An Empirical Analysis of Survey Errors in North American Land Operations

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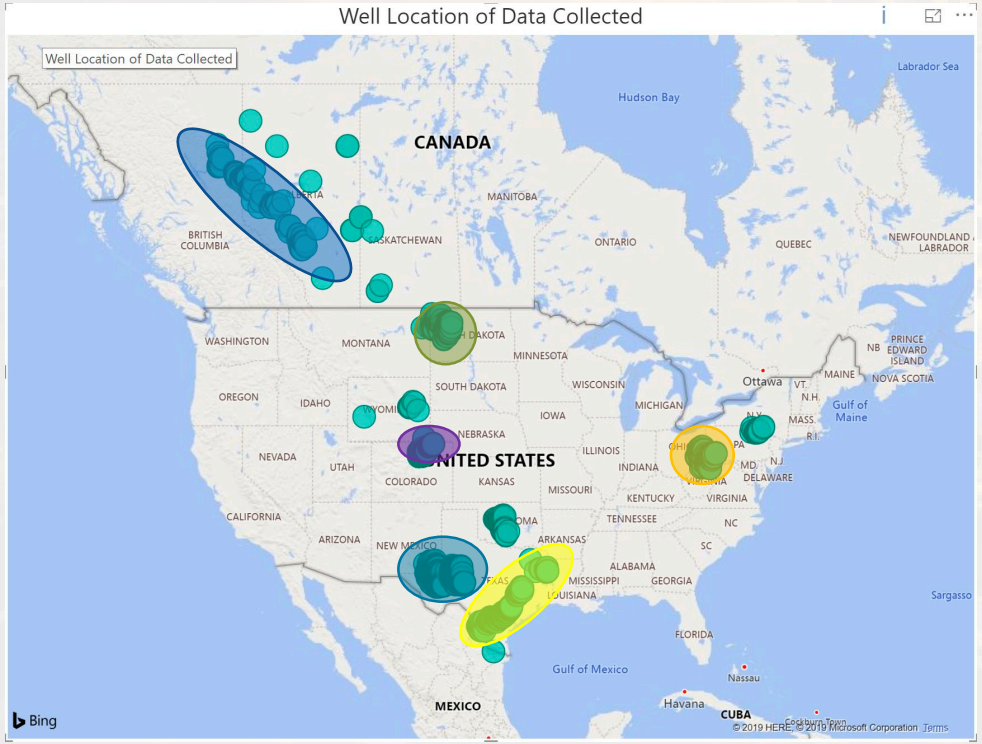
ISCWSA

Speaker Bio

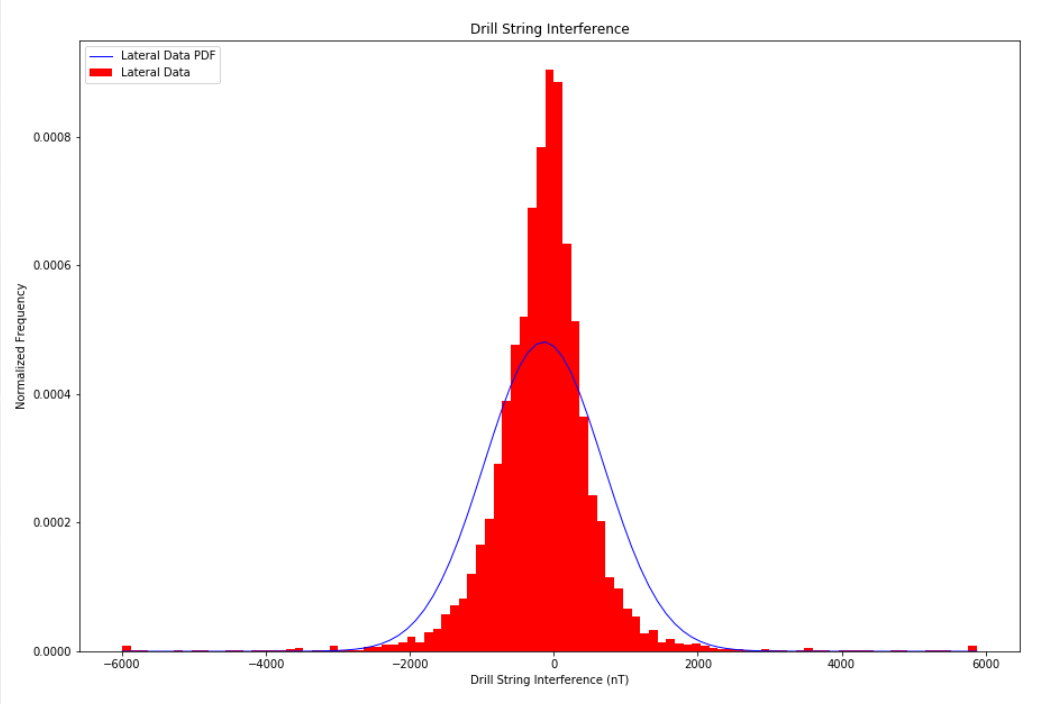
- Shuba Love
  - H&P Technologies
  - 7 years Schlumberger and 2+ years MagVAR
  - BS Mechanical Engineering
  - Denver, CO
  - Specialized in:
    - Survey Correction
    - Data Analytics

Data Summary



- North America
- >9000 wells
- >35000 runs
- >90 Operators
- >50 Service Company
- Basins with large amount of data:
  - Permian
  - Eagle ford
  - Denver Julesberg
  - Bakken
  - Marcellus
  - Western Canada

DSI and Axial Magnetometer Bias

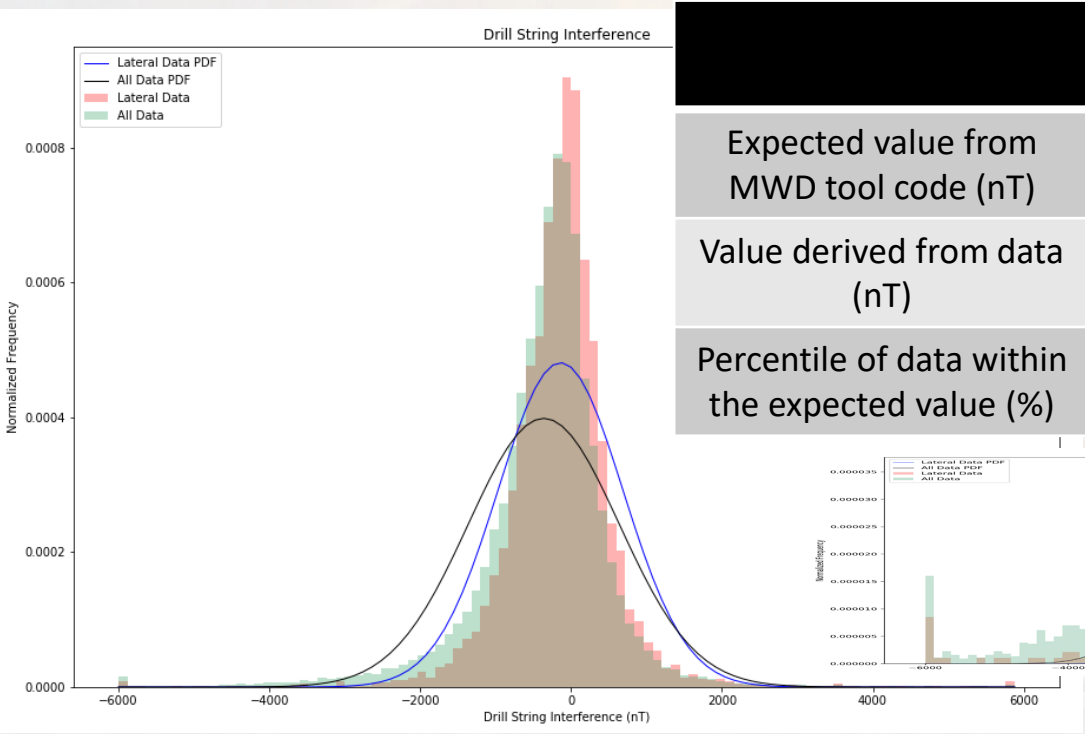


- Bell curve with the following characteristics:
  - Leptokurtic
  - Fat tails

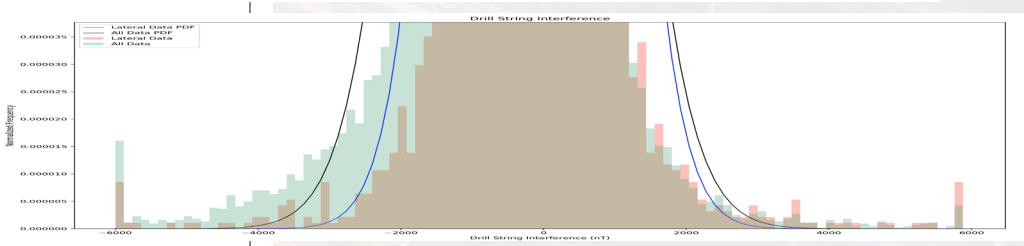
- Expected axial magnetometer bias is derived from MBZ and AMIL from the MWD tool code

- $\sqrt[2]{MBZ^2 + AMIL^2}$ = 231nT

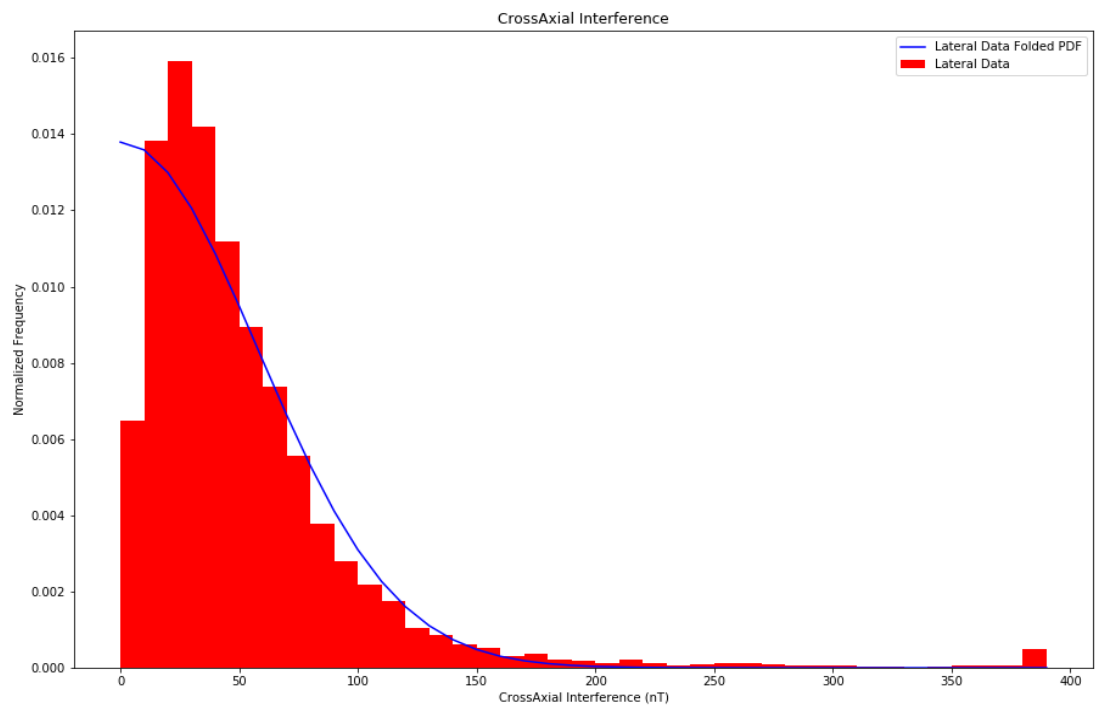
DSI and Axial Magnetometer Bias - Summary



	1-sigma	2-sigma	3-sigma
Expected value from MWD tool code (nT)	231	462	692
Value derived from data (nT)	540	1400	4840
Percentile of data within the expected value (%)	37	62	78

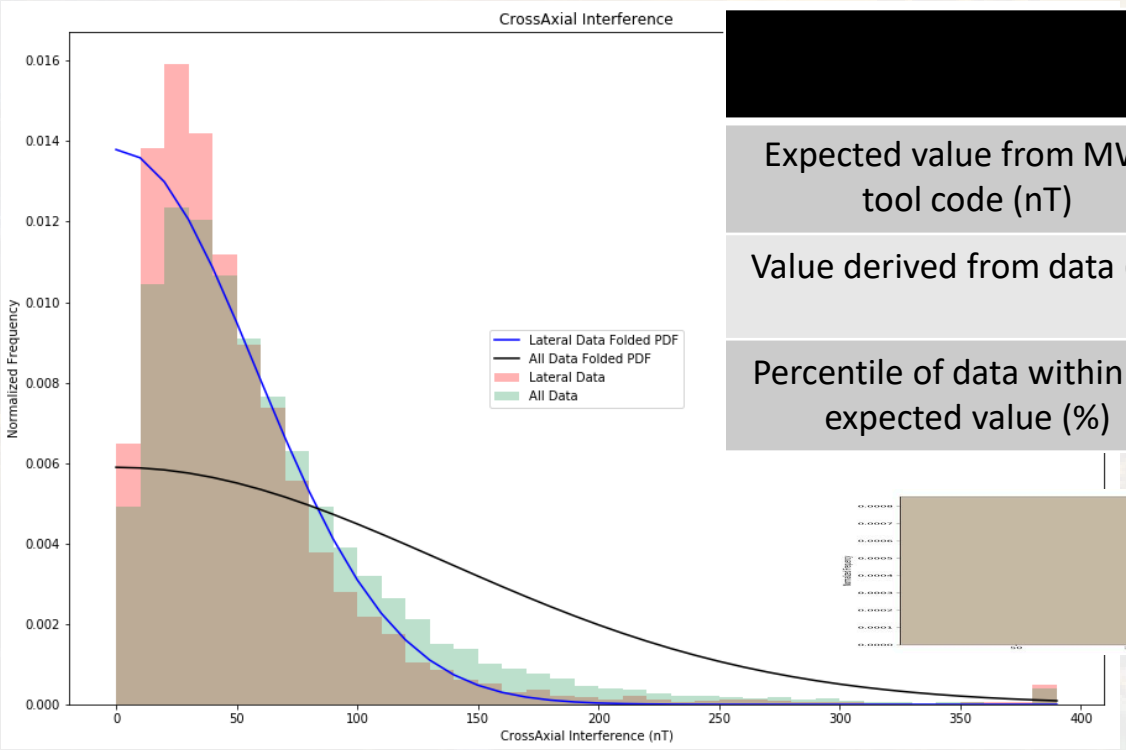


Cross-axial Magnetometer Bias

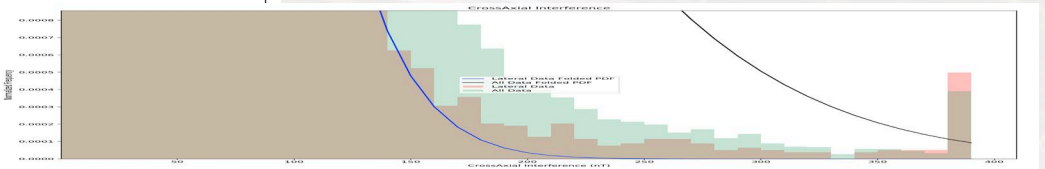


- RMS of magnetometers parallel to the tool axis
- Data that includes vertical has a much higher variance
- Expected error of 70nT in MWD tool code at 1-sigma
- Fat Tail

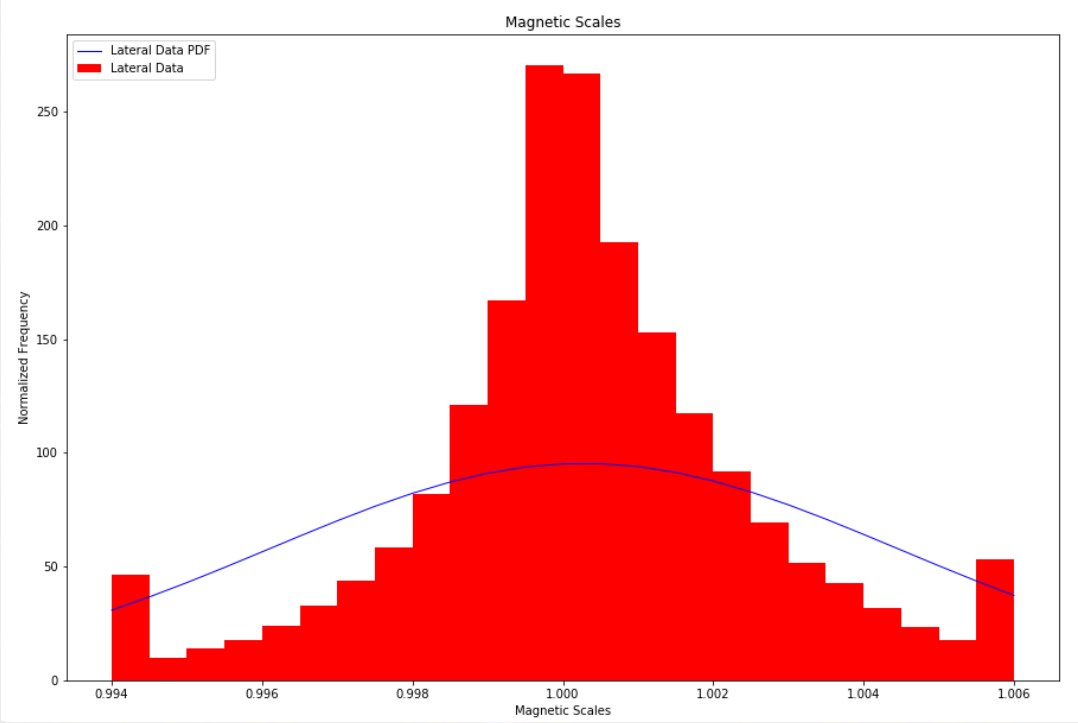
Cross-axial Magnetometer Bias - Summary



	1-sigma	2-sigma	3-sigma
Expected value from MWD tool code (nT)	70	140	210
Value derived from data (nT)	57	130	435
Percentile of data within the expected value (%)	78	96	98

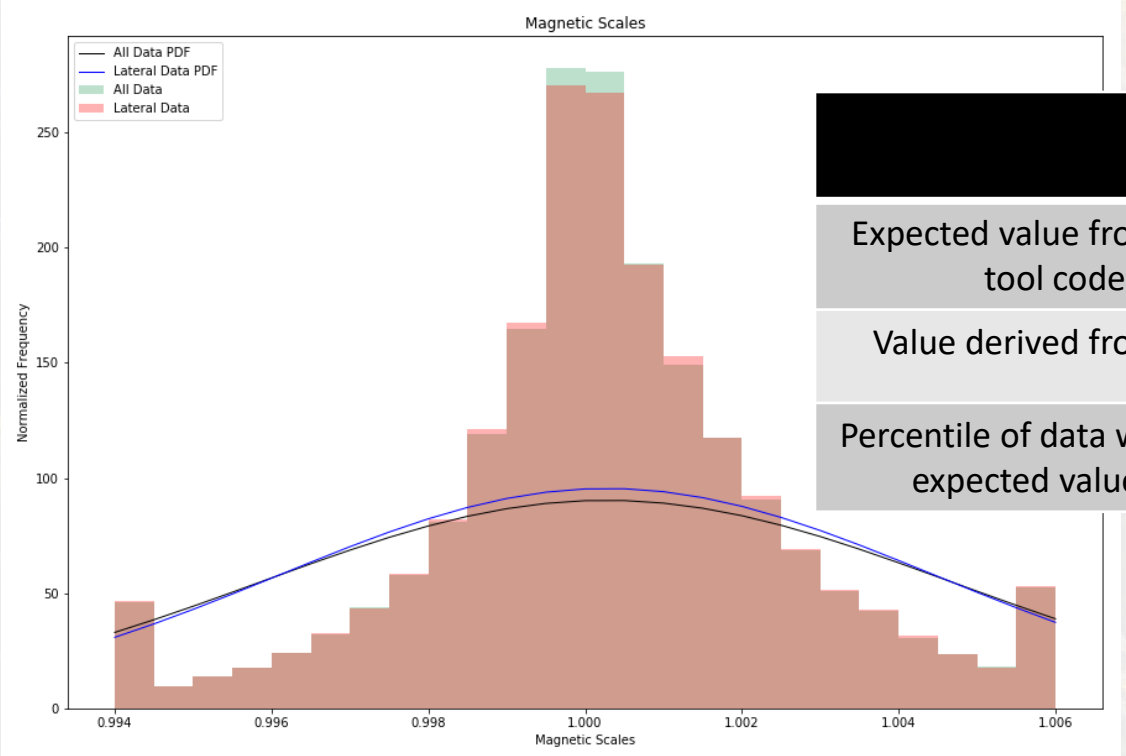


Cross-axial Magnetometer Scales



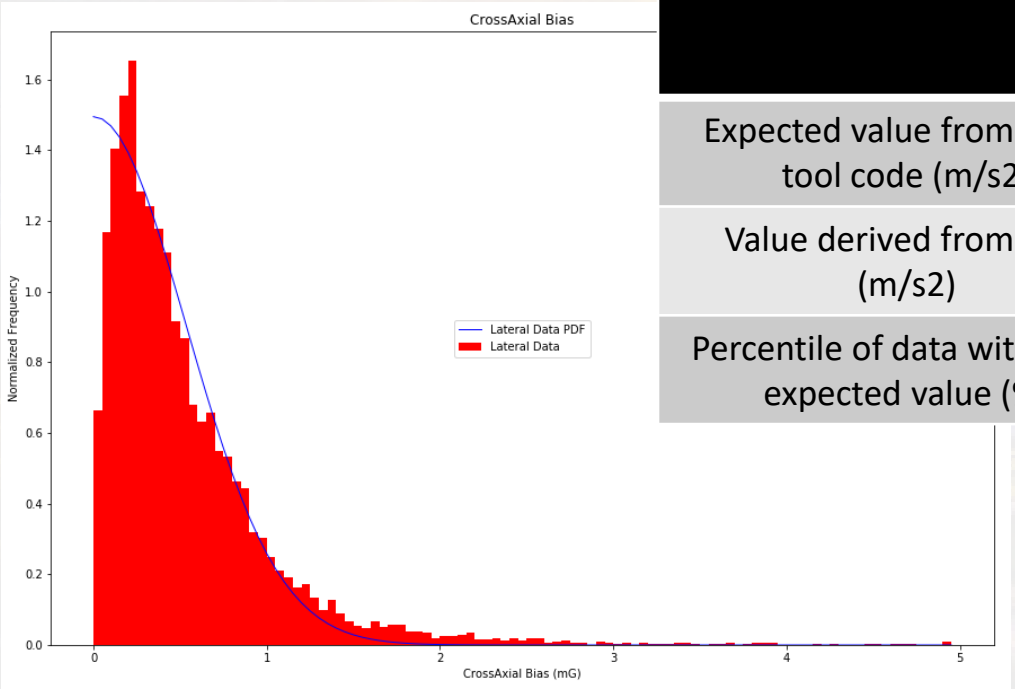
- Slight skew to the right – *possible indication of magnetic mud*
- High variance
- Expected 1-sigma error of 0.0016
- Fat tail

Cross-axial Magnetometer Scales - Summary



	1-sigma	2-sigma	3-sigma
Expected value from MWD tool code	0.0016	0.0032	0.0048
Value derived from data	0.0020	0.0055	0.0135
Percentile of data within the expected value (%)	61	83	93

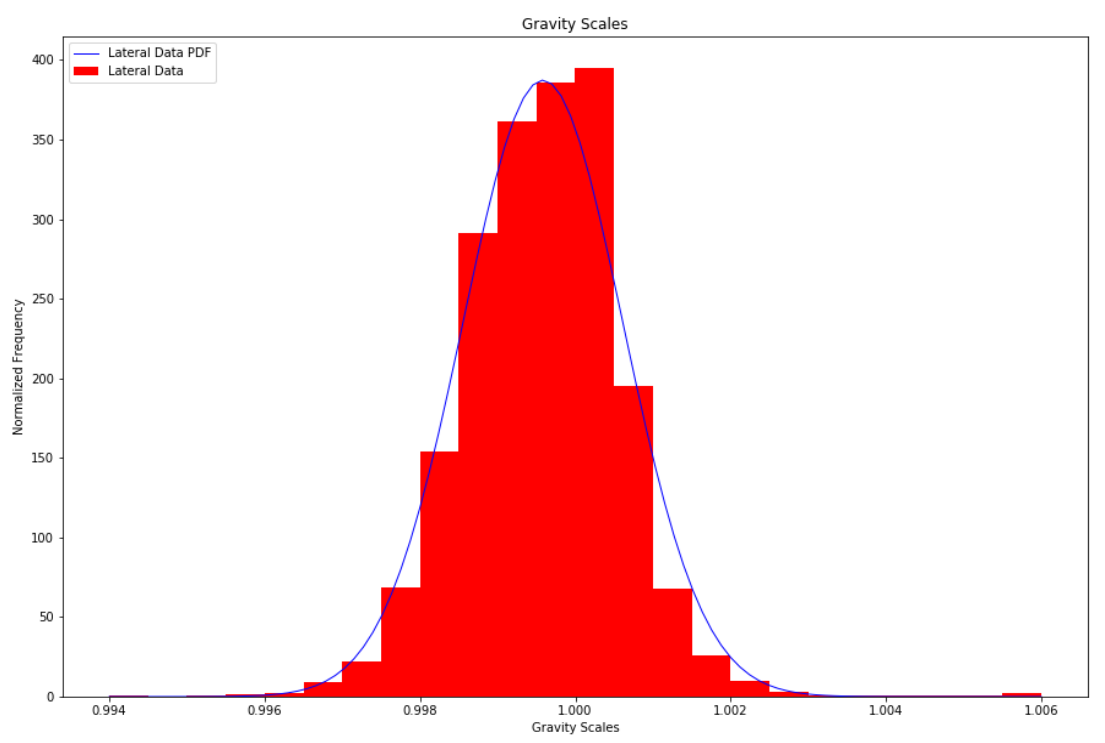
Gravity Cross-axial Bias



	1-sigma	2-sigma	3-sigma
Expected value from MWD tool code (m/s2)	0.004	0.008	0.012
Value derived from data (m/s2)	0.006	0.014	0.034
Percentile of data within the expected value (%)	52	81	93

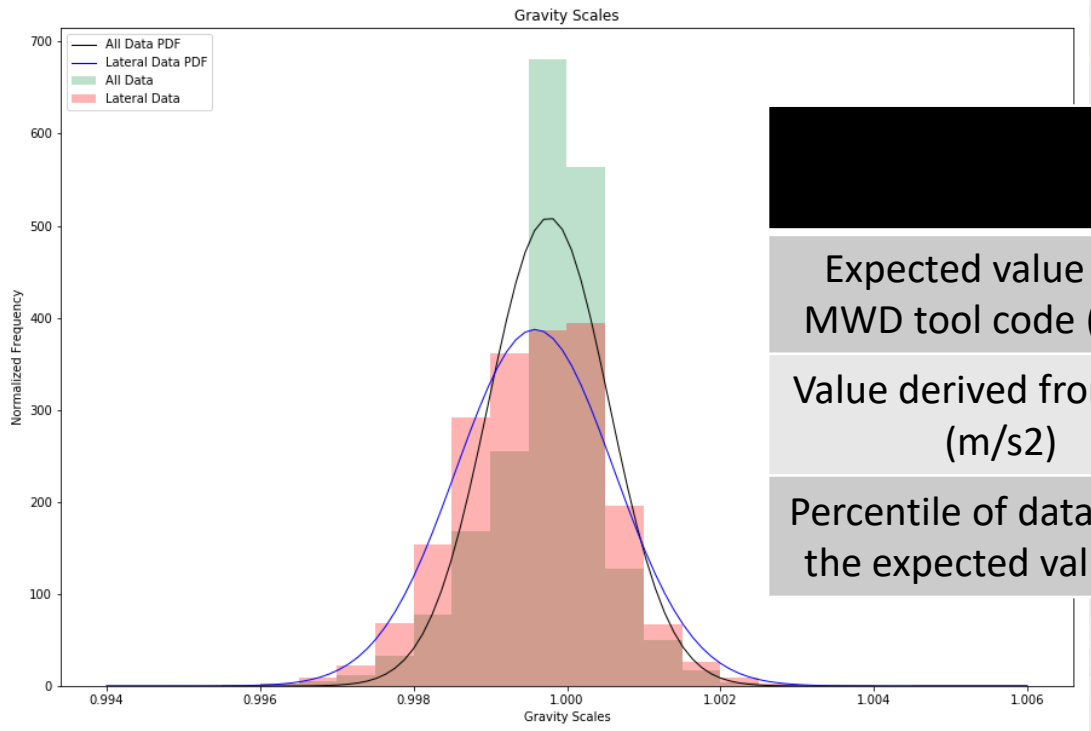
- RMS of accelerometer parallel to tool axis
- Only resolved when enough data at higher inclination is available, hence only lateral data is presented
- Expected 1-sigma error of 0.004m/s2
- Fat Tail

Gravity Cross-axial Scale



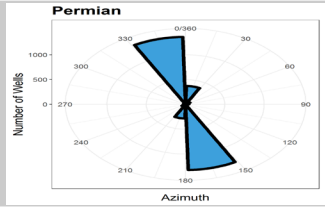
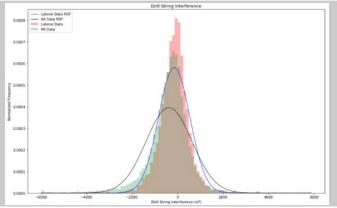
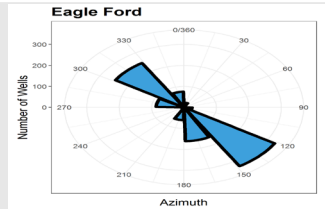
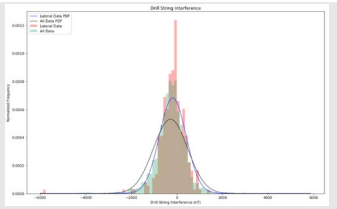
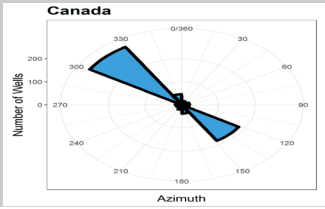
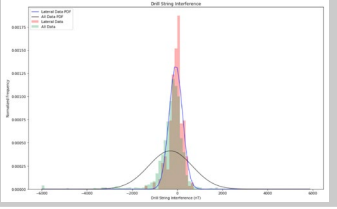
- Skewed to left – *Possible indication of calibration using higher reference value (1G)*
- Expected 1-sigma value – 0.0005

Gravity Cross-axial Scale - Summary

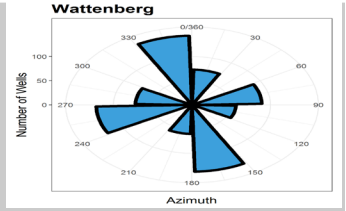
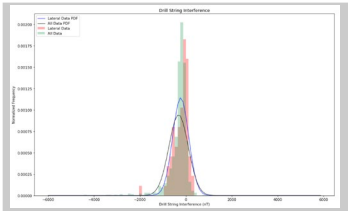
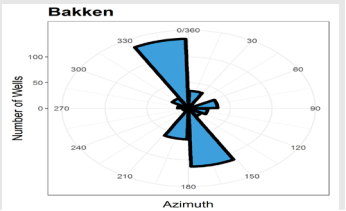
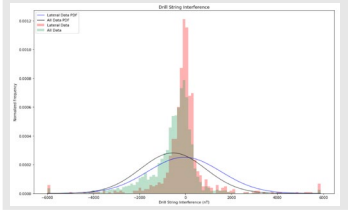
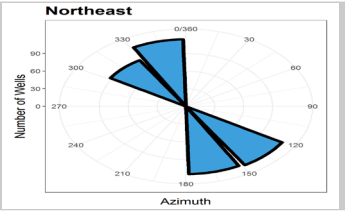
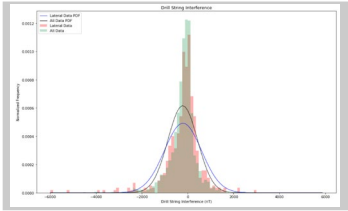


	1-sigma	2-sigma	3-sigma
Expected value from MWD tool code (m/s2)	0.0005	0.0010	0.0015
Value derived from data (m/s2)	0.007	0.0018	0.0035
Percentile of data within the expected value (%)	58	79	91

Basin Summary

Basin	Pseudo 1-sigma Lateral DSI (nT)	BHL Movement ft for every 10,000ft	Well Direction	DSI Histogram
Permian	566	20		
	708			
	1195			
Eagle ford	468	25		
	487			
	893			
Canada	255	41		
	335			
	369			

Basin Summary

Basin	Pseudo 1-Sigma Lateral DSI	BHL Movement (	Well Direction	DSI Histogram
DJ	291	27		
	390			
	600			
Bakken	454	14		
	1150			
	4602			
Marcellus	516	15		
	830			
	1580			

Conclusion

- Observed drill string interference is significantly larger than error model expectation
  - Holds thru for all basins
- Cross-axial bias estimations are closer to expectation
  - Still has fat tails
  - Might be running procedure issues
- Scale magnitudes are larger than expectation
  - Might reflect calibration and running procedures
- Author welcomes feedback on other possibilities and concerns