Transport of Outdoor Pollutants into the Indoor Environment

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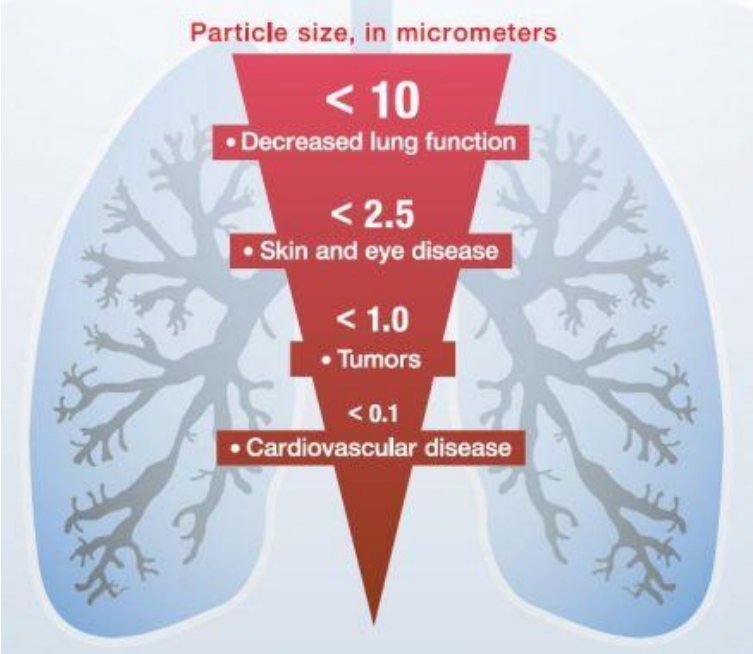
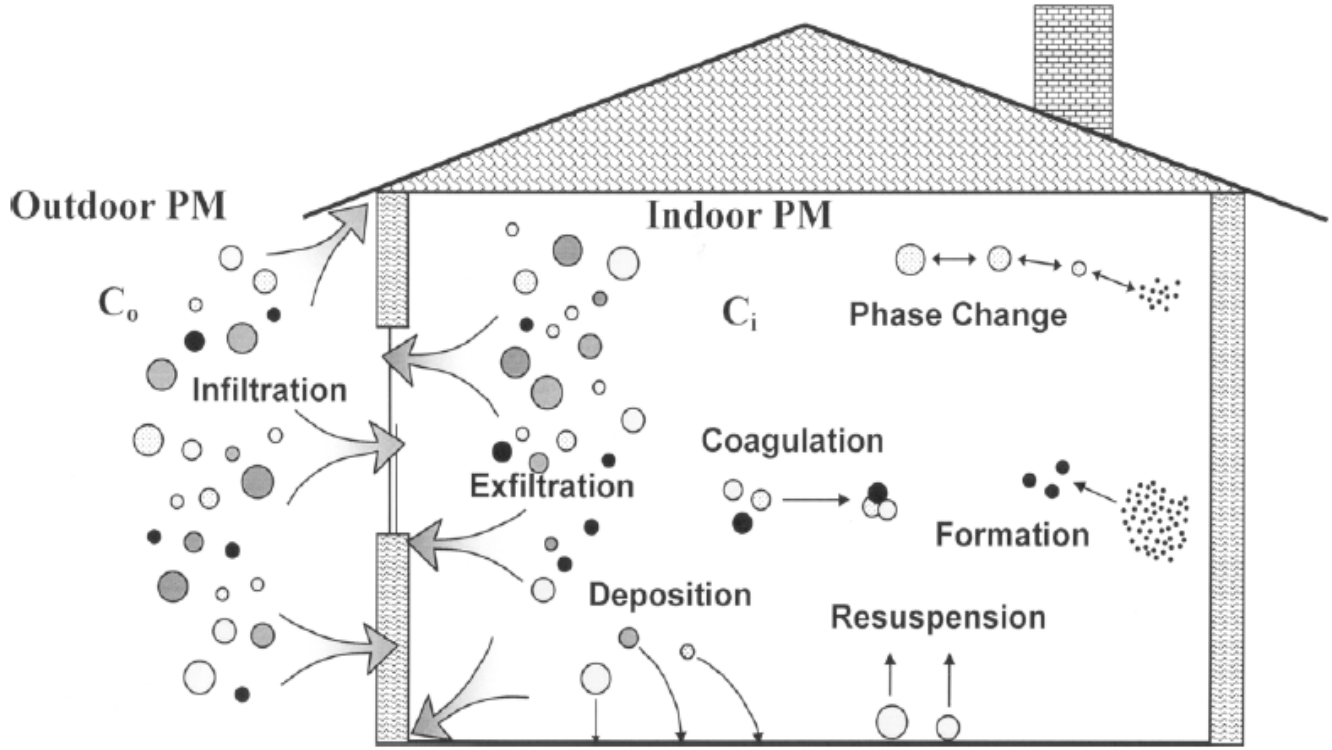
Overview of Indoor Air Pollution

- Pollution usually related to outdoors
- Many sources of indoor pollution
- Can penetrate from outdoors to indoors
- Particle pollution can have adverse health effects
- We will focus on particle and ozone infiltration



Particle and Ozone Infiltration

- Indoor pollution affected by outdoors through a variety of factors
- These factors affect certain mathematical factors:
  - Air Exchange Rate, AER (**λ**)
  - Penetration Factor (**P**)
  - Deposition Rate (**k**)



Measuring Concentrations

- Particulates and ozone measured through different instruments
- Particle measuring equipment:

Optical Particle Sizer (OPS) Size range: 0.3 – 10 µm	**Dusttrak Aerosol Monitor** Size range: 0.1 to 10 µm	**Condensation Particle Counter (CPC)** Size range: 0.01 to >1.0 µm	**Nanoscan SMPS Nanoparticle Sizer** Size range: Down to 10nm

- Ozone measuring equipment:

2B Brand Model 211 Ozone Monitor	**2B Brand Model 205 Ozone Monitor**

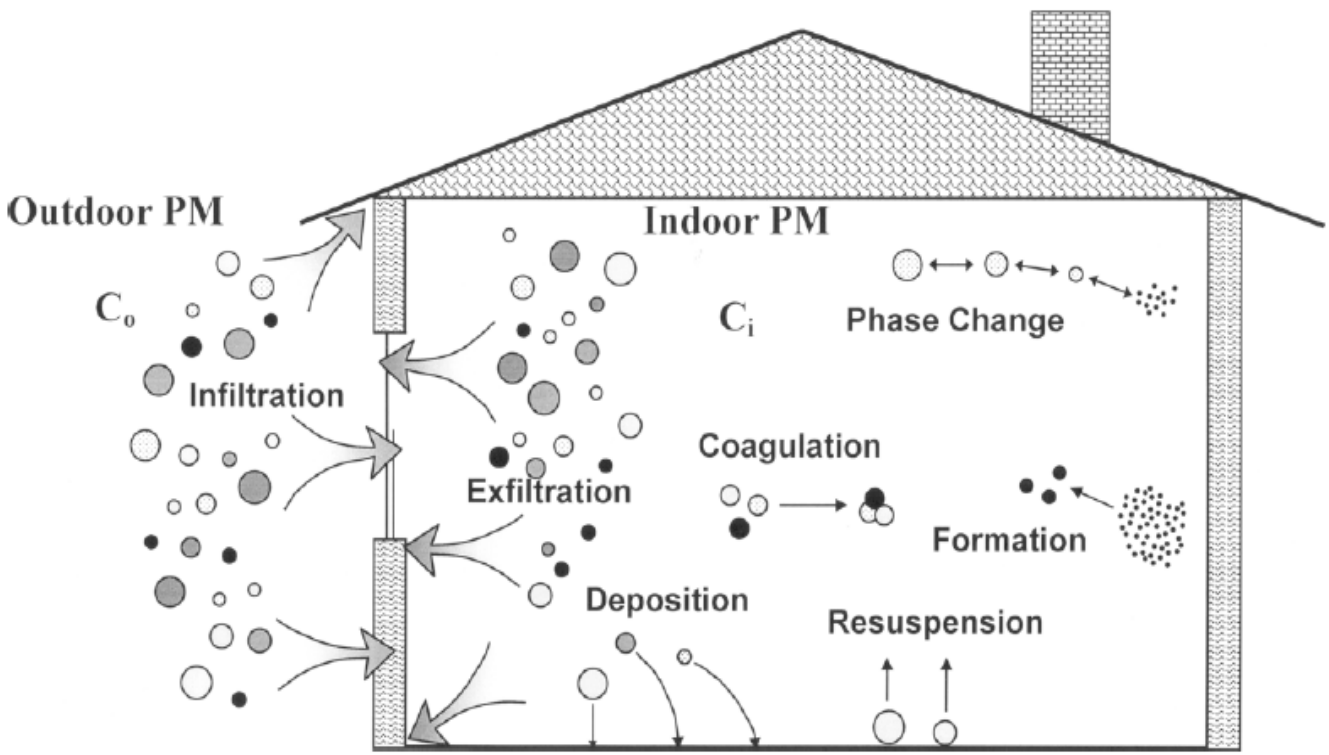
Our Experimental Setup

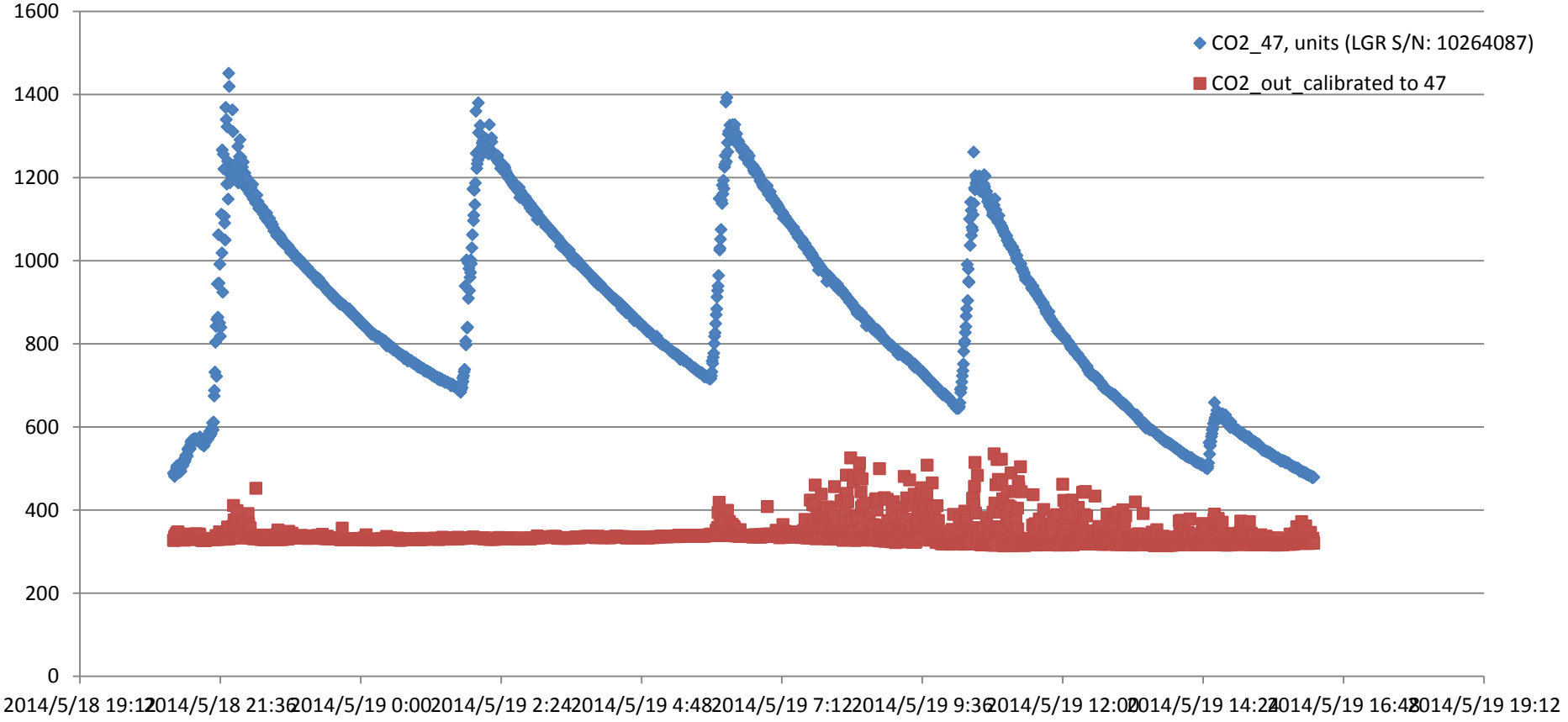
- Indoor and outdoor concentrations measured simultaneously
- Swagelok brand switching valves used to switch environments
- AER measured alongside particles and ozone
- 3rd story Carman Hall apartment test site
- Only one major test done

$$\frac{\partial C_I}{\partial t} = (C_o P - C_I)\lambda_v - C_I\beta + G + S + F + K + H, \quad [1]$$

$$\frac{\partial C_I}{\partial t} = C_o P \lambda_v - C_I(\lambda_v + \beta). \quad [2]$$

$$C_I(t_2) = C_I(t_1) + P C_o(t_1)\lambda_v(t_1)\Delta t - C_I(t_1)(\lambda_v(t_1) + \beta)\Delta t. \quad [3]$$

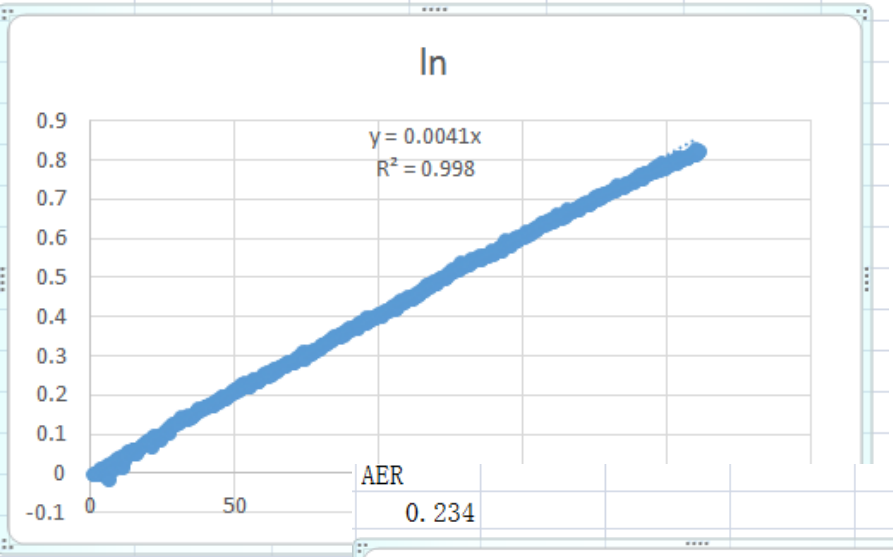



1600
1400
1200
1000
800
600
400
200
0
CO2_47, units (LGR S/N: 10264087)
CO2_out_calibrated to 47
2014/5/18 19:12
2014/5/18 21:36
2014/5/19 0:00
2014/5/19 2:24
2014/5/19 4:48
2014/5/19 7:12
2014/5/19 9:36
2014/5/19 12:00
2014/5/19 14:24
2014/5/19 16:48
2014/5/19 19:12

$$\lambda = \frac{1}{(t - t_0)} \ln\left(\frac{C_{\text{in}}(t) - \bar{C}_{\text{out}}}{C_{\text{in}}(t_0) - \bar{C}_{\text{out}}}\right),$$

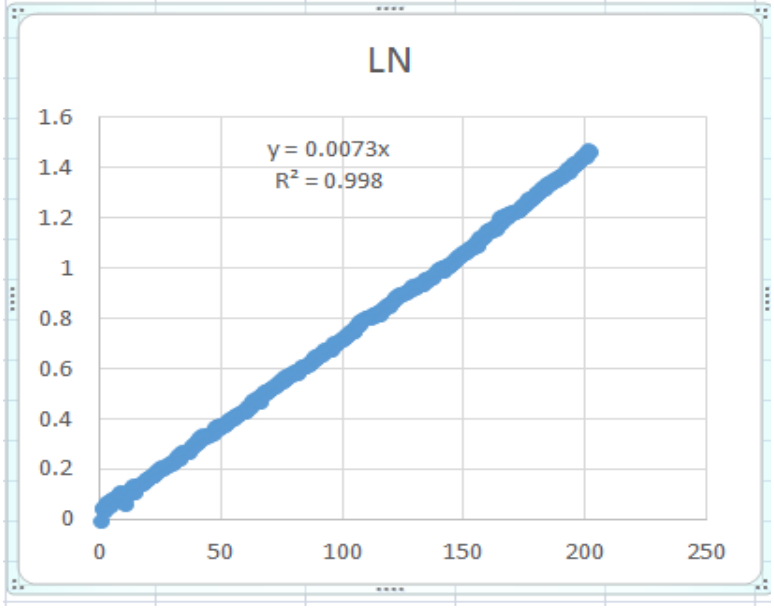
AER

0. 246



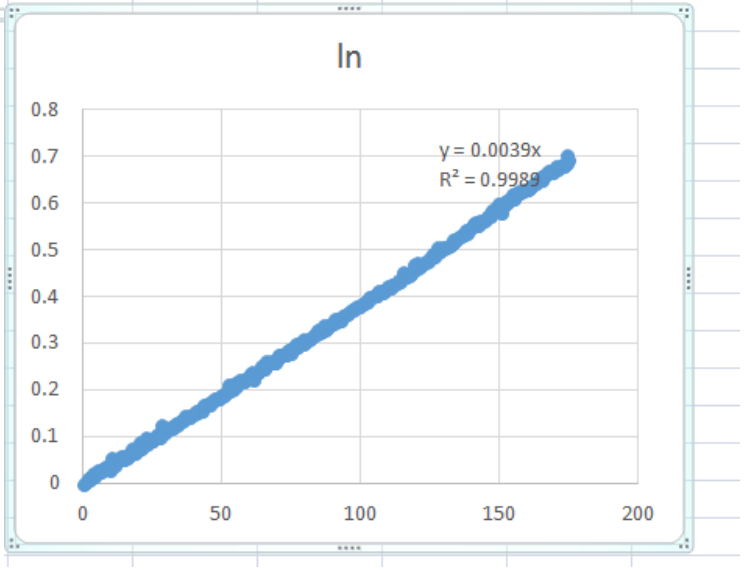
AER

0. 438



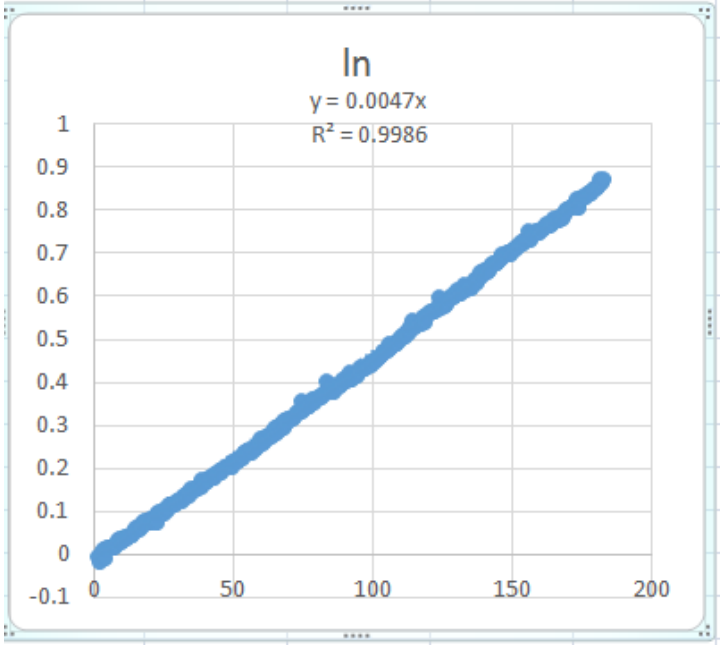
AER

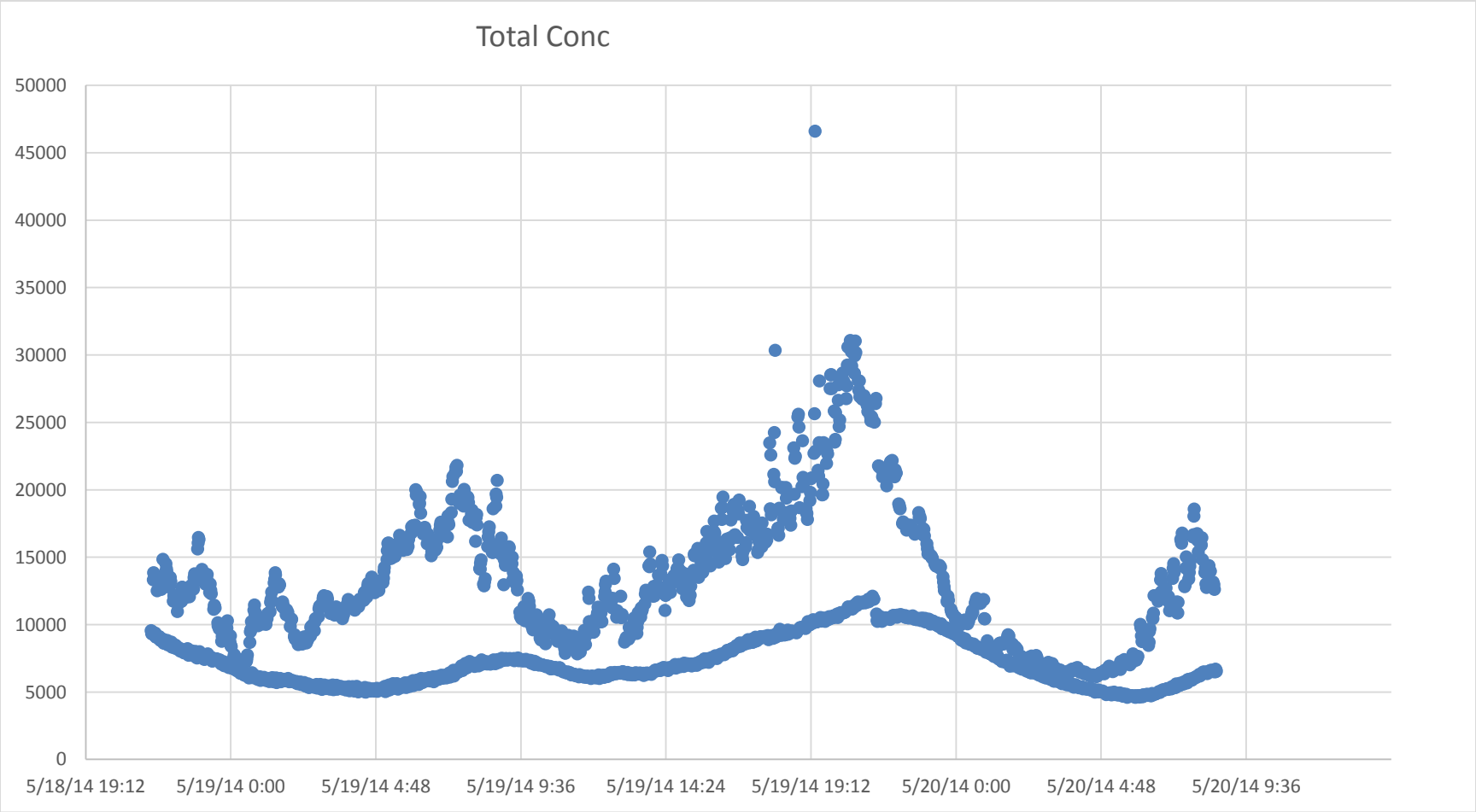
0. 234



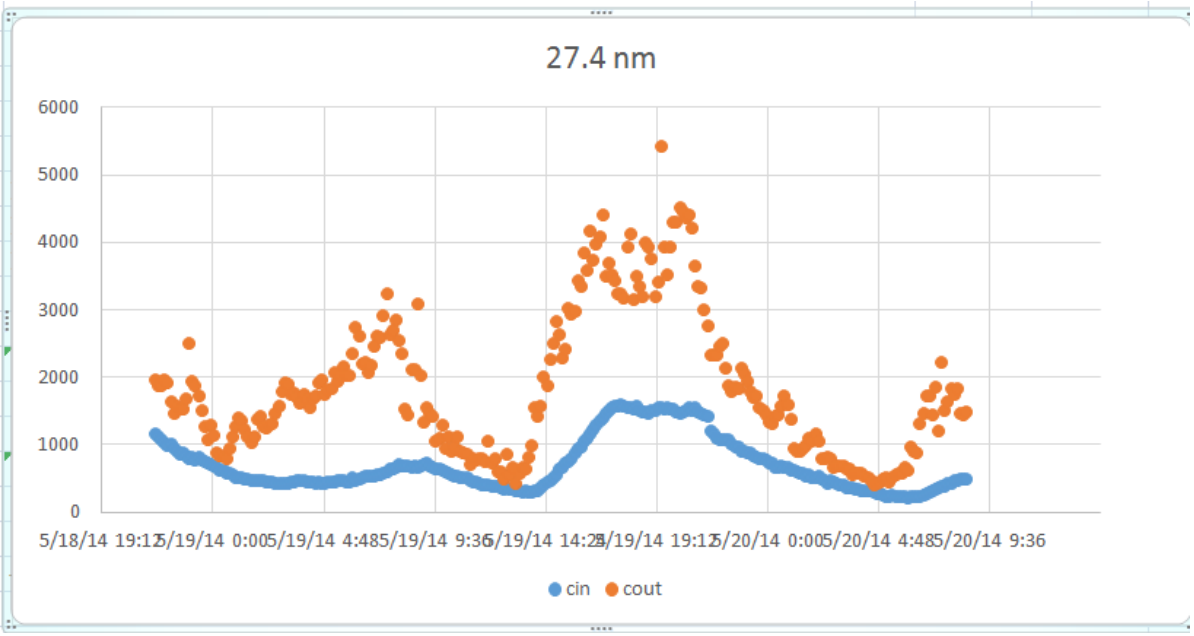
AER

0. 282




Total Conc
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
5/18/14 19:12
5/19/14 0:00
5/19/14 4:48
5/19/14 9:36
5/19/14 14:24
5/19/14 19:12
5/20/14 0:00
5/20/14 4:48
5/20/14 9:36

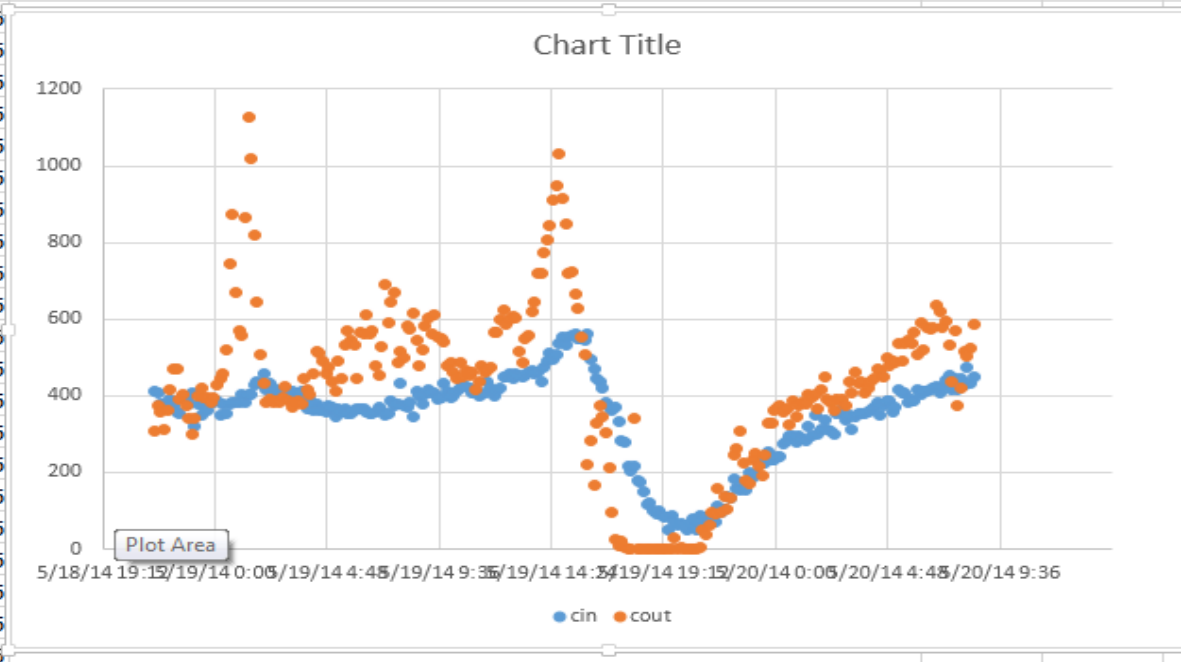
time	cin	cout	AER
5/18/14 21:25	1189.726	1981.489	0.246
5/18/14 21:33	1157.053	1891.676	0.246
5/18/14 21:41	1115.061	1884.351	0.246
5/18/14 21:49	1064.547	1966.601	0.246
5/18/14 21:57	1024.261	1924.135	0.246
5/18/14 22:05	1033.152	1641.346	0.246
5/18/14 22:13	985.613	1471.262	0.246
5/18/14 22:21	937.709	1584.856	0.246
5/18/14 22:29	887.4086	1544.475	0.246
5/18/14 22:37	899.6987	1550.904	0.246
5/18/14 22:45	875.5537	1690.205	0.246
5/18/14 22:53	830.9664	2515.157	0.246
5/18/14 23:01	855.1786	1951.563	0.246
5/18/14 23:09	811.2381	1887.874	0.246
5/18/14 23:17	835.6492	1730.541	0.246
5/18/14 23:25	808.0864	1520.637	0.246
5/18/14 23:33	784.4673	1275.613	0.246



Source	SS	df	MS		
				Number of obs =	125
Model	464058132	23202906.3		R-squared =	0.9992
Residual	36114.05123	293.610141		Adj R-squared =	0.9992
				Root MSE =	17.13506
Total	46441927125	371535.413		Res. dev. =	1063

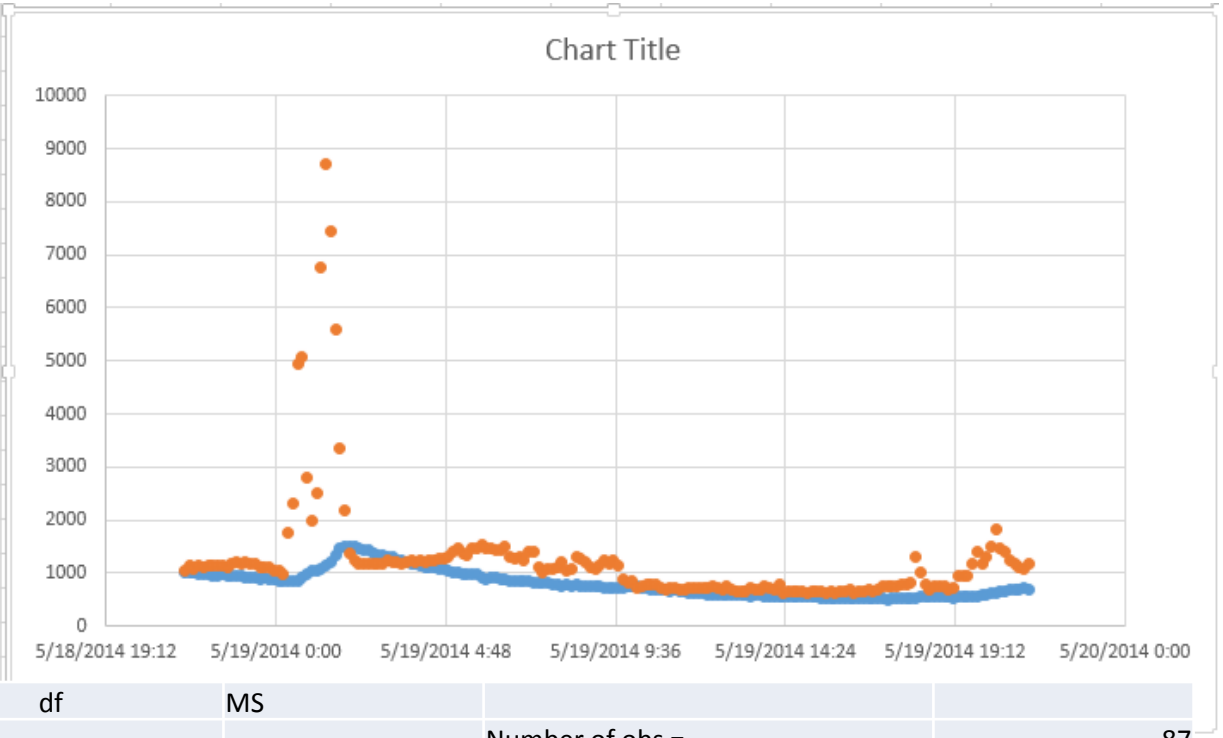
cin	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
/p	0.4973068	.0602505	25	0.000	.3780439	0.616568
/loss	0.1610963	.0447889	60	0.000	.0724395	0.2497531

time	cin	cout	AER
5/18/14 21:25	411.9338	308.467	0.246
5/18/14 21:33	409.0517	374.3918	0.246
5/18/14 21:41	377.7736	359.9041	0.246
5/18/14 21:49	377.8424	312.0327	0.246
5/18/14 21:57	381.8194	363.5957	0.246
5/18/14 22:05	389.8971	417.6117	0.246
5/18/14 22:13	374.6072	471.8967	0.246
5/18/14 22:21	356.9272	470.2056	0.246
5/18/14 22:29	354.3569	393.0481	0.246
5/18/14 22:37	395.9905	405.4692	0.246
5/18/14 22:45	389.2327	372.7106	0.246
5/18/14 22:53	376.6193	341.8983	0.246
5/18/14 23:01	407.5	300.1522	0.246
5/18/14 23:09	322.1161	341.7758	0.246
5/18/14 23:17	376.6486	399.7358	0.246
5/18/14 23:25	349.1329	421.5172	0.246
5/18/14 23:33	370.3962	393.465	0.246
5/18/14 23:41	360.607	397.0125	0.246
5/18/14 23:49	381.3548	384.2451	0.246
5/18/14 23:57	383.4131	396.2443	0.246
5/19/14 0:05	387.0793	429.6812	0.246
5/19/14 0:13	350.5239	444.8964	0.246
5/19/14 0:21	377.2324	459.6911	0.246
5/19/14 0:29	352.64	520.1262	0.246



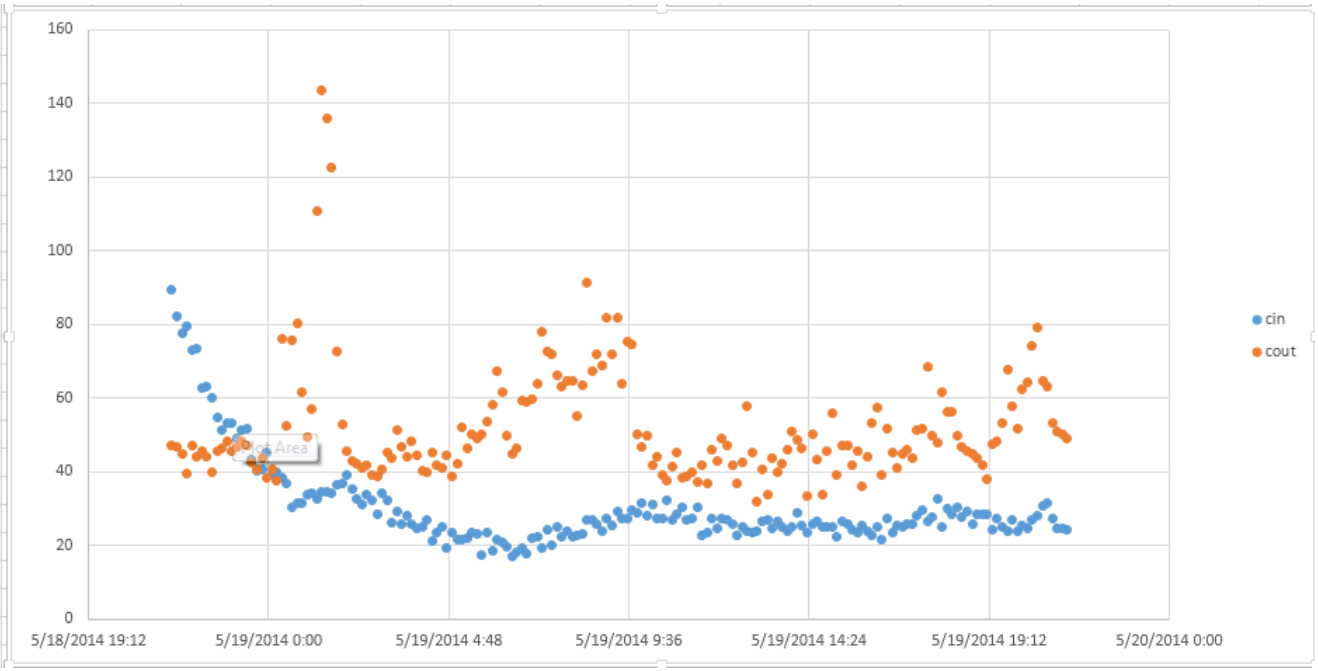
154	Source	SS df MS		
			Number of obs =	125
	Model	19688730.2 2 9844365.11	R-squared =	0.9974
	Residual	51915.8204 123 422.079841	Adj R-squared =	0.9973
			Root MSE =	20.54458
	Total	19740646 125 157925.168	Res. dev. =	1108.368
	cin	Coef. Std. Err. t	P>t [95% Conf.	Interval]
	/p	1.01652 .2461727 4.13	0.000 .5292366	1.503804
	/loss	.0963151 .1037351 0.93	0.355 -.1090222	0.3016524

time	cin	cout	AER
5/18/2014 21:25	999.1429	1040.714	0.246
5/18/2014 21:33	1025.857	1133.143	0.246
5/18/2014 21:41	1009	1090.143	0.246
5/18/2014 21:49	965.2857	1135	0.246
5/18/2014 21:57	979.4286	1116.857	0.246
5/18/2014 22:05	973	1128.429	0.246
5/18/2014 22:13	948.1429	1129.857	0.246
5/18/2014 22:21	950.5714	1143.143	0.246
5/18/2014 22:29	973	1138.143	0.246
5/18/2014 22:37	947.2857	1116.143	0.246
5/18/2014 22:45	941.7143	1188.429	0.246
5/18/2014 22:53	941	1210.571	0.246
5/18/2014 23:01	939.4286	1169.143	0.246
5/18/2014 23:09	913.2857	1194	0.246
5/18/2014 23:17	910	1183.714	0.246
5/18/2014 23:25	899.5714	1166.286	0.246
5/18/2014 23:33	884.4286	1104.857	0.246
5/18/2014 23:41	899	1092.429	0.246
5/18/2014 23:49	893.1429	1094.571	0.246

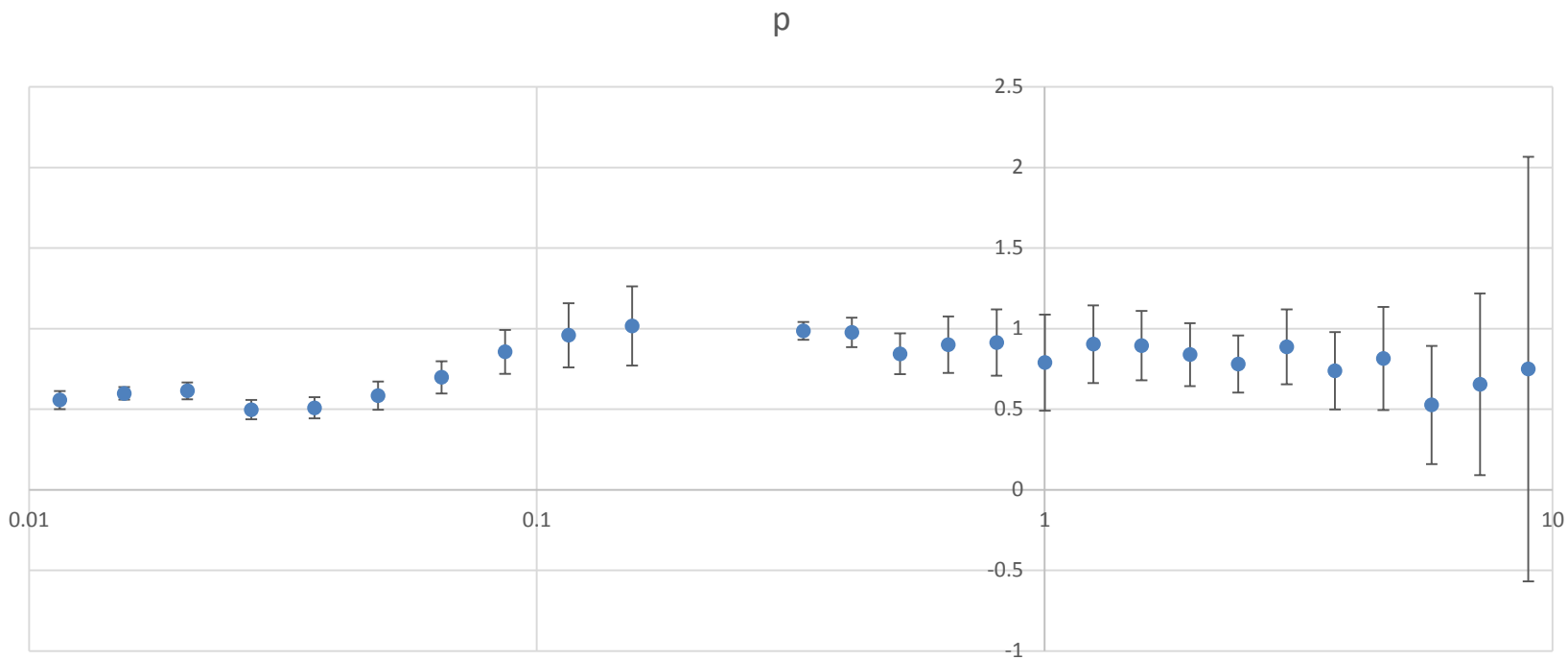


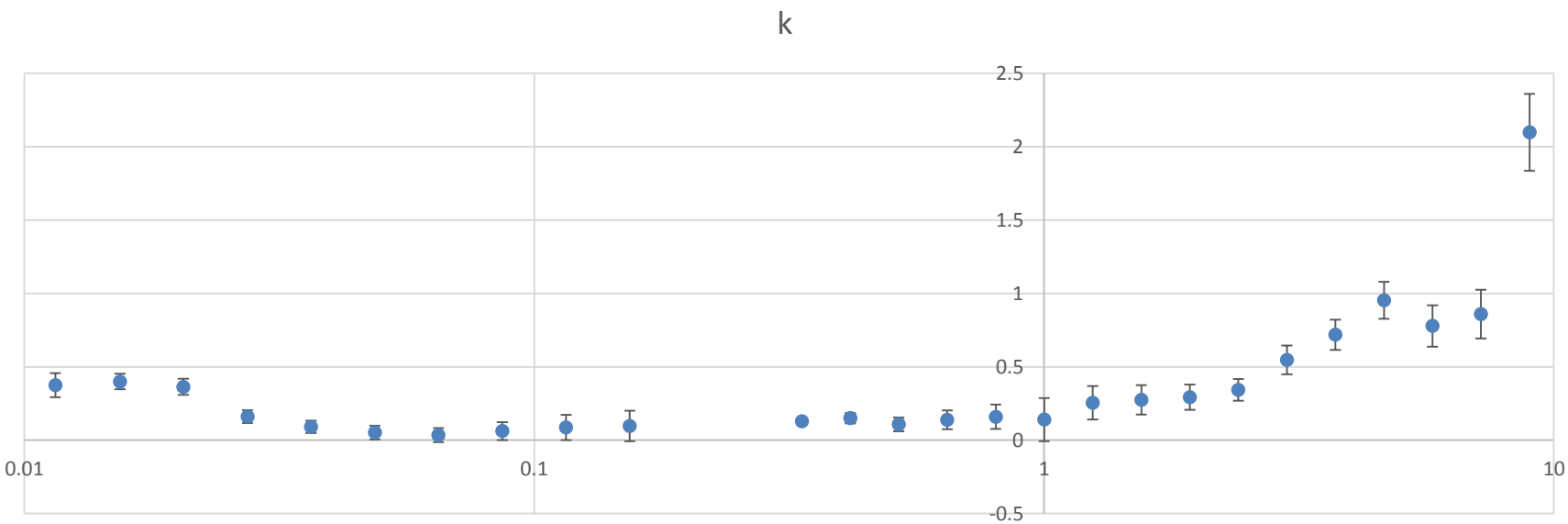
0.52	Source	SS	df	MS	
				Number of obs =	87
	Model	65238296	2	32619147.9	R-squared = 0.9997
	Residual	20276.32	85	238.544888	Adj R-squared = 0.9997
				Root MSE =	15.4449
	Total	6525857 2	87	750098.531	Res. dev. = 721.1585
	cin	Coef.	Std. Err.	t	P>t [95% Conf. Interval]
	/p	0.843971	.1267107	6.66	0.000 .5920361 1.095906
	/loss	0.10809	.0462042	2.34	0.022 .0162234 0.199956

time	cin	cout	AER
5/18/2014 21:25	89.42857	47	0.246
5/18/2014 21:33	82.14286	46.85714	0.246
5/18/2014 21:41	77.71429	44.71429	0.246
5/18/2014 21:49	79.42857	39.57143	0.246
5/18/2014 21:57	73.14286	47.14286	0.246
5/18/2014 22:05	73.42857	44	0.246
5/18/2014 22:13	62.57143	45.42857	0.246
5/18/2014 22:21	63	44.14286	0.246
5/18/2014 22:29	60	39.71429	0.246
5/18/2014 22:37	54.85714	45.42857	0.246
5/18/2014 22:45	51.14286	46.14286	0.246
5/18/2014 22:53	53.28571	48.28571	0.246
5/18/2014 23:01	53.14286	45.71429	0.246
5/18/2014 23:09	49	46.85714	0.246
5/18/2014 23:17	51.28571	48.14286	0.246
5/18/2014 23:25	51.71429	47	0.246
5/18/2014 23:33	43.28571	42.42857	0.246
5/18/2014 23:41	40.14286	40.57143	0.246
5/18/2014 23:49	40.42857	43.57143	0.246
5/18/2014 23:57	45	38.28571	0.246
5/19/2014 0:05	39	40.71429	0.246
5/19/2014 0:13	39.71429	37.57143	0.246
5/19/2014 0:21	38.14286	76	0.246



1.55	Source	SS	df	MS		
					Number of obs =	125
	Model	145657.2	2	72828.6118	R-squared =	0.9926
	Residual	1085.002	123	8.82115731	Adj R-squared =	0.9925
					Root MSE =	2.970043
	Total	146742.2	125	1173.93781	Res. dev. =	624.8626
	cin	Coef.		Std. Err. t	P>t [95% Conf.	Interval]
	/p	0.894406		.2158249 4.14	0.000 .4671939	1.321618
	/loss	0.275244		.1005813 2.74	0.007 .0761498	0.474339


p
2.5
2
1.5
1
0.5
0
-0.5
-1
0.01
0.1
1
10


k
2.5
2
1.5
1
0.5
0
-0.5
0.01
0.1
1
10

Problems solved

- Connections and leakage
- Dead volume
- CO_2 tank PM emission

Current problems

- Instruments
- Blank interval (200nm-300nm)
- Zero value(PM) & negative value (ozone)

- Set up the ozone measuring equipment
- Compare the long term test with the short

References

- Horton, Jennifer. "HowStuffWorks "Causes of Indoor Air Pollution""*HowStuffWorks*. N.p., n.d. Web. 09 June 2014. <http://home.howstuffworks.com/home-improvement/household-safety/tips/indoor-air-pollution1.htm>.
- Thatcher, Tracy L., Melissa M. Lunder, Kenneth L. Revzan, Richard G. Sextro, and Nancy J. Brown. "A Concentration Rebound Method for Measuring Particle Penetration and Deposition in the Indoor Environment." *Aerosol Science and Technology* (2003): 847-53. Web. 10 June 2014.