

Performance Evaluation of a Condensation Particle Counter Near the I-710 Freeway in Southern California

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Background

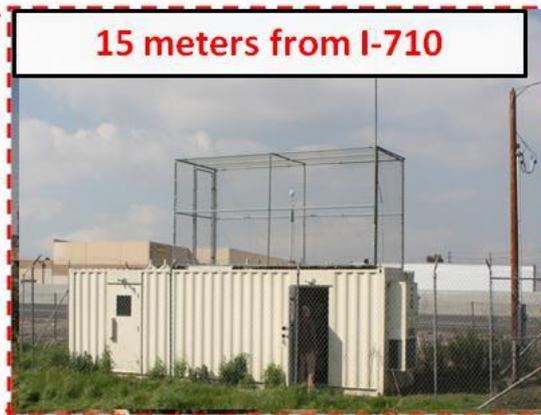
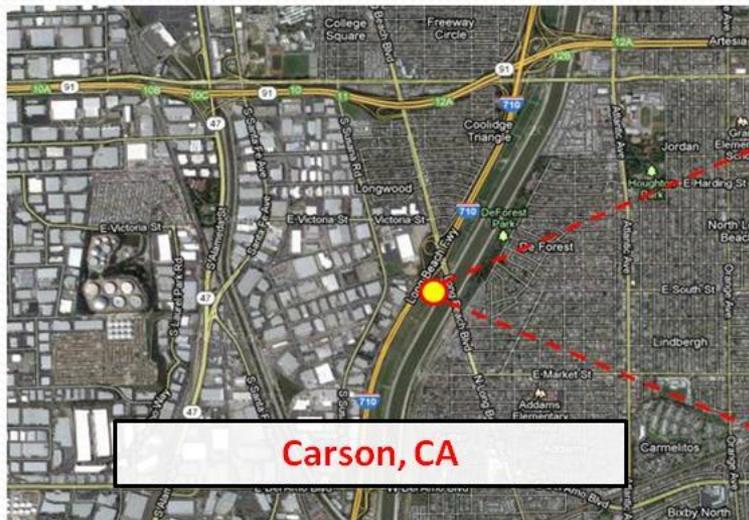
- Exposure to ultrafine particles (UFP) may contribute to heart and lung diseases leading to hospitalization and premature death
- Condensation Particle Counters (CPC) characterize UFP by measuring particle number (PN) concentrations
- 2011: TSI released a water-based CPC (model 3783) intended for long-term, 24/7 operation (network use) in background and near-source (e.g. near-road) environments
- 2013: TSI released updated version of model 3783
- TSI 3783 now sold as TAPI 651
- UFP are/will be measured near California roadways by local air districts

Outline

- Collaboration between SCAQMD, ARB, UCLA, TSI and TAPI to study the performance and reliability of the 3783 TSI model:
 - 2011 Study (Phase I): SCAQMD, UCLA, and ARB
 - May 16 to June 14
 - Three CPC models: 3781 (x3), 3783 (x3), and 3785 (x3)
 - Inter- and Intra-model variability
 - Pre-MATES IV evaluation
 - 2011 Study (Phase II): ARB, SCAQMD, TSI, and TAPI
 - June 2011 to April 2012
 - 3783 model (x3)
 - Continued testing of durability
 - Stopped due to continual instrument breakdown
 - 2013 Study: ARB, SCAQMD, TSI, and TAPI
 - August 21, 2013 to April 17, 2014
 - Upgraded 3783 / 651 model (x3)
 - Testing of durability and precision



Site Location and Instrument Set-up



Teledyne 651



Minimum Detectable Diameter	7 nm
Maximum Detectable PN (#/cm³)	1 x 10⁶
Fast response	
Particle Counting Errors	± 10% <i>at 1x10⁶ /cm³</i>
Aerosol Flow Rates (L/min)	0.12 ± 0.012

BGI SCC0.732, 0.6 μm at 3 L/min Inlet Flow
Short sample residence time

- Meets most requirements for ambient # concentration monitoring

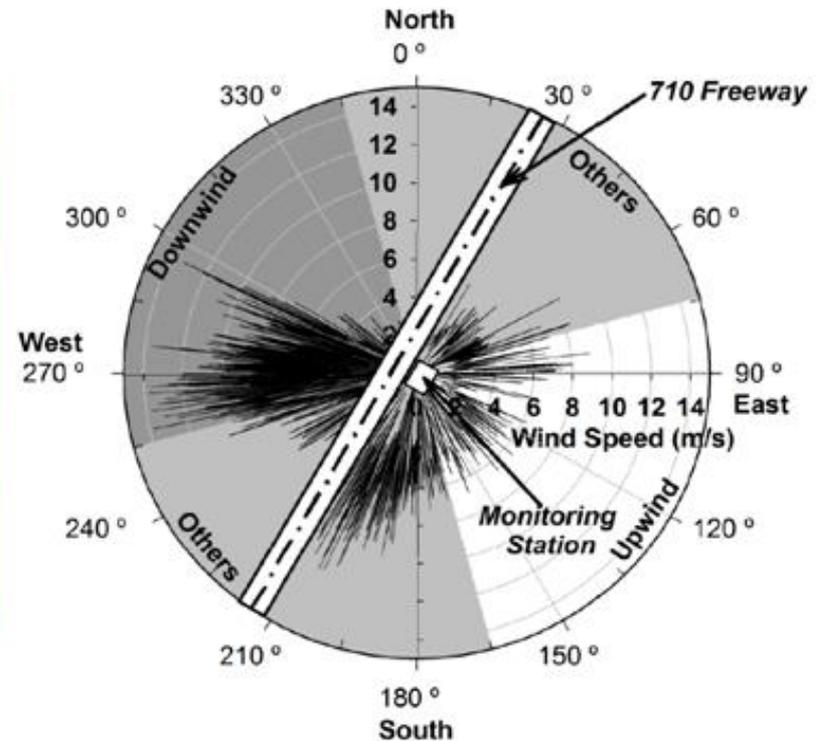
Site Location and Instrument Set-up

Sampling Period: 5/16/2011 – 6/15/2011

Surrounding Environment



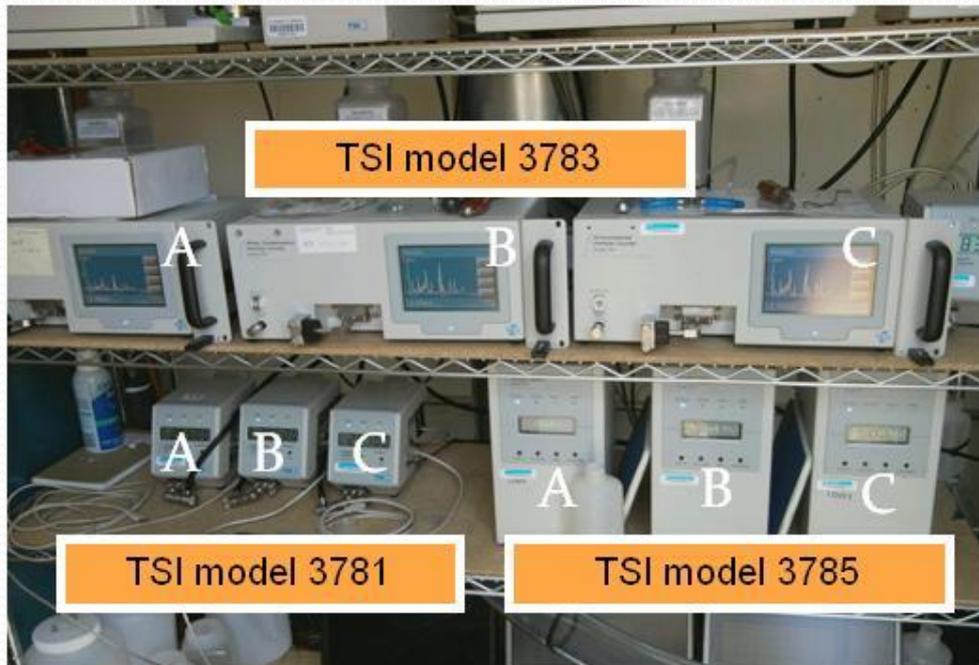
Wind Condition



- Site is downwind of the I-710 freeway ~50% of the time

2011 Study (Phase I; May 16 - June 14) TAPI 651 Variability

WCPCs

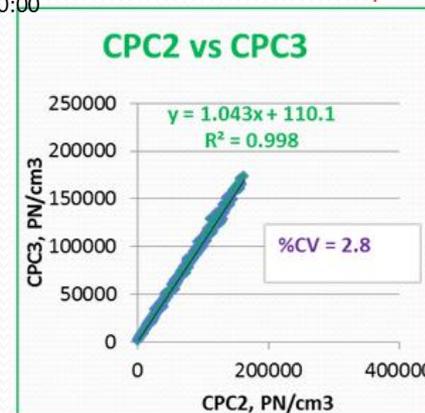
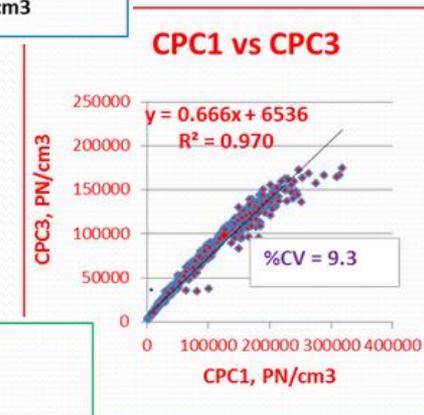
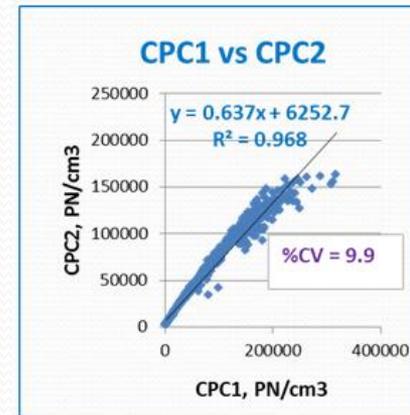
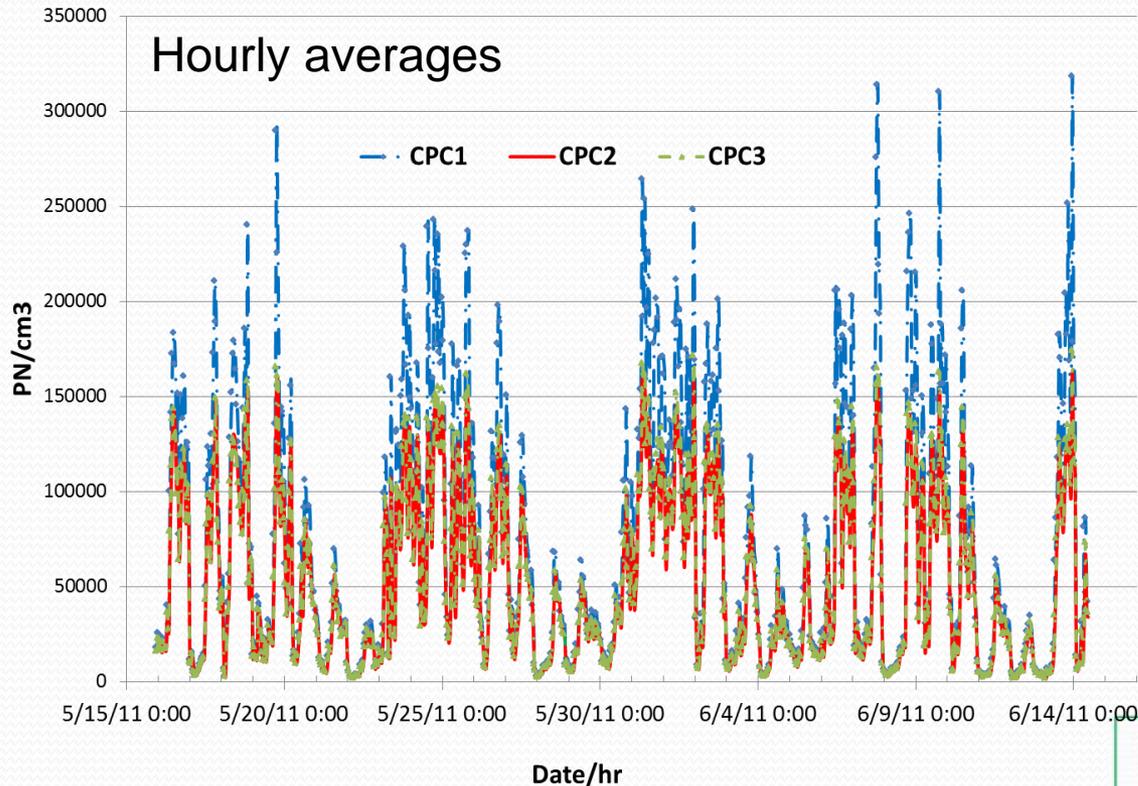


SMPSs



2011 Study (Phase I; May 16 - June 14)

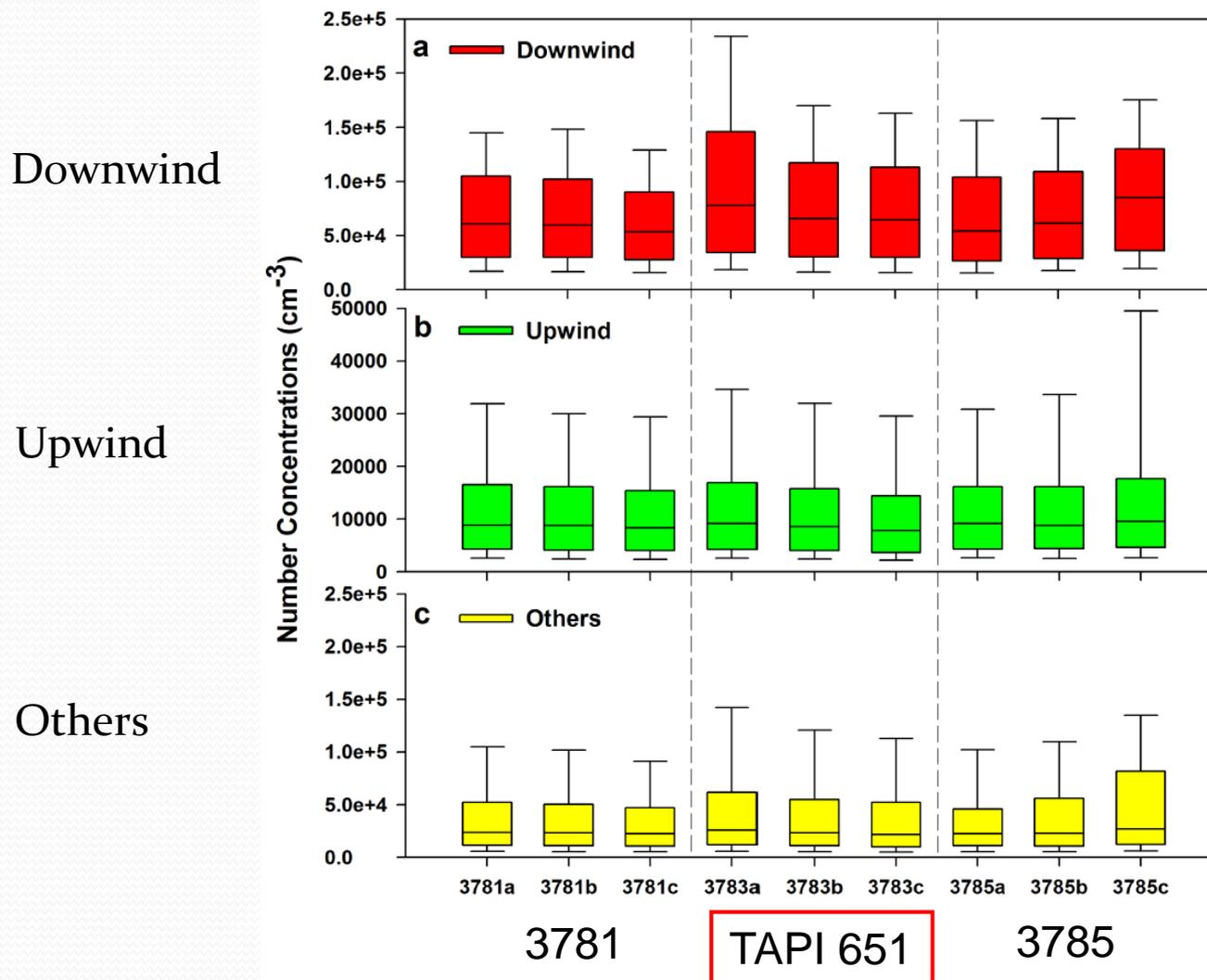
TAPI 651 Variability



- TAPI 651 exhibited some intra-model bias
 - Two CPCs within 5%
 - Third CPC differed by ~30%

2011 Study (Phase I; May 16 - June 14)

TAPI 651 Variability

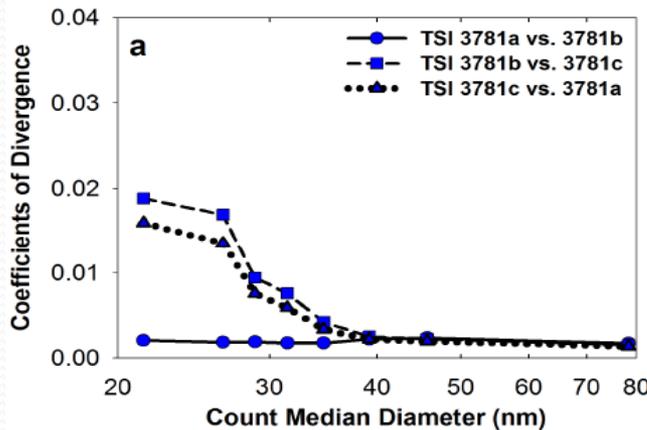


2011 Study (Phase I; May 16 - June 14)

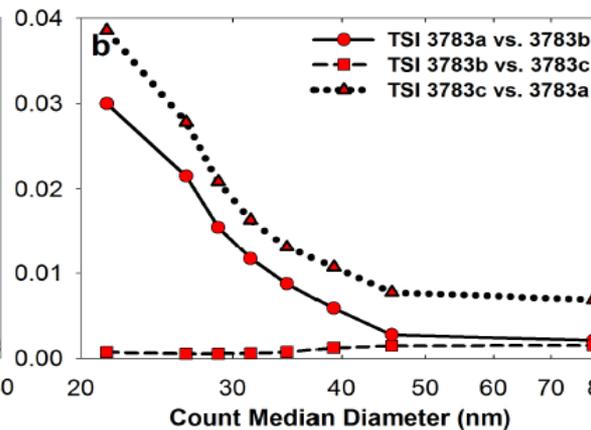
TAPI 651 Variability

Intra-model comparison

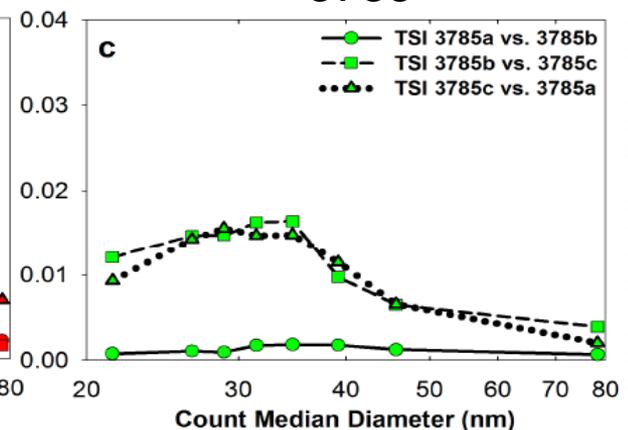
3781



TAPI 651



3785



$$COD_{jk} = \sqrt{\frac{1}{n} \sum_{i=1}^n \left(\frac{N_{ij} - N_{ik}}{N_{ij} + N_{ik}} \right)^2}$$

where,

COD_{jk} : Coefficients of divergence between two WCPC models (or units) j and k

n : Total number of observations

i : Individual observation

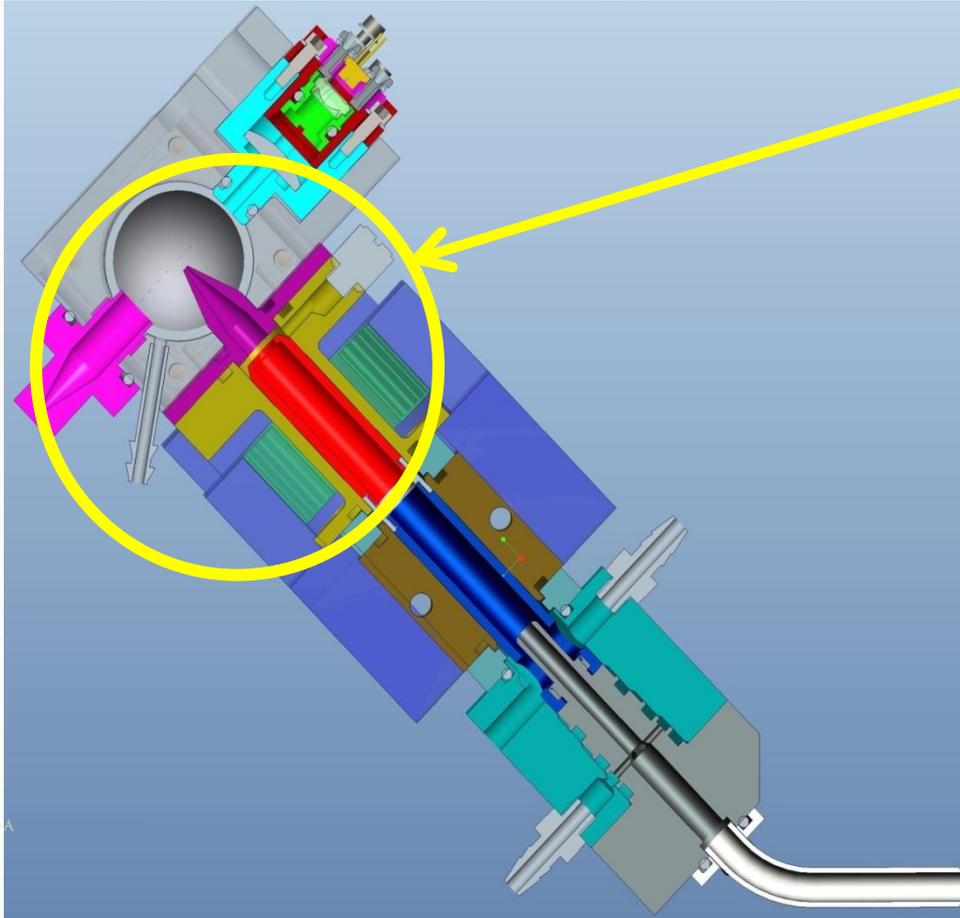
N : Particle number concentration (cm^{-3})

2011 Study (Phase II; June 2011 - April 2012)

TAPI 651 Durability

- Assessment based on continued operation of the instrument without major equipment breakdown using routine monitoring practices
- TAPI 651 unable to run reliably for extended time periods:
 - Flooding of the optics system
 - Pulse height declined over time
 - Clock drift
 - Corrupt data files during download
- Work needed to improve instrument durability and reliability

TAPI 651 Design Modifications



- Vent assist to prevent flooding
- New optics block with water drain
- Longer growth tube accommodates longer wick cartridge



Old

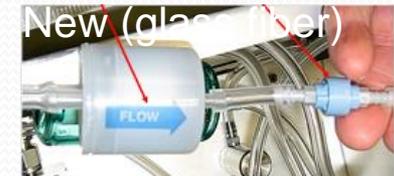


New

- New Protection Filters



Old (paper)



New (glass fiber)

- New ejector pump for better reliability combined with lower water separator temp (7°C vs 20°C)

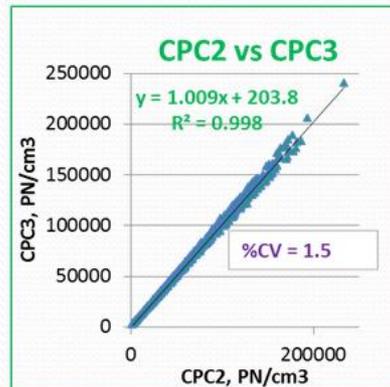
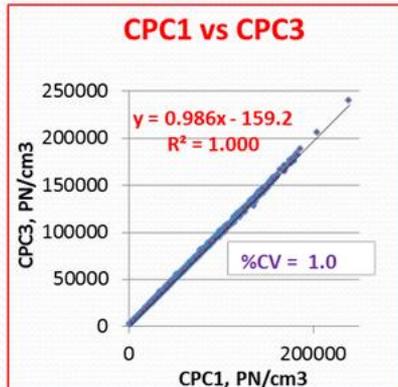
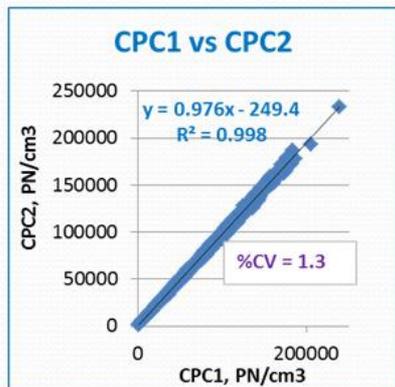
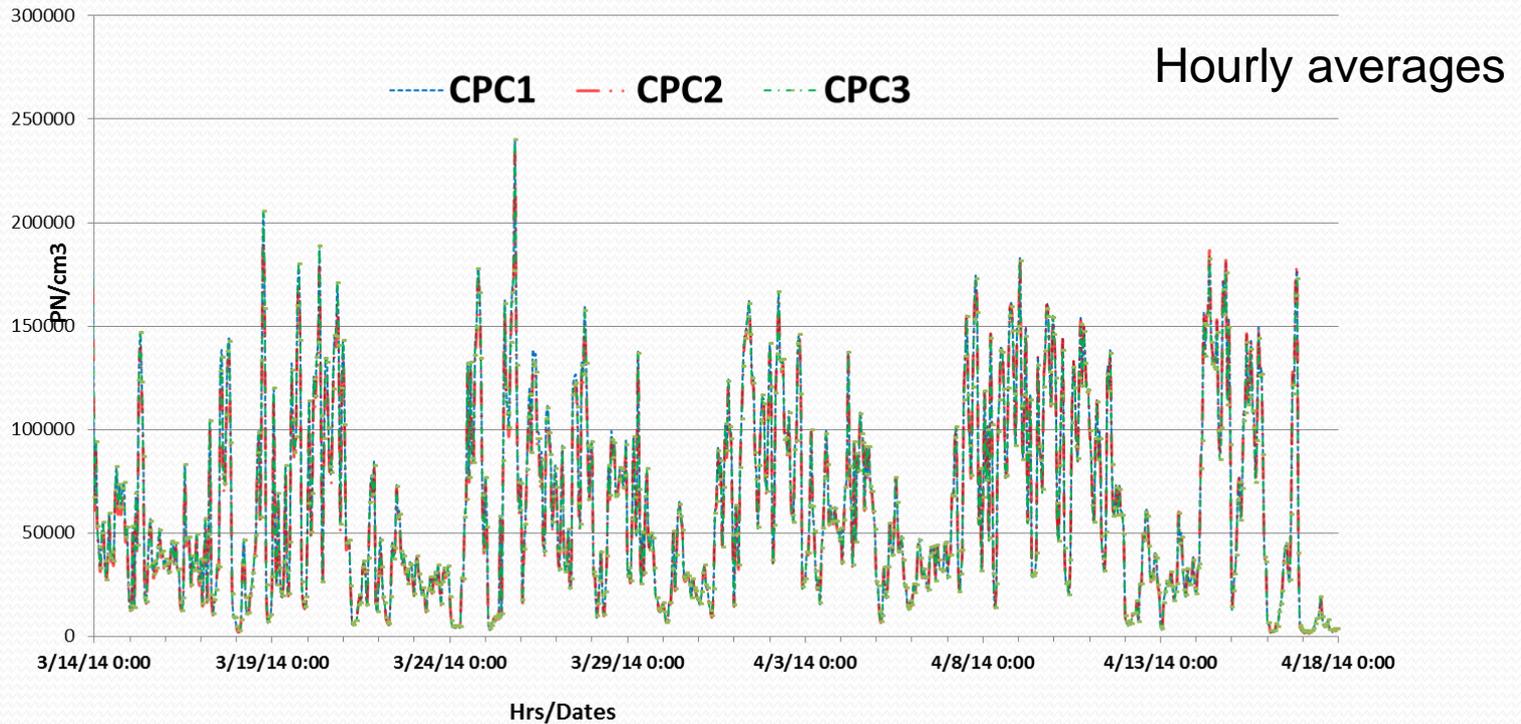
2013 Study (August 21, 2013 – April 17, 2014)

Upgraded TAPI 651 Performance

- Set-up
 - Three modified TAPI 651
 - CPCs synced with ARB datalogger
- Objectives
 - Evaluate precision and durability
- *August 21 to December 31, 2013*: set-up issues (e.g. old firmware, shared pump)
 - Good durability but low precision
- *January 1 to April 17, 2014*: substantial work done to improve QA/QC procedures (e.g. new firmware, individual pumps, static dissipative tubing, consistent maintenance procedure)
 - Optimal configuration resulted in higher precision

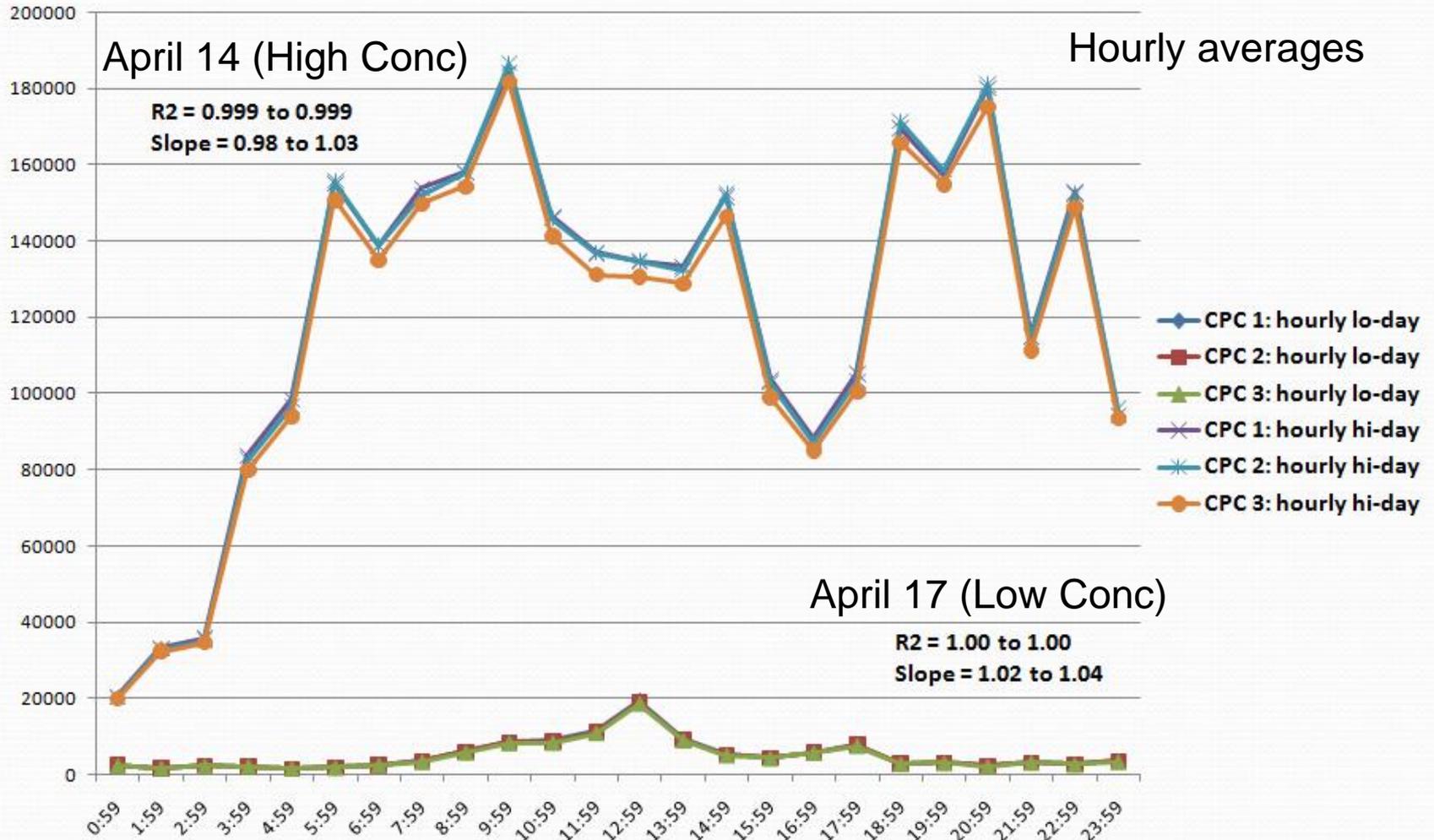
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Upgraded TAPI 651 Performance

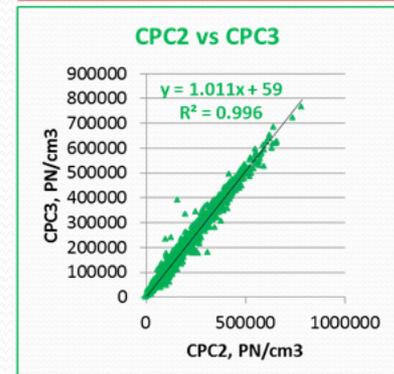
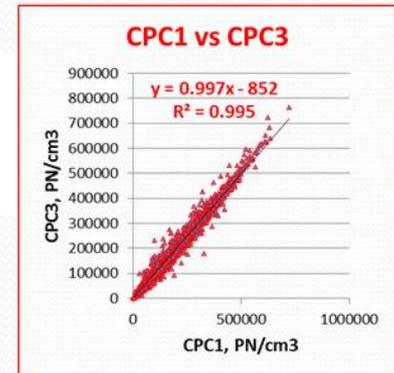
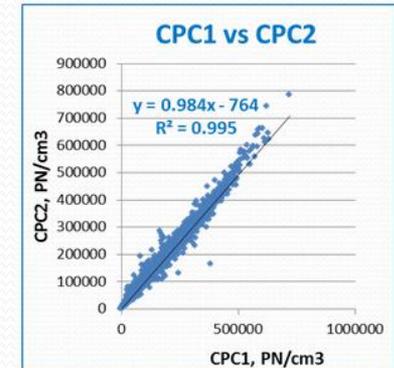
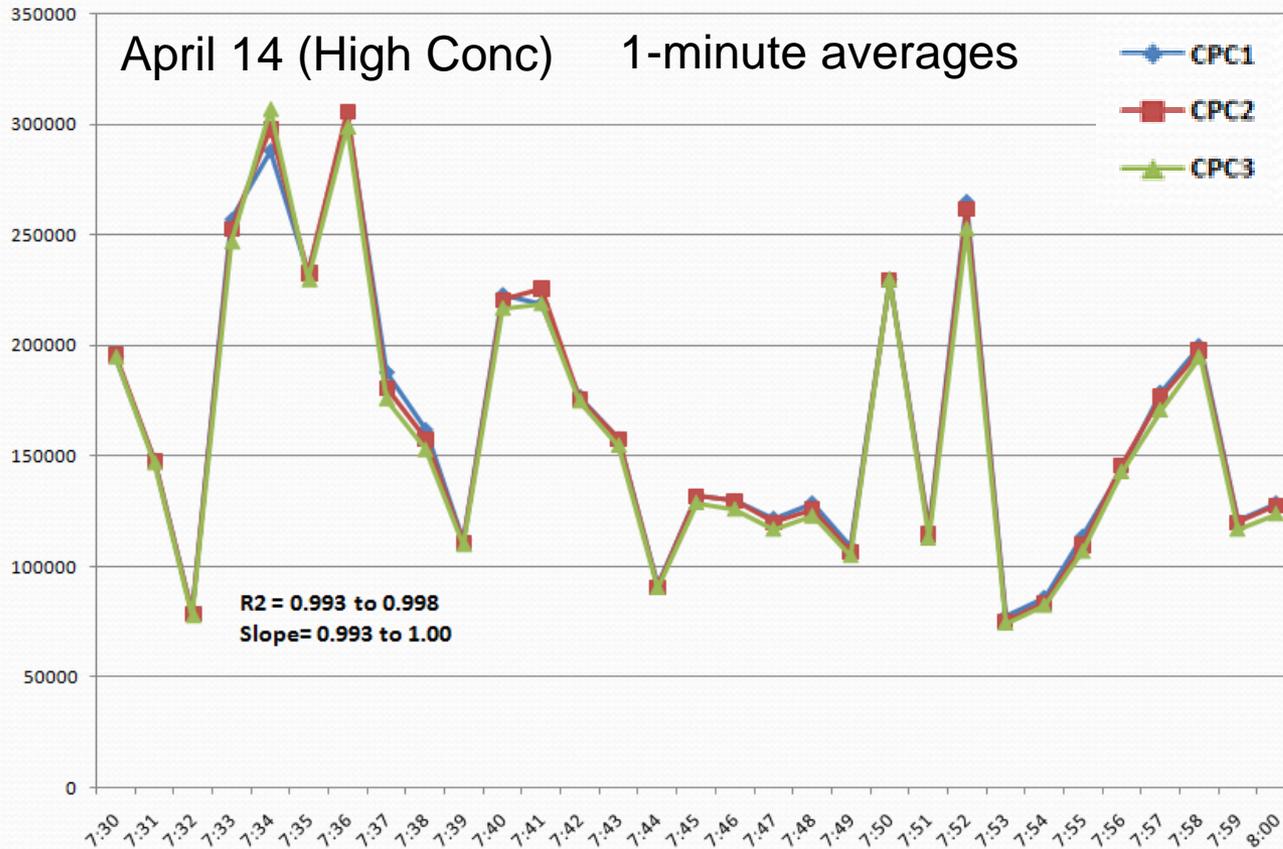


- %CV = Upper bound coefficient of variation; U.S. EPA criteria at network level for PM_{2.5} is 10%

2013 Study (August 21, 2013 – April 17, 2014) Upgraded TAPI 651 Performance



2013 Study (August 21, 2013 – April 17, 2014) Upgraded TAPI 651 Performance



- Excellent correlation even for 1-minute data between March 14 and April 17, 2014

Upgraded TAPI 651 Performance

Lessons Learned – QA/QC

- Monthly inlet cleaning is sufficient even at highly polluted locations
- Turn off vacuum pump when replacing wicks and performing inlet cleaning
- Service vacuum pump every year and provide backup pump at site
- Use datalogger when operating CPCs:
 - Time synchronization
 - Prompt review of diagnostic and PN data
- Periodic collocation with an independent CPC is recommended (no calibration standard available)
- *An SOP summarizing these QA/QC checks is available from Teledyne*

Conclusions

- When proper QA/QC practices are followed the TAPI 651 operates reliably for extended periods of time. >75% data capture can be expected

Acknowledgement

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*ARB and SCAQMD participation in the study does not indicate approval or endorsement of a particular product or vendor. Any opinions, findings, conclusions, or recommendations expressed in this presentation are those of the authors and do not necessarily reflect the views of ARB or SCAQMD.