



RPUG 2018 CONFERENCE - SOUTH DAKOTA

30 Years On The Road To Progressively Better Data

Rapid City September 18-21

EVALUATING TRANSVERSE PROFILE MEASUREMENTS USING THE CROSS- CORRELATION TECHNIQUE

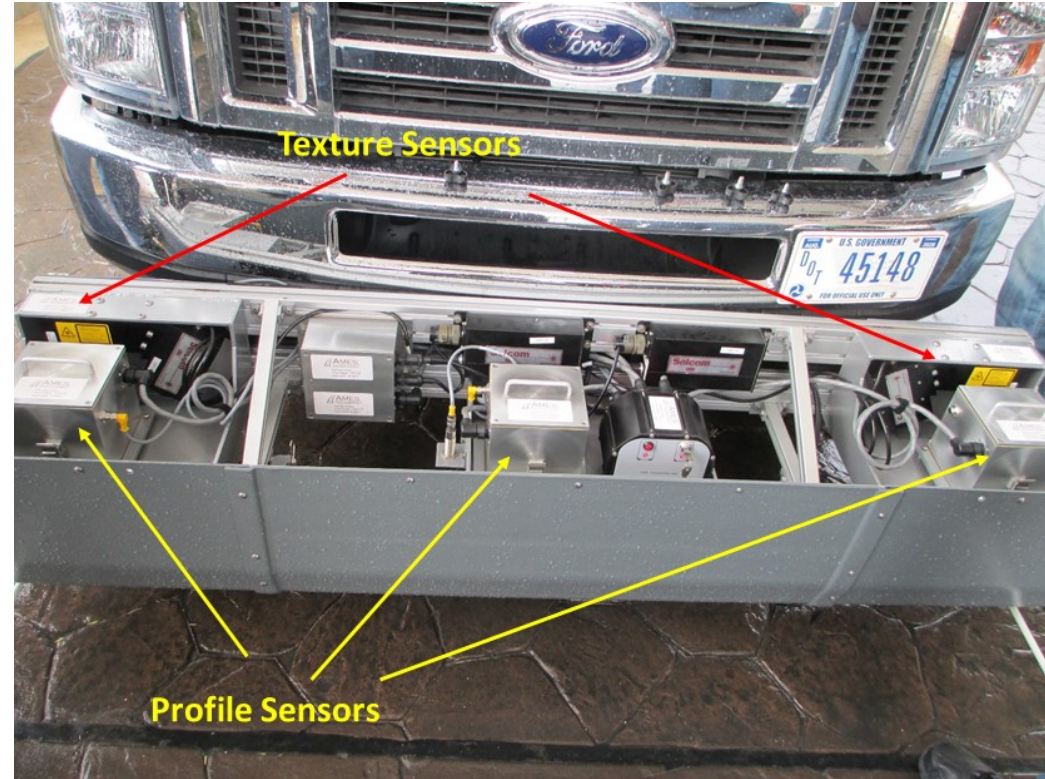
Rohan W. Perera, SME, Plymouth, Michigan

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Long-Term Pavement Performance High-Speed Survey Vehicle



Manufactured by Ames Engineering

Ames Engineering Transverse Profile Measuring System (TPMS)



**TPMS installed in each
LTPP High-Speed
Survey Vehicle**

Features of Ames TPMS

- Single camera mounted at center of vehicle 84 inches from ground.
- Collects transverse profile over a 13 ft width.
- Each transverse profile has 2048 data points (spacing 0.076 inches, 1.94 mm).
- A transverse profile is obtained longitudinally at 1 inch intervals.
- Resolution of TPMS is 0.0256 inches (0.65 mm).
- Vertical range ± 4 inches.
- No system for measuring roll of vehicle, cross-slope cannot be obtained.

Objective of Study

- Can the TPMS collect repeatable transverse profiles?
- Can the TPMS collect accurate transverse profiles?

Test Sections

- Established seven 50 ft long test sections.

Section	Rut Depth (in)	
	Inside Half of Lane	Outside Half of Lane
NB-1	0.19	0.10
NB-2	0.12	0.10
NB-3	0.17	0.09
SB-1	0.22	0.12
SB-2	0.19	0.12
SB-3	0.14	0.10
X Avenue	0.09	0.06



Reference Data Collection



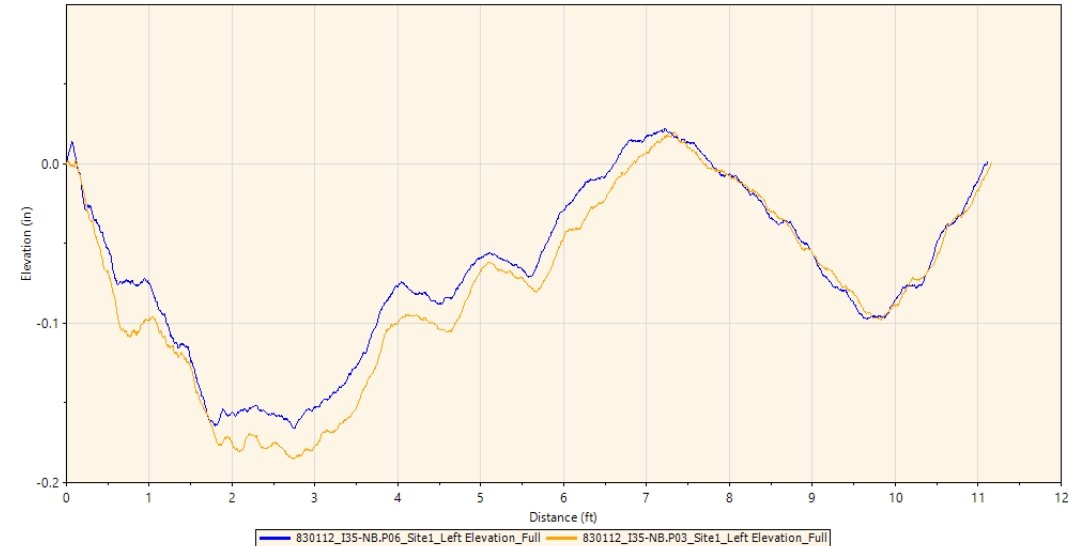
- Beam device developed by Ames Engineering.
- Single point laser.
- Equipped with an encoder.
- Data recording interval = 0.077 inches (1.95 mm).
- Reference measurements obtained at one location in each test section.
- Three repeat measurements at each location.

DATA ANALYSIS

UTILIZING PROVAL AND CROSS-CORRELATION TECHNIQUE

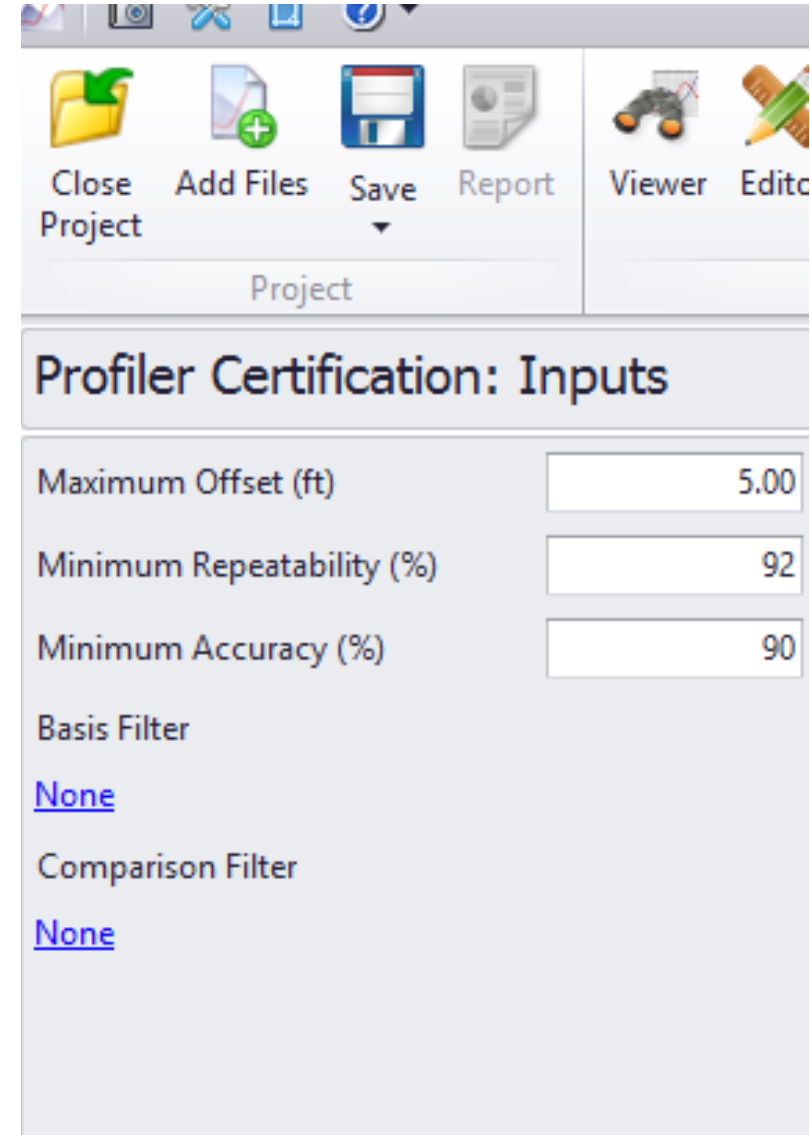
Cross-Correlation

- Cross-Correlation (CC): Agreement between two signals. Perfect agreement, CC = 100%.
- Repeatability: Compare transverse profile collected at a single location from TPMS for repeat runs.
- Accuracy: Compare transverse profile collected at a single location from TPMS and reference device.



ProVAL

- Profiler certification module in ProVAL uses cross-correlation. Filter is set to IRI.
- Setting filter to “None” will compare profiles, with no filter applied.



ProVAL: Cross-Correlation

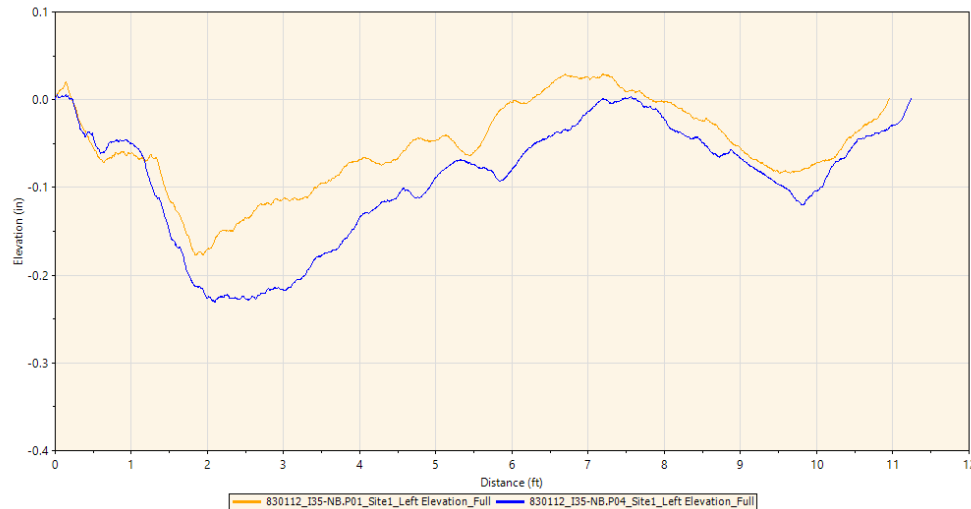
- Constant vertical offset between two profiles will not influence the computed cross-correlation.



Two identical profiles, constant offset between profiles, CC = 100%

ProVAL: Cross-Correlation

- Horizontal offset between profiles handled by ProVAL to get maximum CC.



Close Add Files Save Report Viewer Edit

Project

Profiler Certification: Inputs

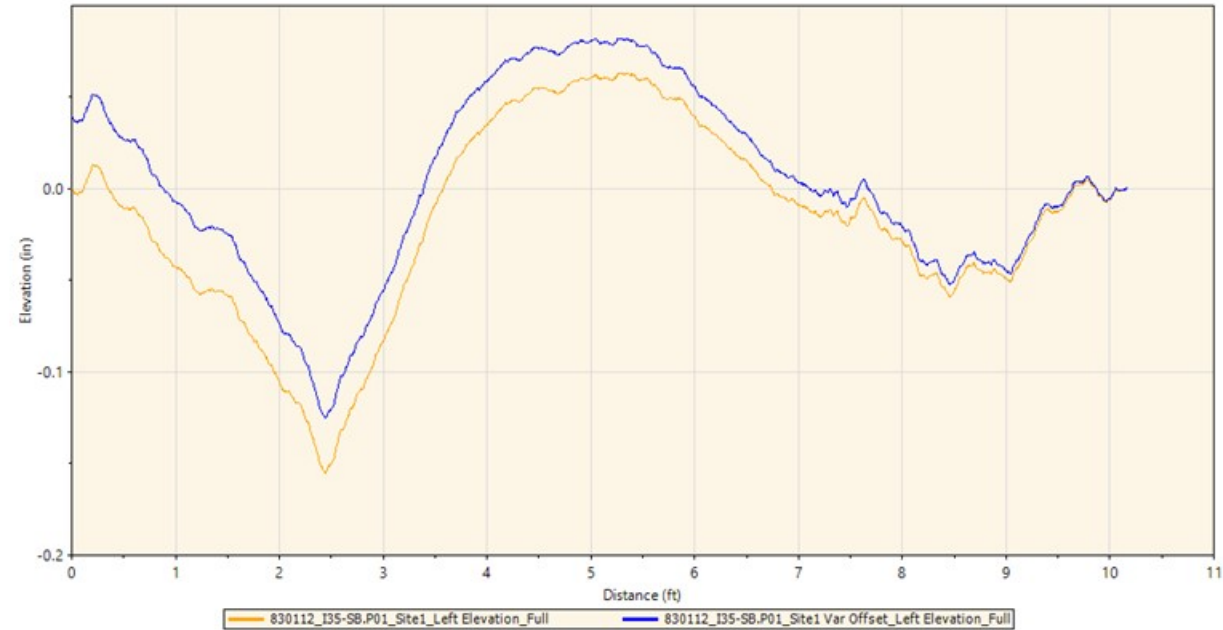
Maximum Offset (ft)	5.00
Minimum Repeatability (%)	92
Minimum Accuracy (%)	90

Basis Filter
[None](#)

Comparison Filter
[None](#)

ProVAL: Cross-Correlation

- Cannot handle situation where one profile is rotated.

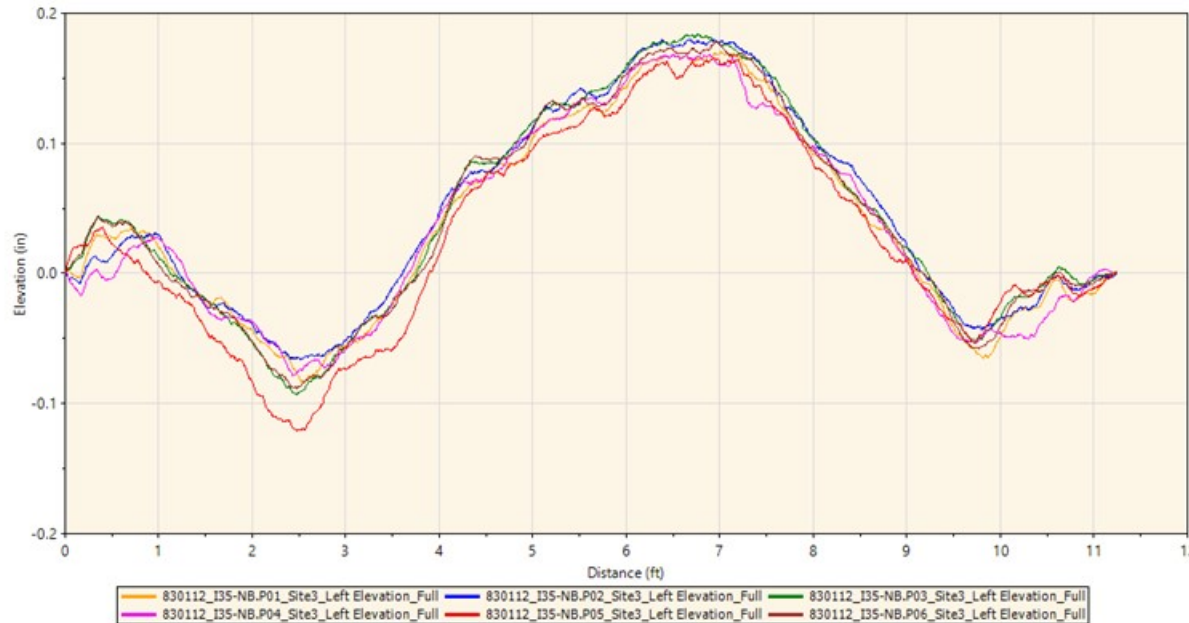


Identical profiles, one profile rotated with respect to the other. CC = 95%

REPEATABILITY OF TRANSVERSE PROFILE DATA

Transverse Profile at a Location from Repeat Runs (NB-3)

- TPMS data averaged over a 1 ft distance centered at that location and a 2 inch moving average applied to data.
- Normalized transverse profiles used for analysis.
- Start 4" from edge stripe at right side of lane.
- Data in ERD format loaded to ProVAL.



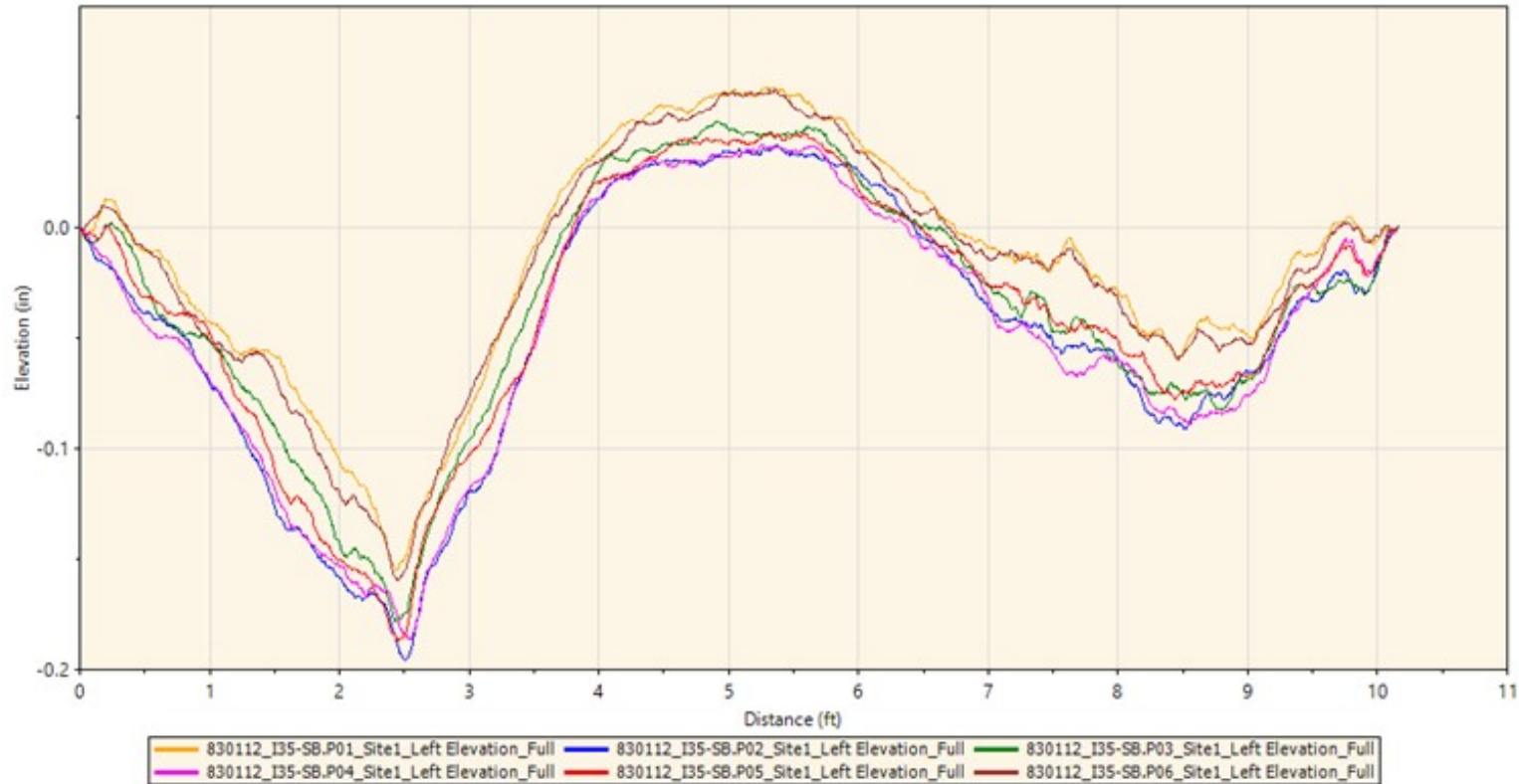
NB-3, 830112. Six Profiles.

Results from Repeatability Analysis

Repeatability - Left Correlations (%)						
Run	2	3	4	5	6	
1	97.32	93.83	98.62	92.57	95.99	
2		95.65	97.77	94.30	97.75	
3			93.34	99.16	97.64	
4				91.77	95.32	
5					96.90	

Average = 95.9%

Transverse Profile at a Location from Repeat Runs (SB-1)



Average Repeatability CC = 92.2%

Results from Repeatability Analysis

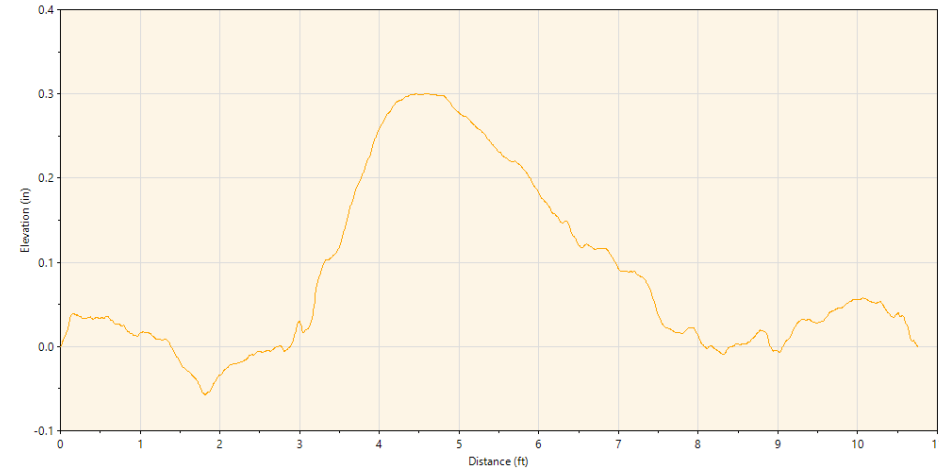
Test Section	Repeatability Cross-Correlation (%)			
	Van 1	Van 2	Van 3	Van 4
NB-1	85	94	93	96
NB-2	95	97	92	92
NB-3	96	96	91	89
SB-1	92	97	94	94
SB-2	98	99	97	98
SB-3	92	97	91	90
X Avenue	89	97	93	85
Average	92	97	93	92

ACCURACY OF TRANSVERSE PROFILE DATA

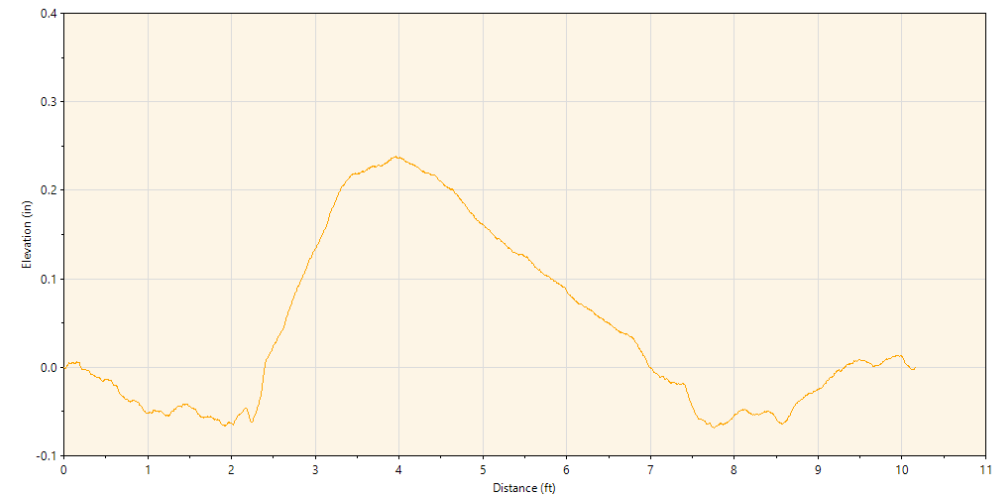
Accuracy Cross-Correlation (Section SB-2), Van 1

Accuracy	
Run	Left
1	92.10
2	93.28
3	89.91
4	93.94
5	92.98
6	90.27

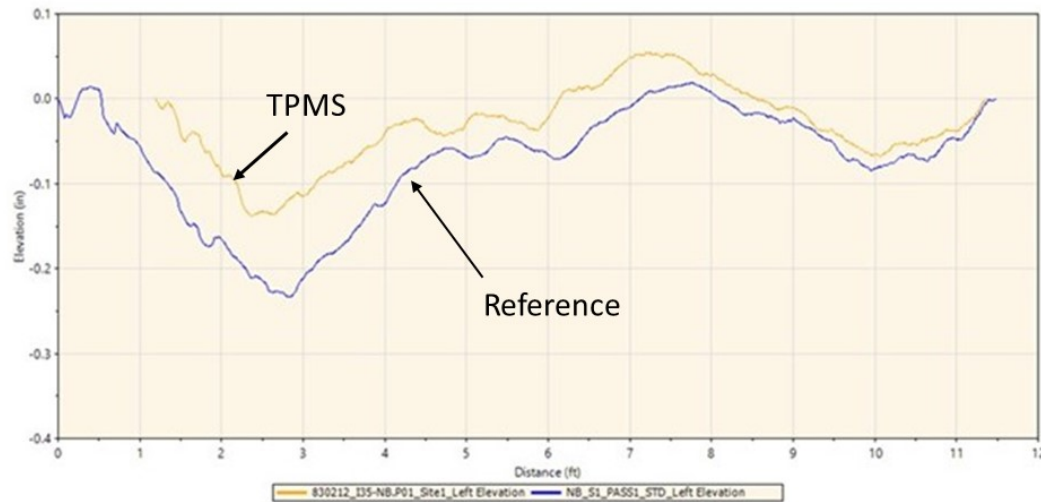
Profile from Reference



Profile from TPMS



Effect of Rotation of Profiles on Accuracy CC



Accuracy CC = 62%



Rotate TPMS Profile Manually, Accuracy
Cross-Correlation = 88%

Note: ProVAL cannot rotate a profile.

Results from Accuracy Cross-Correlation Analysis

Test Section	Average Accuracy Cross-Correlation (%)				Average
	Van 1	Van 2	Van 3	Van 4	
NB-1	80	69	87	80	79
NB-2	82	90	68	71	78
NB-3	81	94	83	83	85
SB-1	92	94	75	88	87
SB-2	92	98	84	91	91
SB-3	83	82	77	91	83
Overall Average	85	88	79	84	84

For above results no profiles were rotated.

CONCLUSIONS

Conclusions

- The cross-correlation technique can be used to evaluate repeatability and accuracy of transverse profile data.
- ProVAL can be utilized, but as ProVAL does not rotate profiles to get the maximum cross-correlation, results will be affected if one profile is rotated with respect to the other.

Questions?

