2. Quantifying the contributions of pasture burning on air quality

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Pasture burning smoke management and air quality workshop
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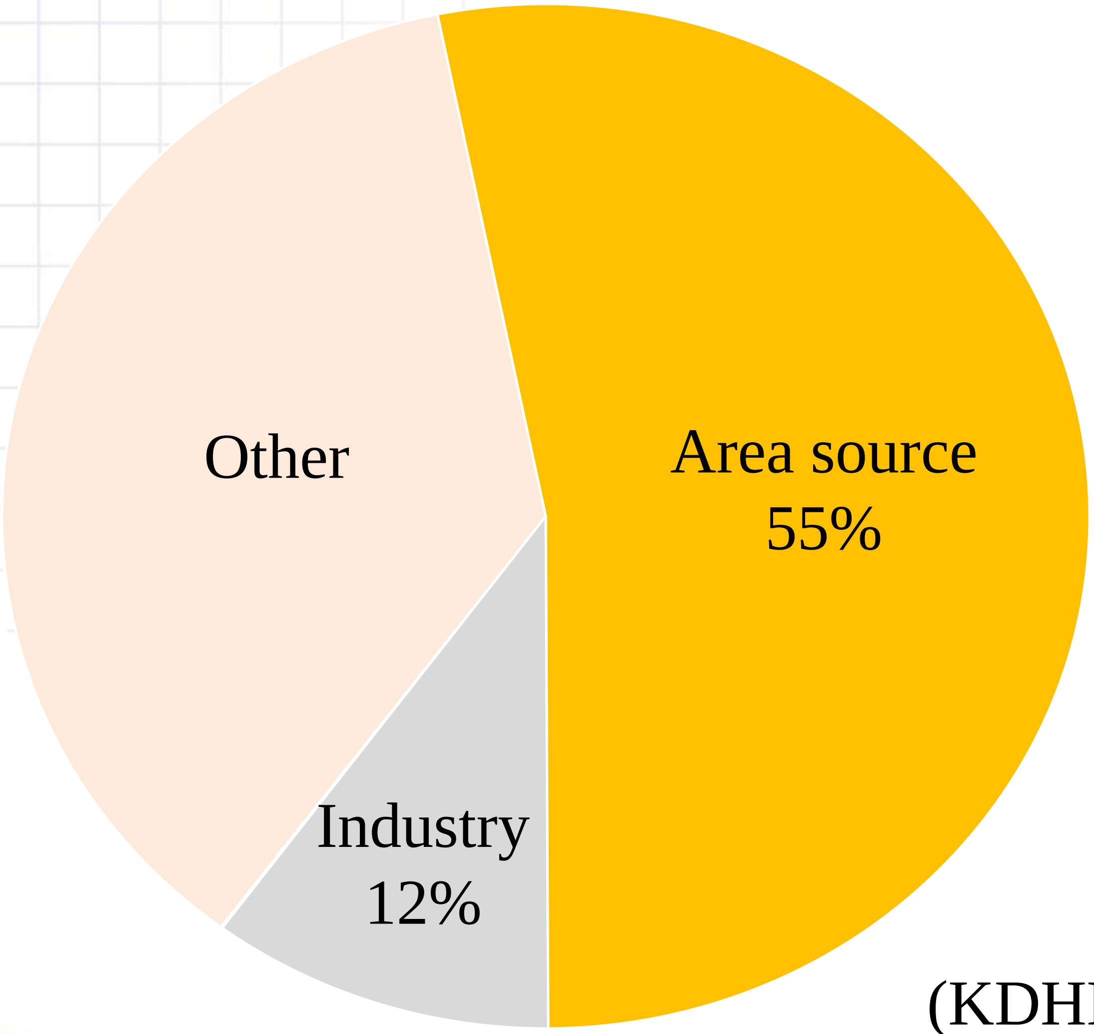
K·STATE Research and Extension | Biological and Agricultural Engineering

Knowledge for Life

Air pollution sources in Kansas



Contribution from pasture burning?

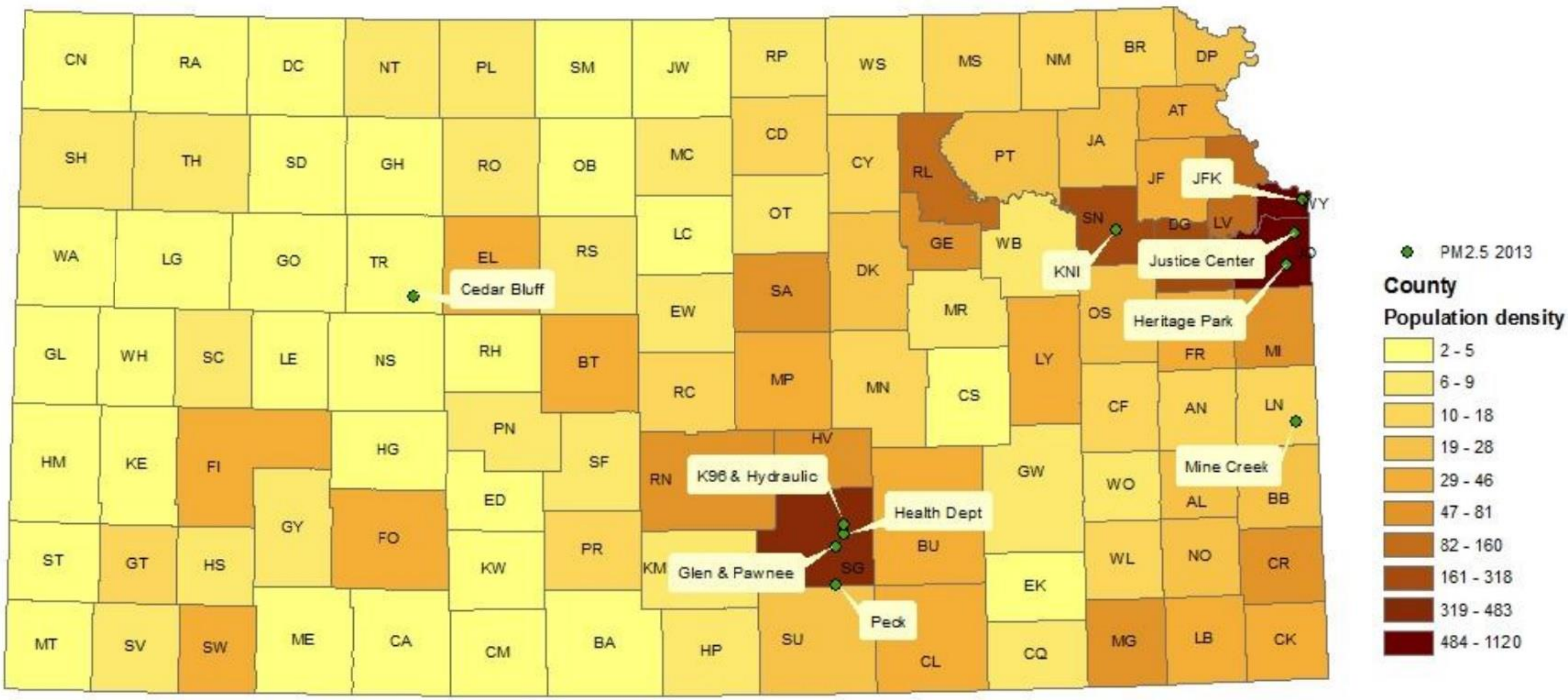
(KDHE air quality report)

Source apportionment

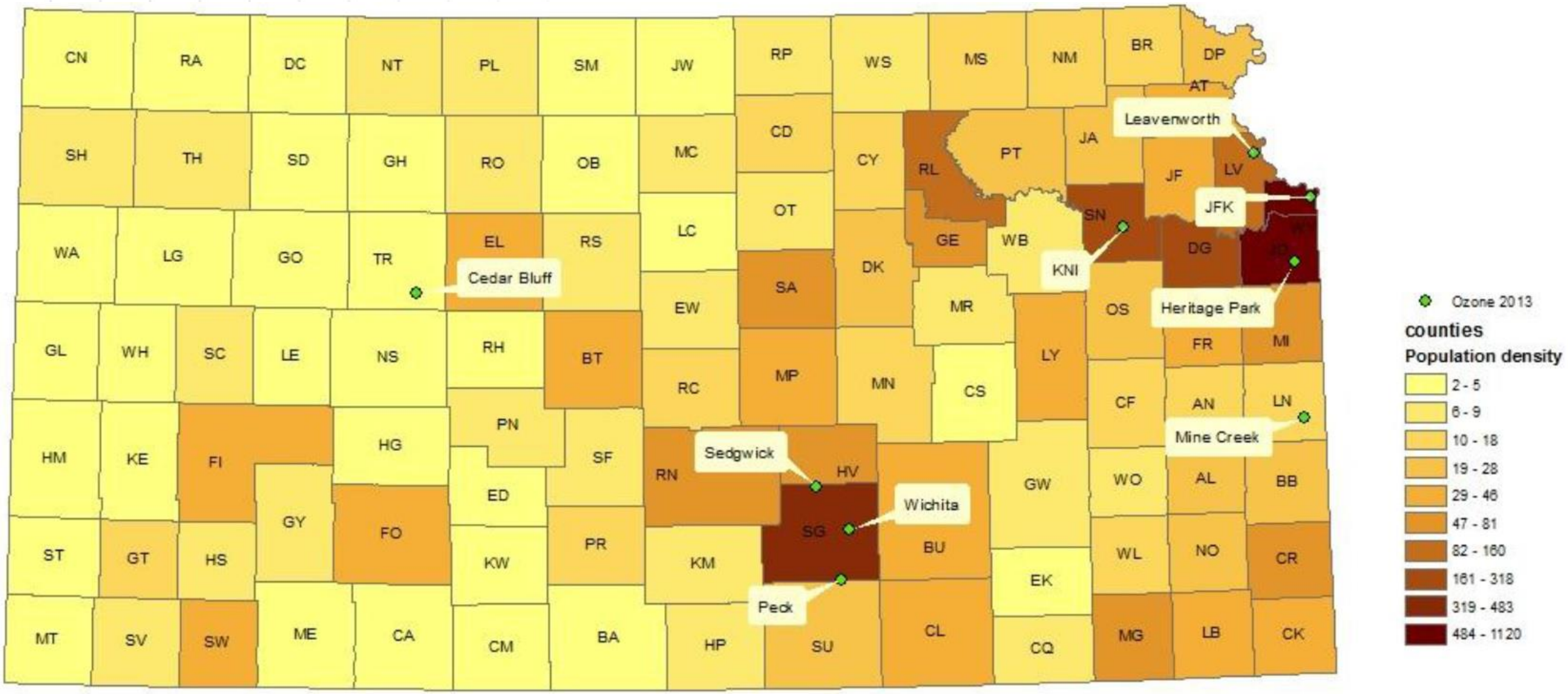
Receptor models

- Chemical mass balance (CMB)
- Unmix
- Positive matrix factorization (PMF)

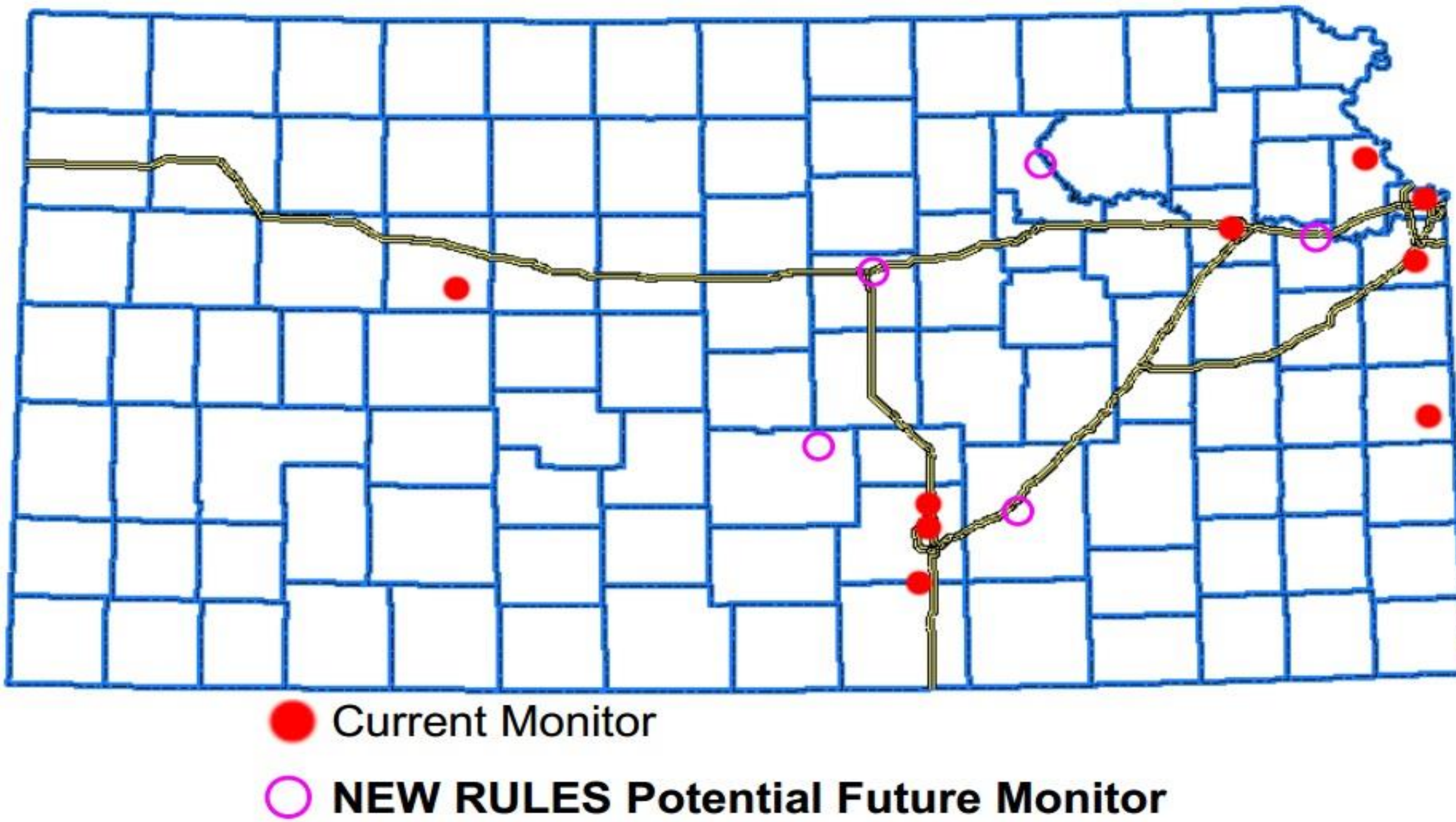
Population density map and location of the 10 $PM_{2.5}$ monitoring sites run by KDHE



Population density map and location of the 9 O_3 monitoring sites run by KDHE



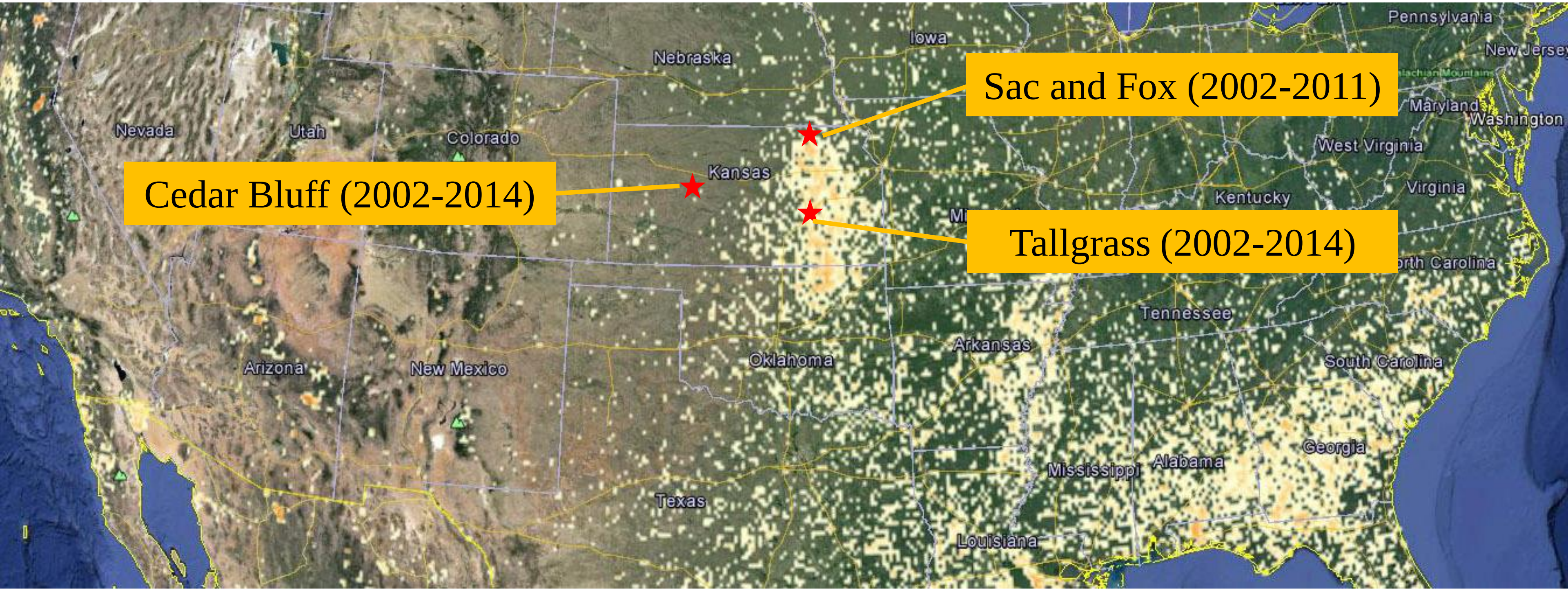
Current and Proposed Kansas Ozone Monitor Locations



Three Interagency Monitoring of Protected Visual Environments (**IMPROVE**) sites

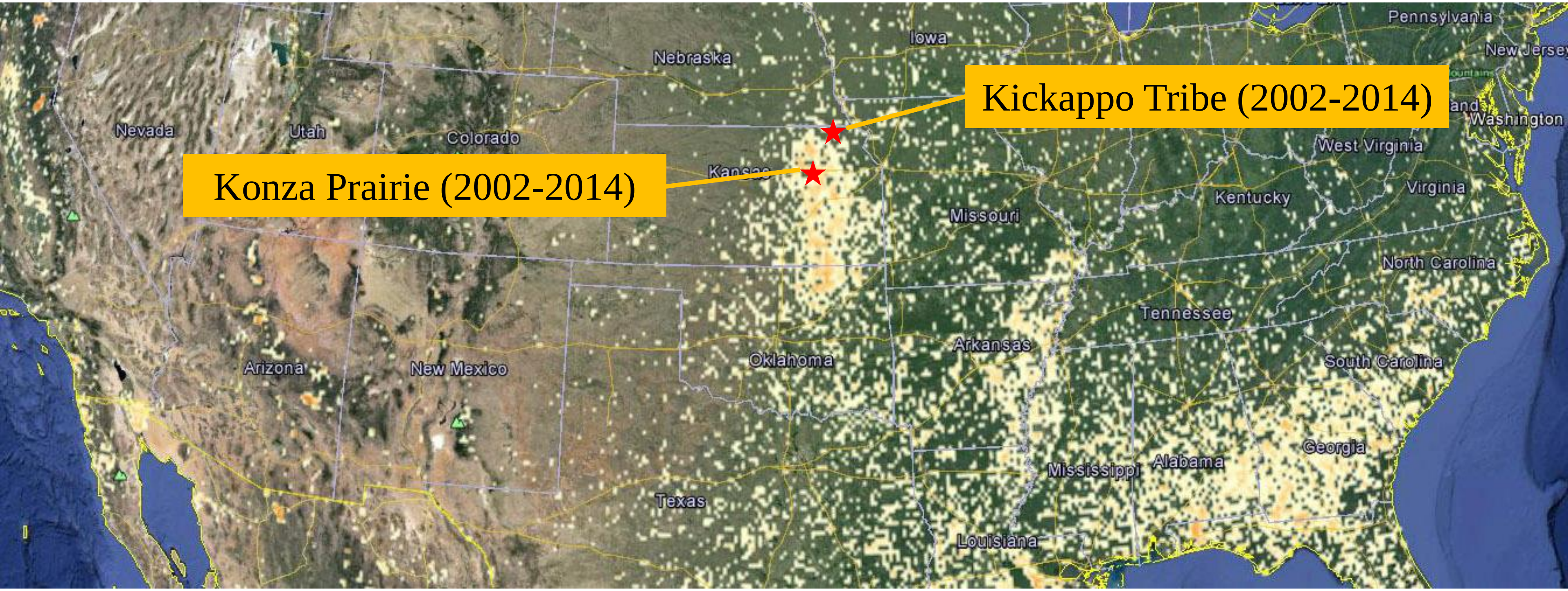
Provide multiple years of quality assured data on speciated $PM_{2.5}$

http://vista.cira.colostate.edu/improve/

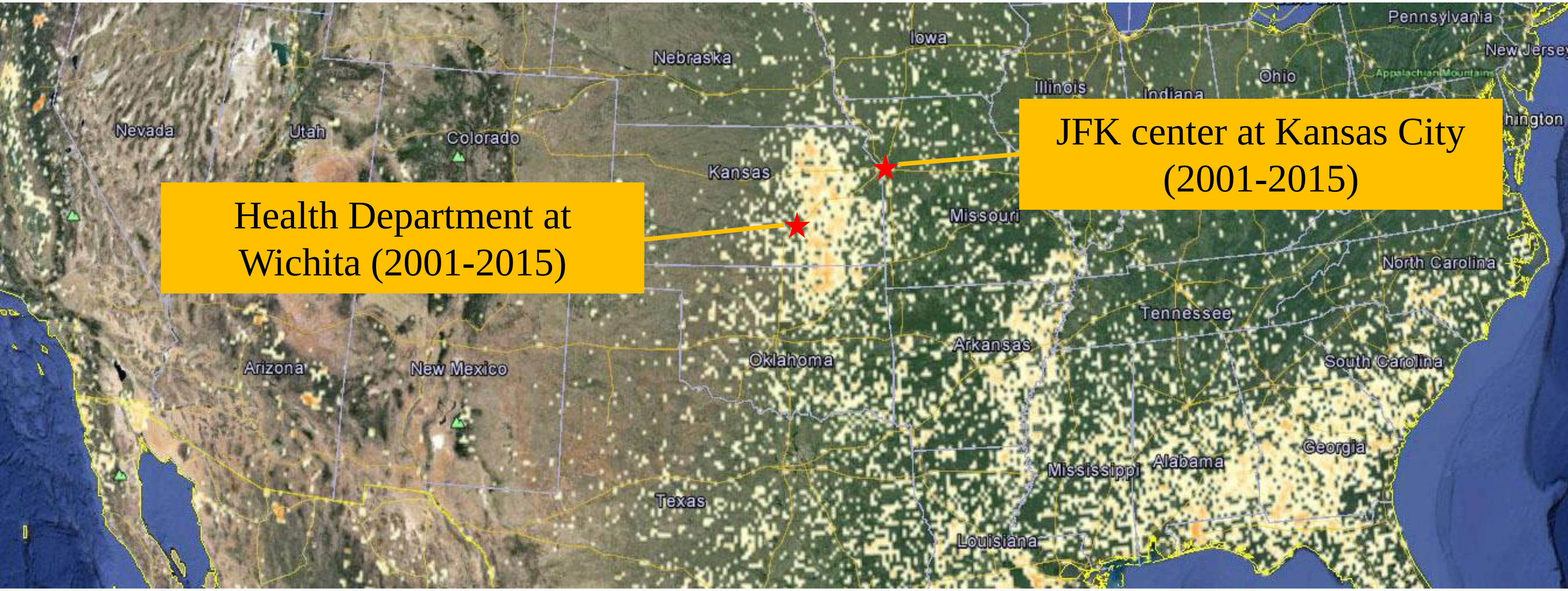


Two Clean Air Status and Trends Network (**CASTNET**) sites Provide air quality data (including O_3) in rural areas.

http://epa.gov/castnet/



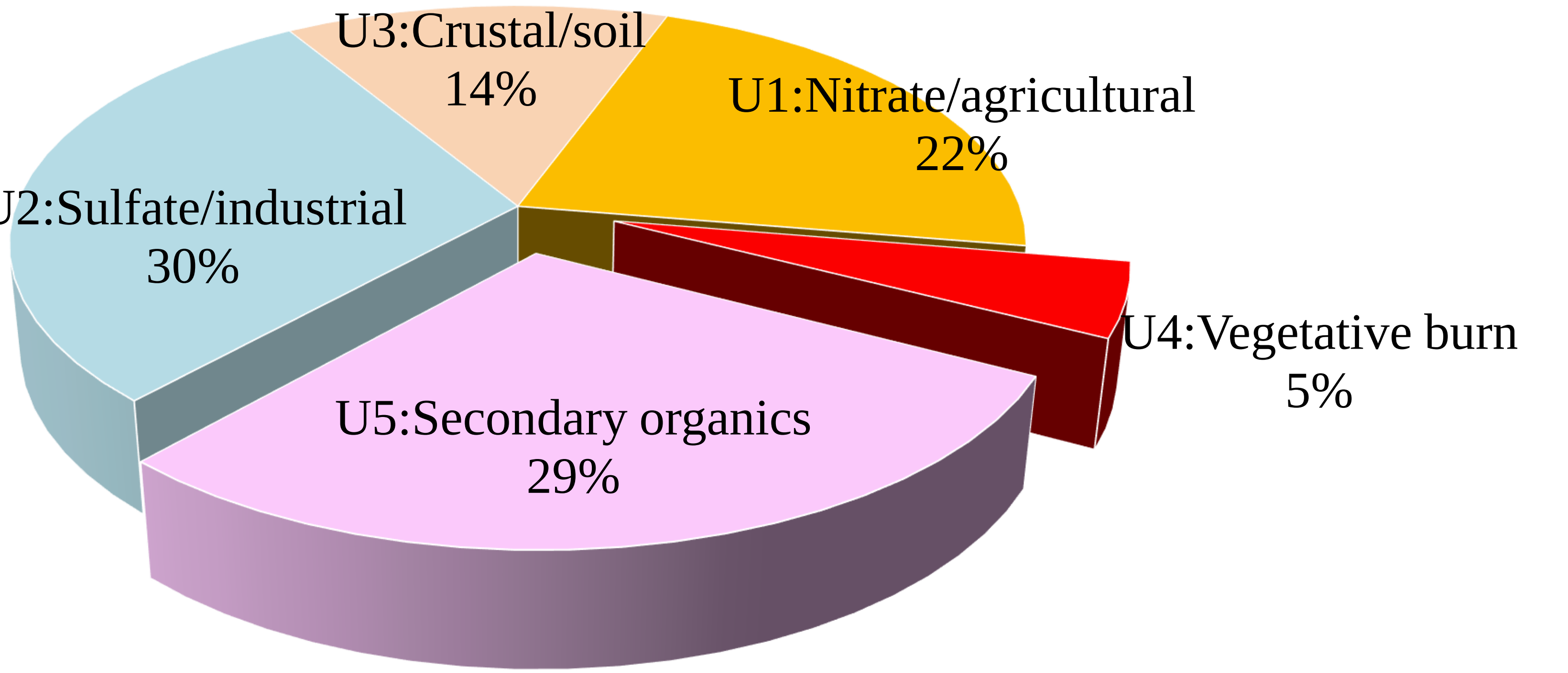
Two Chemical Speciation Network (**CSN**) sites Provide $PM_{2.5}$ speciation data in two big cities in Kansas



Objective

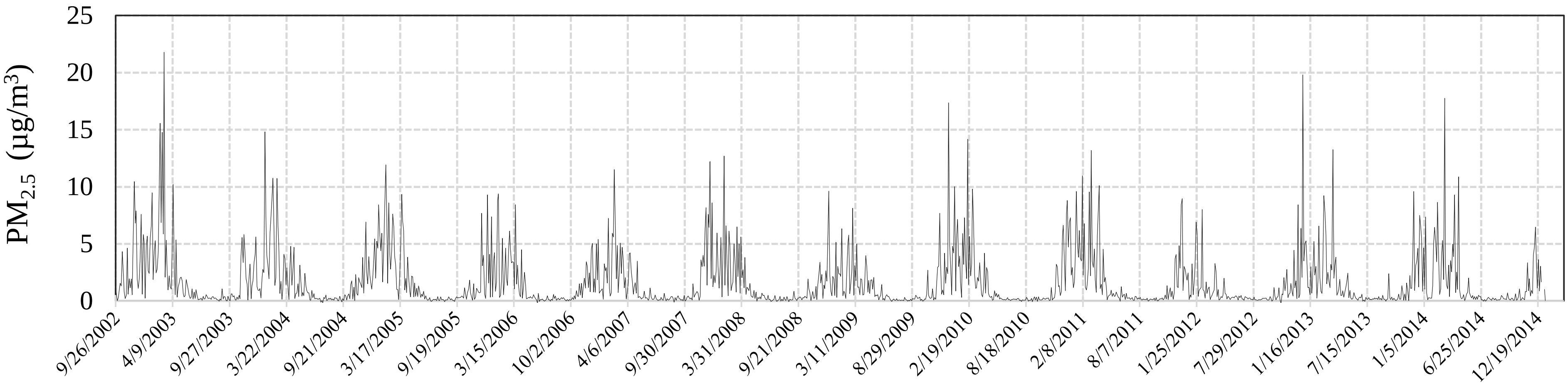
- Quantify the contribution of prescribed pasture burning to local ambient $PM_{2.5}$ through comparative analysis using Unmix and PMF models.
- First study:
  - Using data at the Tallgrass IMPROVE site
  - 1428 data points from 9/26/2002 to 12/31/2014

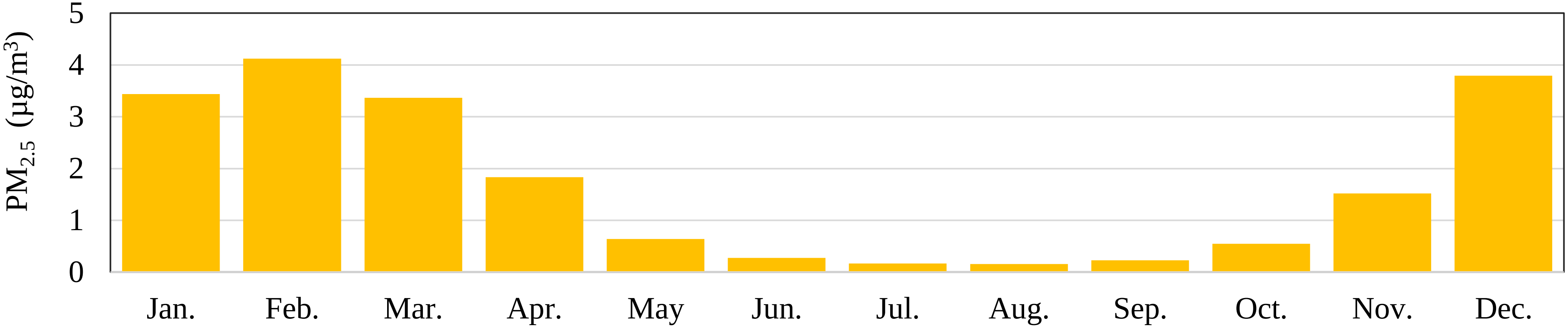
Results from the Unmix model



Annual average source contributions to $PM_{2.5}$

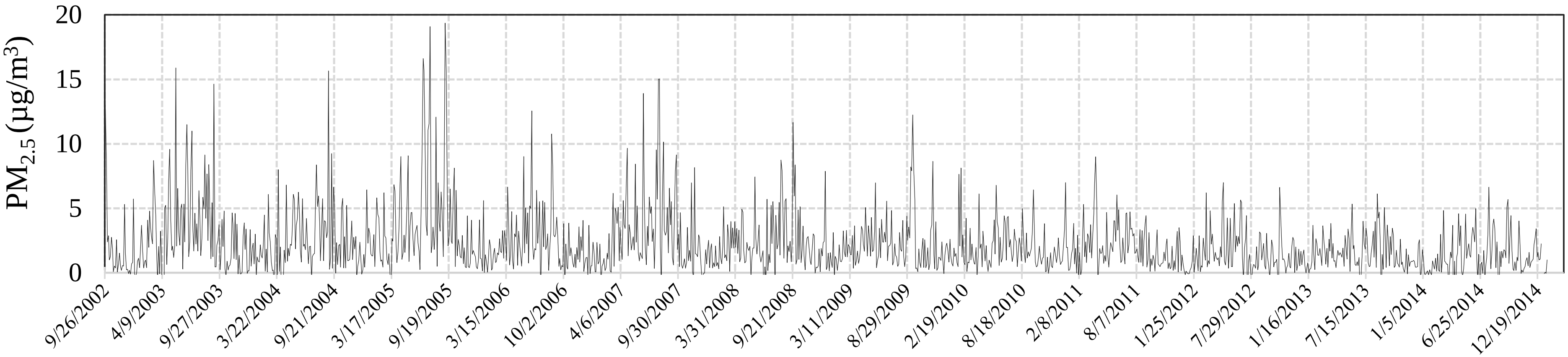
U1: Nitrate/Agricultural

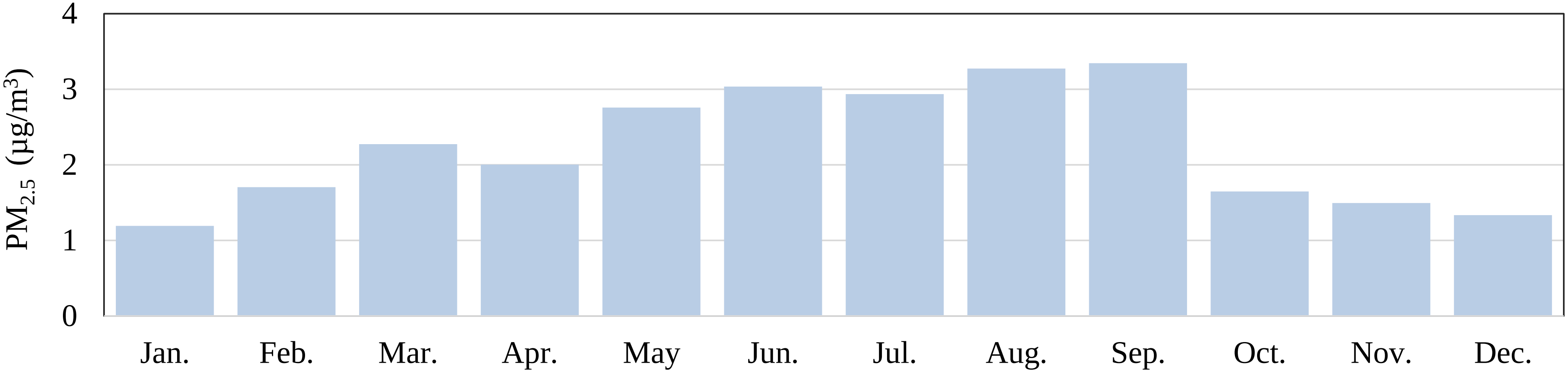




Featured with high nitrate associated with NH_3 emissions. Demonstrated a regular seasonal pattern (high in winter and low in summer).

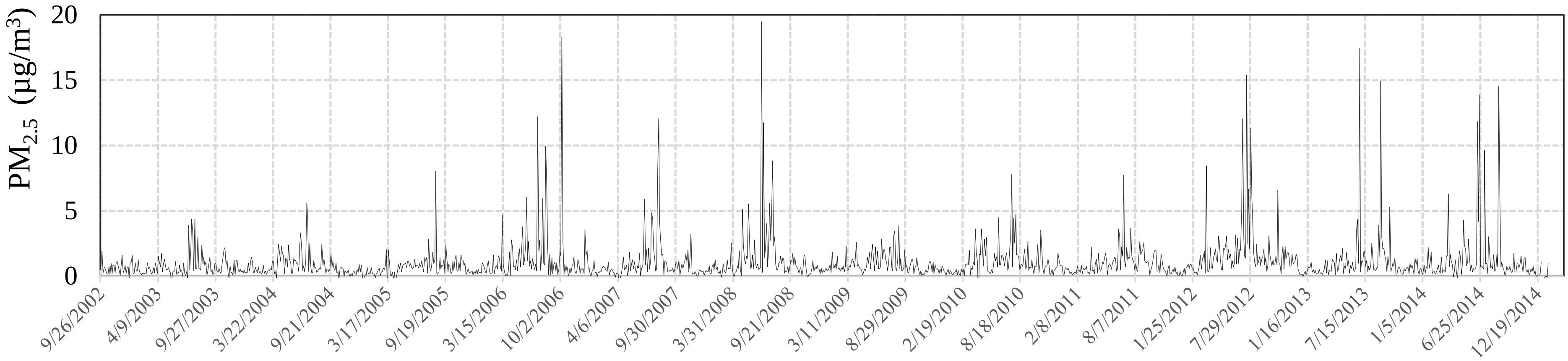
U2: Sulfate/Industrial

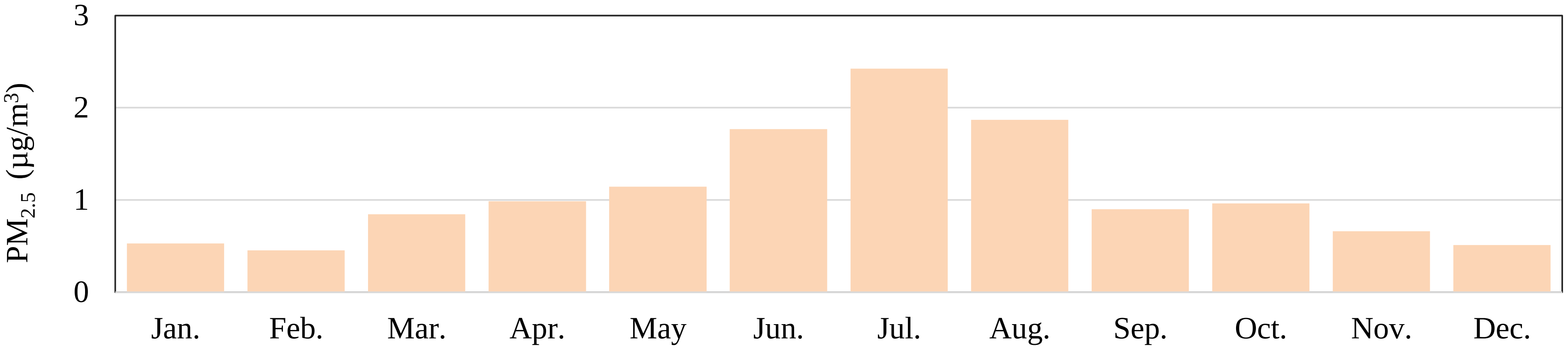




Featured with high sulfate associated with SO_2 emissions. Decreasing trend reflected regulation effects. High in summer due to photochemistry effect and presence of oxidants on secondary sulfate formation.

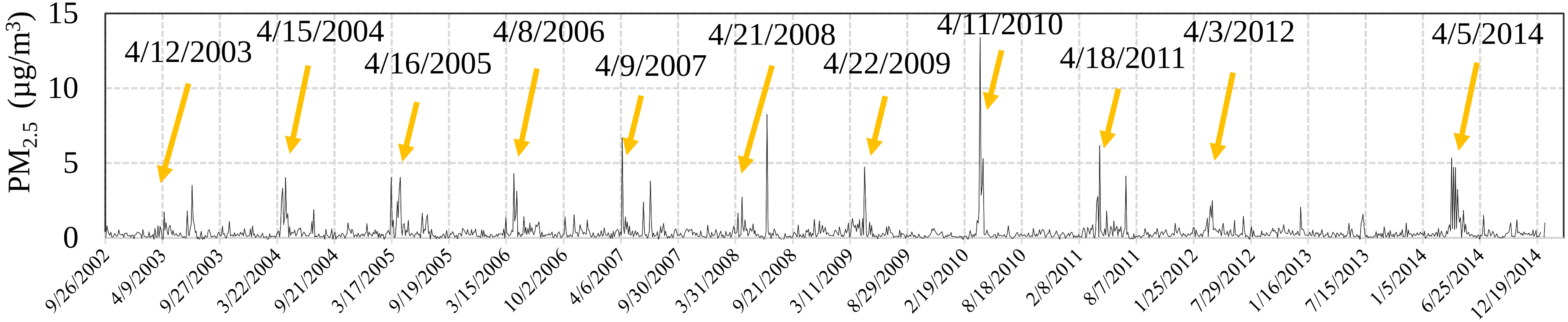
U3: Crustal/Soil

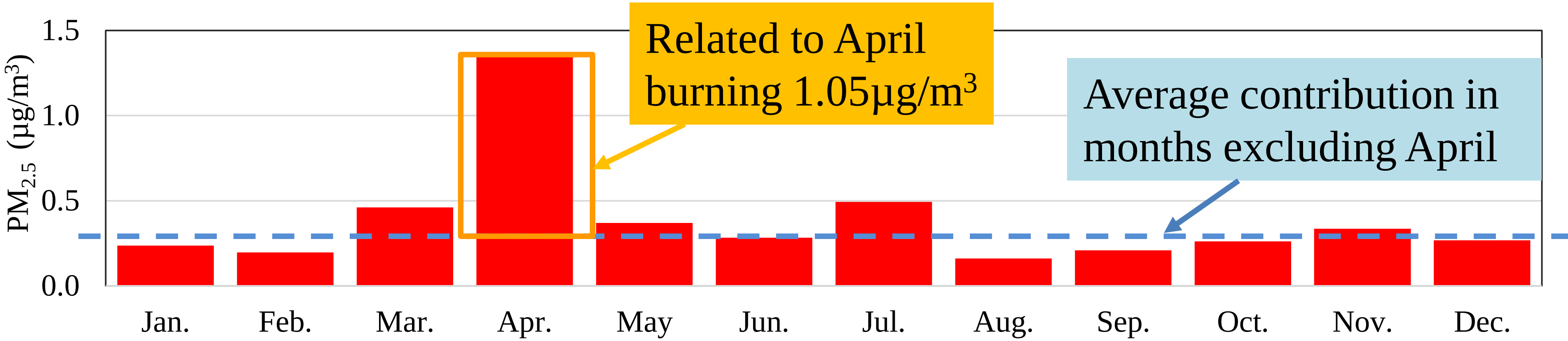




Identified by soil elements (Si, Fe, Al, …).
Spikes were observed on windy days.

U4: Vegetative burning

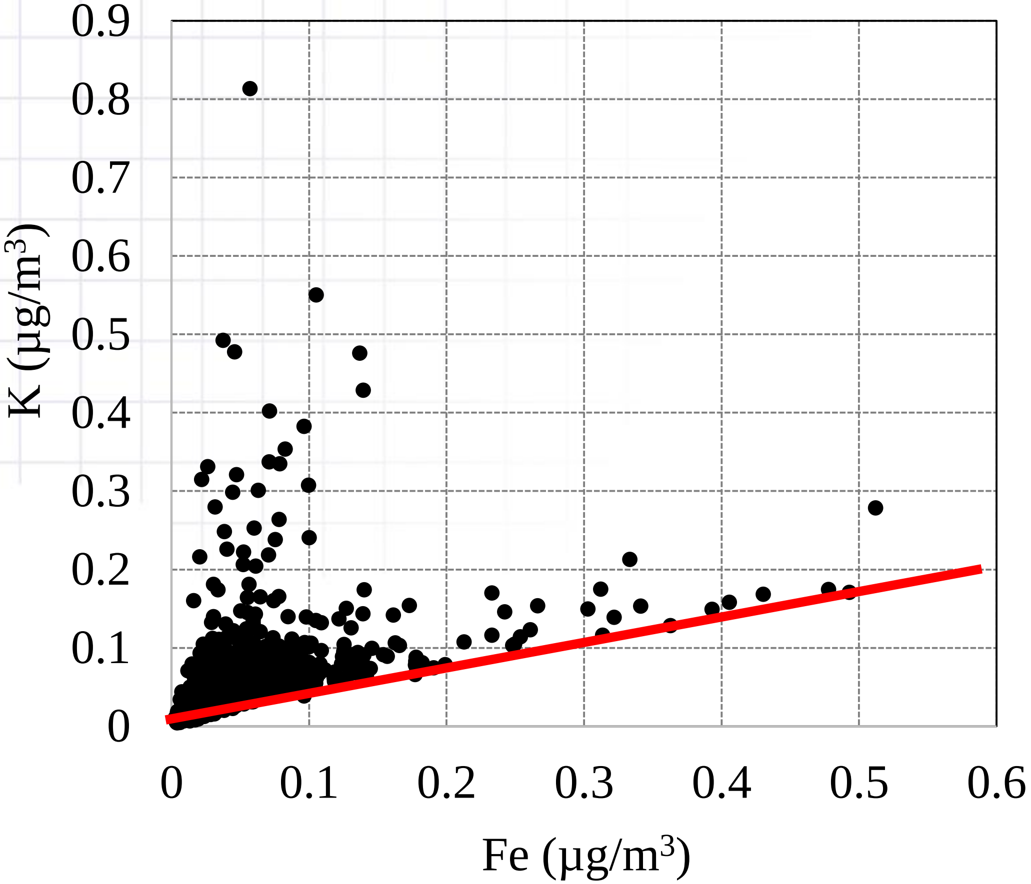




Characterized by non-soil potassium (K_{non}), OC/EC, and some soil elements.

Spikes were consistently observed in April, when intensive prescribed pasture burning activities usually occur in the Flint Hill region.

Estimation of non-soil potassium (K_{non})

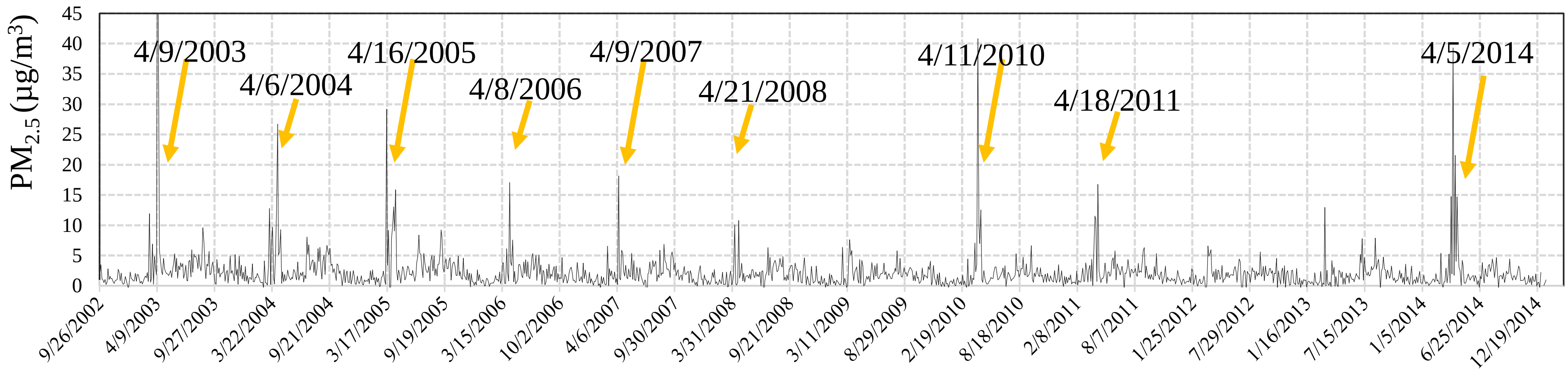


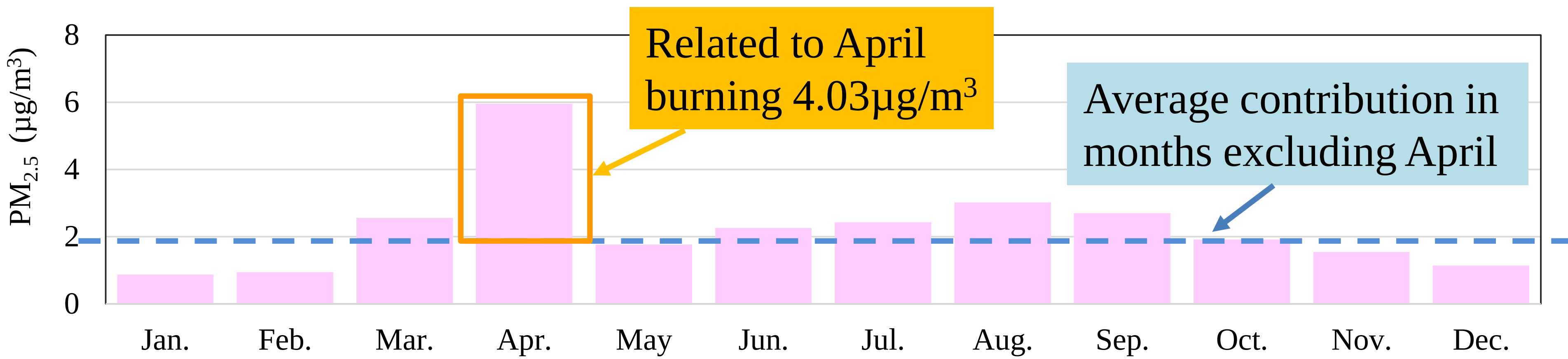
Fine potassium (K) particles have two major sources, soil and smoke,

K_{non}=K-0.34Fe

The coefficient of 0.34 was derived from the lower edge of the K versus Fe scatterplot.

U5: Secondary organic aerosol





Identified by large OC/EC ratio. U5 also had spikes in Aprils.

U5 correlated with U4 with Pearson correlation coefficient of 0.49.

Spikes in source strength of U4 and U5

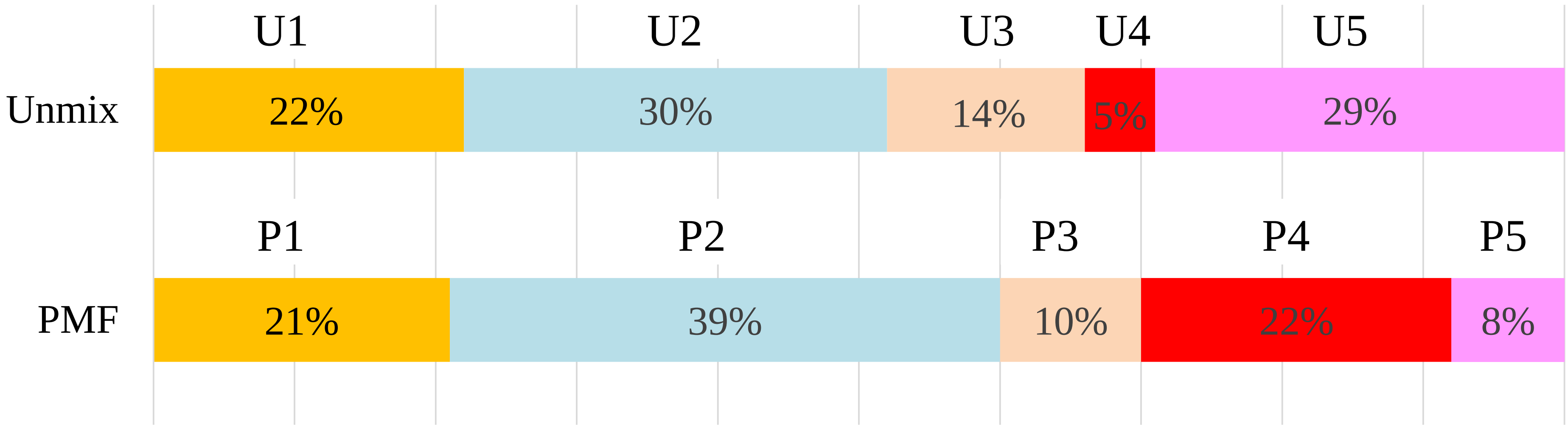
Date	U4 contributions in $PM_{2.5}$ ($\mu g/m^3$)	Date	U5 contributions in $PM_{2.5}$ ($\mu g/m^3$)	Acres burned in April (Million)
4/12/2003	1.729	4/9/2003	72.099	2.9
4/15/2004	4.031	4/6/2004	26.705	1.9
4/16/2005	4.045	4/16/2005	15.870	3.5
4/8/2006	4.307	4/8/2006	17.079	2.0
4/9/2007	6.669	4/9/2007	18.161	1.1
4/21/2008	2.727	4/21/2008	10.809	2.9
4/22/2009	4.727	4/-/2009	No spike	3.2
4/11/2010	13.399	4/11/2010	40.836	2.5
4/18/2011	6.187	4/18/2011	16.779	2.7
4/3/2012	2.499	4/-/2012	No spike	0.7
4/-/2013	No spike	4/-/2013	No spike	0.2
4/5/2014	4.706	4/5/2014	39.321	2.5
12-year average	0.376		2.220	2.2

Source profiles with selected species

Model	Sources	OC	EC	Sulfate	Nitrate	Si	K_{non}
Unmix	U1	0.067	0.021	0.1	0.679	-0.001	0.002
	U2	0.022	0.021	0.566	-0.001	0.011	0.001
	U3	0.078	0.005	0.189	0.025	0.104	0.001
	U4	0.302	0.203	-0.149	0.034	0.033	0.055
	U5	0.481	0.051	0.13	0.022	0.003	0.004
PMF	P1	0.074	0.035	0.162	1.132	0.000	0.002
	P2	0.329	0.068	1.552	0.000	0.027	0.001
	P3	0.055	0.000	0.077	0.040	0.107	0.000
	P4	0.943	0.135	0.027	0.045	0.003	0.036
	P5	0.032	0.046	0.012	0.000	0.023	0.000

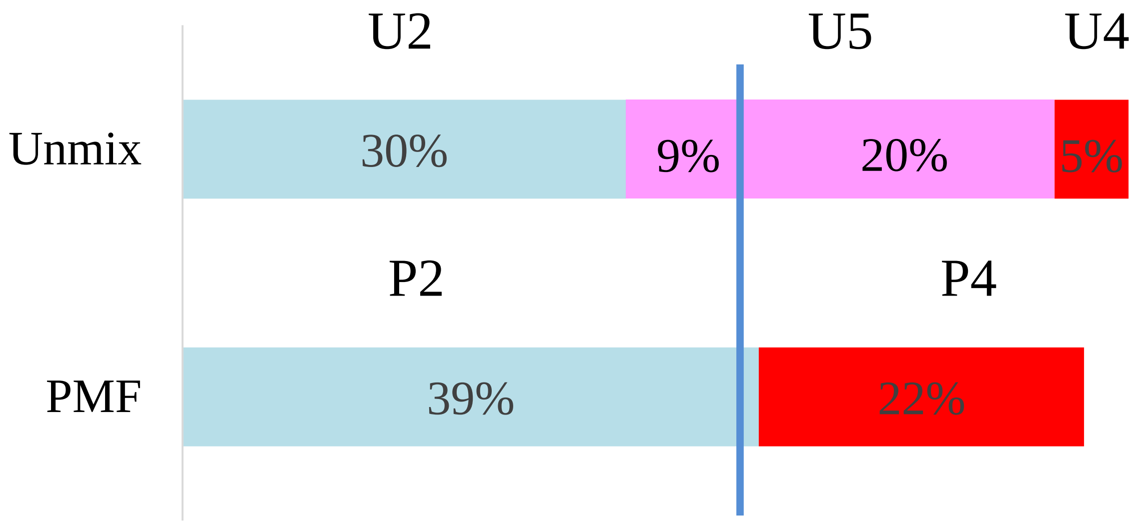
Unit: $\mu g/m^3$

Comparing results from PMF and Unmix



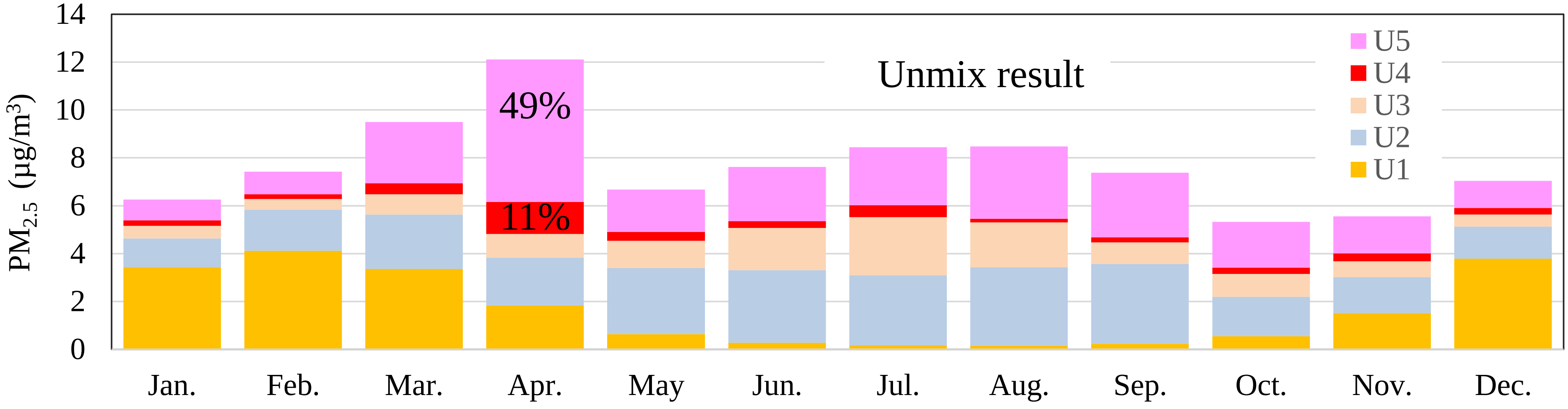
Annual average source contributions to $PM_{2.5}$

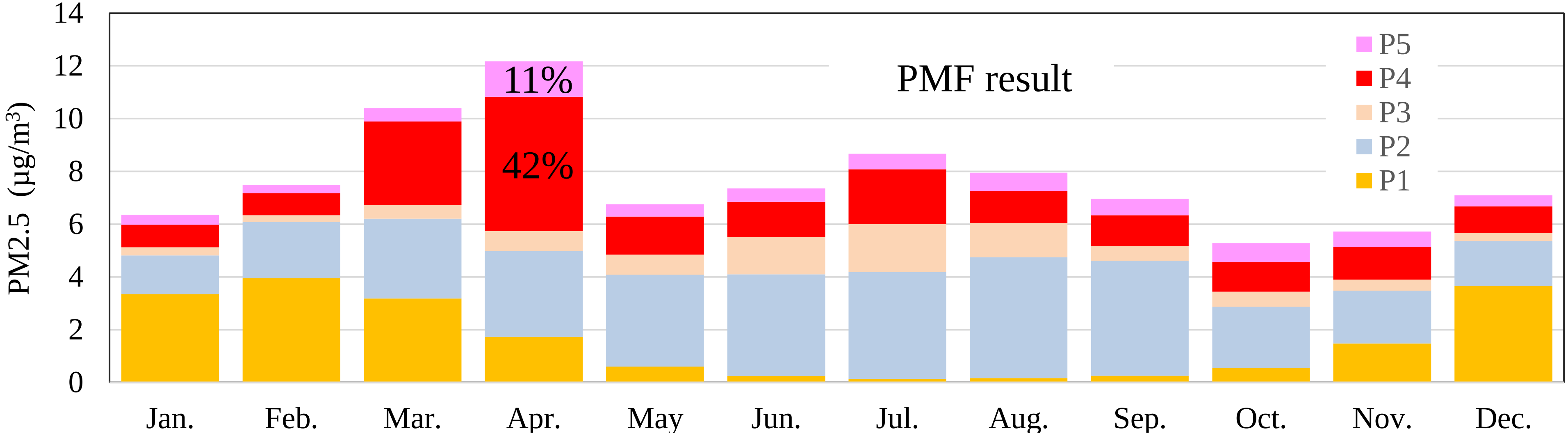
Comparing results from PMF and Unmix



- Around 2/3 of secondary organic aerosol are burning related.
- Burning related secondary aerosols was around 4 four times higher than that of primary smoke aerosols.

Seasonal variations of source contributions to $PM_{2.5}$

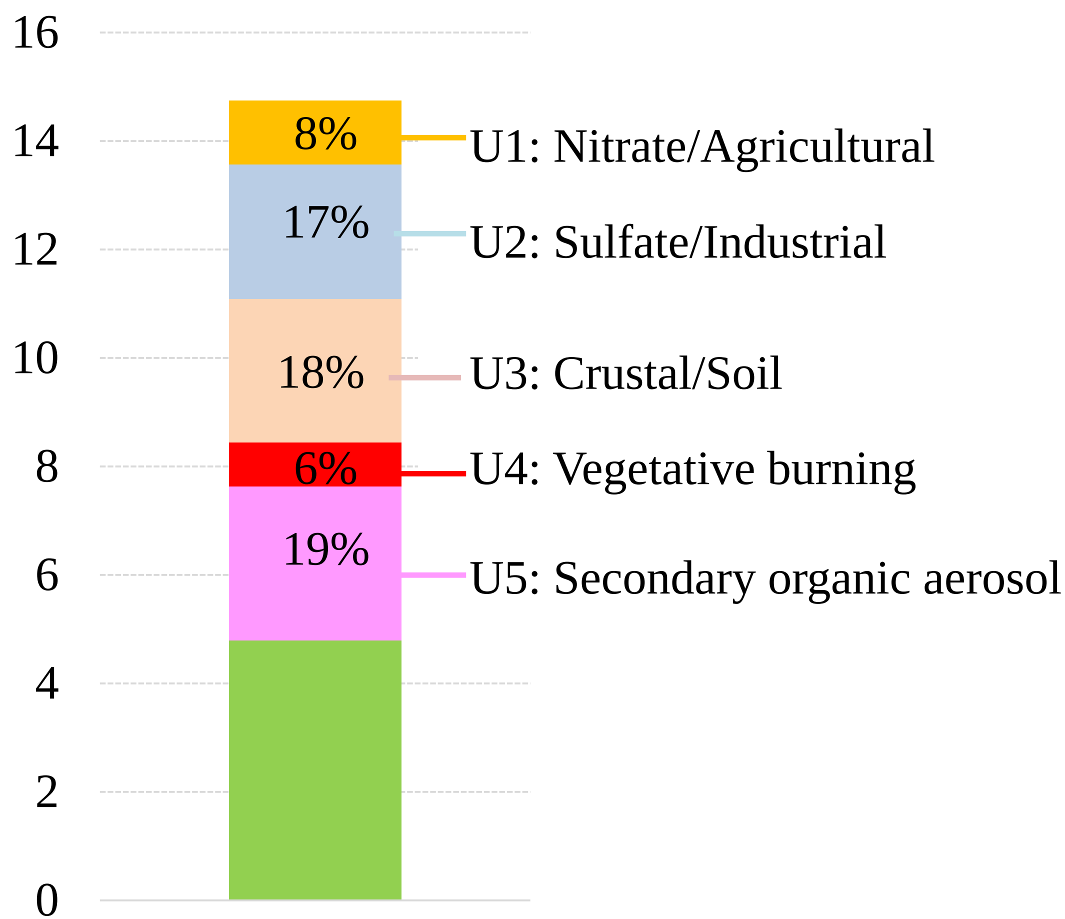




Conclusion

- Burning related emissions contributed around 22%-30% of annual average ambient $PM_{2.5}$ in the Tallgrass site.
- In April, pasture burning contributed around 40% of average $PM_{2.5}$ (42% based on Unmix results, 37% based on PMF result).
- April burning contributed 1.05μg/m^3 as primary smoke aerosols and 4.03μg/m^3 as secondary aerosols, which highlighted the importance of secondary aerosols in smoke management.

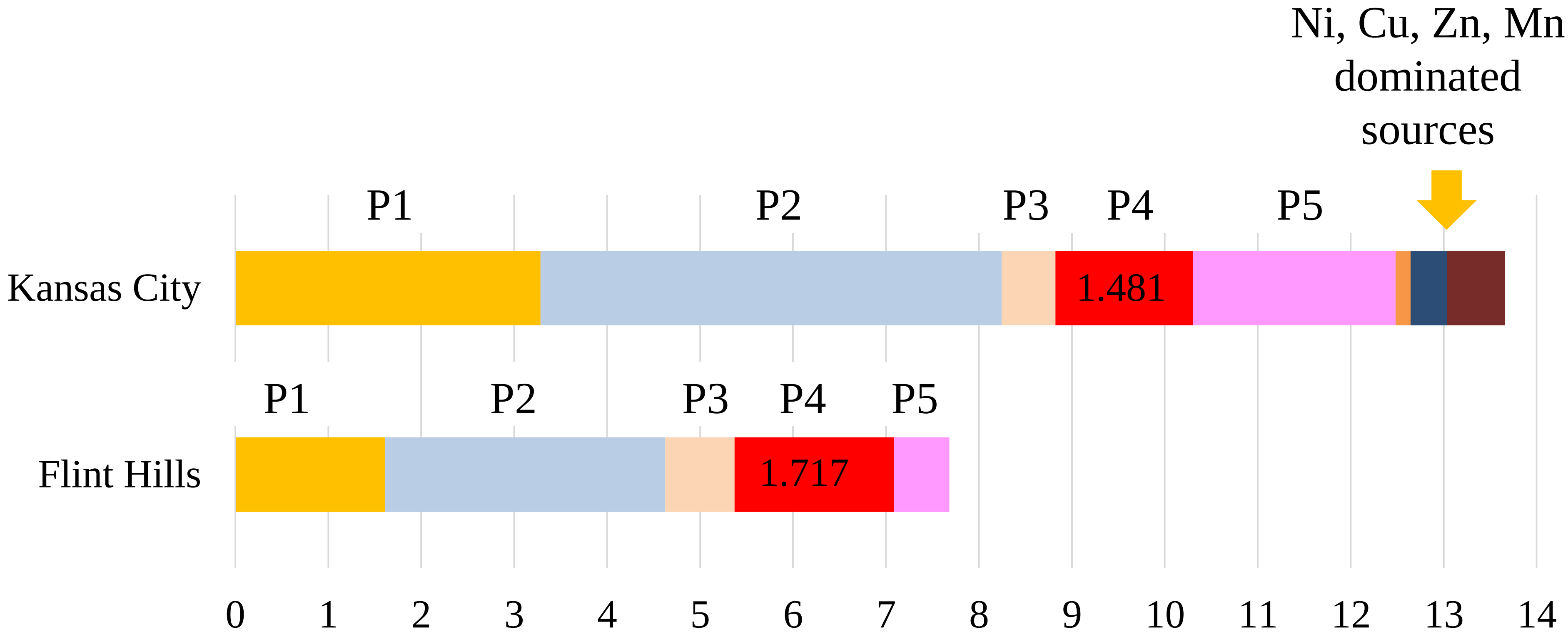
How about PM_{10}?



70% of variation of PM_{10} can be explained by strength of the 5 sources of $PM_{2.5}$

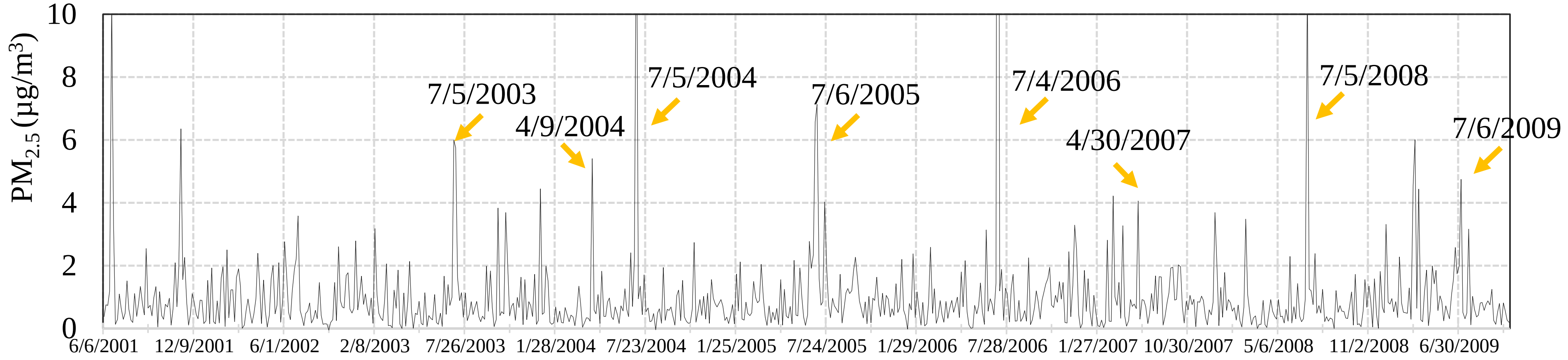
Annual average PM_{10} at the Tallgrass IMPROVE site ($\mu g/m^3$)

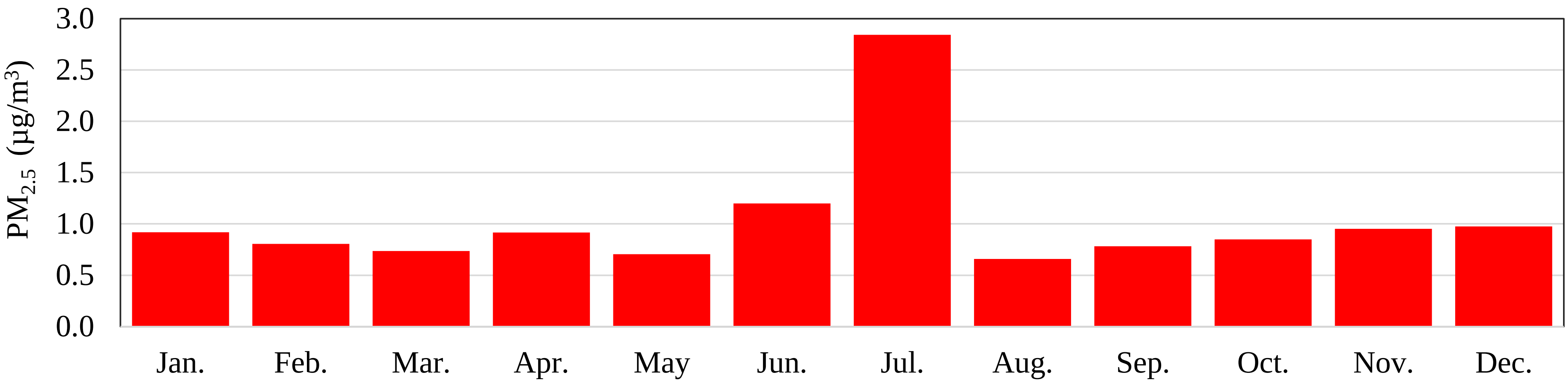
How about contribution to $PM_{2.5}$ at Kansas City?



Annual average source contributions to $PM_{2.5}$ ($\mu g/m^3$) based on PMF results

Contribution of U4 (Vegetative burning) at Kansas City

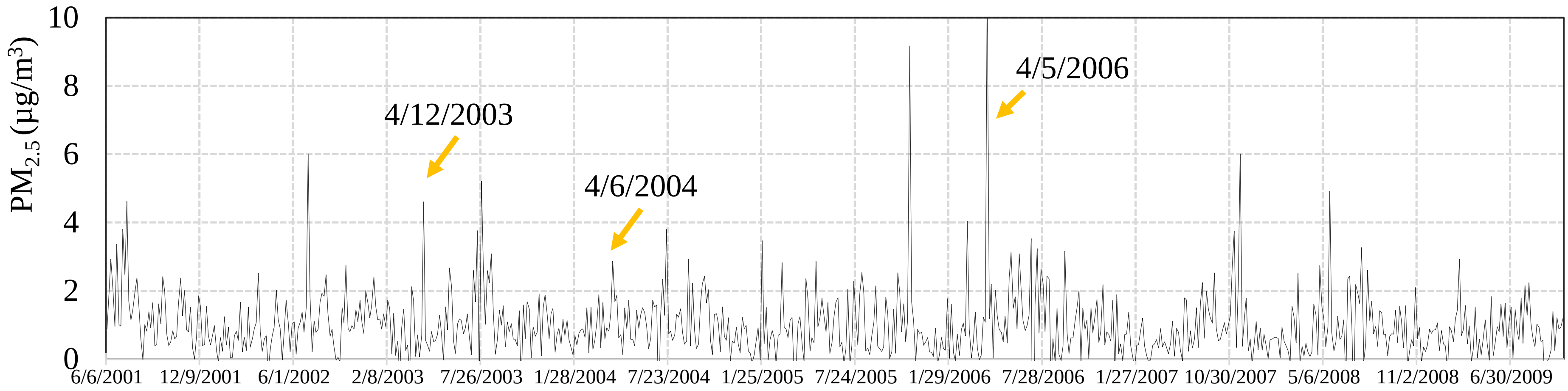


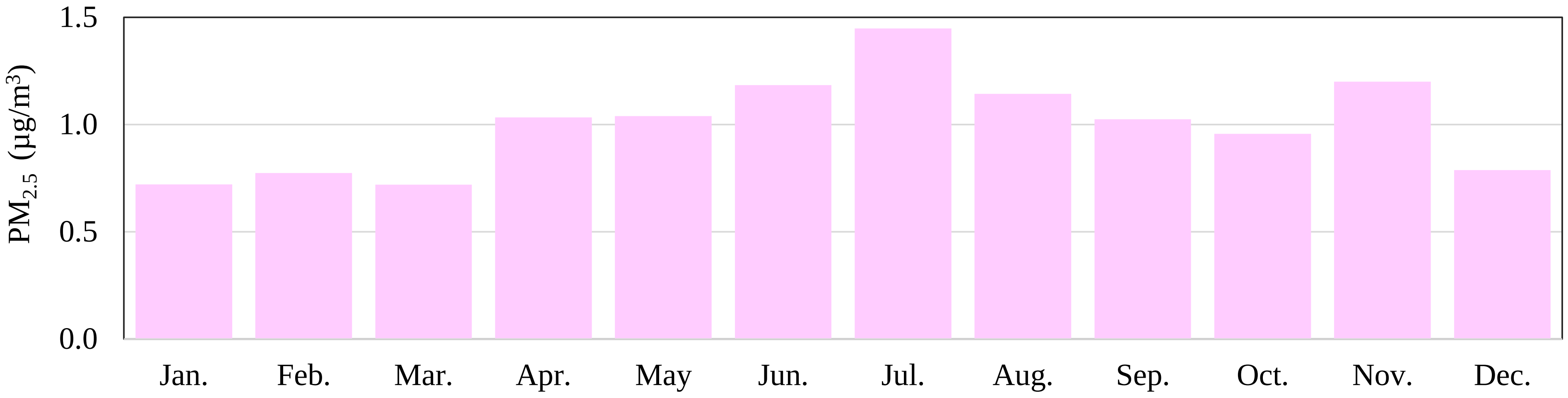


Consistent spikes were observed around July 4th.

Spikes in April were occasional and not as much significant as in July.

Contribution of U5 (Secondary organic aerosol) at Kansas City

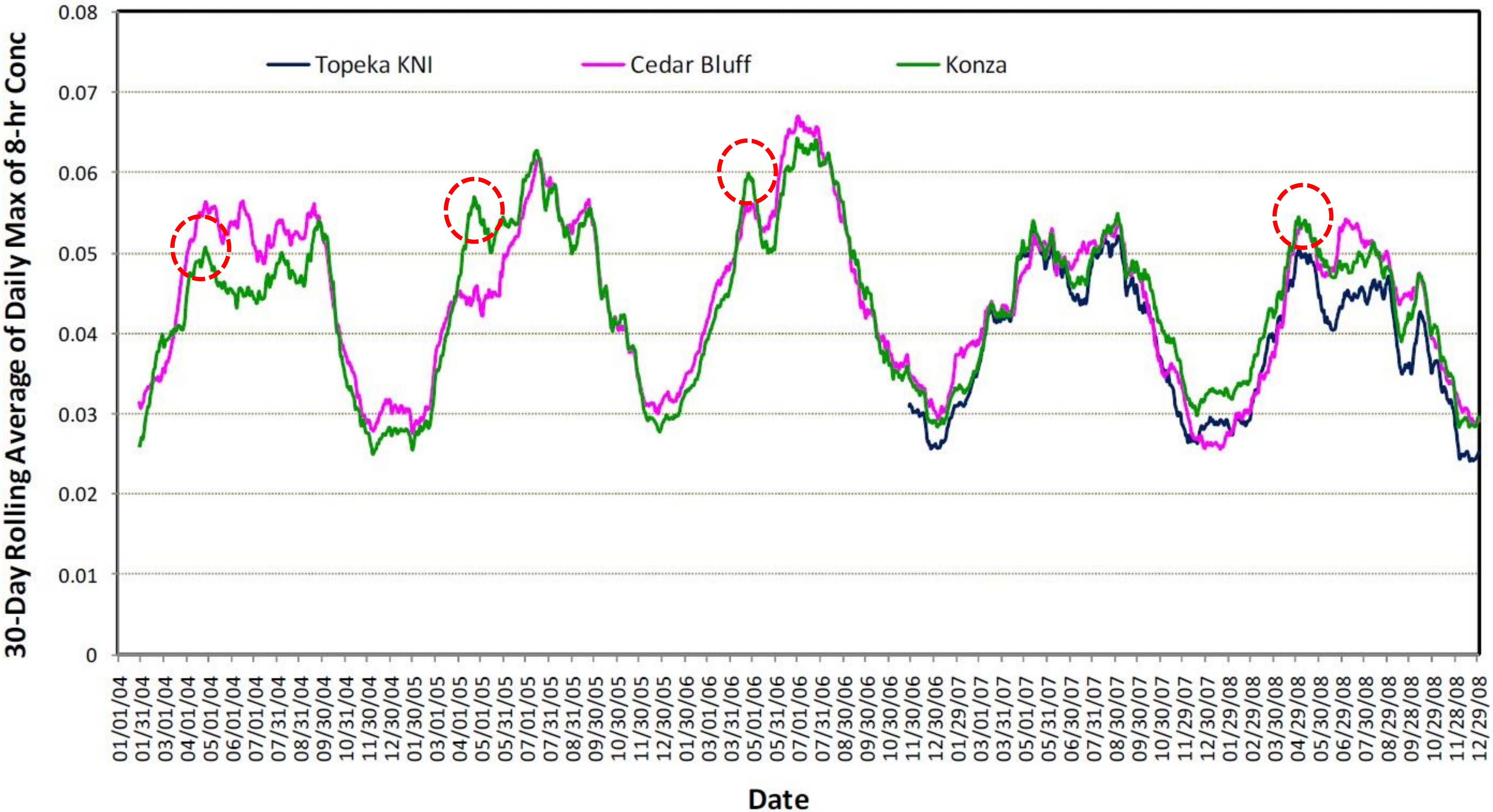




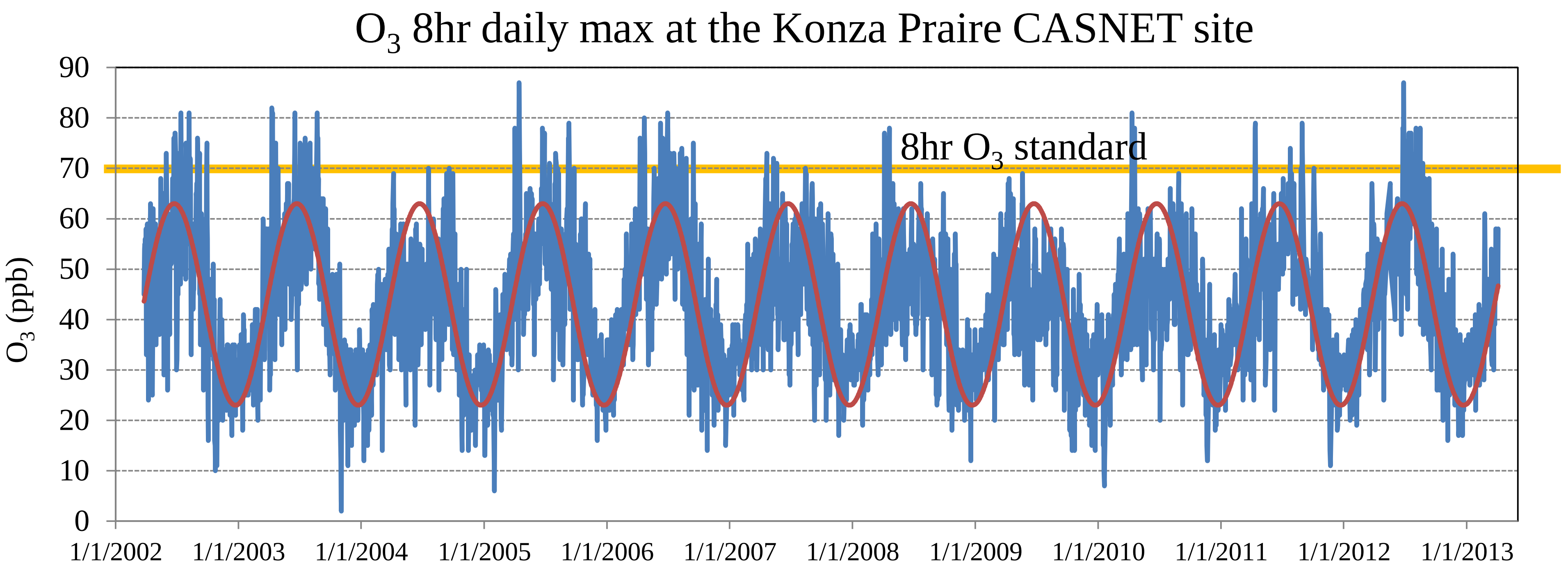
Peak in July.

Occasional spikes were observed in April.

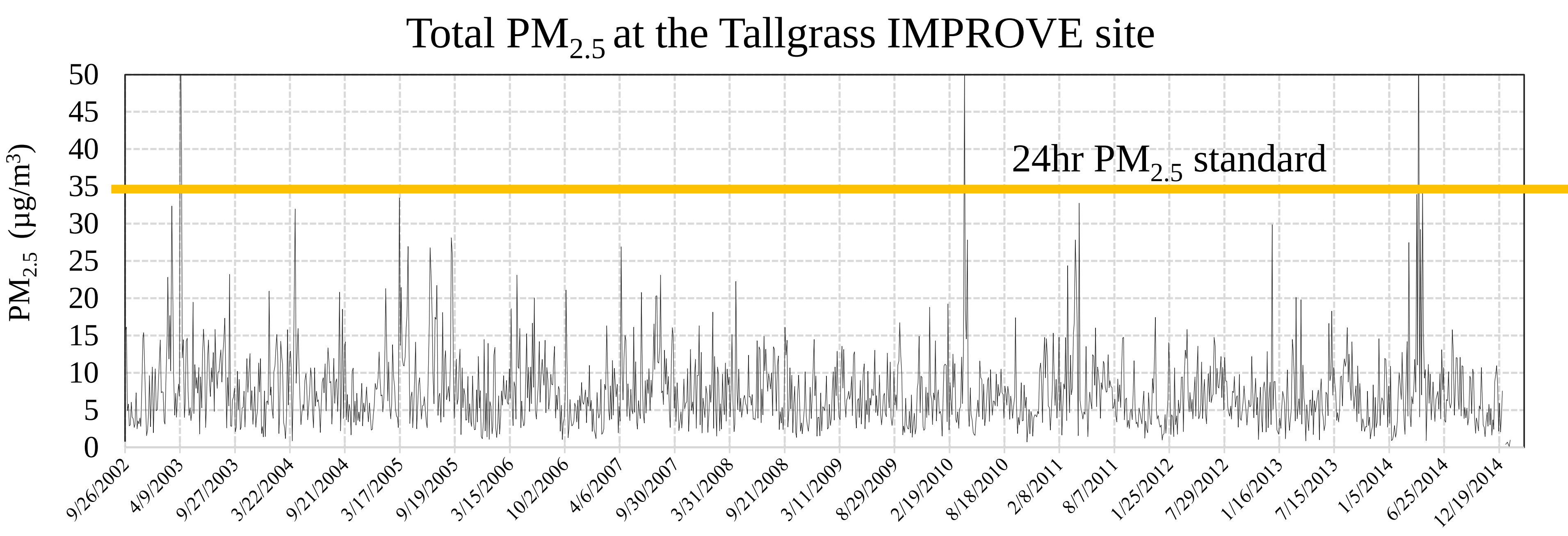
How about contribution to O_3?



30-day Rolling Average of Daily Maximum 8-hour O_3 Concentration
(Kansas 5-year monitoring network assessment, KDHE)



O_3 8hr daily max at the Konza Praire CASNET site
8hr O_3 standard
O_3 (ppb)
0
10
20
30
40
50
60
70
80
90
1/1/2002
1/1/2003
1/1/2004
1/1/2005
1/1/2006
1/1/2007
1/1/2008
1/1/2009
1/1/2010
1/1/2011
1/1/2012
1/1/2013



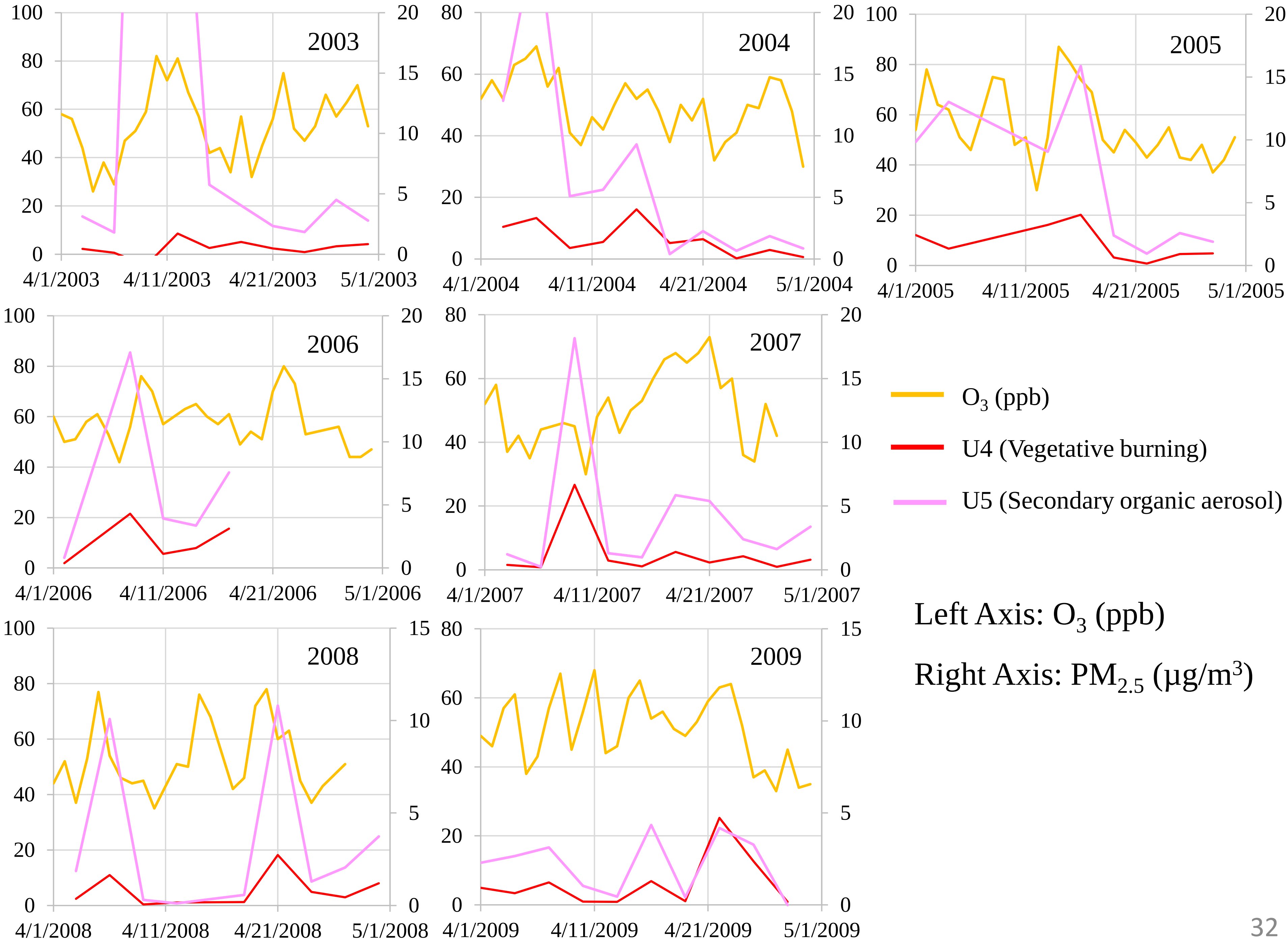
Total $PM_{2.5}$ at the Tallgrass IMPROVE site
24hr $PM_{2.5}$ standard
$PM_{2.5}$ ($\mu g/m^3$)
0
5
10
15
20
25
30
35
40
45
50
9/26/2002
4/9/2003
9/27/2003
3/22/2004
9/21/2004
3/17/2005
9/19/2005
3/15/2006
10/2/2006
4/6/2007
9/30/2007
3/31/2008
9/21/2008
3/11/2009
8/29/2009
2/19/2010
8/18/2010
2/8/2011
8/7/2011
1/25/2012
7/29/2012
1/16/2013
7/15/2013
1/5/2014
6/25/2014
12/19/2014

O_3 and $PM_{2.5}$

- O_3 and $PM_{2.5}$ controls are traditionally considered separately because their high pollution periods are not concurrent on seasonal timescales
  - O_3 usually peaking in summer and $PM_{2.5}$ often peaking in winter.
- Temperature and relative humidity (RH) exert opposite effects on O_3 and nitrate aerosols.
  - Higher temperature and lower RH promote O_3 formation but cause volatilization of nitrate aerosols.

O_3 and $PM_{2.5}$

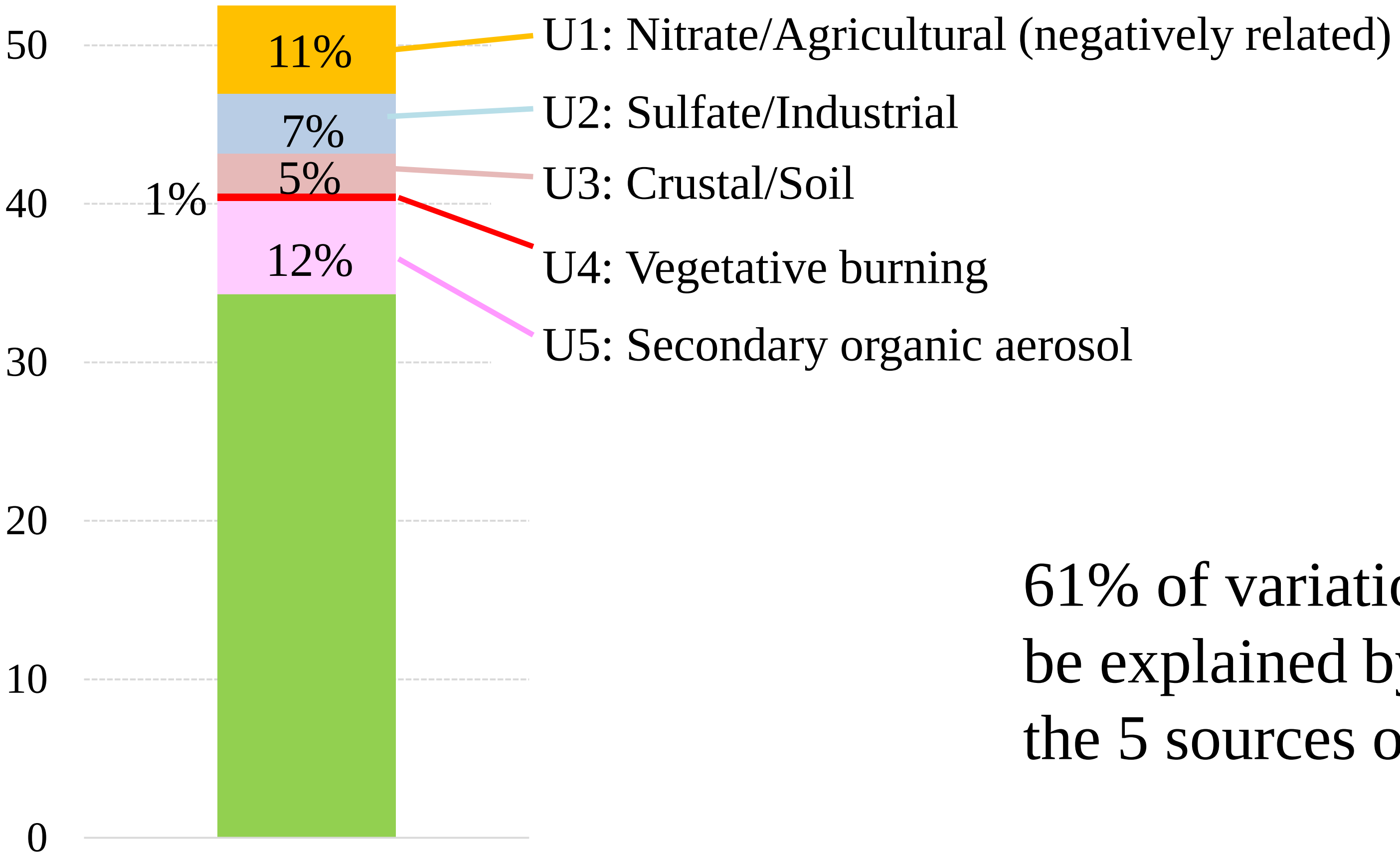
- After source contributions to $PM_{2.5}$ are resolved through receptor modeling, the time series pattern or trend of individual source categories can be more clearly characterized and the hidden correlation between O_3 and these source categories will be revealed.
- A major part of ambient O_3 and $PM_{2.5}$ are generated from pasture burning smoke and share the same precursor compounds, and therefore they could be partially correlated with each other.



Left Axis: O_3 (ppb)

Right Axis: $PM_{2.5}$ ($\mu g/m^3$)

How was O_3 related with $PM_{2.5}$ sources?



61% of variation of O_3 can be explained by strength of the 5 sources of $PM_{2.5}$

Average O_3 in April at the Konza Praire CASNET site (ppb)

CMAQ modeled O_3 (ppb) at Konza Prairie

Date	Observed	CMAQ All Fires	CMAQ No Flint Hills Fires	Impact of Flint Hills Fires
4/12/2011	78	60	53	7
4/13/2011	79	92	62	30

(Kenneth Craig, et al., 2015; Sonoma Technology, Inc.)

Future study

- To investigate burning contributions on $PM_{2.5}$ and O_3 in urban communities, including Kansas city and Wichita.
- To model O_3 using time series techniques and to reveal the effects of emission sources as well as selected meteorological variables, while considering interaction of burning emission with other pollution sources.
- To develop effective techniques to assimilate satellites aerosol products such as aerosol optical depth (AOD) into the current emission processing model in order to improve emission estimation of prescribed burns.