Use of Probe and Bluetooth data for arterial performance measures in the I-95 Corridor Coalition

February 12, 2015
MWCOG Vehicle Probe Data Users Group Meeting

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Outline

- Background on I-95 Vehicle Probe Project
- Results of first multi-vendor validation (freeways)
- Fundamental Challenges with Arterials
- Traditional & Distribution Based Methods
- ***"A tale of three arterials"* …**
- Recommendations/Conclusions
- Next Steps -
  - Maryland Supplemental Coverage
  - Validation on Route 1 in VA

Probe & Re-identification

GPS Probe

- Vehicles self-report positions and speed based on GPS equipment
- Individual vehicle data is aggregated to overall traffic
  - Speed samples & point-pair processing
- Third party (INRIX, HERE, TomTom) reports traffic data
  - 24/7/365, in real-time
  - Every minute using TMC codes
- Scales to large networks
- No roadside equipment, and therefore less costly

Re-Identification

- Directly samples travel time of the traffic stream – Sensor Based
- Road-side detectors record vehicle ID such as license plates, toll tags, Bluetooth, WiFI, etc.
- Detector network determines traffic travel time
- Costs and sample (penetration rate) vary by technology
- Data only available when trip is complete, vehicle must be re-observed for trip to be recorded

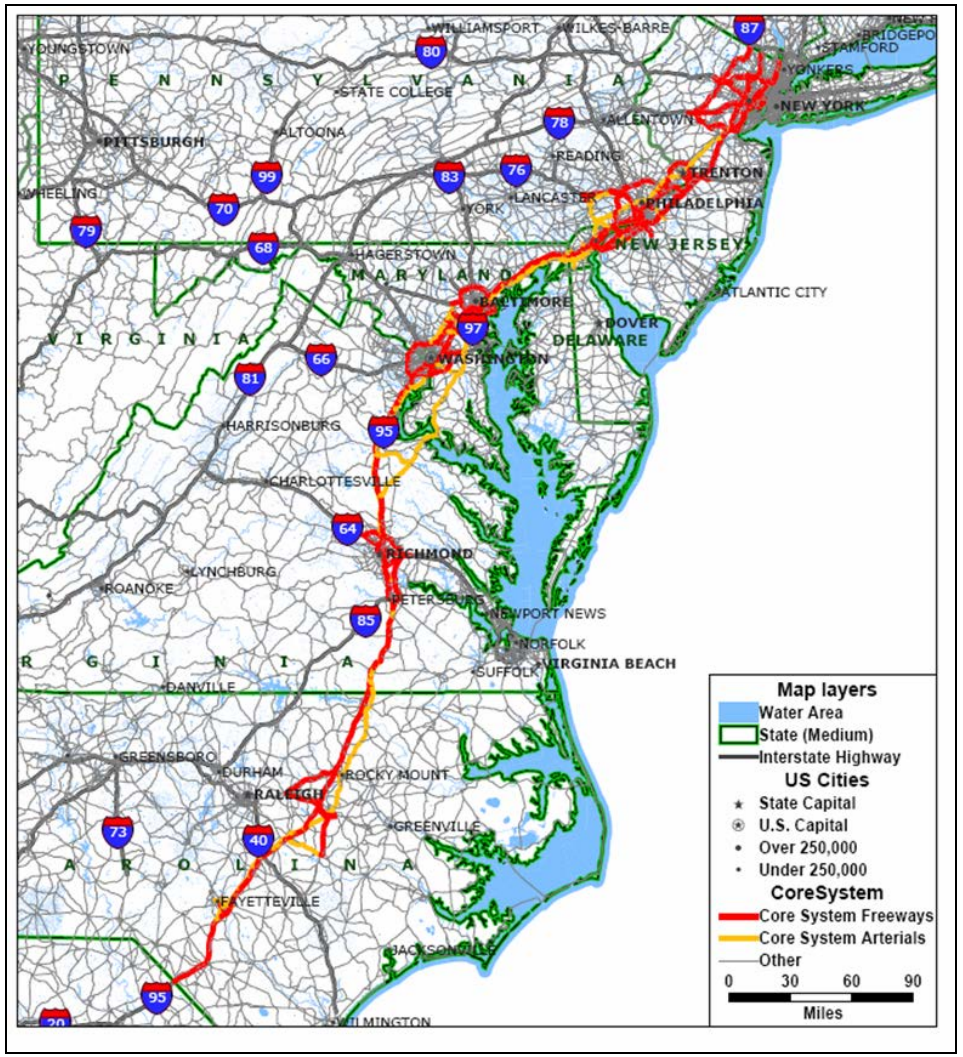
Vehicle Probe Project in 2008

Core Coverage

- 1500 Freeway miles
- 1000 Arterial miles
- New Jersey to North Carolina

Roadways

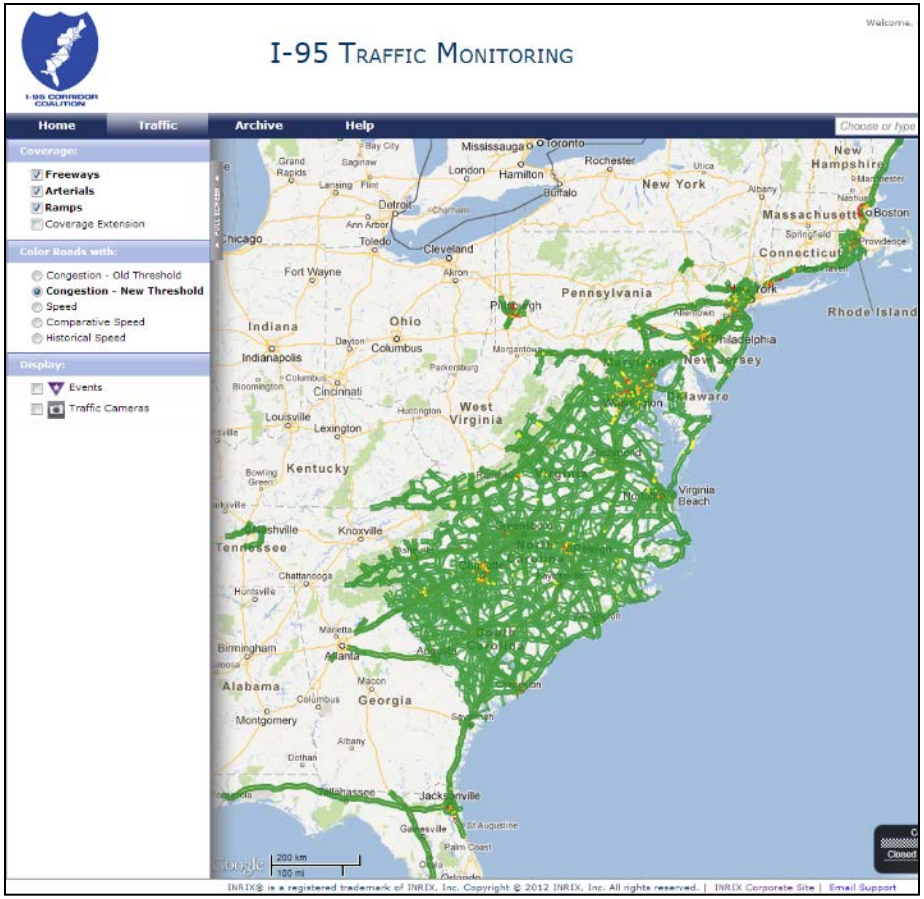
- I-95/Parallel Freeways
- Beltways & Cross-linking Freeways
- Alternate Route Arterials



I-95 Corridor Coalition Vehicle Probe Project

www.I95Coalition.org

VPP as of 2013



State	Freeway Miles	Other Miles	Total Miles
Maine	66	0	66
New Hampshire	16	0	16
Massachusetts	96	0	96
Rhode Island	162	597	759
Connecticut	111	0	111
New Jersey	895	63	958
Pennsylvania	637	118	755
Maryland	781	3779	4,560
Washington DC	31	233	264
Virginia	1,411	7,213	8,624
North Carolina	1,553	12,996	14,549
South Carolina	934	7,187	8,121
Georgia	398	0	398
Florida	718	0	718
Total	7,809	32,186	39,995

VPPII – starting Aug 2015

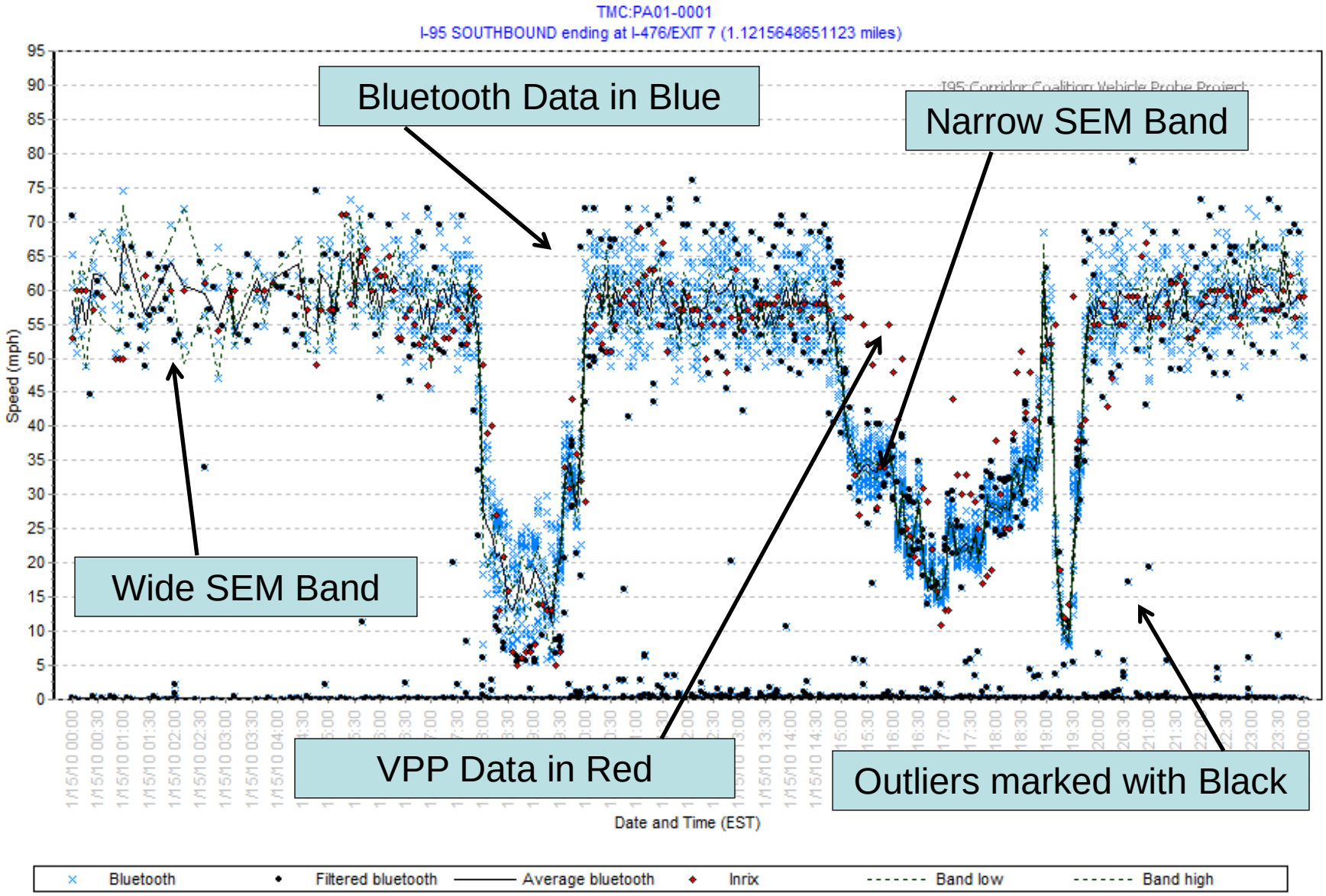
- Three Vendors
  - INRIX
  - HERE,
  - TomTom
- Emphasis on latency & arterial roadways
- Multi-vendor validations
  - (as well as NPMRDS)

Traditional Validation

- Compares Vendors Data to Bluetooth Reference Data:
  - Average Absolute Speed Error : Measures deviation from ground truth (10 MPH spec)
  - Speed Error Bias : Measures any consistent over or under estimation of reported speed (+/- 5 MPH Max)
- Accuracy is assessed in four flow regimes

  0 - 30 MPH 30-45 MPH
  45-60 MPH > 60 MPH
- Specs are applied **against Standard Error of the Mean (SEM) band** when flow exceeds 500 vph

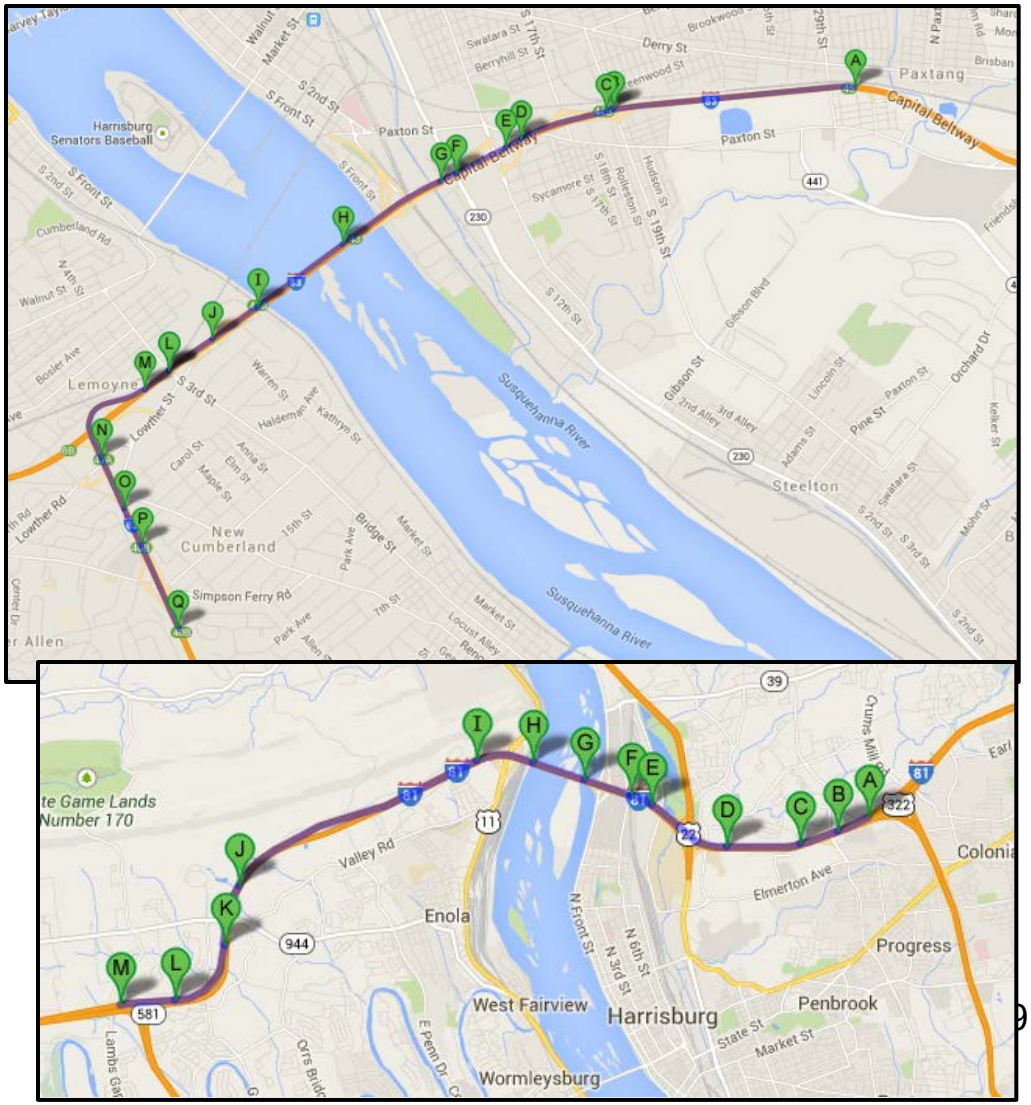
Freeway Validation Ex. – Jan 2010



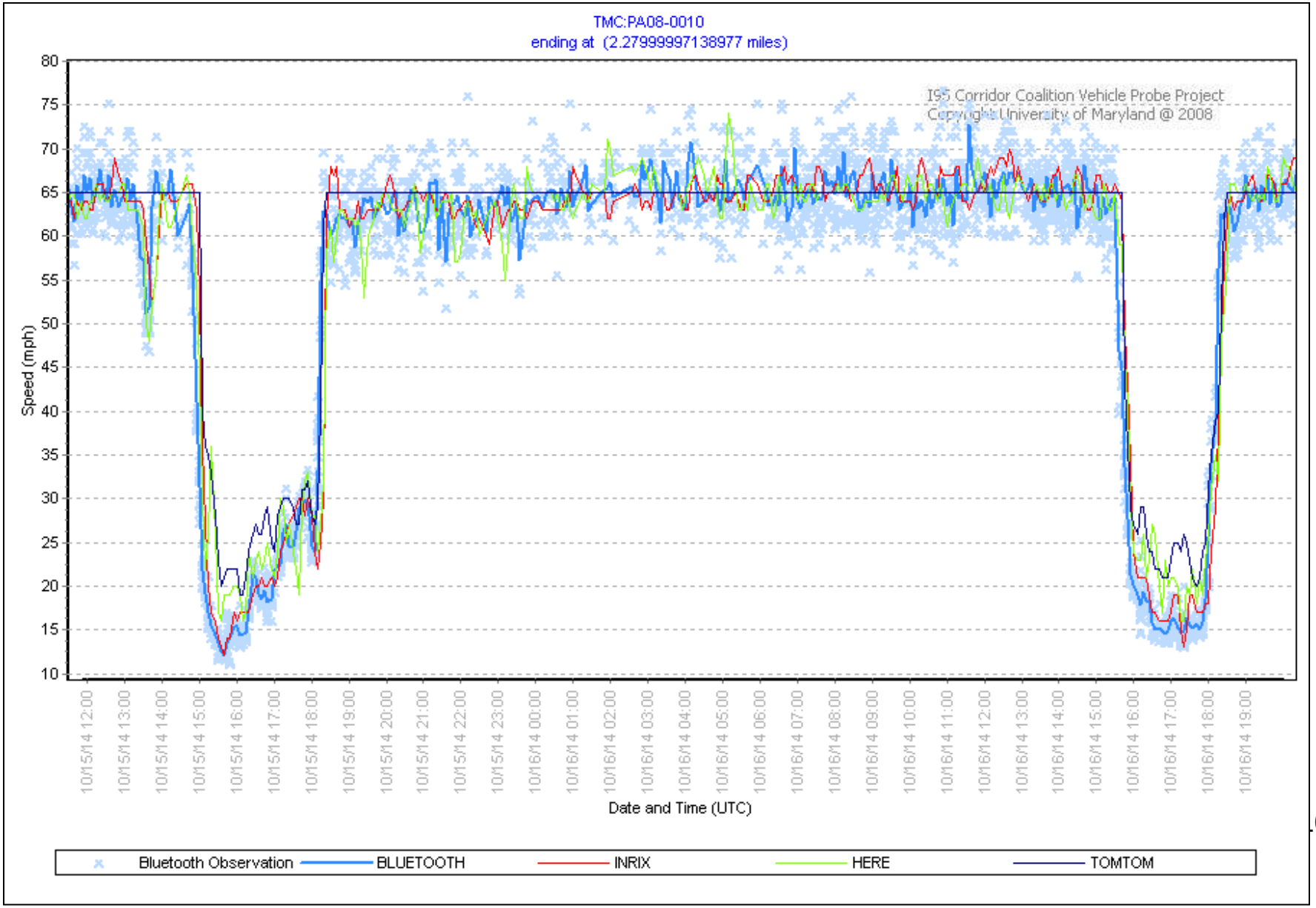
PA-08 I-83 & I-81 Harrisburg

October 9-22, 2014

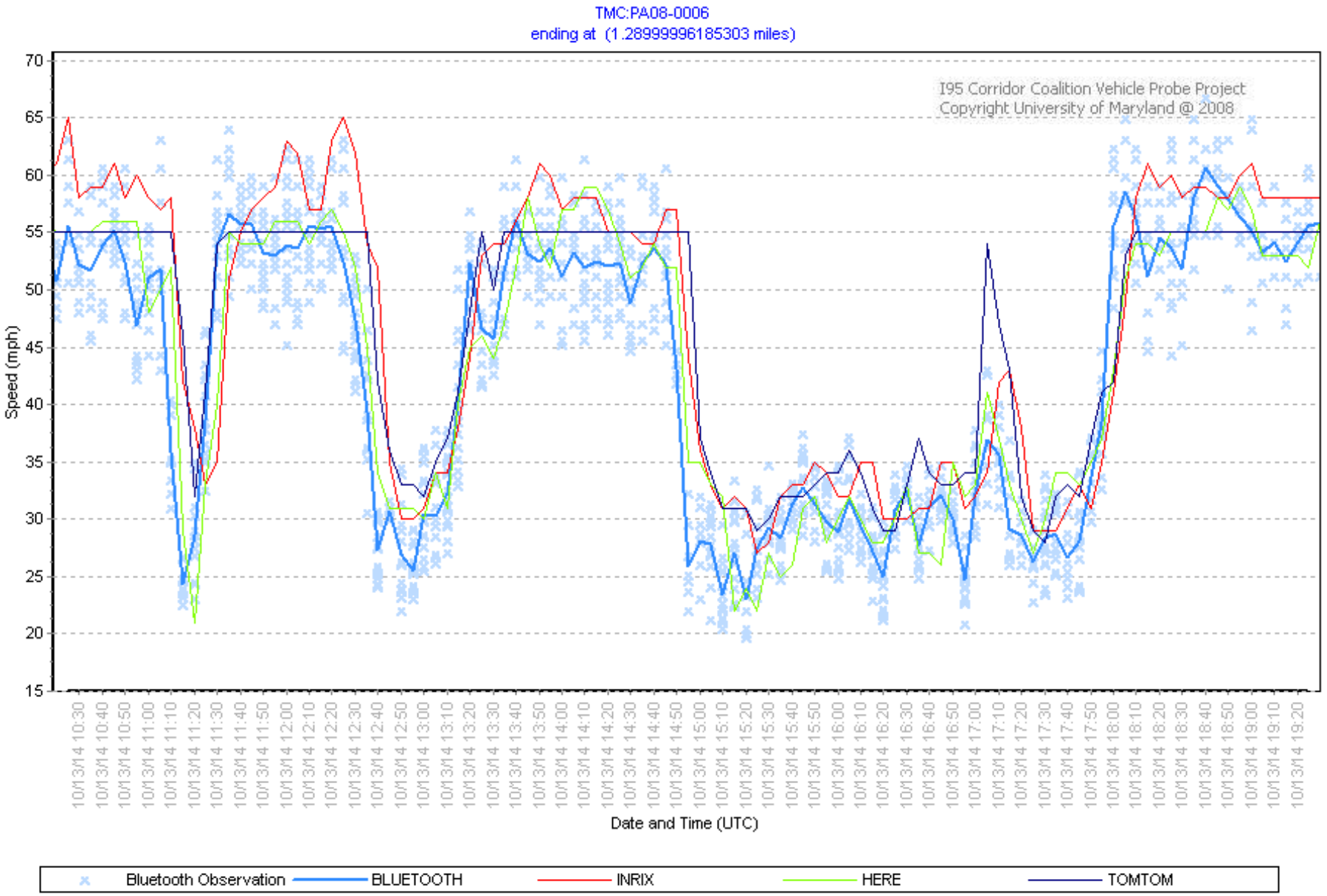
- PA-08
  - 14 Segments
  - 31.3 miles
- Data collection
  - 2300 to 2555 total hrs
  - 71 to 80 hrs [0-30]
  - 53 to 66 hrs [30-45]
- AASE
  - 2.1 to 4.1 mph [0-30]
  - 3.1 to 5.8 mph [30-45]



PA-08 PM Peak Hour *(Oct 15-16, 2014)*



PA-08 10AM-7PM (Oct 13, 2014)



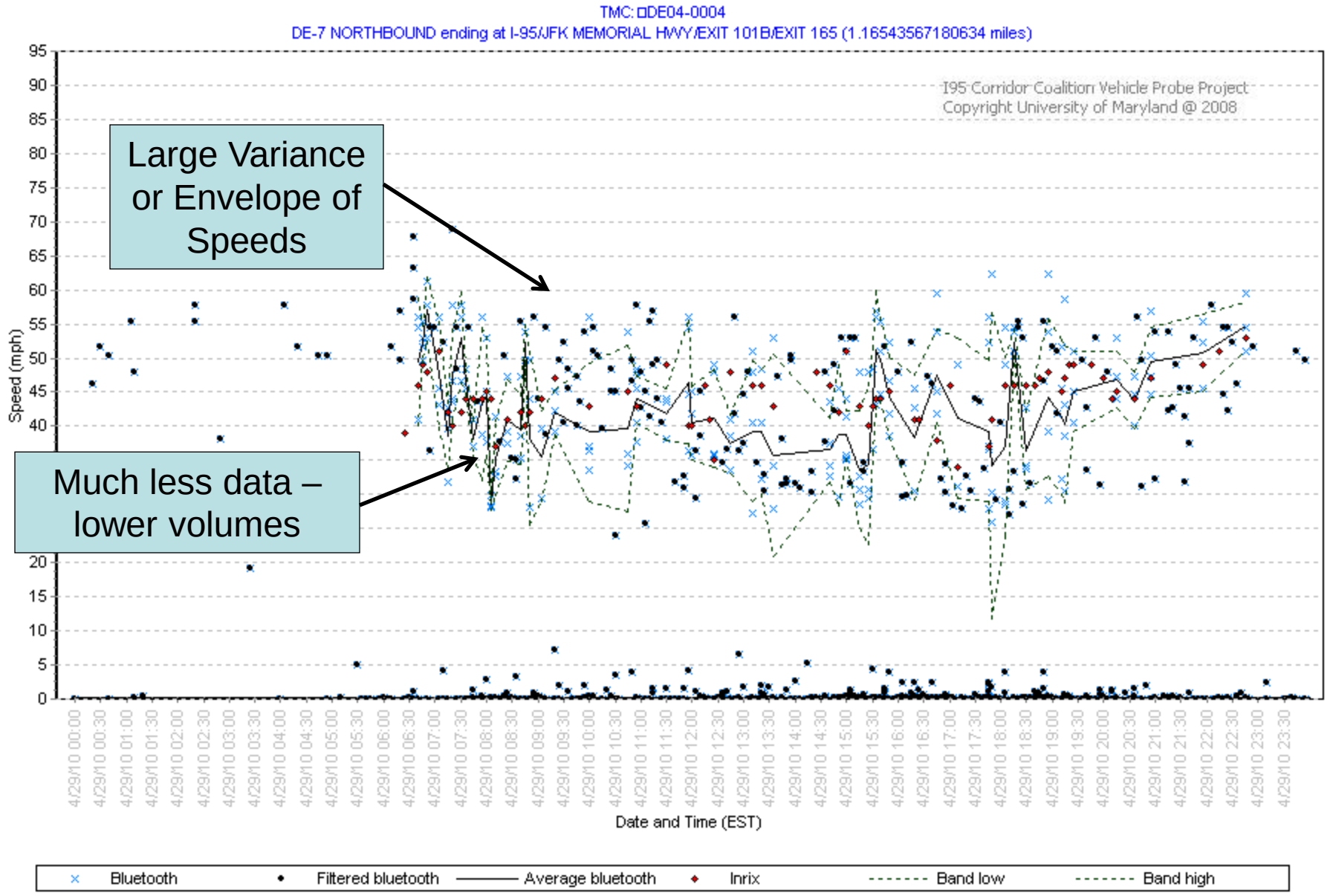
PA-08 Summary

- **All vendors were within spec**
- **More similarities than differences**
- All individual reports, graphs and data available for review
- Challenges
  - Maintain ‘Apples-to-Apples’ comparison
  - Timestamp consistency for Latency

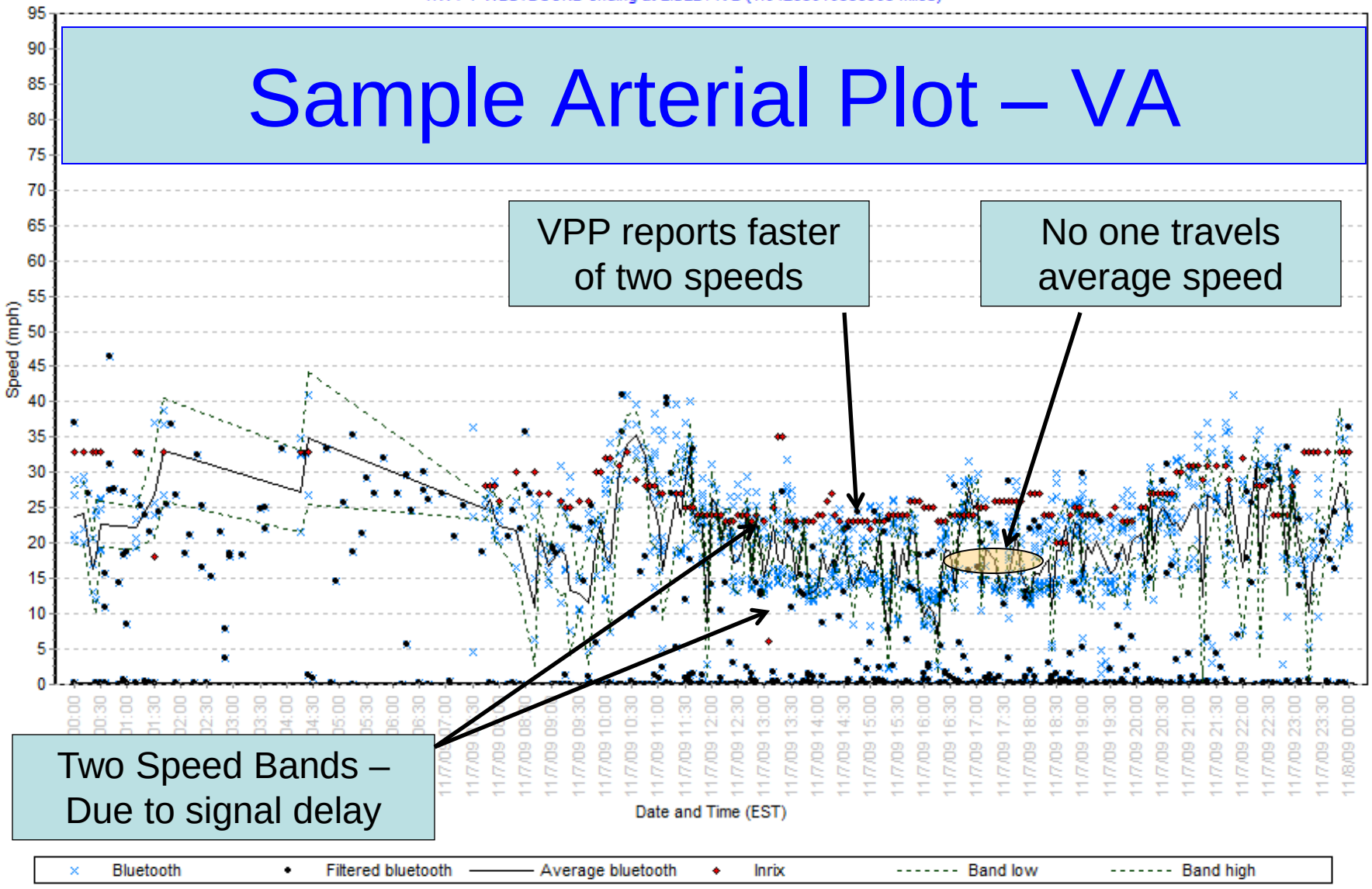
Freeways vs. Arterials

	Freeways	Arterials
Volume	2200 vphpl	1400 vphpl on green
Speed Range	20-70 mph	10-45 mph
Freeflow	65 mph	Unknown
Congestion Types	Recurring / Non-recurring	Cycle Failure / Mid-Block Friction
Congestion Signature / Incident	Slowdowns < 55 mph	Difficult to recognize
Flow characteristic	Uniform	Higher Variance, Frequently Bi-Modal

Arterial Data Example



Sample Arterial Plot – VA



TMC Issues on Arterials

- Segments often too long
- TMCs slow to update for new alignments/roads
- May not be available on roads that warrant coverage
- TMCs designed primarily for freeways, may not work for all arterials
- **Alternatives are propriety**

Summary of Issues - 2011

- Validation of arterials complicated by …
  - Broad definition of Arterials (No prevailing objective standard)
  - Freeway methodology/specifications inappropriate
  - Arterial congestion patterns more complex
  - Travel time often not uniform, frequently bi-modal
  - TMC codes problematic

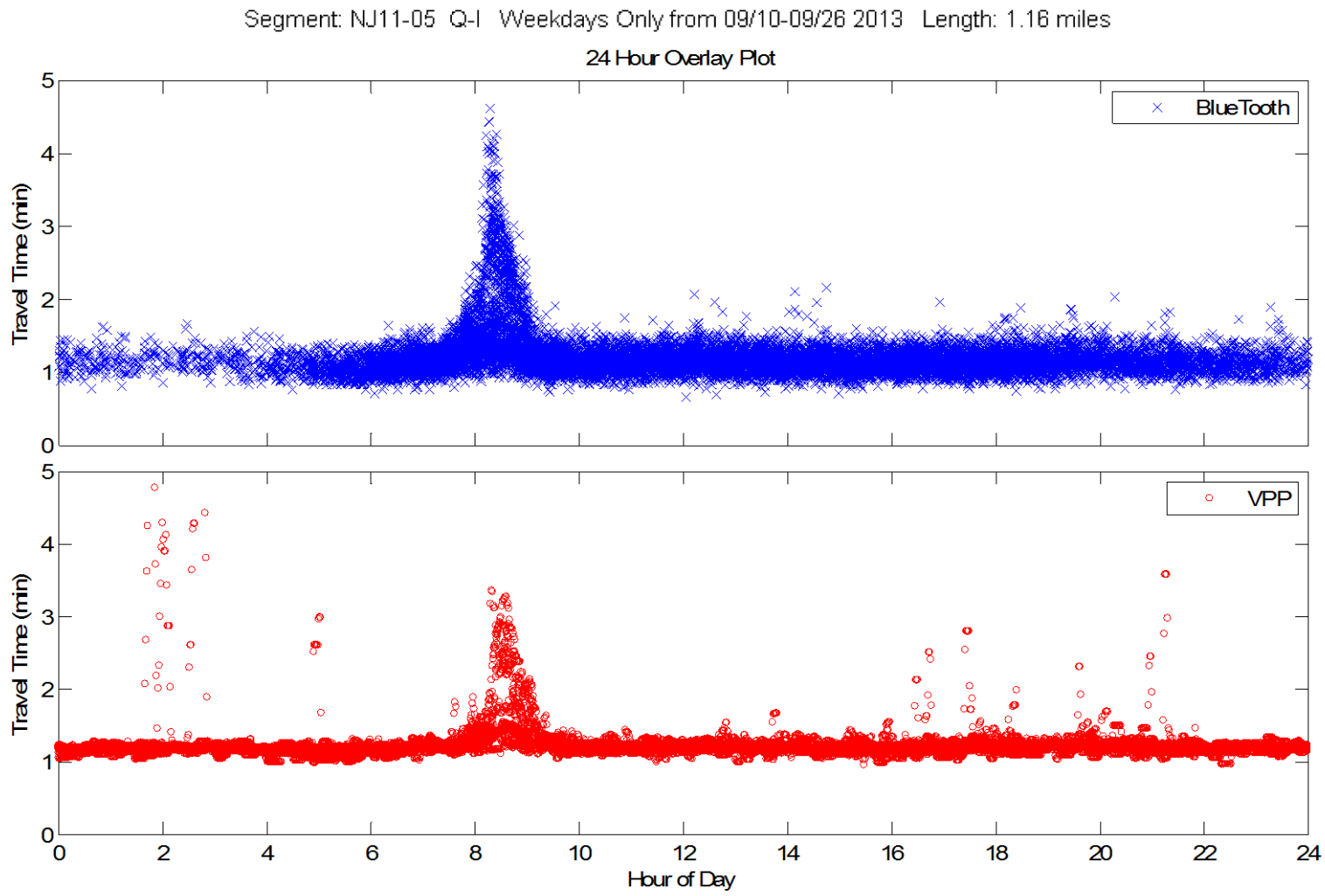
Shift in Thought 2012-2014

- Requirements for performance measurement differ than that needed for operations
  - Resulted in alternate ways of observing/contrasting travel time of probe data using **weekday overlays** to show trends
- Validation shifted from comparing means to comparing the distributions of travel times
  - Resulted in comparing **Cumulative Frequency Diagrams (CFDs)** rather than means
- Travel time and reliability are best characterized by the distributions, not a single measure.
  - Reliability literature now reflects travel time distribution concepts, rather than simple measures.

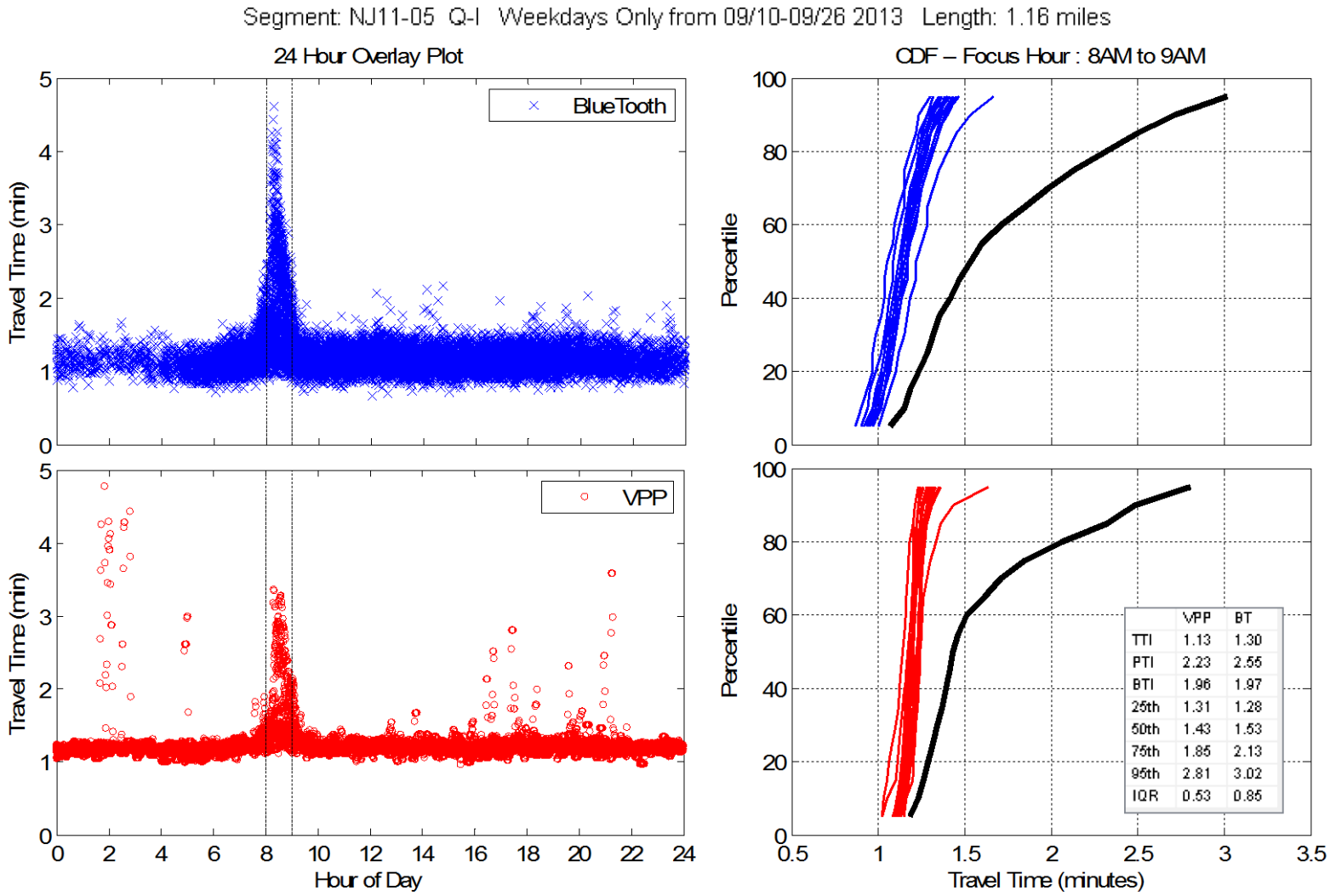
Analysis Method
Sampled Distribution Method

- Analyze VPP and BTM based on recurrent traffic patterns
  - 24-hour overlay plots reveal impacts of signal timing and cycle failures
  - Travel Time distributions (in the form of CFDs) provide direct comparisons of performance.
- Traditional performance measures can be directly calculated from the distribution:
  - TTI, PTI, BTI, Percentiles, IQR, etc.
- **Strengths**
  - Captures complex flow dynamics (that are repeatable)
  - Can characterize the ‘nature’ of variation

Sample of 24 Hour Overlay Plot



Sample of CFD Plot and 24 Hour Overlay Plot



Case Study Locations
Validation of Arterials

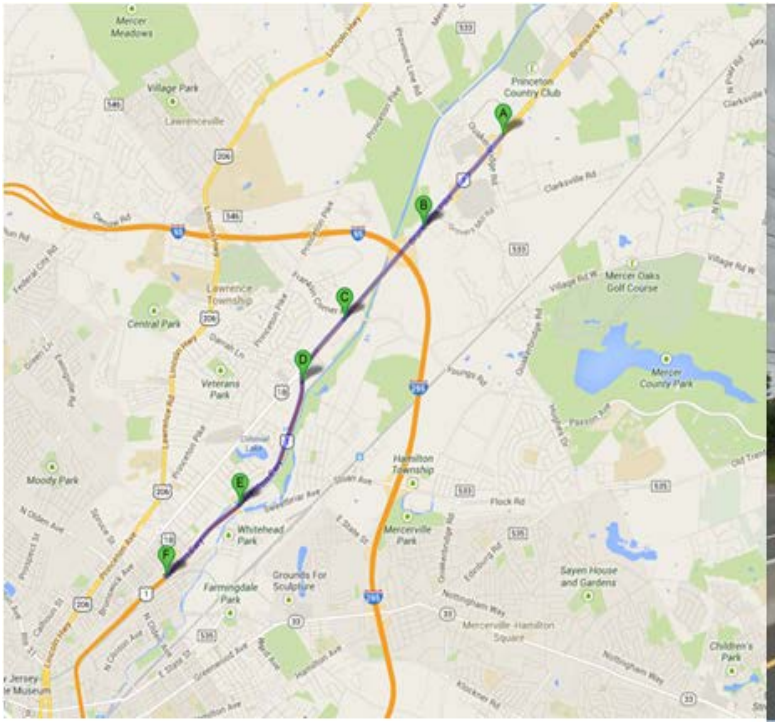
State / Set ID	Road Number	Road Name	Validation Date Span	# of Segments	# of Through Lanes	AADT Range (in 1000s)	Length* (mile)	# Signals / Density	# of Access Points	Median Barrier	Speed Limit (mph)
NJ-11	US-1	Trenton Fwy, Brunswick Pike	Sep 10 - 24, 2013	10	2-4	33 - 90	14.2	10 / 0.7	112	Yes	55
	NJ-42	Black Horse Pike		8	2	25-54	12.5	23 / 1.8	260	Yes	45-50
	US-130	Burlington Pike		10	3	42	14.3	28 / 2.0	229	Yes	50
NJ-12	NJ-38	Kaighn Ave.	Nov 5-19, 2013	16	2-4	32-80	24.5	44 / 1.8	235	Yes	50
	NJ-73	Palmyra Bridge Rd.		18	2-4	33-74	23.9	41 / 1.7	236	Yes	45-55
PA-05	US-1	Lincoln Highway	Dec 3 - 14, 2013	28	2 - 3+3	21 - 100	30.62	107 / 3.5	178	Yes	40 - 50
	US-322	Conchester Highway		6	1-2	22 - 34	14.28	7 / 0.5	48	No	35 - 45
PA-06	PA-611	Easton Rd	Jan 9 - 22, 2014	10	2-4	18-31	6.7	21/ 3.13	98	NO	40-45
	PA-611	Old York Rd		8	1-2	21-30	7.3	26/ 3.56	105	Partial	15-40
	PA-611	N Broad St		16	2-4						
VA-07	VA-7	Leesburg Pike and Harry Byrd Hwy	April 5-16, 2014	30	2-4						
	US-29	Lee Hwy (S Washington St)		4	2						
VA-08	US-29	Lee Hwy	May 8-19, 2014	26	2-4						
MD-08	MD-140	Reistertown Rd	June 5-14, 2014	12	1 - 3						
		Baltimore Blvd		6	2 - 4						

- 9 Case Studies from 2013-14
- Spans NJ through NC
- Test extent of probe data
  >20K AADT & 2+ lanes
- Range of signal density and access
- Objective: Reference case studies

A tale of three arterials …

- Segments where VPP performed well:
  - **NJ11_US-1**
- … mixed performance:
  - **NJ11_NJ42**
- … poor performance:
  - **VA07_VA-7**

Sample of Well Performed VPP_ NJ11_US-1



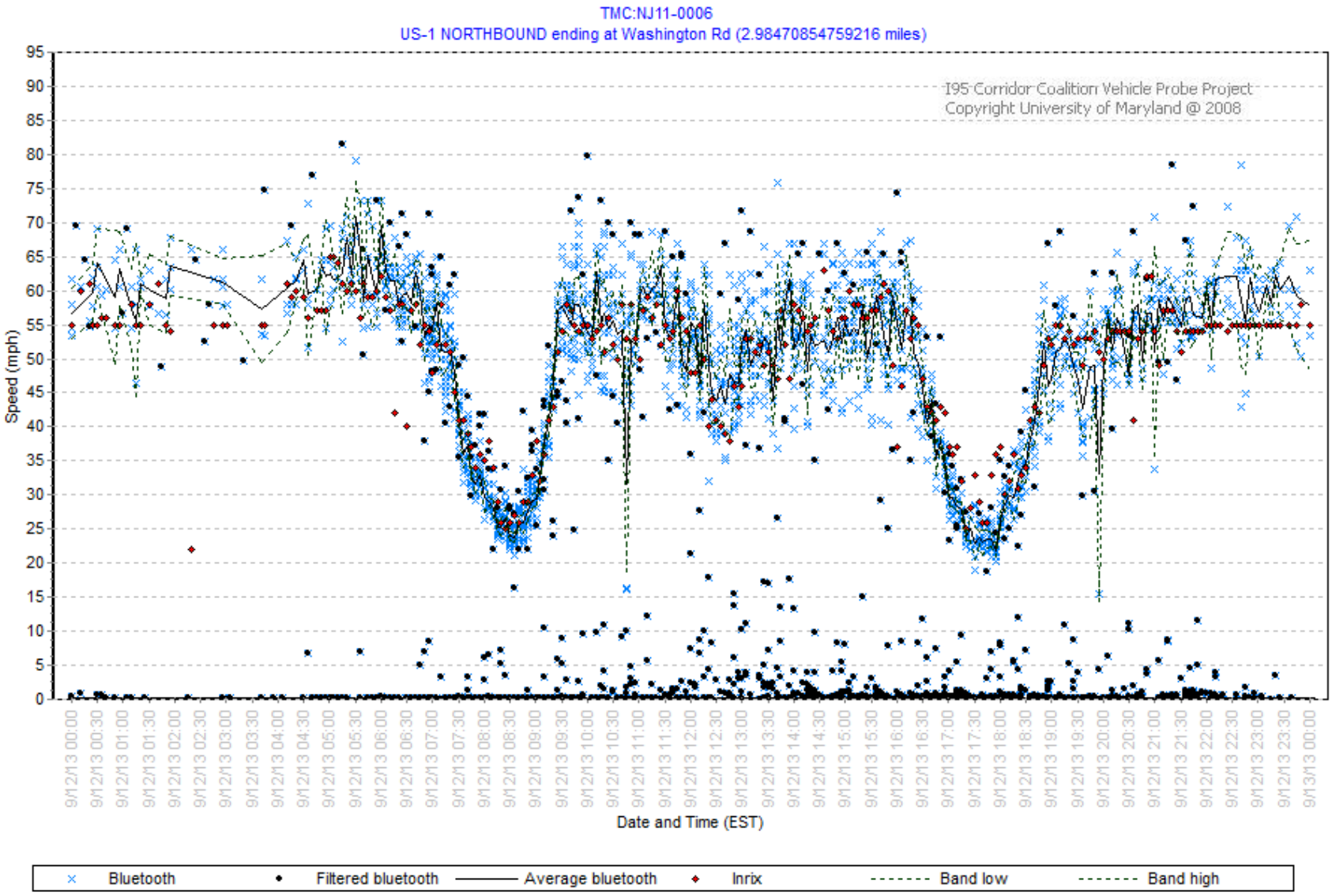
Data Set Name	Road Number	Road Name	Validation Date Span	# of Segments	# of Through Lanes	AADT Range (in 1000s)	Length (mile)	# Signals / Density	# of Access Points	Median Barrier	Speed Limit (mph)
NJ-11	US-1	Trenton Fwy, Brunswick Pike	Sep 10 - 24, 2013	10	2-4	33 - 90	14.2	10 / 0.7	112	Yes	55

Traditional Analysis_ AASE and SEB (NJ11_US-1 Corridor)

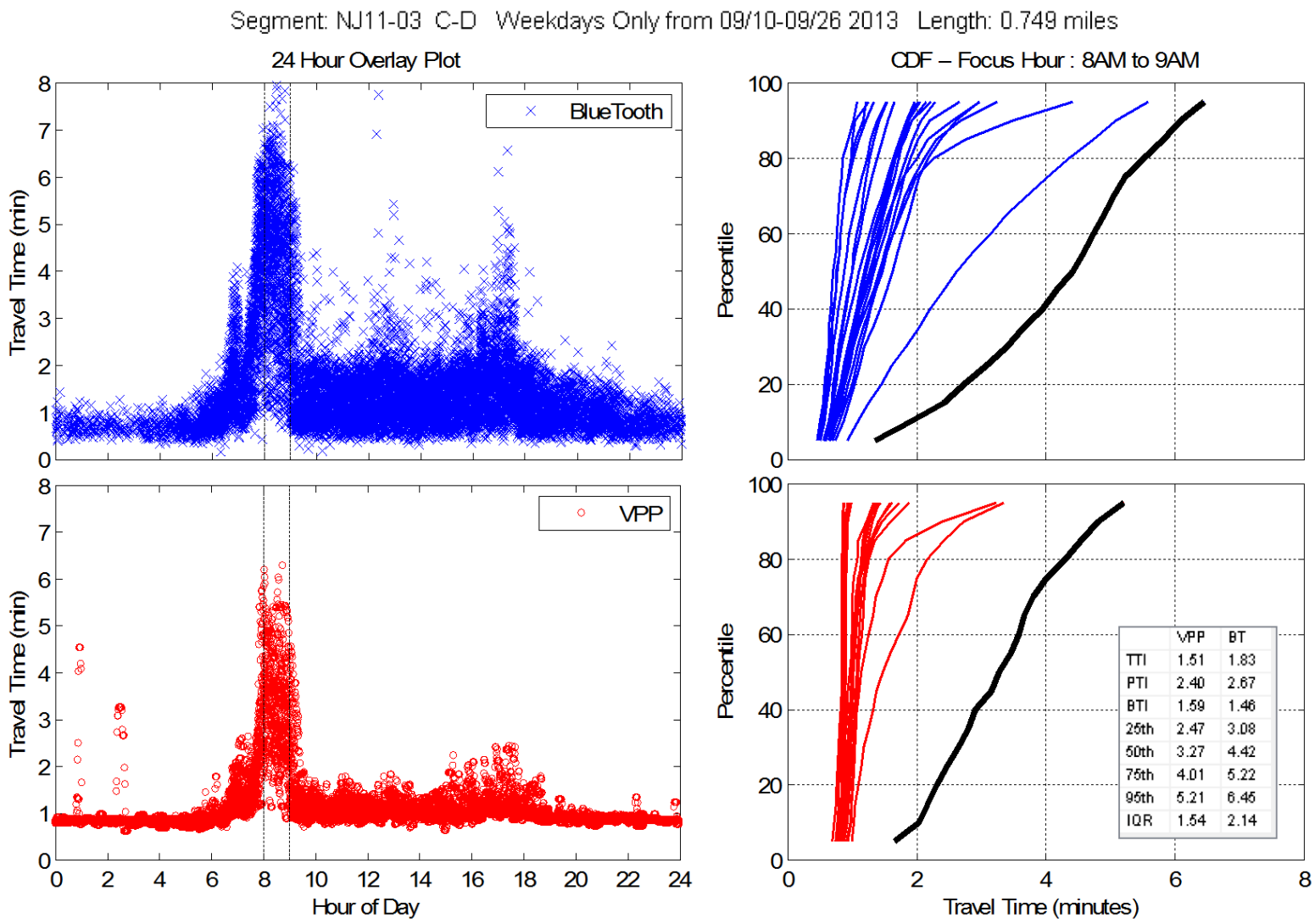
Table CS3-2-2 US-1 Evaluation Summary

Speed Bin	Absolute Speed Error (<10mph)		Speed Error Bias (<5mph)		Number of 5 Minute Samples	Hours of Data Collection
	Comparison with SEM Band	Comparison with Mean	Comparison with SEM Band	Comparison with Mean		
0-15 MPH	2.9	4.4	2.8	3.8	224	18.7
15-25 MPH	5.3	7.3	5.2	6.9	1742	145.2
25-35 MPH	5.4	9.6	5.2	8.8	3155	262.9
>35 MPH	2.3	6.5	-1.3	-2.9	21276	1773.0
All Speeds	2.9	6.9	-0.1	-0.8	26397	2199.8

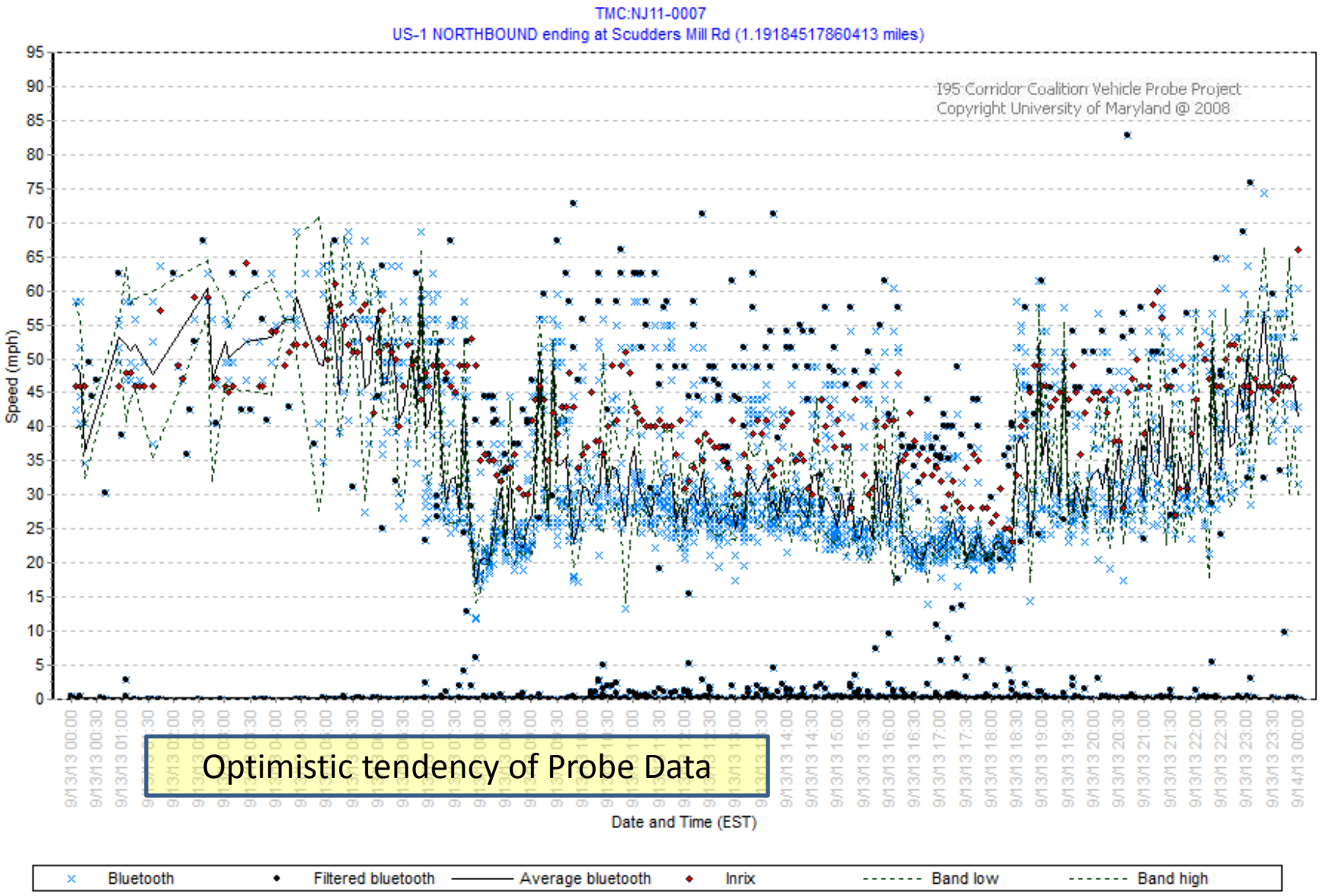
US-1 (NJ11-06) 9/12/2013



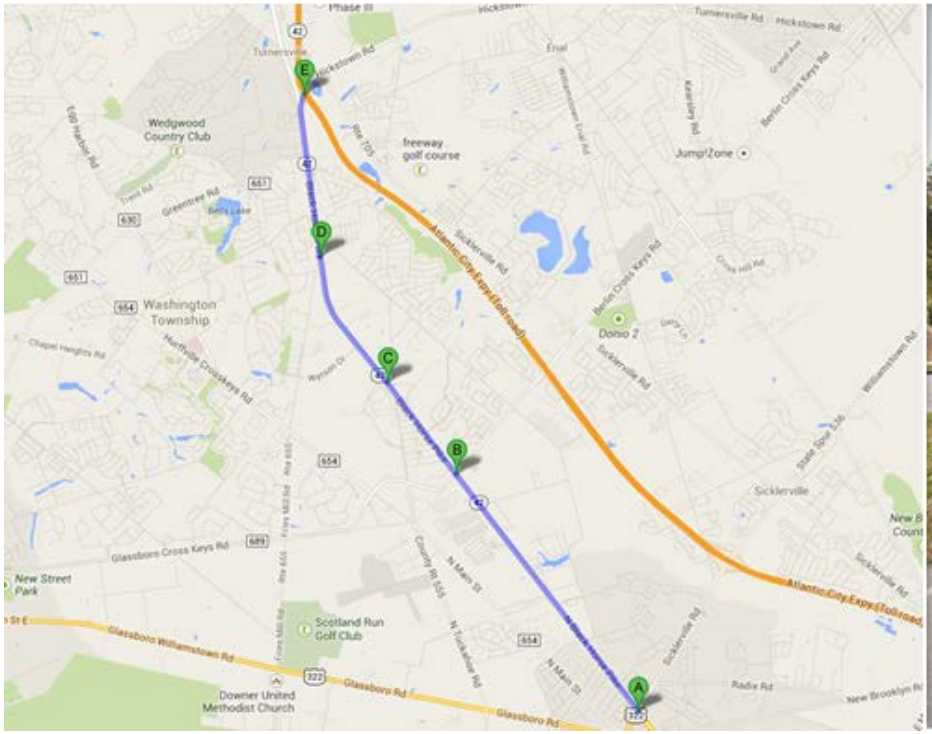
NJ11-03, 8AM – 9AM



US-1 (NJ11-07) 9/13/2013

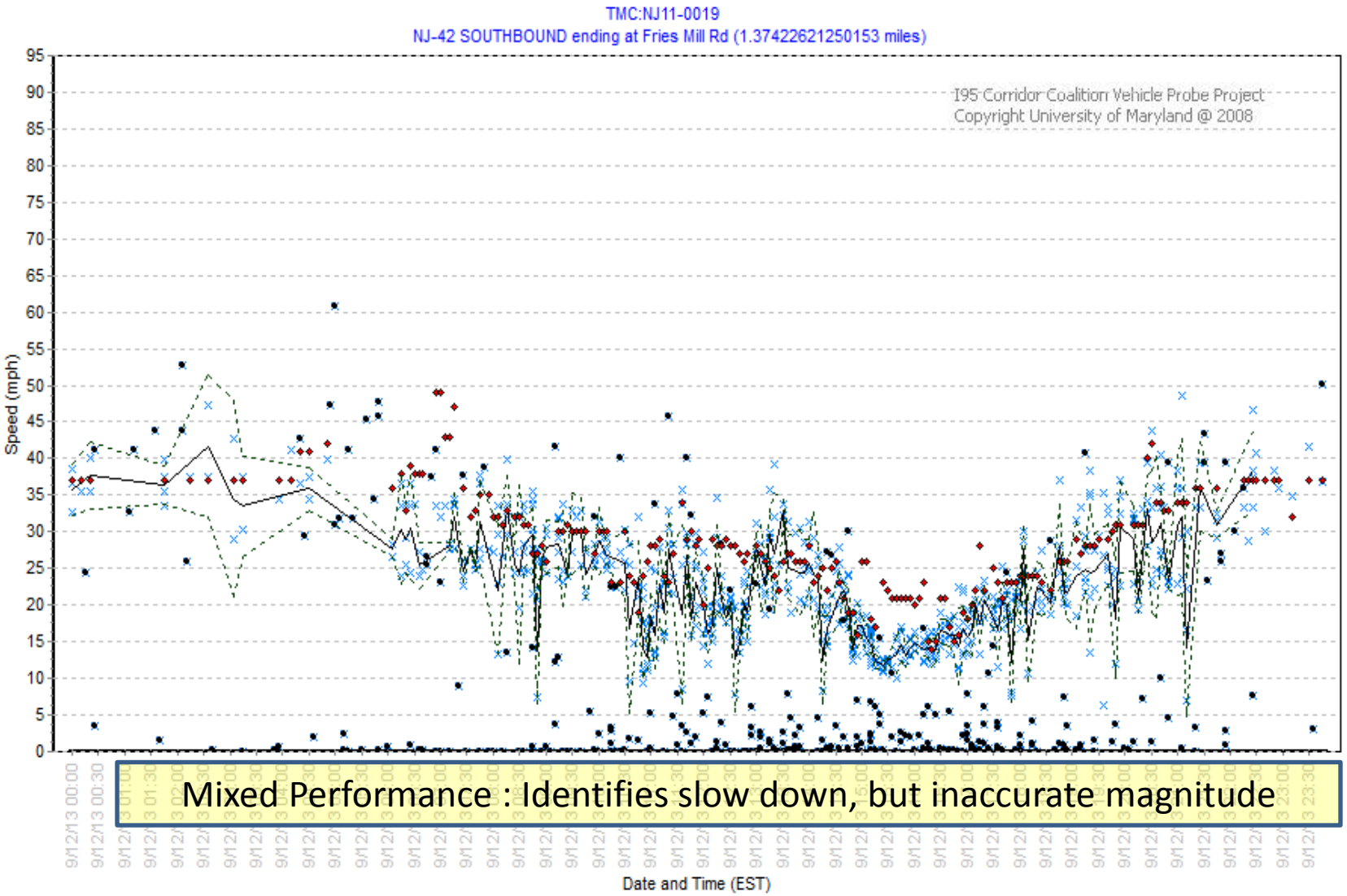


Sample of Mixed Performed VPP_ NJ11_NJ-42

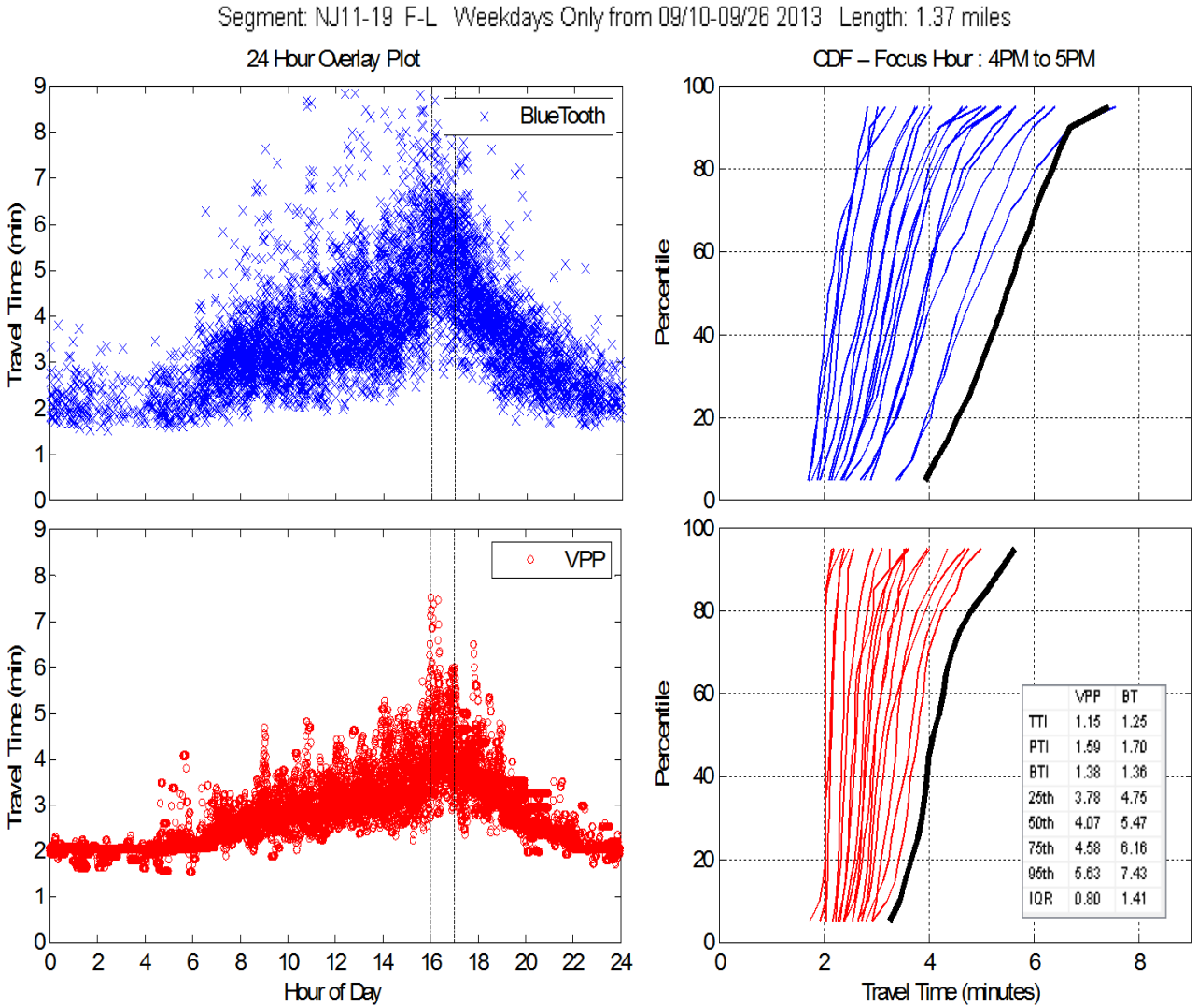


Data Set Name	Road Number	Road Name	Validation Date Span	# of Segments	# of Through Lanes	AADT Range (in 1000s)	Length (mile)	# Signals / Density	# of Access Points	Median Barrier	Speed Limit (mph)
NJ-11	NJ-42	Black Horse Pike	Sep 10 - 24, 2013	8	2	25-54	12.5	23 / 1.8	260	Yes	45-50

NJ-42 (NJ11-19)

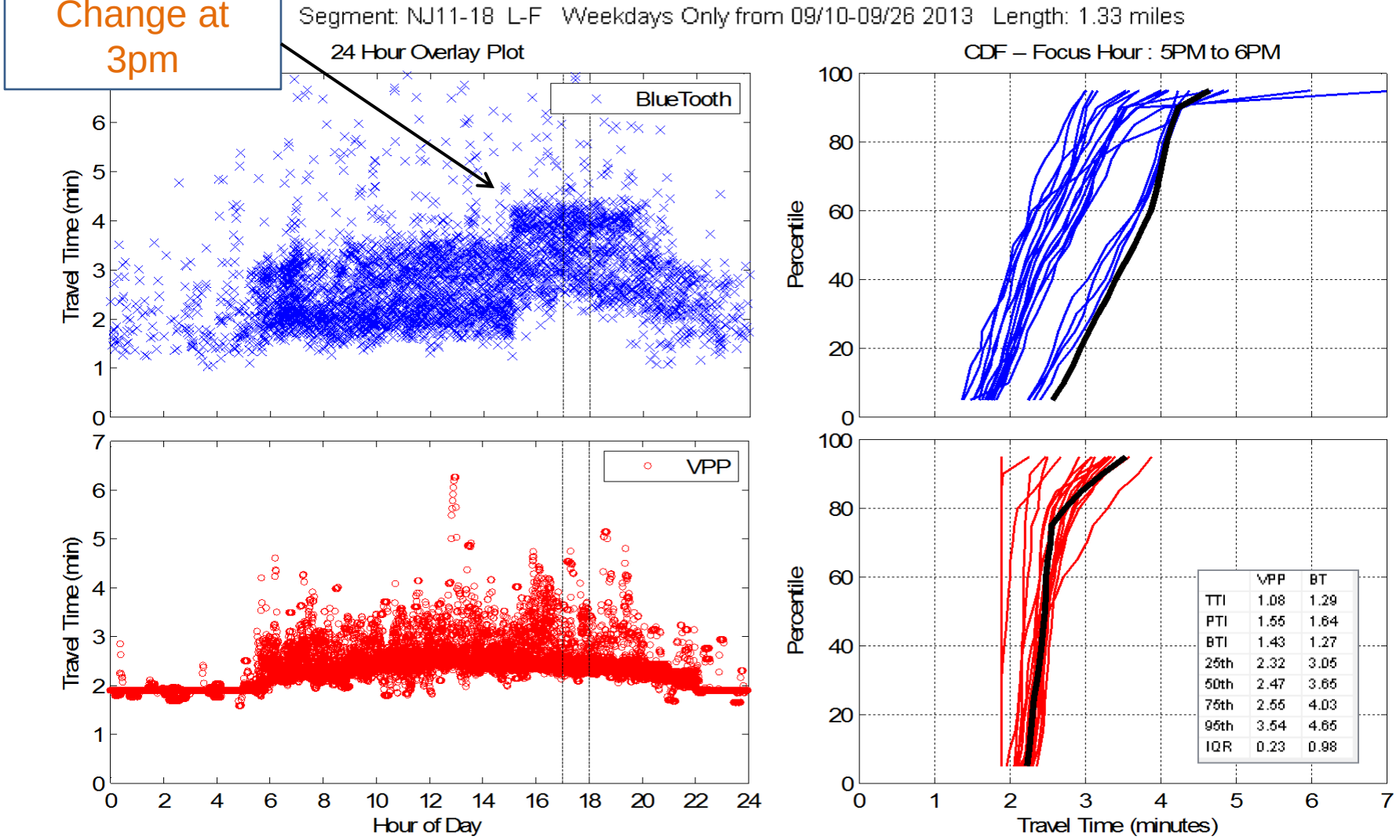

TMC:NJ11-0019
NJ-42 SOUTHBOUND ending at Fries Mill Rd (1.37422621250153 miles)
I95 Corridor Coalition Vehicle Probe Project
Copyright University of Maryland @ 2008
Speed (mph)
Date and Time (EST)
Mixed Performance : Identifies slow down, but inaccurate magnitude
Bluetooth
Filtered bluetooth
Average bluetooth
Inrix
Band low
Band high

Sampled Distribution Method (NJ11-19, 4PM – 5PM)

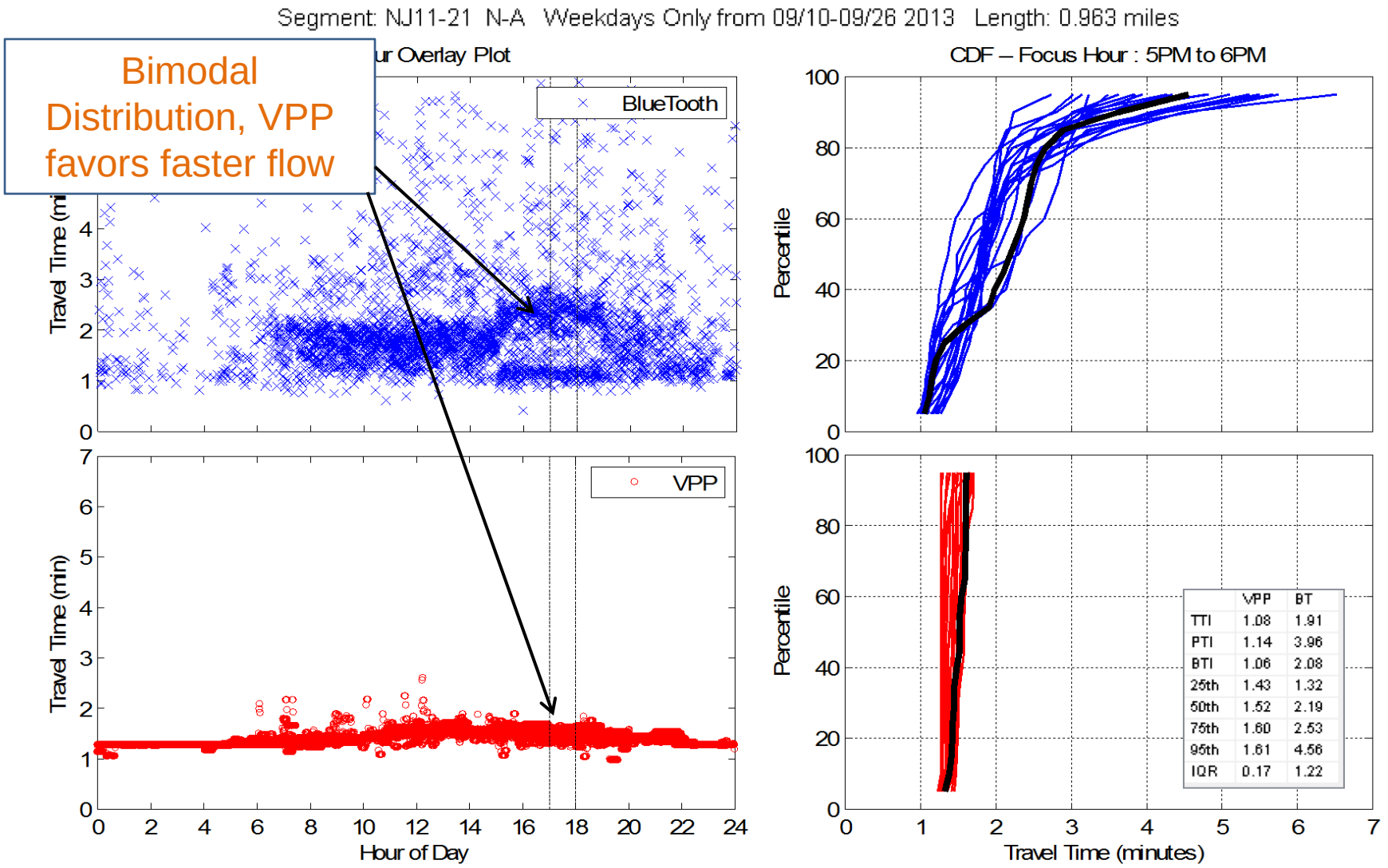


NJ11-18, 5PM – 6PM

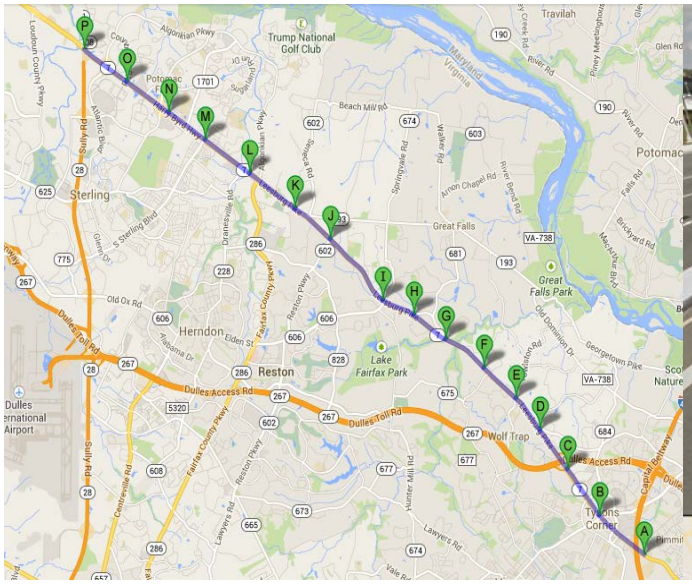
Signal Timing Change at 3pm



NJ11-21, 5PM – 6PM

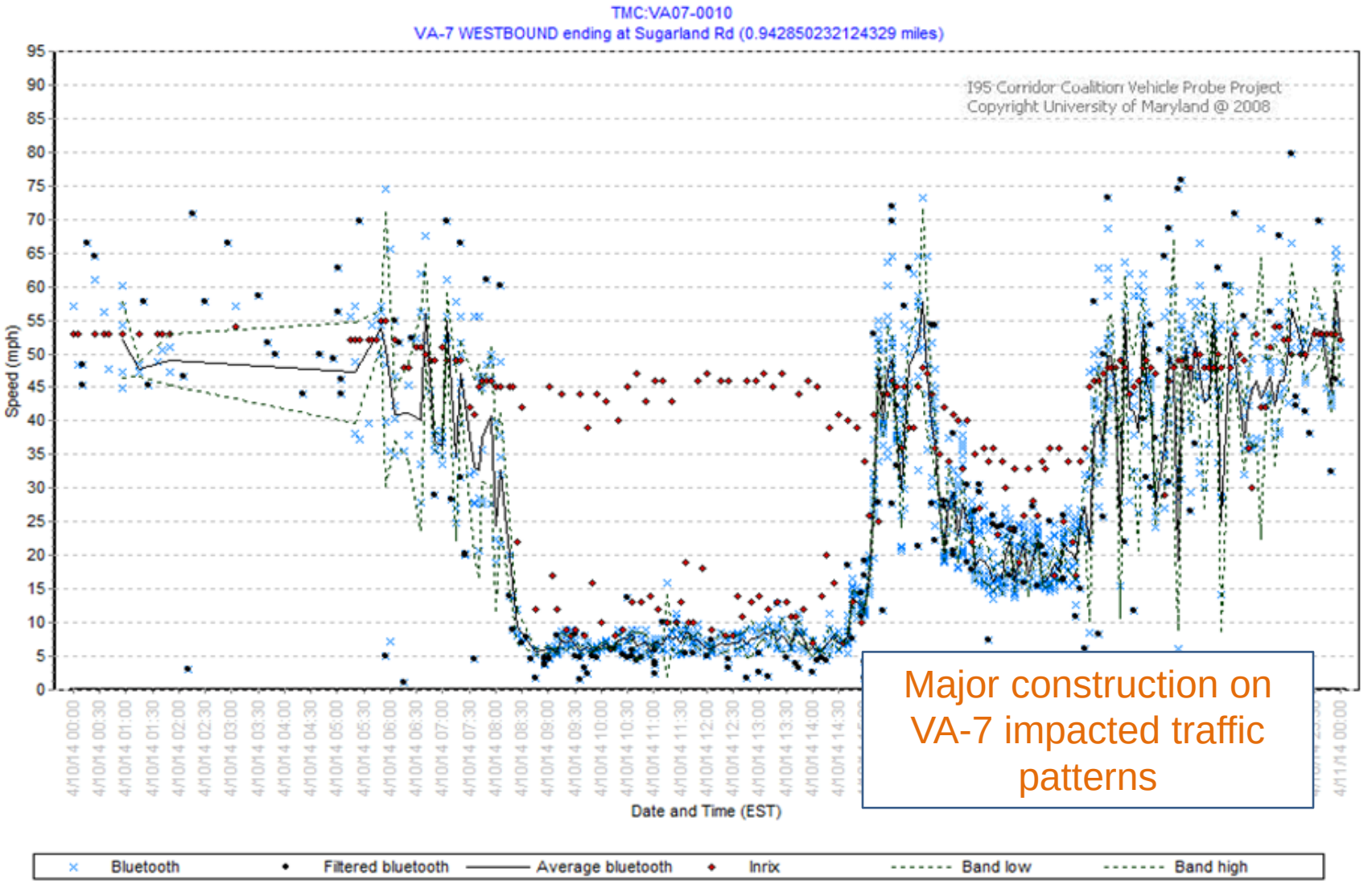


Sample of Poorly Performed VPP_ VA07_VA-7



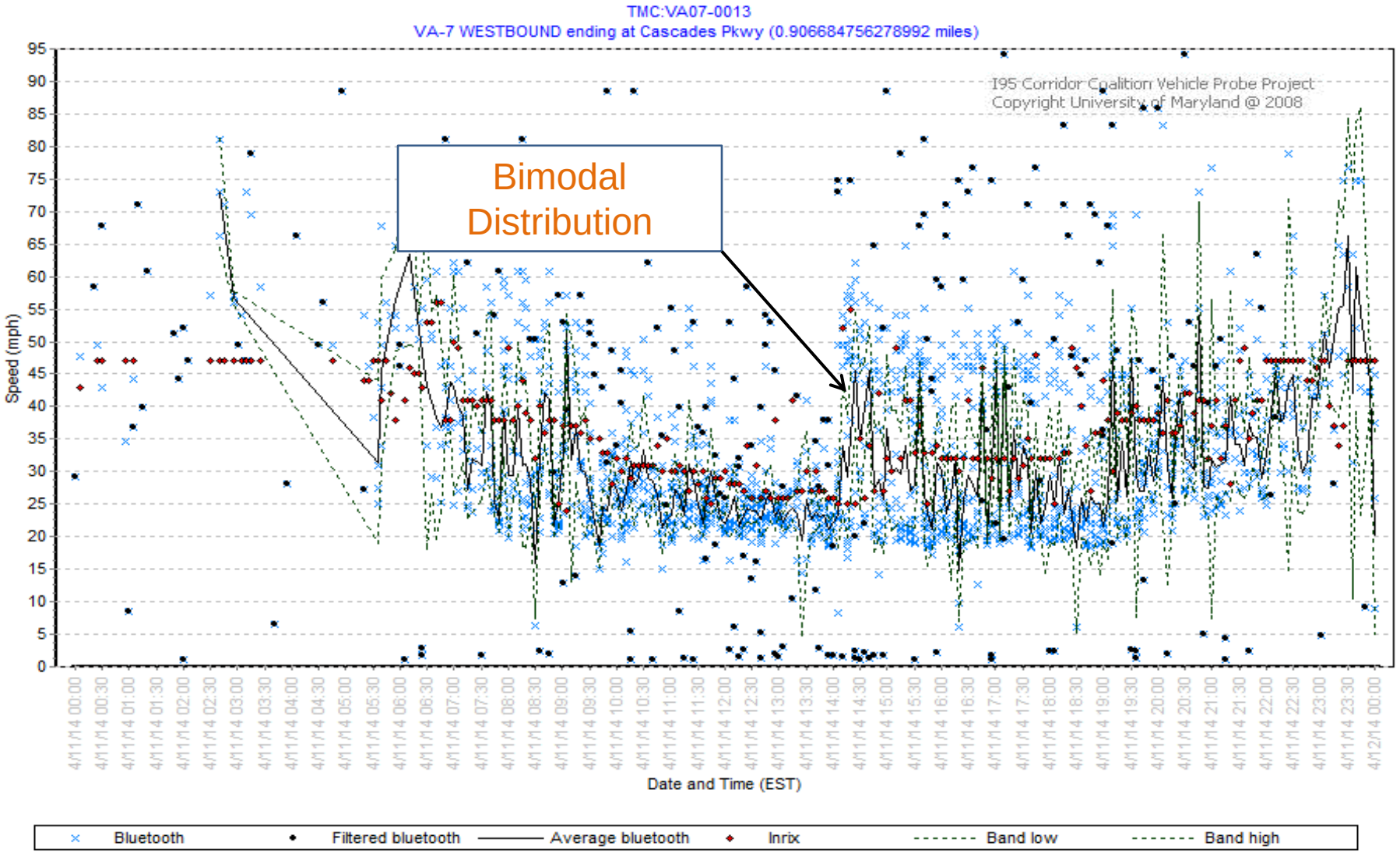
Data Set Name	Road Number	Road Name	Validation Date Span	# of Segments	# of Through Lanes	AADT Range (in 1000s)	Length (mile)	# Signals / Density	# of Access Points	Median Barrier	Speed Limit (mph)
VA-07	VA-7	Leesburg Pike and Harry Byrd Hwy	April 5-16, 2014	30	2-4	45-60	30.5	57 / 1.9	203	Yes	35-55

VA-7 (VA07-10) 4/10/2014

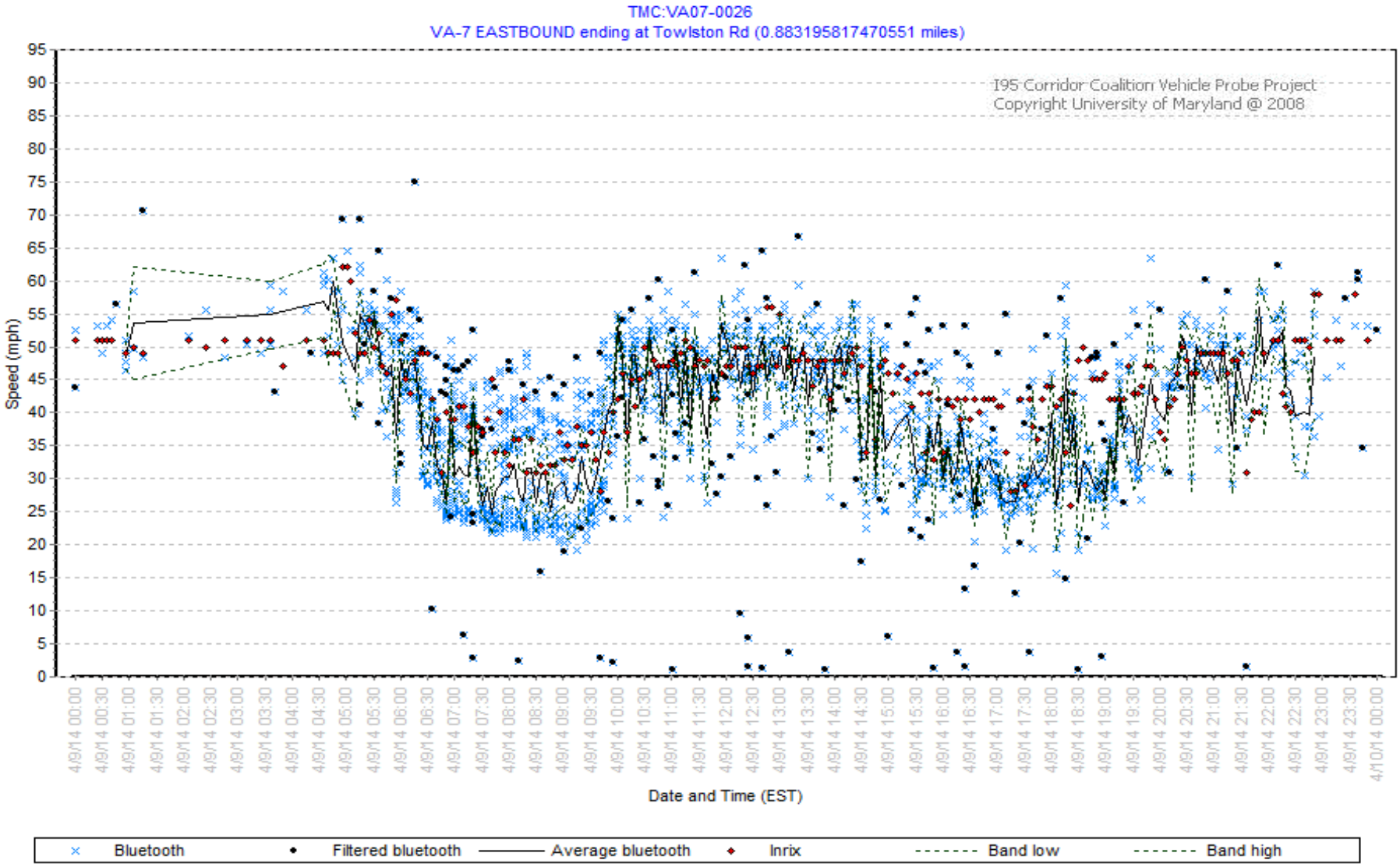


Major construction on VA-7 impacted traffic patterns

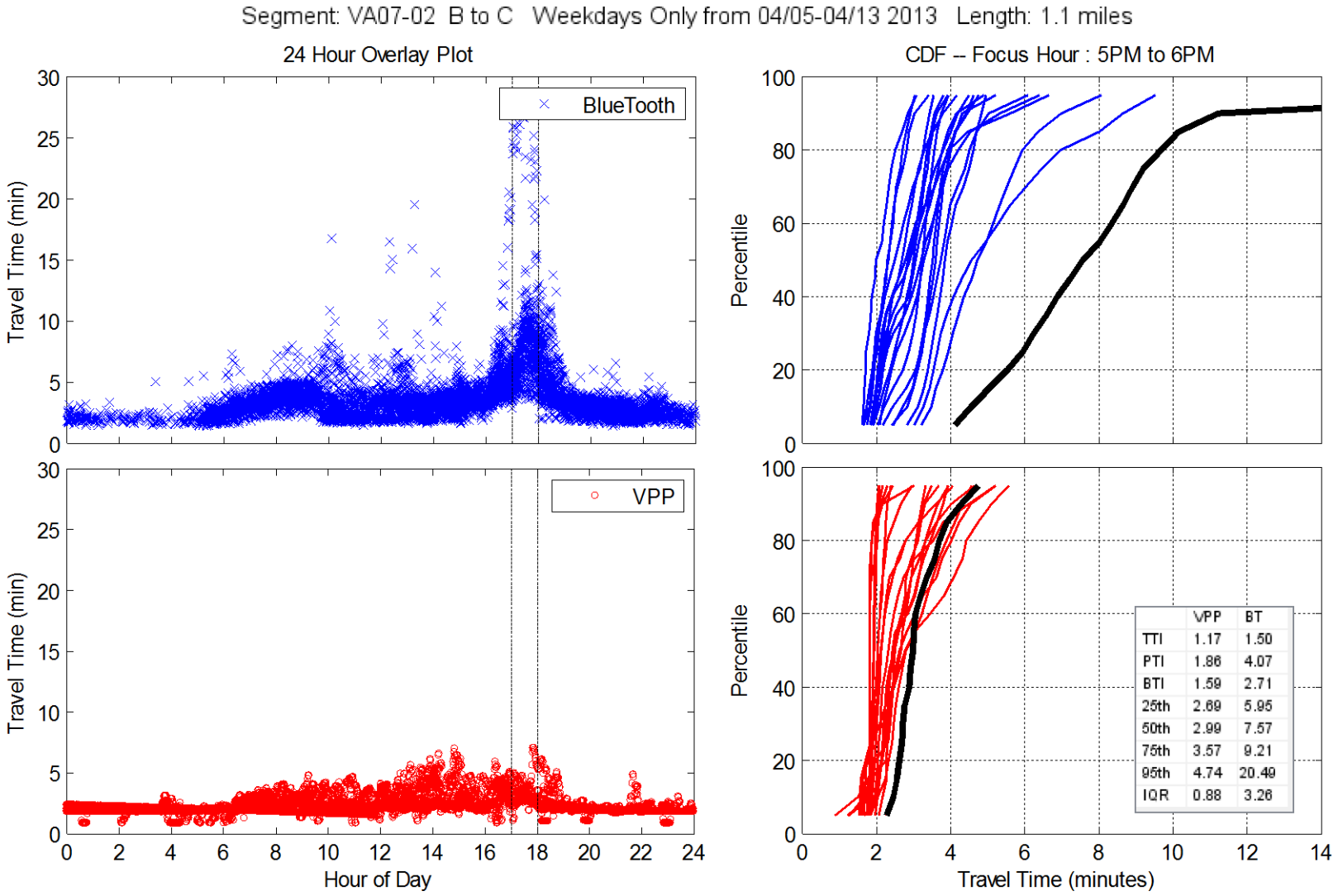
VA-7 (VA07-13) 4/11/2014



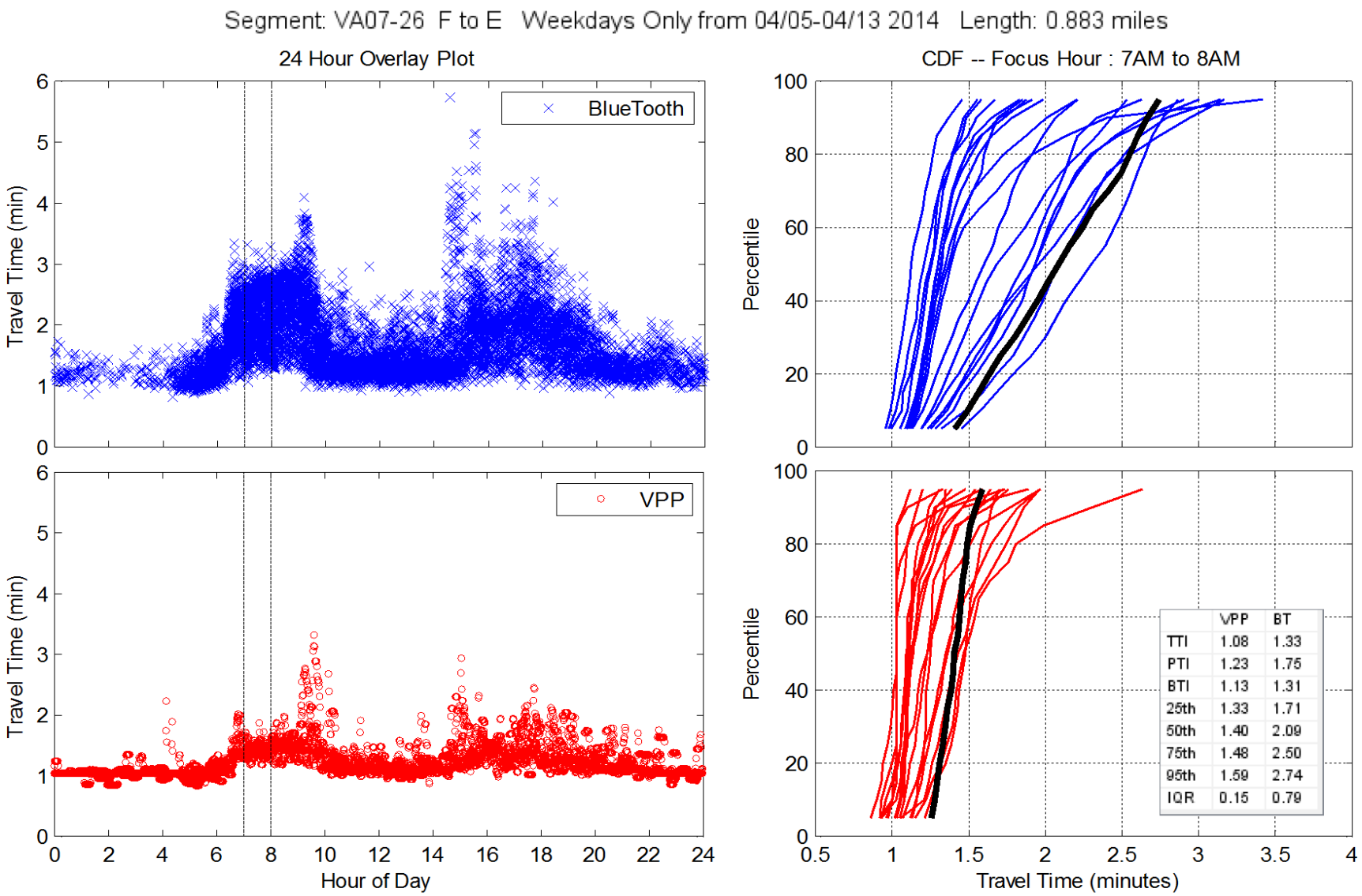
VA-7 (VA07-26) 4/9/2014



VA07-02, 5PM – 6PM



VA07-26, 7AM – 8AM



Arterial Probe Data Rec's

Likely to have usable probe data	Possibly usable probe data	Unlikely probe data is usable
• AADT >40000 • 2+ lanes • **<= 1 signals per mile** • Principal Arterials (HPMS) • Limited Curb cuts	• AADT 20K to 40K • 2+ lanes • <= 2 signals per mile • Minor Arterials (HPMS) • Should be tested	• Low volume, < 20K AADT • >=2 signals per mile • Major Collectors (HPMS) • Not recommended

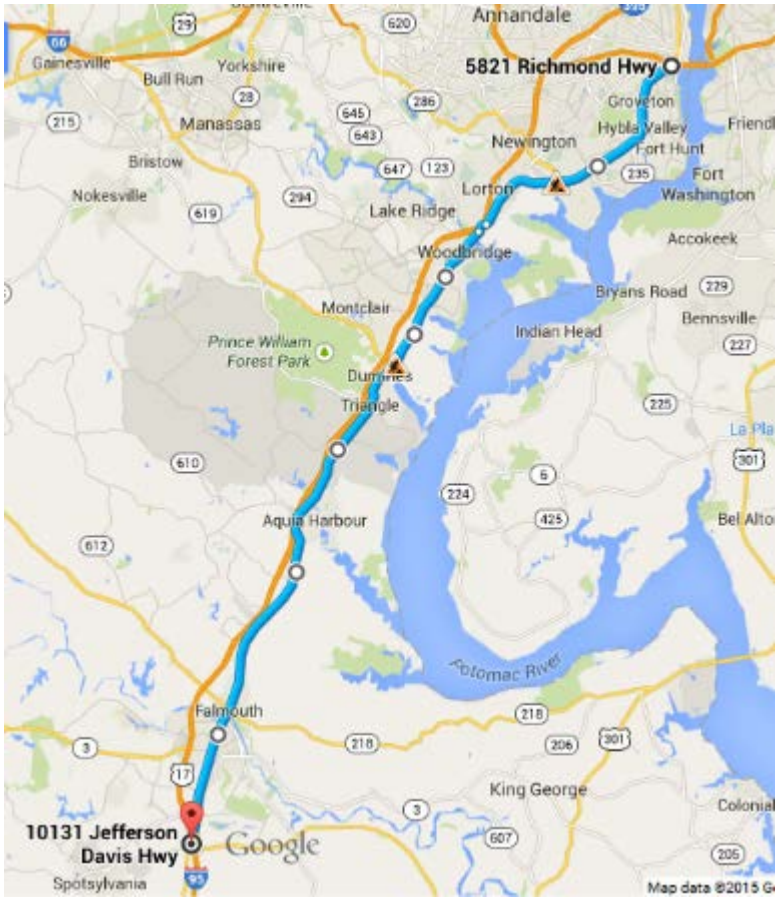
- Probe data is anticipated to improve in time
  - Increased probe density and better processing
- As Probe data degrades, delay is underestimated
  - As probe technology matures, measured delay may increase
  - Challenged by queuing or cycle failure
  - Not sensitive to / confused by bi-modal traffic patterns

Parting Thoughts

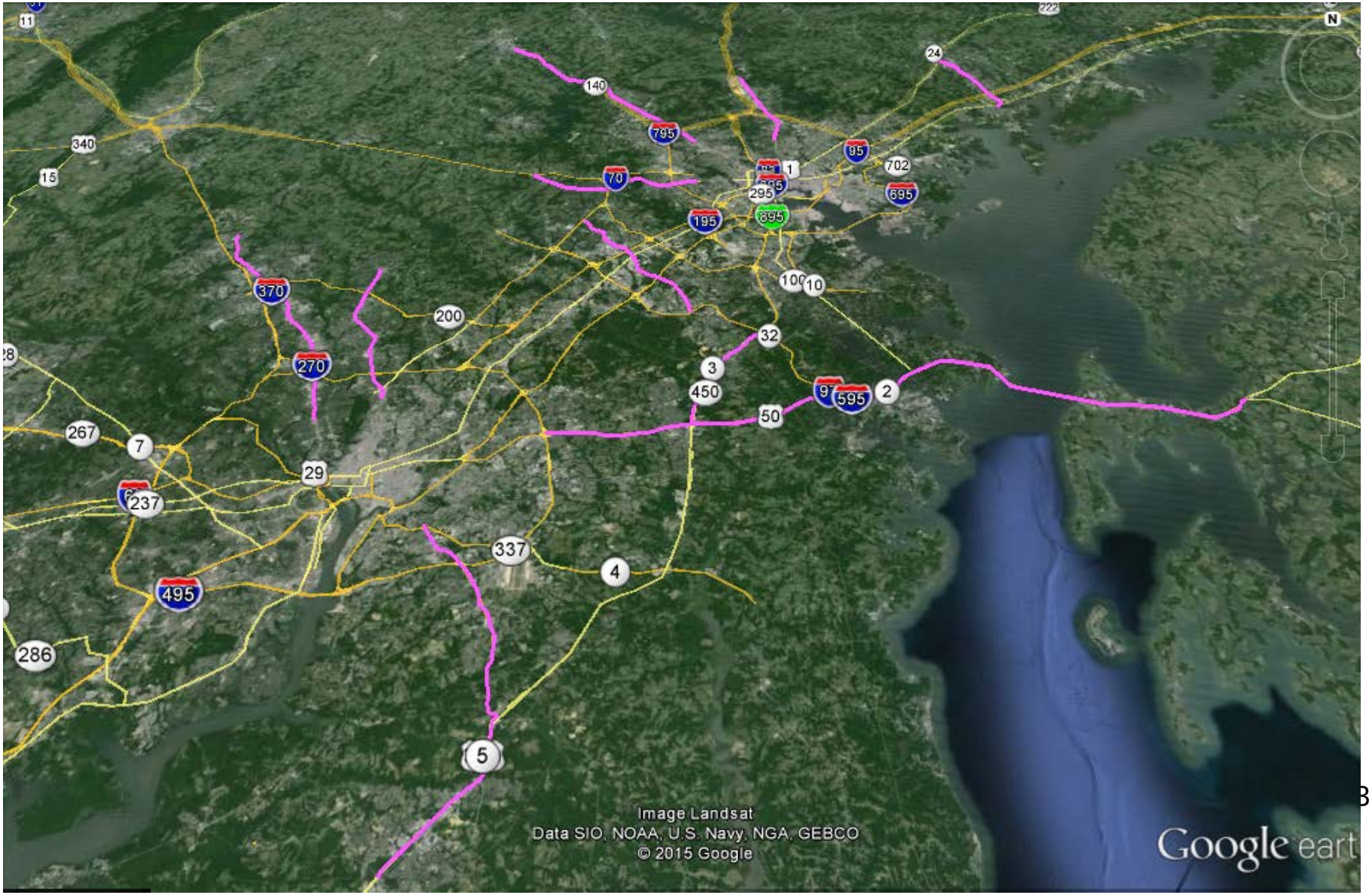
- **Expectations are running ahead of reality**
  - Probe data works on highest class arterials
  - Use with caution on mid class and below
- Arterial Performance
  - Travel time is the measure of choice
  - CDF's tell a concise story
    - Facilitates before/after, degradation in time, compare difference facilities, different signal timings
- Need reviewers / Arterial Focus Group

Future Validations

- US-1 in VA
  - DC to Fredericksburg
  - 50 miles
  - Currently being processed
- Spring 2015
  - Maryland Supplemental Coverage (120 miles all three vendors)
  - Freeway & Arterial



Maryland Supplemental Coverage



Questions?

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