Field Validation of the UCB Particle Monitor



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Background

- Fine particles ($PM_{2.5}$) best single indicator for health effects from combustion
  - Difficult to monitor personal exposure from PM
  - Expensive (light scattering devices: ~$4000)
  - Labor intensive and high initial setup cost (Gravimetric pump-filter)
  - Lacks sufficient battery power for multi-day use in remote field settings
- Need for a cheap particle monitoring instrument for measuring IAP
- Faced with above problems, developed our own particle monitor (costs ~$350-$400) from smoke detector technology
  - First Alert (FA302) Smoke Detector converted into UCB Particle Monitor!

Theory Behind Smoke Detector Technology
(Litton et al. 2002, 2004)

Operates on principles of ion depletion and optical scattering by smoke particles

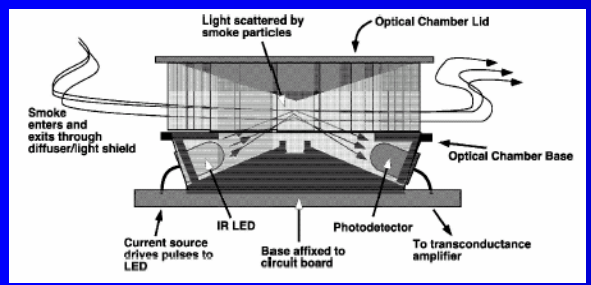
FA302 unit combines both ionization chamber and optical scattering sensing

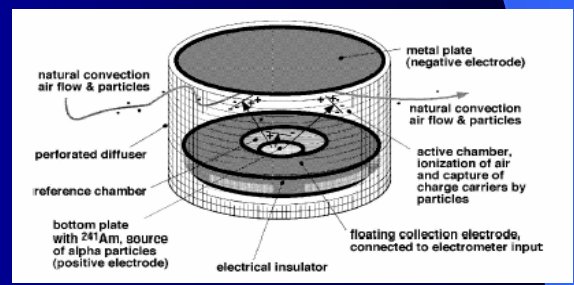
Photoelectric Chamber

- Responds to larger particles produced from smoldering.
- Uses LED with an output wavelength of 880 nm and a photodiode that measures the intensity of scattered light at a 45^0 angle from forward direction.

Ionization Chamber

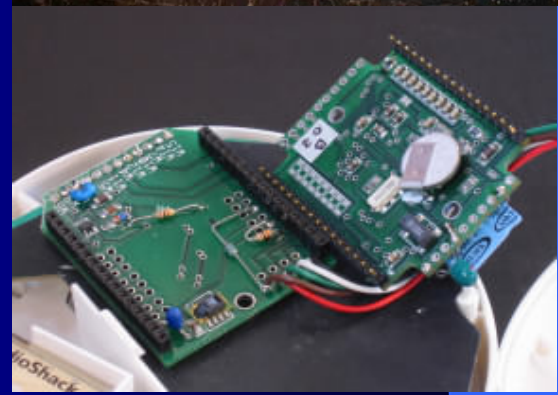
- Responds to small particles produced during flaming.
- Ions are produced from alpha particles using a 0.9 μCi source of 241 Americium. As particles enter, current is disrupted proportionally to the particle levels.

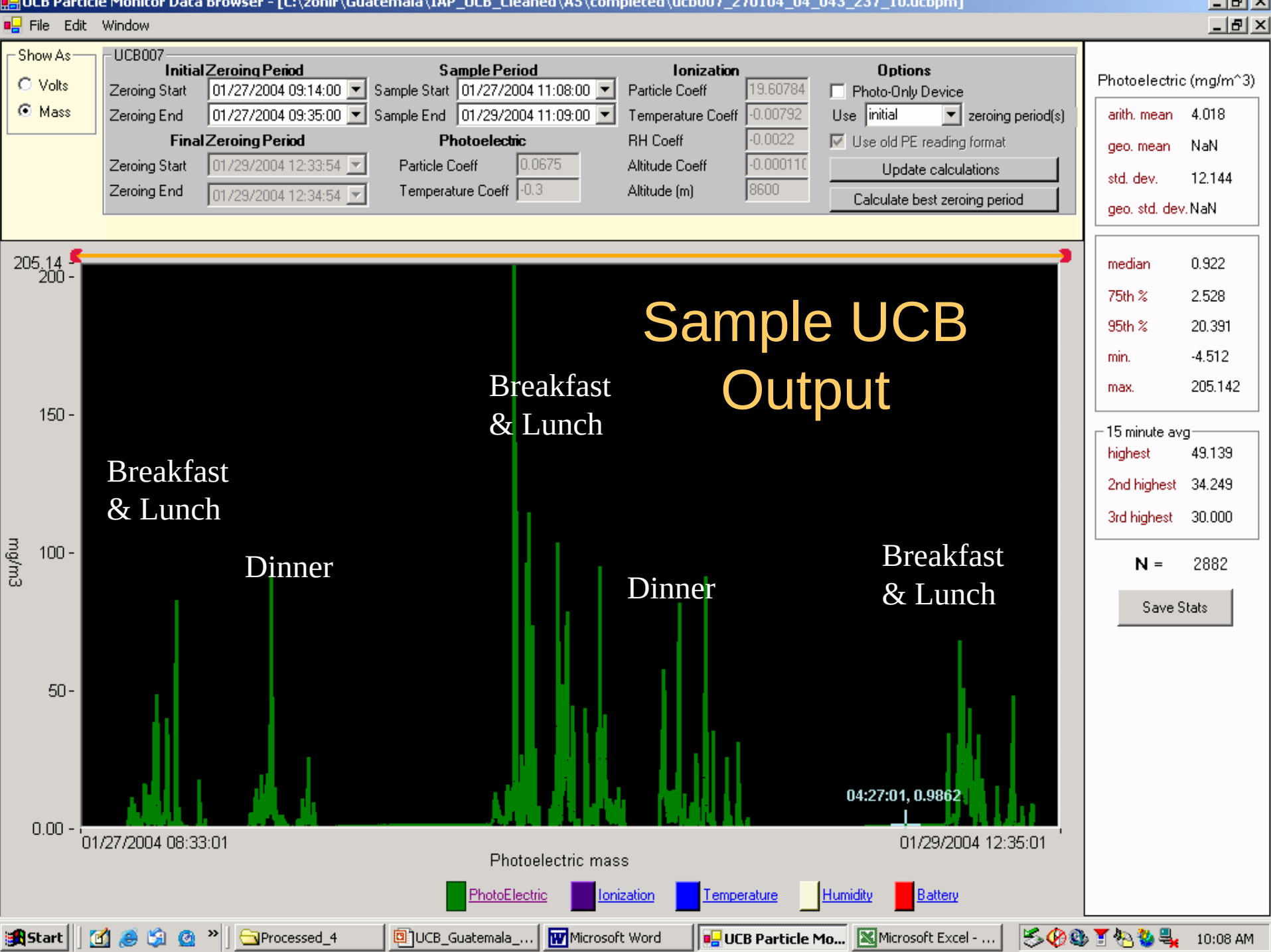




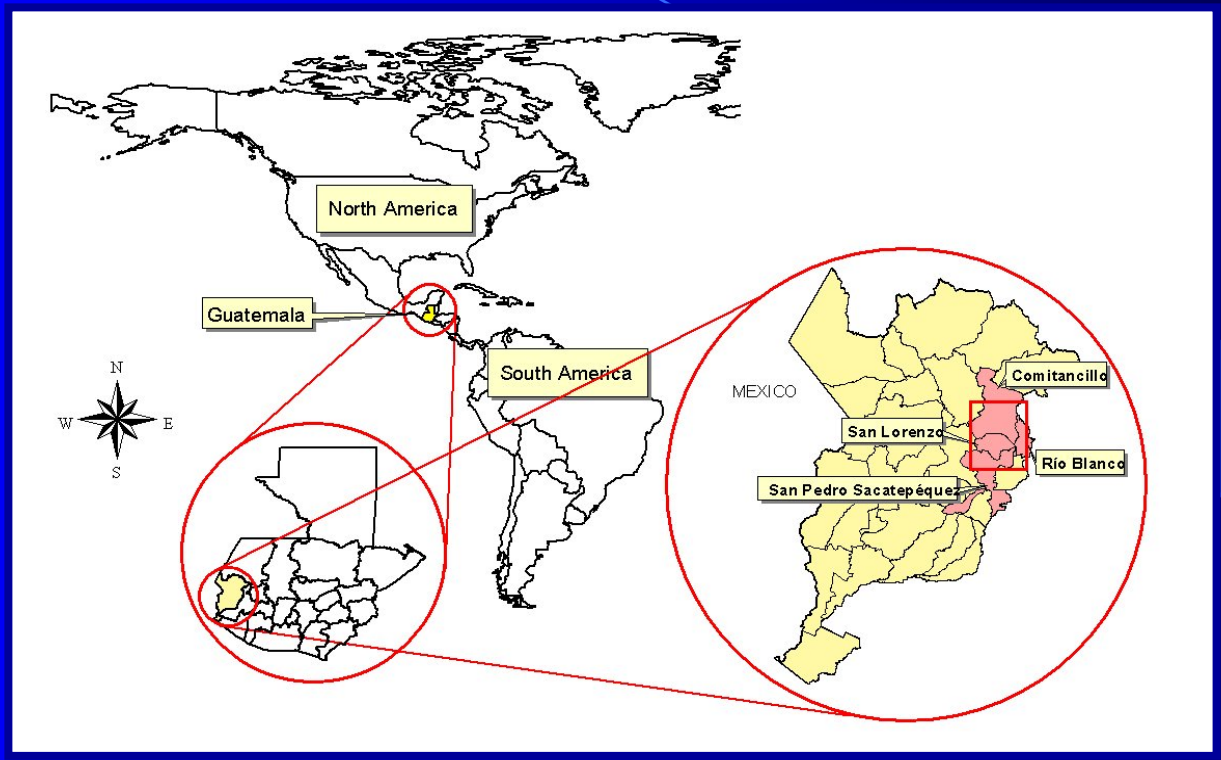
Development of UCB Particle Monitor

- First and foremost: keep cost as low as possible for wider use in developing countries (~$350-$400)
- Changes from First Alert (FA302) unit:
  - Added a clock, temperature and humidity sensors
  - Removed horn & substituted with a programmable datalogger with control circuits
  - Developed firmware for controlling device
  - Developed software for launching, downloading, and processing data as needed for proper sampling
- Lab Testing and validation
  - Aerosol Dynamics
  - UC Irvine
  - Aprovecho
- Field Validation
  - Two years of piloting in rural Guatemala homes
  - Other field studies: India, Nepal, Mexico, China, Ghana, Ethiopia, Mongolia, Uganda, etc.




UCB Particle Monitor Data Browser - [C:\zohir\Guatemala\IAP_UCB_Cleaned\A5\completed\ucb007_270104_04_043_237_10.ucbpm]
File Edit Window
Show As
Volts
Mass
UCB007
Initial Zeroing Period
Zeroing Start 01/27/2004 09:14:00
Zeroing End 01/27/2004 09:35:00
Final Zeroing Period
Zeroing Start 01/29/2004 12:33:54
Zeroing End 01/29/2004 12:34:54
Sample Period
Sample Start 01/27/2004 11:08:00
Sample End 01/29/2004 11:09:00
Photoelectric
Particle Coeff 0.0675
Temperature Coeff -0.3
Ionization
Particle Coeff 19.60784
Temperature Coeff -0.00792
RH Coeff -0.0022
Altitude Coeff -0.000110
Altitude (m) 8600
Options
Photo-Only Device
Use initial zeroing period(s)
Use old PE reading format
Update calculations
Calculate best zeroing period
Photoelectric (mg/m^3)
arith. mean 4.018
geo. mean NaN
std. dev. 12.144
geo. std. dev. NaN
median 0.922
75th % 2.528
95th % 20.391
min. -4.512
max. 205.142
15 minute avg
highest 49.139
2nd highest 34.249
3rd highest 30.000
N = 2882
Save Stats
205.14
200
150
100
50
0.00
mg/m3
Sample UCB Output
Breakfast & Lunch
Dinner
Breakfast & Lunch
Dinner
Breakfast & Lunch
04:27:01, 0.9862
01/27/2004 08:33:01
01/29/2004 12:35:01
Photoelectric mass
PhotoElectric
Ionization
Temperature
Humidity
Battery
Start
Processed_4
UCB_Guatemala_...
Microsoft Word
UCB Particle Mo...
Microsoft Excel - ...
10:08 AM

Field Piloting



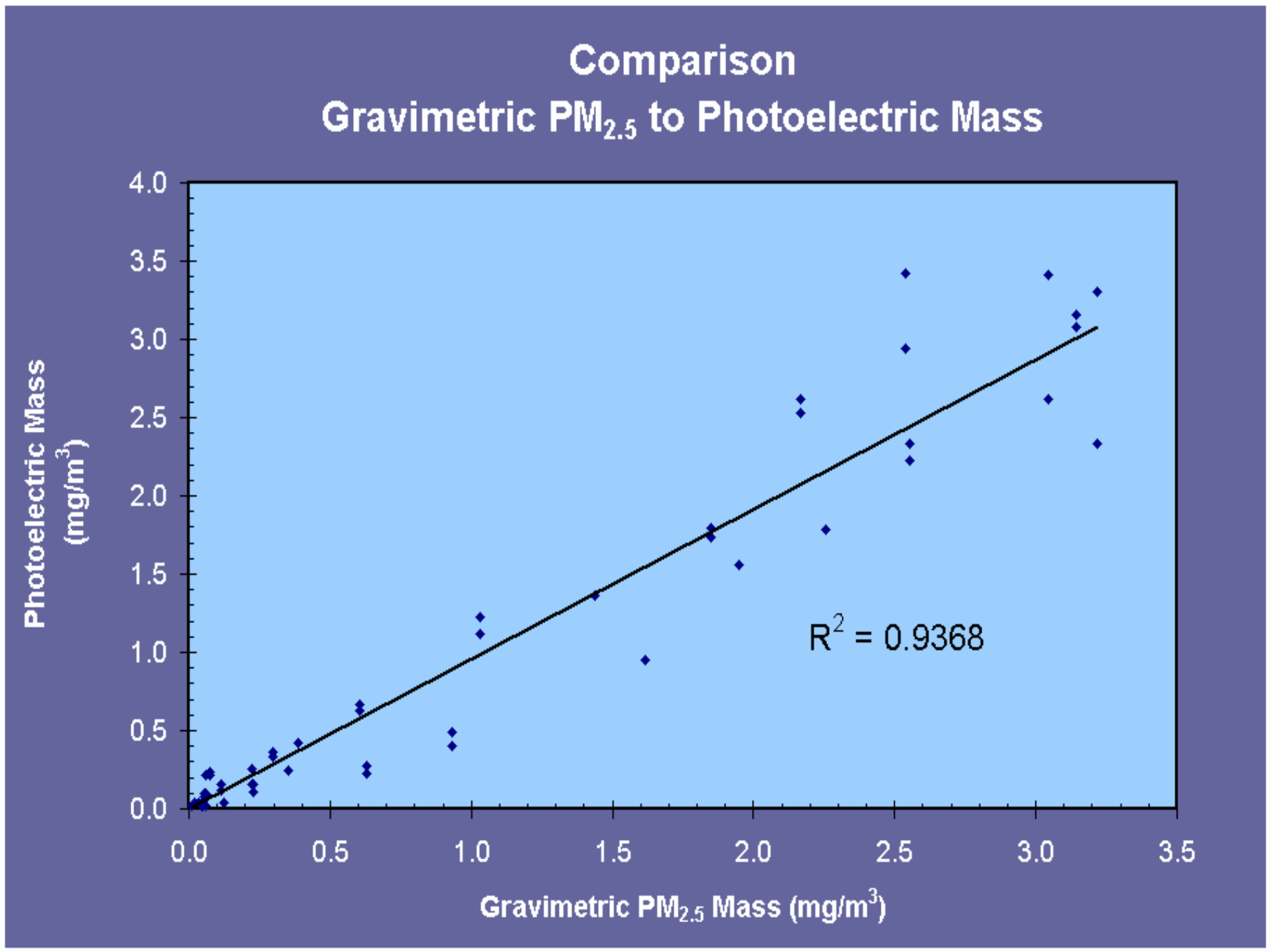
- Gravimetric $PM_{1.0}$ & $PM_{2.5}$ as "gold standard"
- Analyzed first 6 months of co-located gravimetric pump-filter measurements and UCB measurements in the kitchen
- Followed Standard Operating Procedures developed by UC-Berkeley

Lessons Learned from Field Piloting

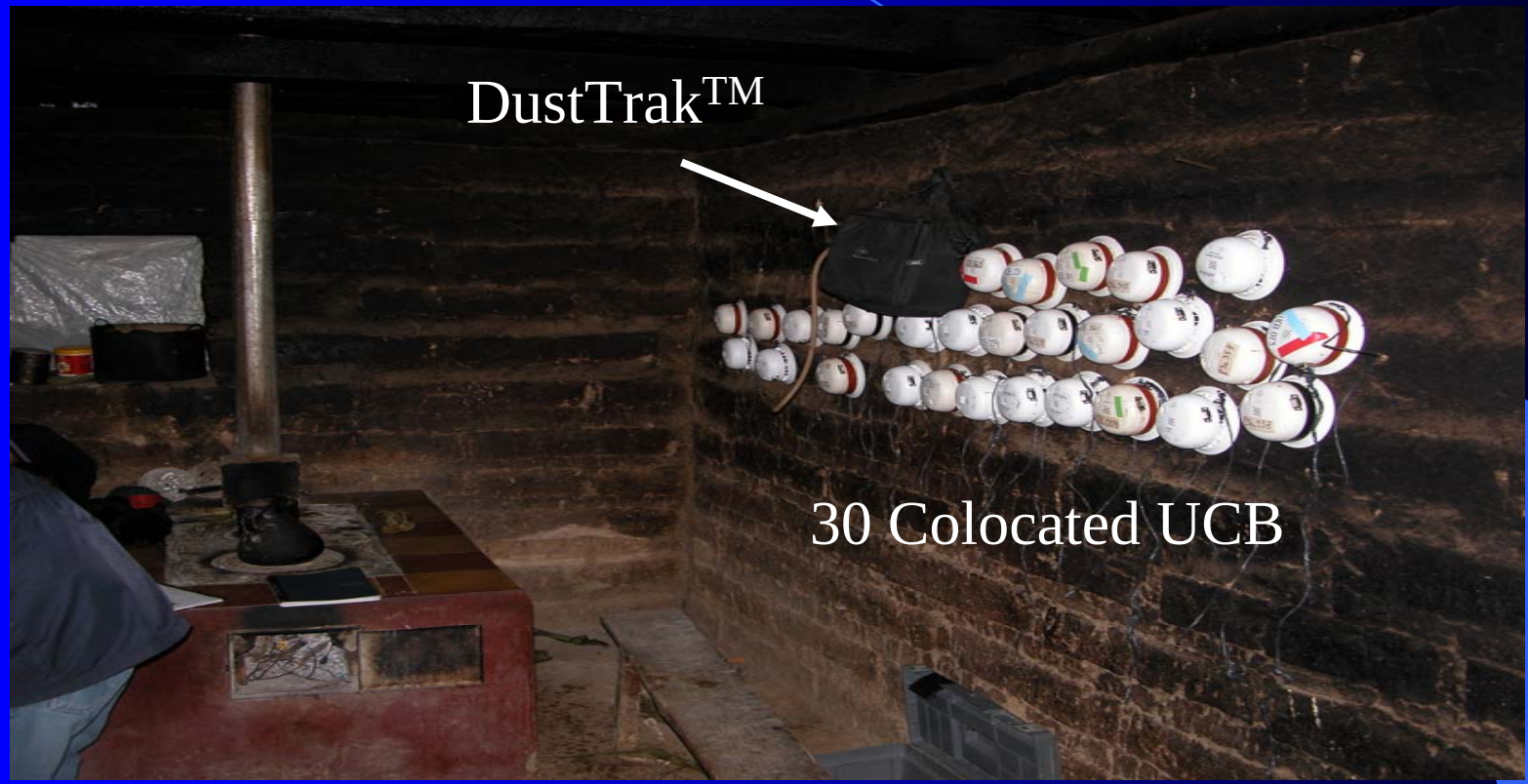
- Easy to deploy in the field, but data analysis is a challenge
  - Solution: Added batch processing of files in the software interface
- Baseline (zero line) of the instrument drifts and shifts during sampling causing negative mass or unrealistic high mass
  - Solution: separated noise from the signal by developing an algorithm for signal processing and currently integrating it with software interface
- Understood device does not work well in
  - Outdoor settings
  - Low pollution indoor settings (less than 50 $\mu g/m^3$)

UCB Field Results

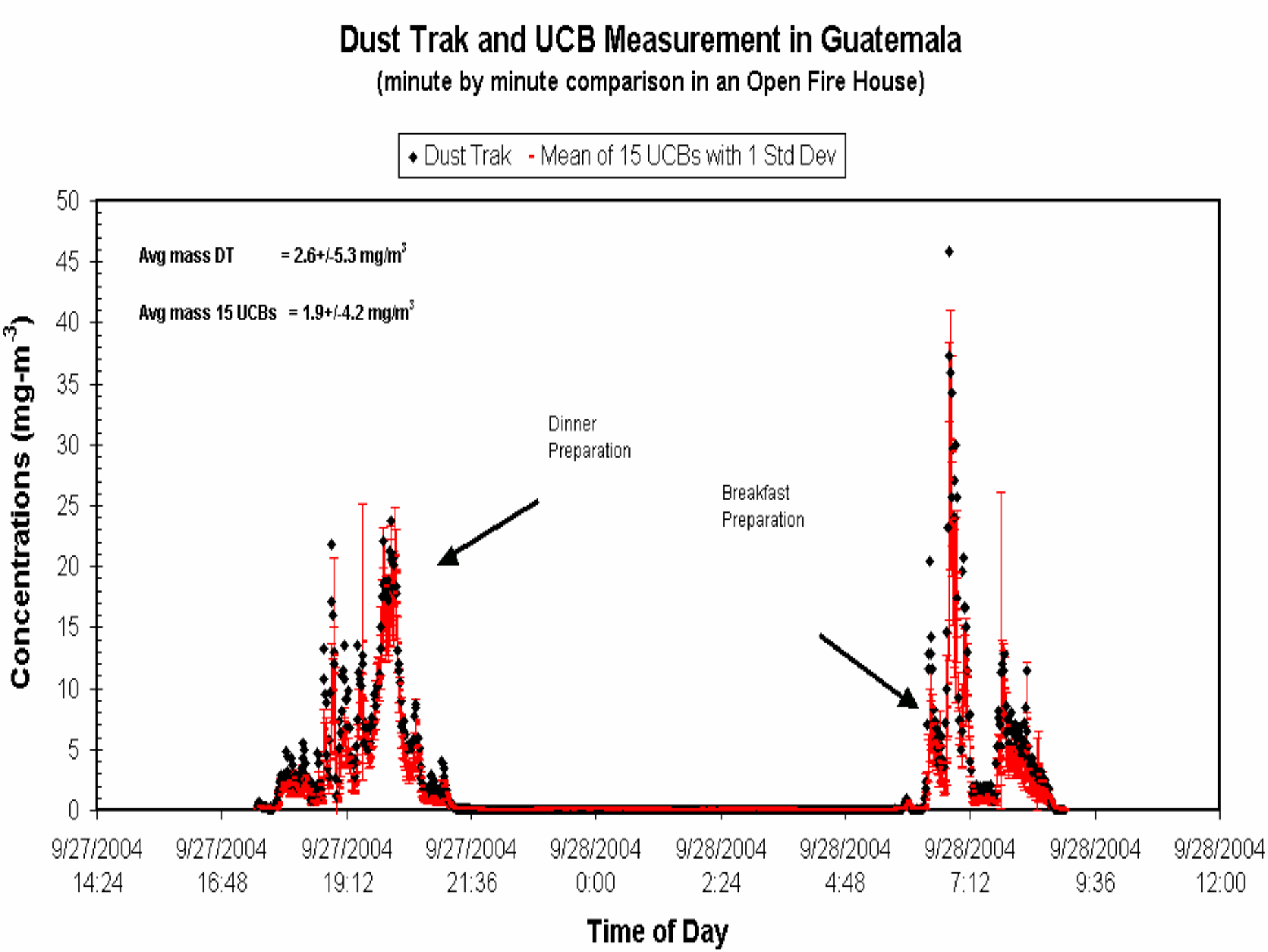
		$PM_{1.0}$ Gravimetric Mass mg/m^3	UCB Photo mg/m^3
Control	**Mean**	0.725	0.859
	Std Dev	0.489	0.492
	Maximum	1.853	1.819
	Minimum	0.211	0.134
	N	21	21


Comparison
Gravimetric PM2.5 to Photoelectric Mass
Photoelectric Mass (mg/m3)
Gravimetric PM2.5 Mass (mg/m3)
R2 = 0.9368
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

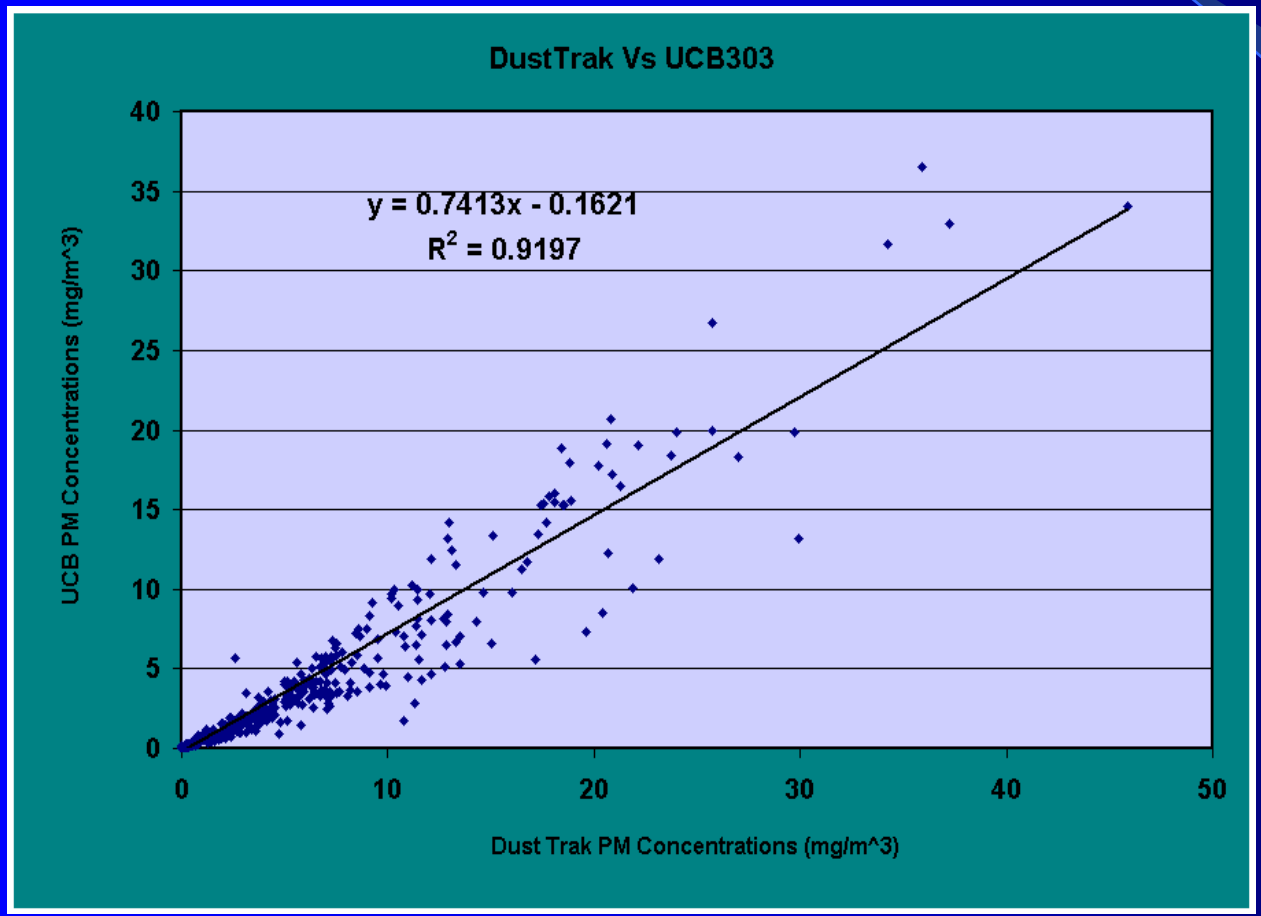
UCB Colocation Experiment



Lopez Kitchen, La Cienaga, Guatemala


Dust Trak and UCB Measurement in Guatemala
(minute by minute comparison in an Open Fire House)
Dust Trak
Mean of 15 UCBs with 1 Std Dev
Avg mass DT = 2.6+/-5.3 mg/m3
Avg mass 15 UCBs = 1.9+/-4.2 mg/m3
Dinner Preparation
Breakfast Preparation
Concentrations (mg-m-3)
0
5
10
15
20
25
30
35
40
45
50
9/27/2004 14:24
9/27/2004 16:48
9/27/2004 19:12
9/27/2004 21:36
9/28/2004 0:00
9/28/2004 2:24
9/28/2004 4:48
9/28/2004 7:12
9/28/2004 9:36
9/28/2004 12:00
Time of Day

Correlation with DustTrak



UCB ID	R^2 with DustTrak
303	0.92
304	0.94
317	0.85
324	0.82
330	0.88
339	0.88
345	0.57
352	0.88
366	0.90
369	0.92
373	0.93
374	0.82
380	0.82
381	0.88
382	0.80

Summary of Field Piloting

- Compares well with integrated Gravimetric method
- Responds to particles like other commercially available instruments
  - DustTrak and pDR

UCB Models

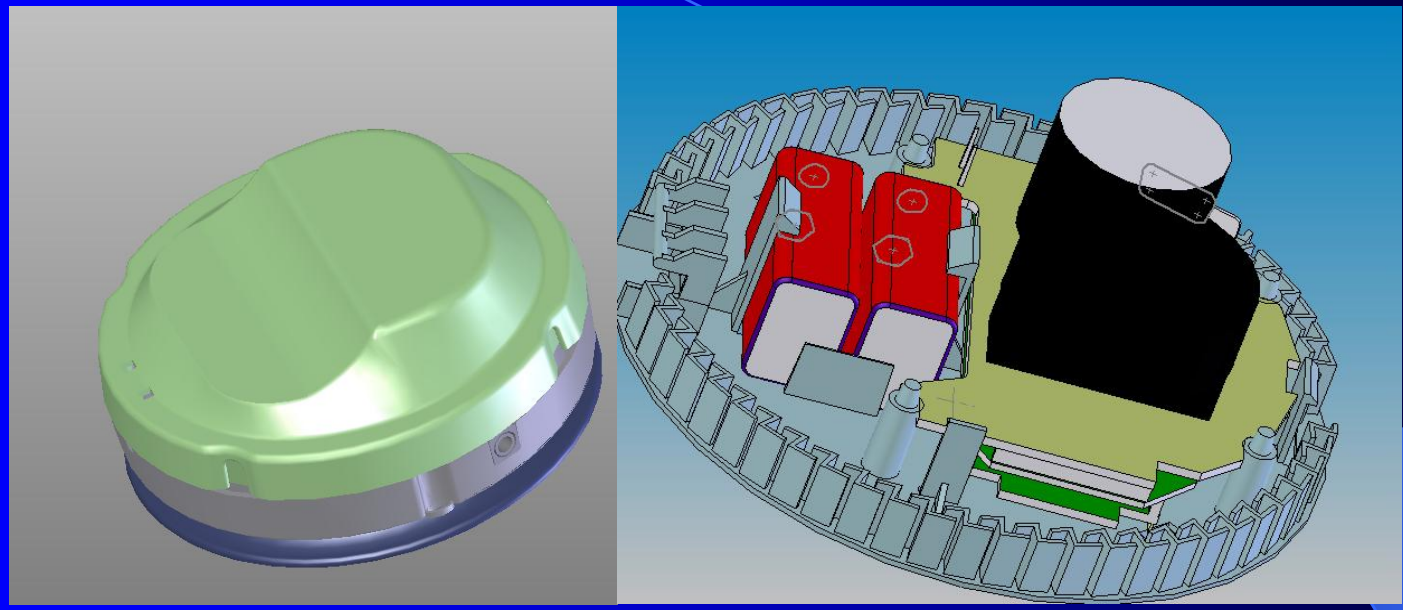
Currently two models available:

- UCB Dual: for research use
  - Used for further development and testing
  - Used to understand size-distribution of particles
- UCB Photo: for NGO use as part of IAP kit
  - Simplified device with only photoelectric chamber
  - Distributed by CEIHD

Improved Software

- CEIHD supported continued improvement of UCB Software
- Enhanced data browser capabilities
- Batch processing of multiple files
- Easier data analysis currently under development by our programmer

New Casing in Development



Mechanical Eng. student from UC Berkeley submitted designs for new casing

- Fancier outside casing
- Make inside electronics easily accessible
- Rechargeable battery pack instead of 9-Volt battery (Cheaper to operate)

UCB Locator for Time Activity Monitoring

To understand human exposure to particles, it is necessary to quantify the total time a subject is exposed to particles

- Developed a UCB Locator to monitor time activity
- Instrument being piloted from Summer 2004-Present in Guatemala
- Will be incorporated with UCB Particle Monitor to quantify human exposure to particles

Resources

http://ehs.sph.berkeley.edu/krksmith

http://ceihd.berkeley.edu

Email: zohir@berkeley.edu

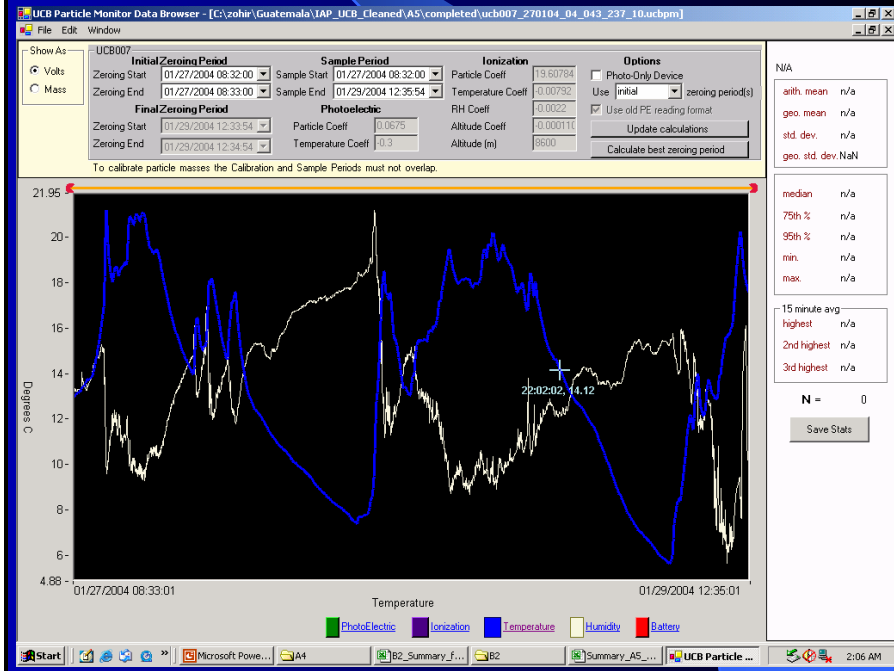
Additional UCB Capabilities

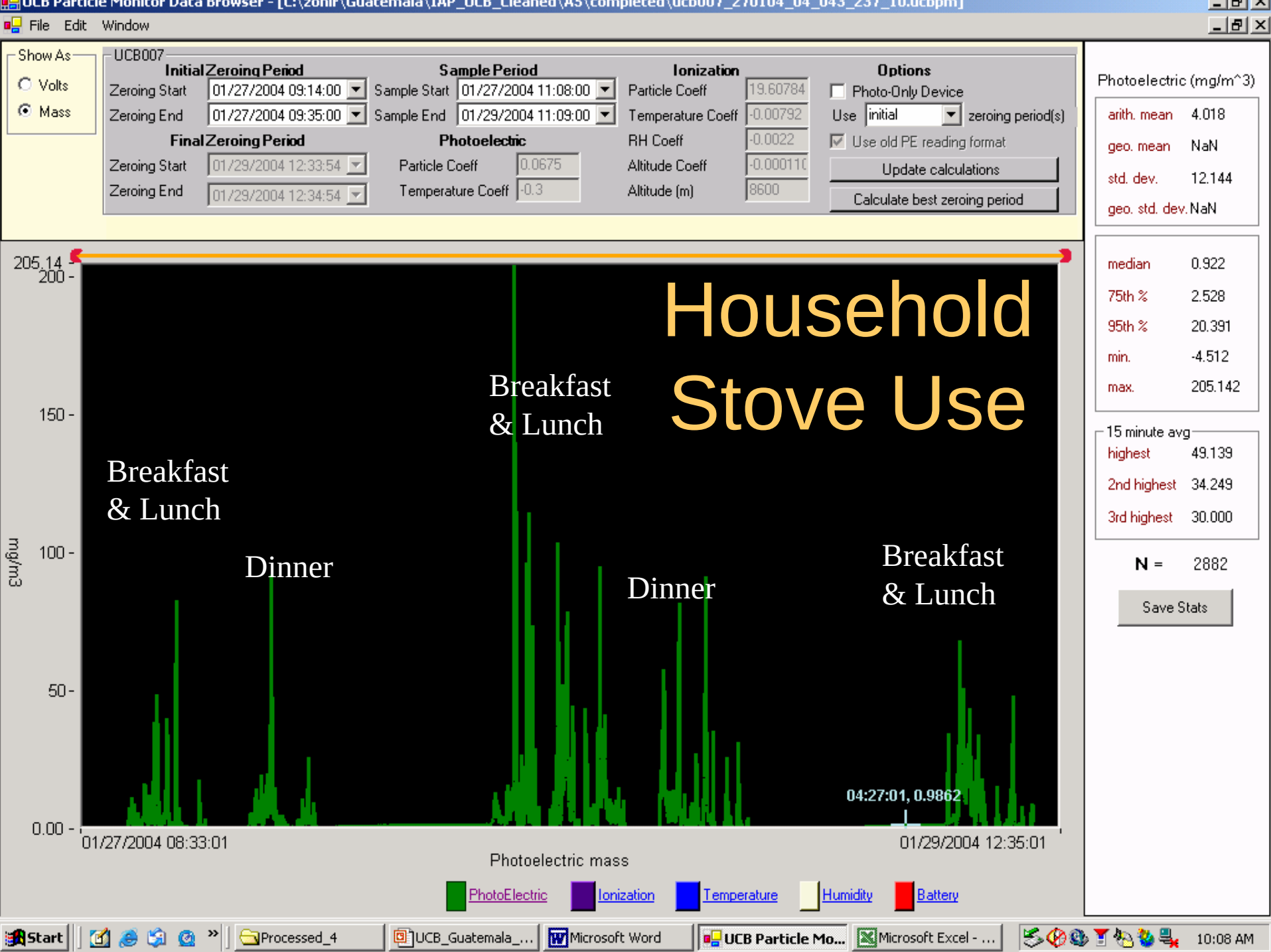
- Measuring Household T and RH
- Measuring Household Stove Use

Measuring Household T and RH

	Temperature (°C)	Relative Humidity (%)
Arithmetic Mean	13.75	64.09
Arithmetic Std Dev	4.19	9.57
Geometric Mean	13.04	63.36
Geometric Std Dev	1.41	1.17
Median	14.12	64.60
Min	5.66	37.00
Max	21.17	91.90
5th %-ile	6.98	49.70
25th %-ile	10.08	56.90
75th %-ile	17.60	70.50
95th %-ile	19.60	79.70
15-min Avg Highest	21.02	89.75
15-min Avg Lowest	5.68	39.35
15-min Mean	13.73	64.18
15-min Std Dev	4.18	9.44

HH ID 04043-237 & UCB007

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Mass
UCB007
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highest 49.139
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3rd highest 30.000
N = 2882
Save Stats
Household Stove Use
Breakfast & Lunch
Dinner
Breakfast & Lunch
Dinner
Breakfast & Lunch
205.14
200
150
100
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0.00
mg/m3
04:27:01, 0.9862
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Photoelectric mass
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Temperature
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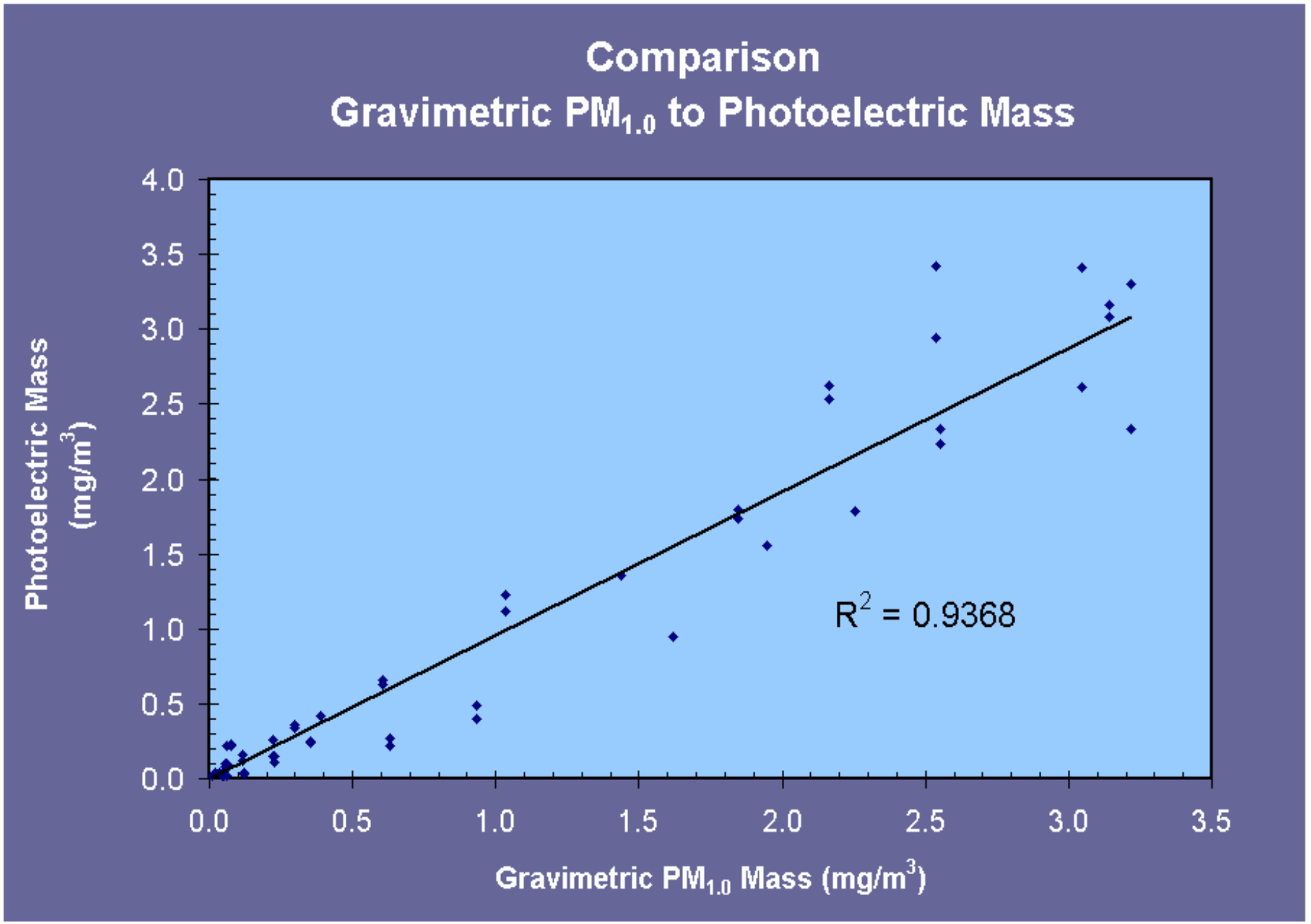
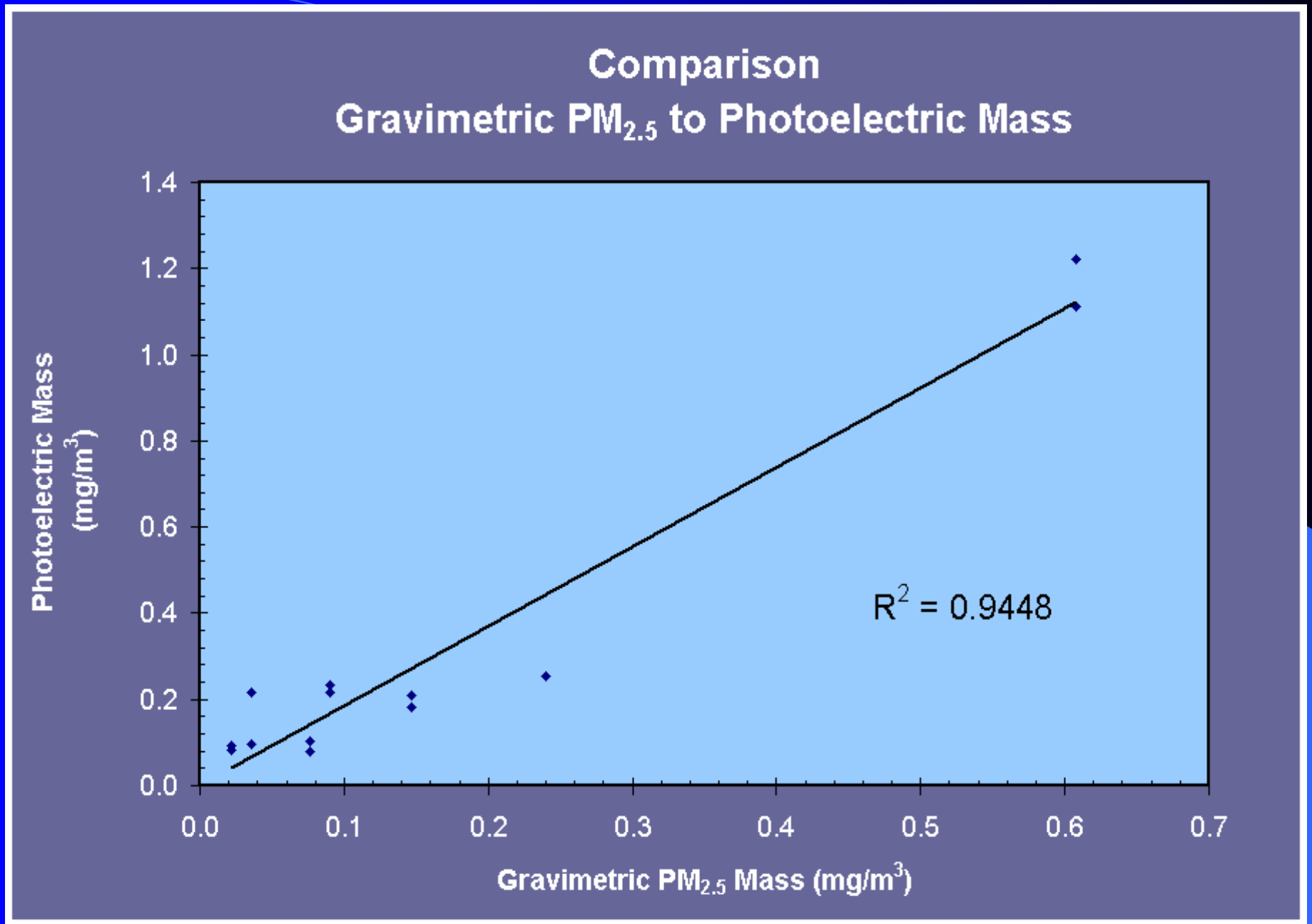
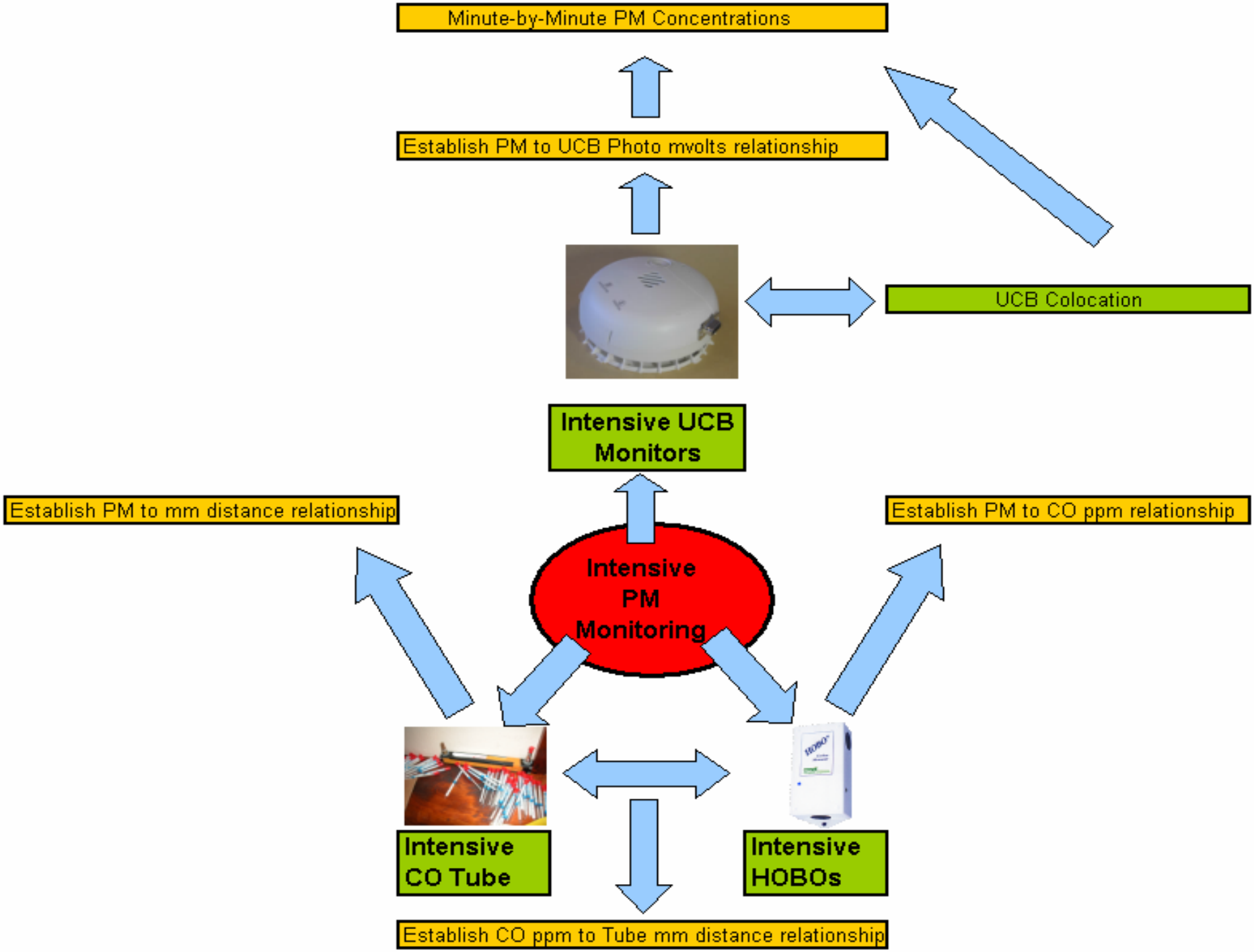
Microsoft Word
UCB Particle Mo...
Microsoft Excel - ...
10:08 AM


Comparison
Gravimetric PM1.0 to Photoelectric Mass
Photoelectric Mass (mg/m3)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
R2 = 0.9368
Gravimetric PM1.0 Mass (mg/m3)


Comparison
Gravimetric PM2.5 to Photoelectric Mass
Photoelectric Mass (mg/m3)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Gravimetric PM2.5 Mass (mg/m3)
R2 = 0.9448


Minute-by-Minute PM Concentrations
Establish PM to UCB Photo mvolts relationship
UCB Colocation
Intensive UCB Monitors
Establish PM to mm distance relationship
Establish PM to CO ppm relationship
Intensive PM Monitoring
Intensive CO Tube
Intensive HOBOs
Establish CO ppm to Tube mm distance relationship