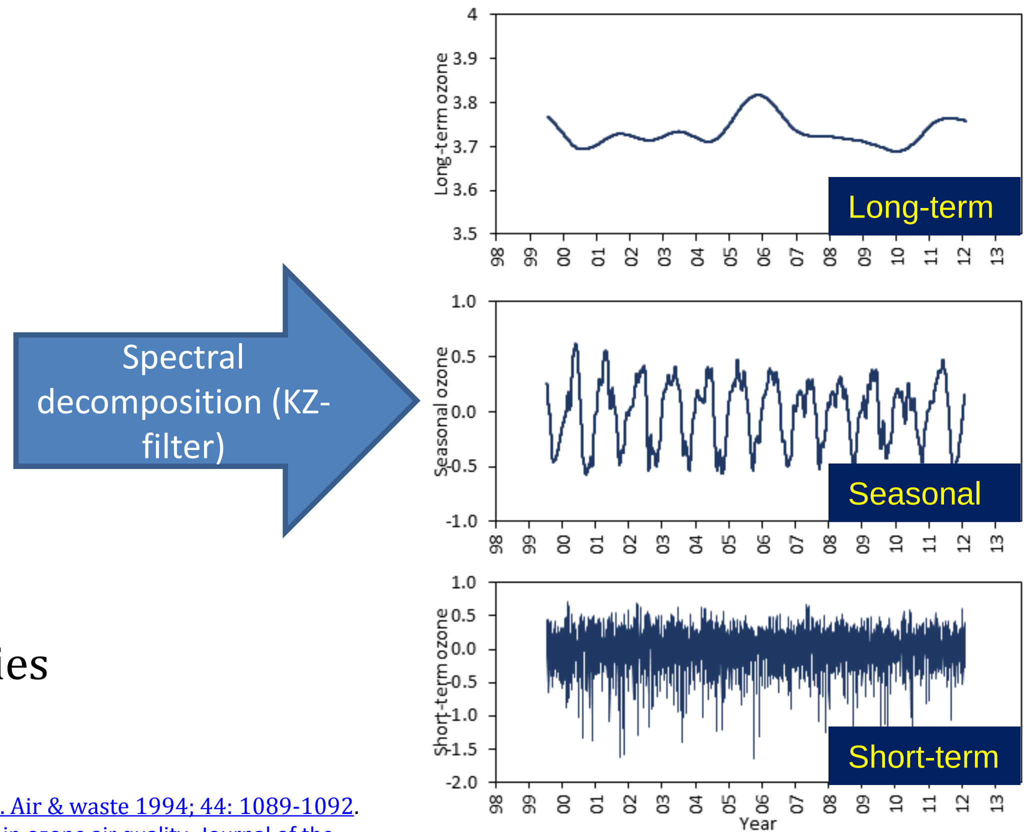
Method – KZ-filter

- **KZ-filter** is a robust low-pass filter used for spectral (frequency-based) decomposition of time-series*
- Computationally KZ-filter is a simple iterative moving average technique

$$Y_i = \frac{1}{m}\sum_{j=-k}^{k} X_{i+j}$$



Log-transformed raw ozone time series



* Rao ST, Zurbenko IG. Detecting and tracking changes in ozone air quality. Air & waste 1994; 44: 1089-1092.
Rao ST, Zalewsky E, Zurbenko IG. Determining temporal and spatial variations in ozone air quality. Journal of the Air & Waste Management Association 1995; 45: 57-61.

Meteorologically Adjusted Ozone

- **Step 1**: Spectral decomposition of the ozone and meteorological time series by applying KZ-filter $X(t) = e(t) + S(t) + W(t)$

$$\begin{cases} e(t) = X_{365,3}(t) \\ S(t) = X_{15,5}(t) - X_{365,3}(t) \\ W(t) = X(t) - X_{15,5}(t) \\ BL(t) = e(t) + S(t) \end{cases}$$

- **Step 2**: Baseline and short-term components of ozone time-series are calculated using a three variable linear regression model (with temperature and solar radiation)
- **Step 3**: Meteorologically adjusted ozone time-series is calculated as the residuals of linear regressions $O(t) = F(T, SR) + O_{\mathrm{MA}}(t)$

$$O_{\mathrm{MA}}(t) = \epsilon_{\mathrm{BL}}(t) + \epsilon_W(t)$$

- **Step 4**: KZ-filter is applied again to M.A. ozone time-series to calculate long-term and baseline components of M.A. ozone

Results – Part II

- Because all expressions are given for the natural logarithm of raw ozone data, M.A. ozone values have multiplicative effects in original ozone time series
- Also since $O_{M.A.}$ values are sufficiently small therefore:

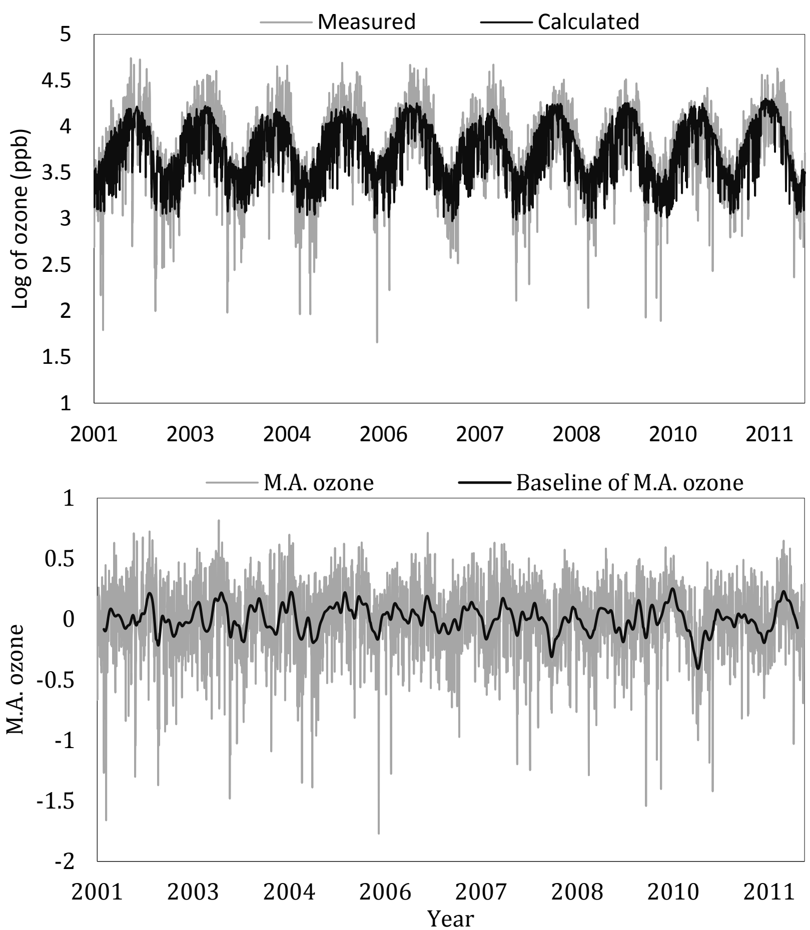
$$\exp(O_{M.A.}) \approx 1 + O_{M.A.}$$

- Therefore $O_{\mathrm{MA}}(t) \times 100$ values represent change in mean value of the original ozone time series

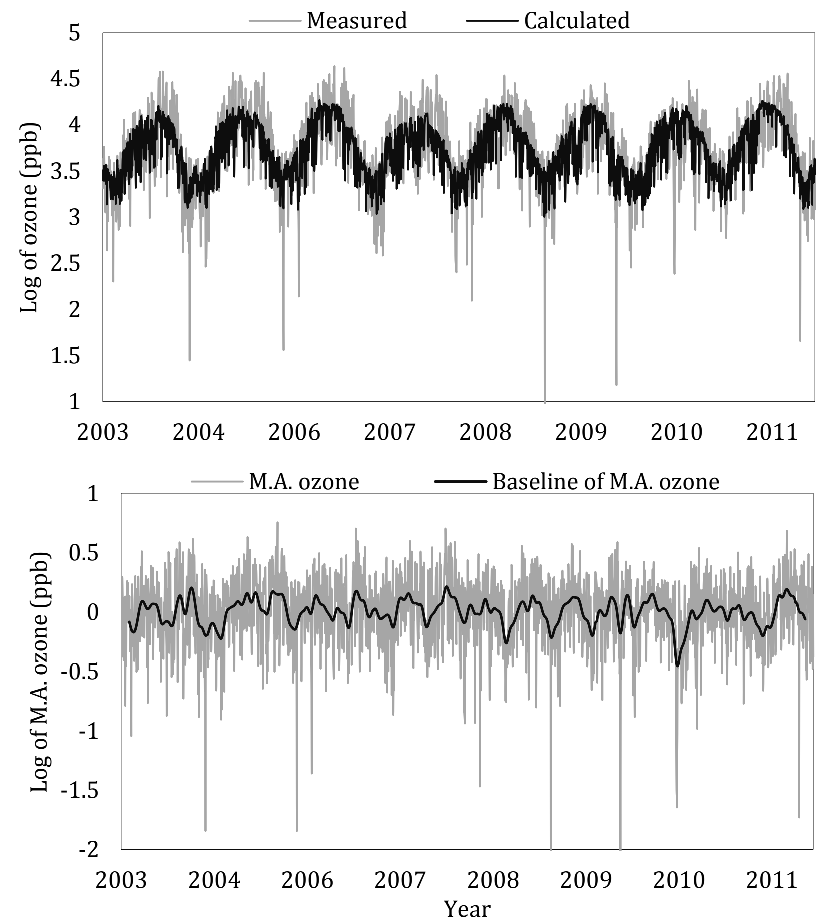
- Statistical evaluation of all components of M.A. ozone (mean value, long-term, short-term, and baseline) is performed to evaluate the contribution of non-meteorological variables including anthropogenic influences affecting ozone formation and destruction.

Results – Part II

- Examples of calculated and measure ozone time series and residuals (M.A. ozone)



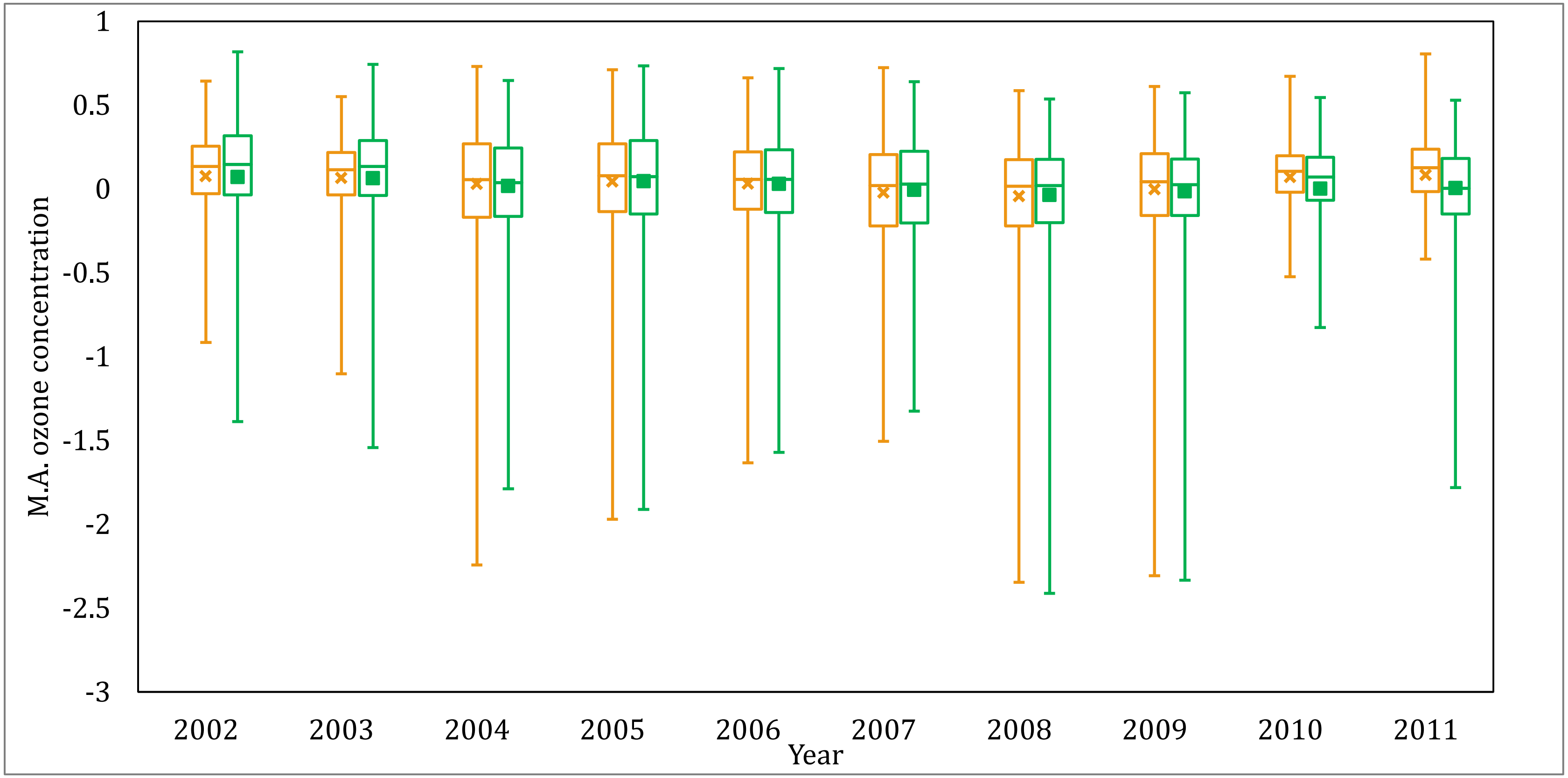
Constructing M.A. ozone for C56 (Denton)



Constructing M.A. ozone for C31 (Frisco)

Results – Part II

- Box plot presentation of $O_{\mathrm{MA}}(t)$ (the maximum, 75th percentile, median, mean, 25th percentile, and minimum) for **FR** and **NFR**



- $O_{\mathrm{MA}}(t) \times 100$ values represent change in mean value of the original ozone time series

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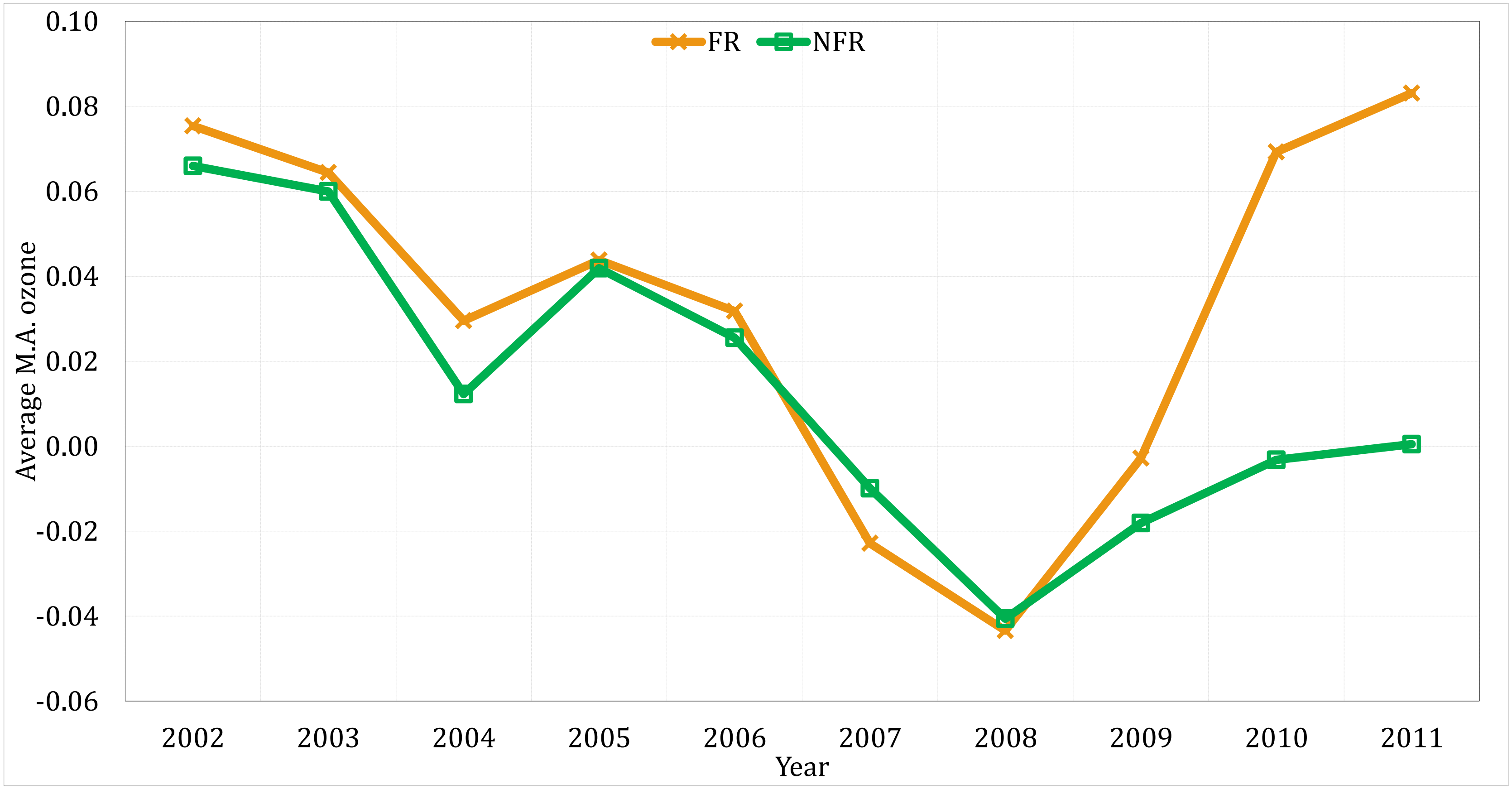
Results – Part II

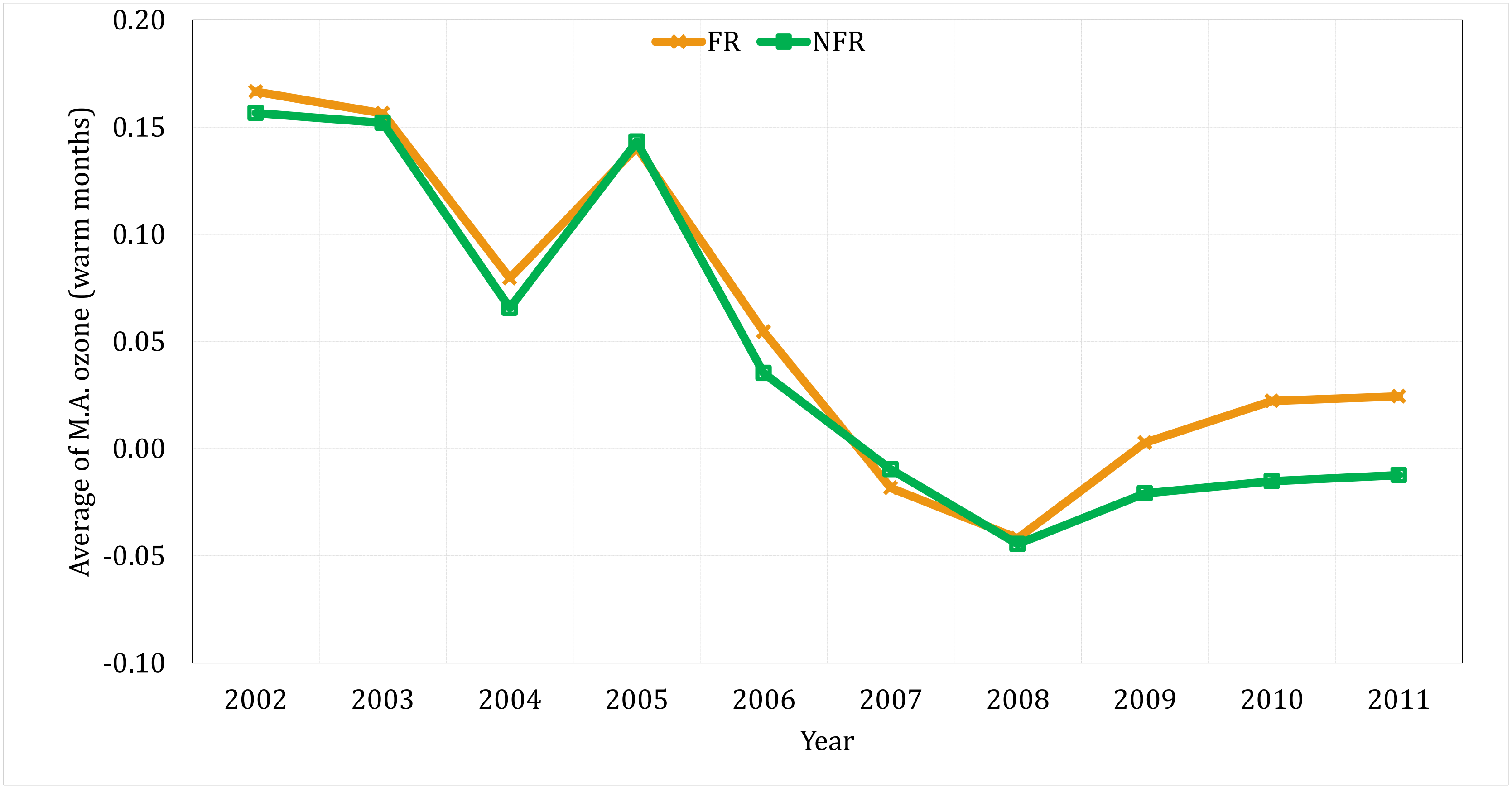
- Mean values of $O_{\mathrm{MA}}(t)$



- $O_{\mathrm{MA}}(t) \times 100$ values represent change in mean value of the original ozone time series

Results – Part II

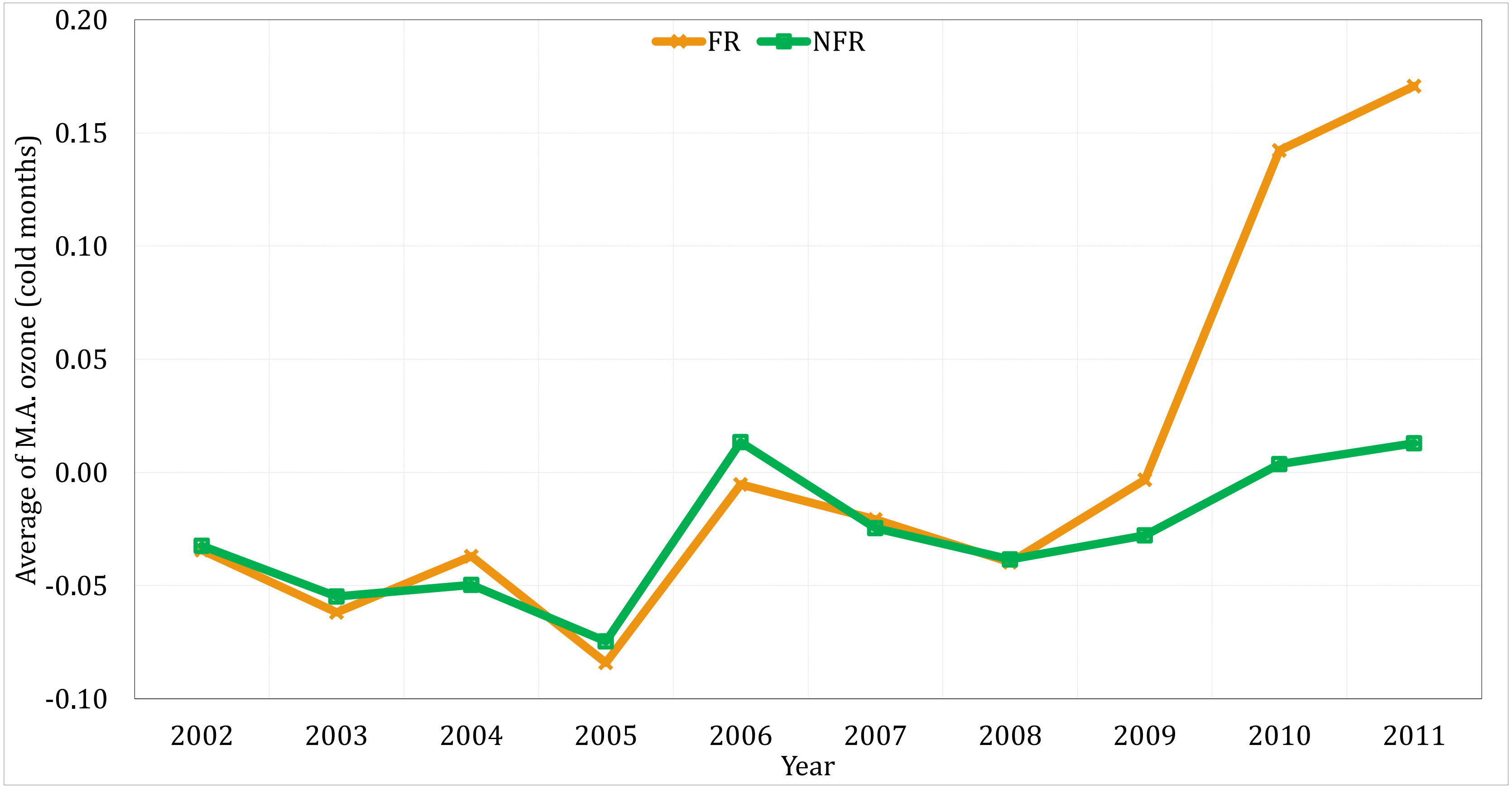
- Mean value of of $O_{\mathrm{MA}}(t)$ during ozone season (May, Jun, Jul, Aug, Sep)



- $O_{\mathrm{MA}}(t) \times 100$ values represent change in mean value of the original ozone time series

Results – Part II

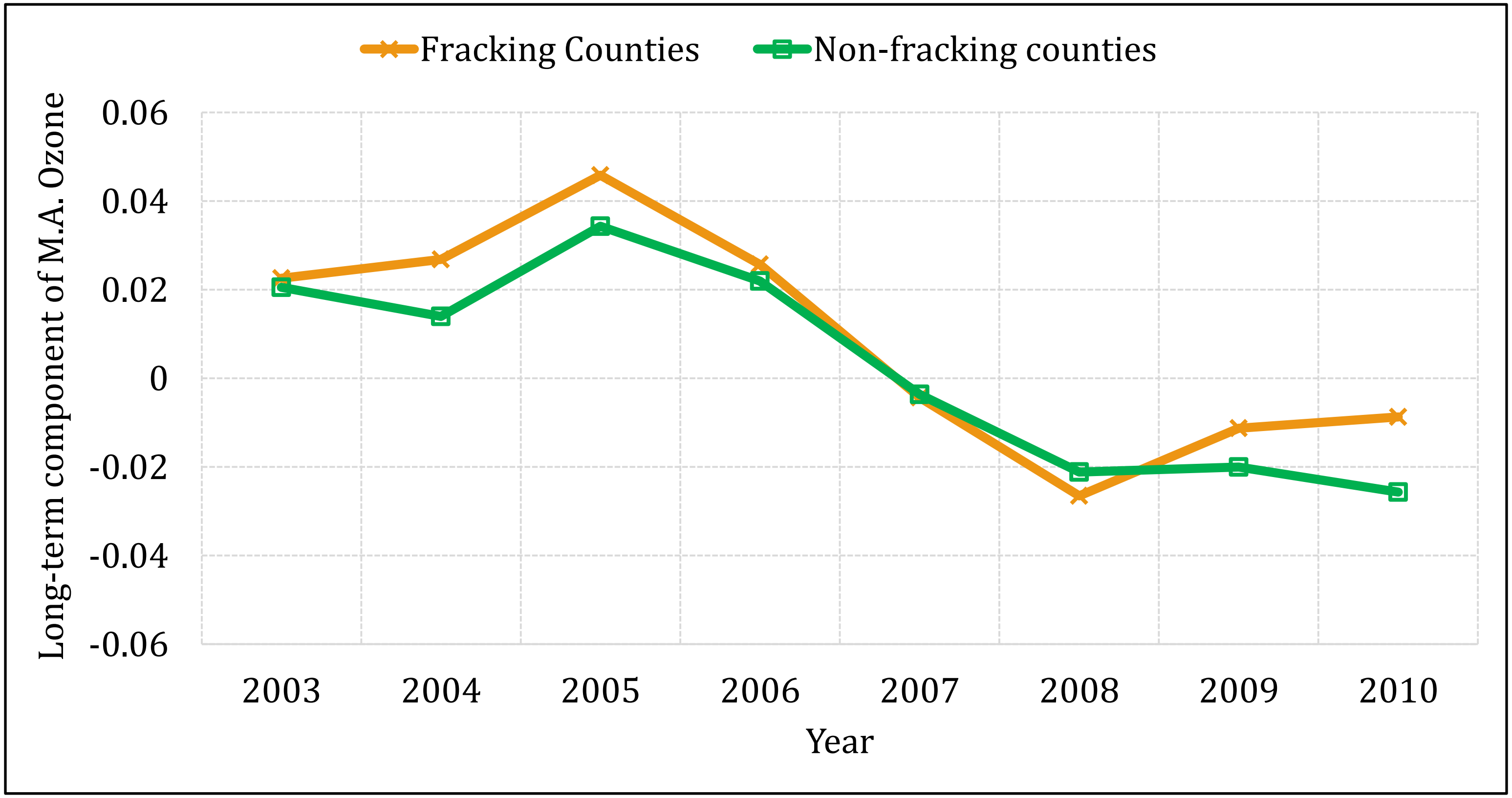
- Mean values of $O_{\mathrm{MA}}(t)$ in **FR** and **NFR** during winter time (Nov, Dec, Jan, Feb)



- $O_{\mathrm{MA}}(t) \times 100$ values represent change in mean value of the original ozone time series

Results – Part II

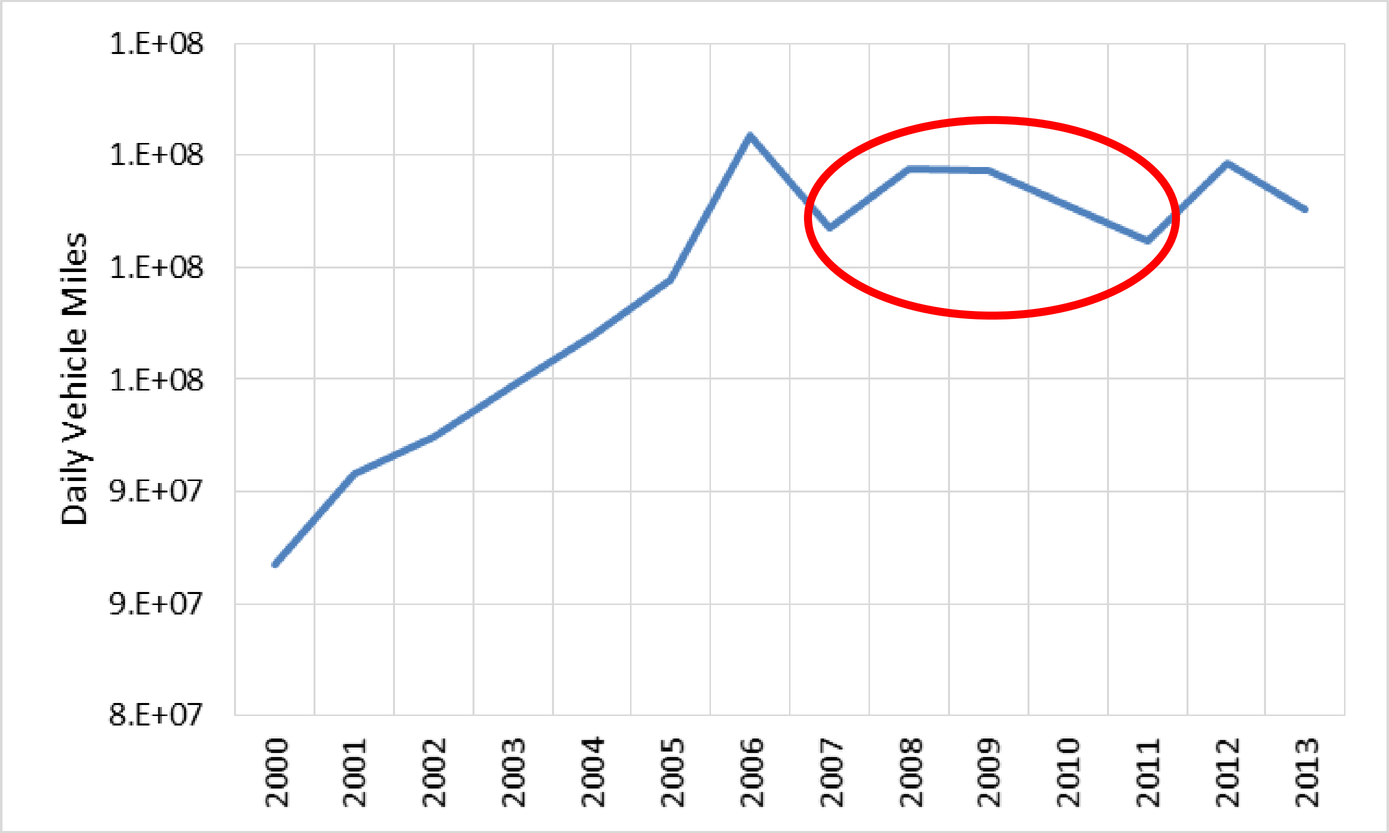
- Mean values of long-term component of $O_{\mathrm{MA}}(t)$ (that is devoid of meteorological influence)



- $O_{\mathrm{MA}}(t) \times 100$ values represent change in mean value of the original ozone time series

Remarks

- Daily vehicle miles traveled (VMT) is relatively flat during 2007-2010.



Source: TxDOT (Total VMT for Dallas, Denton, Wise, Tarrant, Hood, Parker, Hunt, Ellis, Collin, Rockwall & Kaufman counties)

Remarks

- Based on raw ozone data (B07 vs. A07):
  - Sites located in NFR show about 4% more reduction in the number of average ozone exceedances than in FR
  - Average of winter time daily maximum ozone values in FR is 3% more than in NFR

- Based on the mean value of meteorologically-adjusted ozone $O_{\mathrm{MA}}(t)$ (post-2008):
  - 12% increase within FR and a 4% increase in NFR was noted
  - During the winter time, 21% increase within FR and a 5% increase in NFR was noted

Future Research Needs

- Conduct similar adjusted trend analyses using long-term measurements of NOx, VOC and $PM_{2.5}$ in the region.
- Additional rural monitoring of NOx, VOC and $PM_{2.5}$ may be needed.
- Perform source-receptor and source apportionment analyses using measured concentrations.
- Develop a comprehensive regional emissions inventory for a more recent base year.
- Conduct photochemical modeling for a recent episode as well as a year-round modeling using revised estimates of emissions and perform source apportionment analysis for various regions.

Thank you!
Any questions?

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