

Tail Heavy Distributions & Confidence Levels for Directional Survey Measurements

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Basis of Study

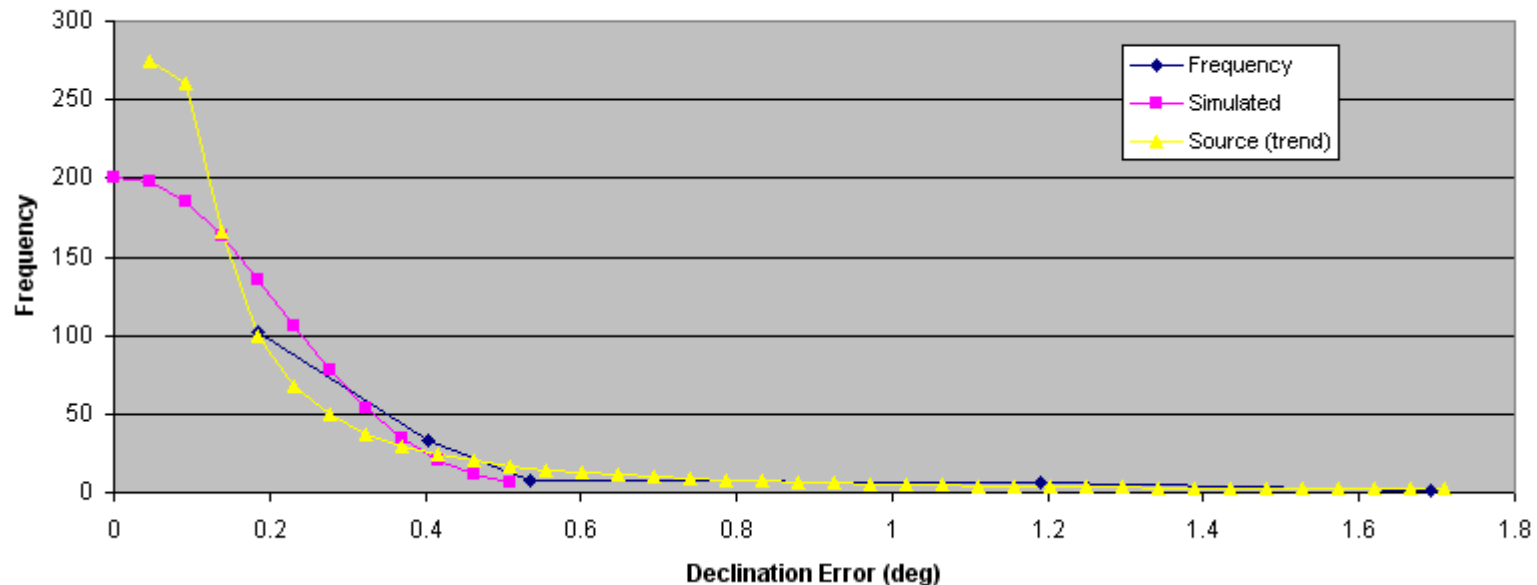
- Magnetic Field study showed that declination errors are highly skewed and cant be treated as Gaussian (normal)
- Are other sources of error similar & how does this affect confidence levels?
- To look at survey comparison data to examine the spread of differences and observe the distribution type
- 2 Survey Comparisons of the same section of hole, commonly tied
- Unit/1000 unit separation, compared Lateral and Highside Axis
- Attempt to isolate some basic sources of error
- Like Gyro/Inrun outrun comparison for drift/inclination errors
- MWD vs EMS for Sag error and Magnetic interference
- Magnetic vs Gyros from BP Alaska, Inclination Model
- Interested in 1 Dimensional confidence because most requirements are 1D

From SPE 119851 “Confidence Limits Associated with Values of the Earth’s Magnetic Field used for Directional Drilling”, MacMillan & Grindrod

TABLE 3—UNCERTAINTY ASSOCIATED WITH THE CRUSTAL FIELD, AT SIX CONFIDENCE LEVELS, CALCULATED USING DATA SETS LOCAL TO OIL AND GAS FIELDS

Confidence Level	Declination Limit (degrees)	Magnetic Dip Angle Limit (degrees)	Total Intensity Limit (nT)
68.3% (1 σ if Gaussian)	0.185	0.081	104
90%	0.403	0.163	187
95%	0.534	0.208	222
95.4% (2 σ if Gaussian)	0.564	0.223	224
99%	1.191	0.575	355
99.7% (3 σ if Gaussian)	1.692	0.703	500

Declination Values



From SPE 36484

Towards Risk Based Well Separation Rules - Williamson

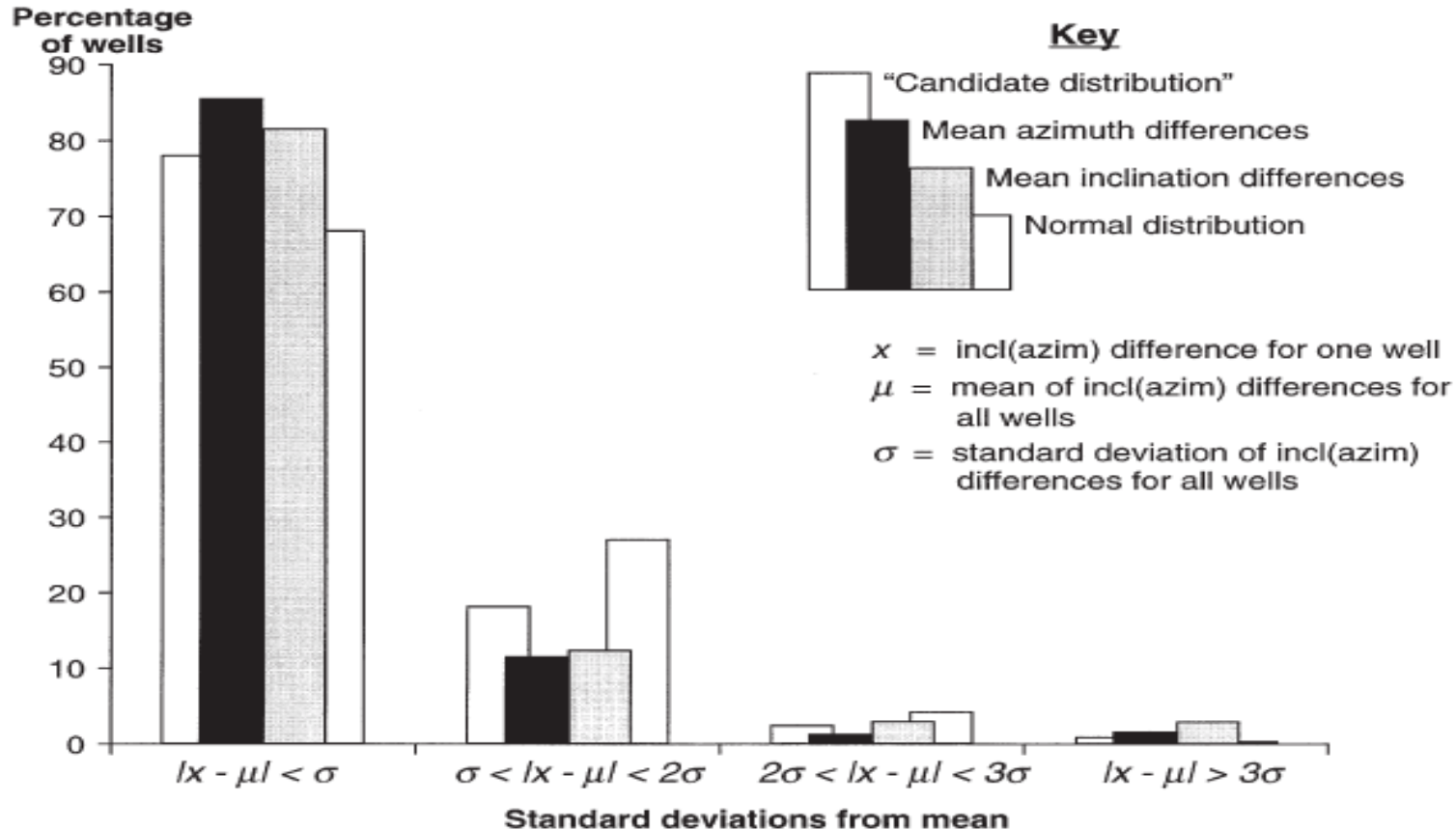
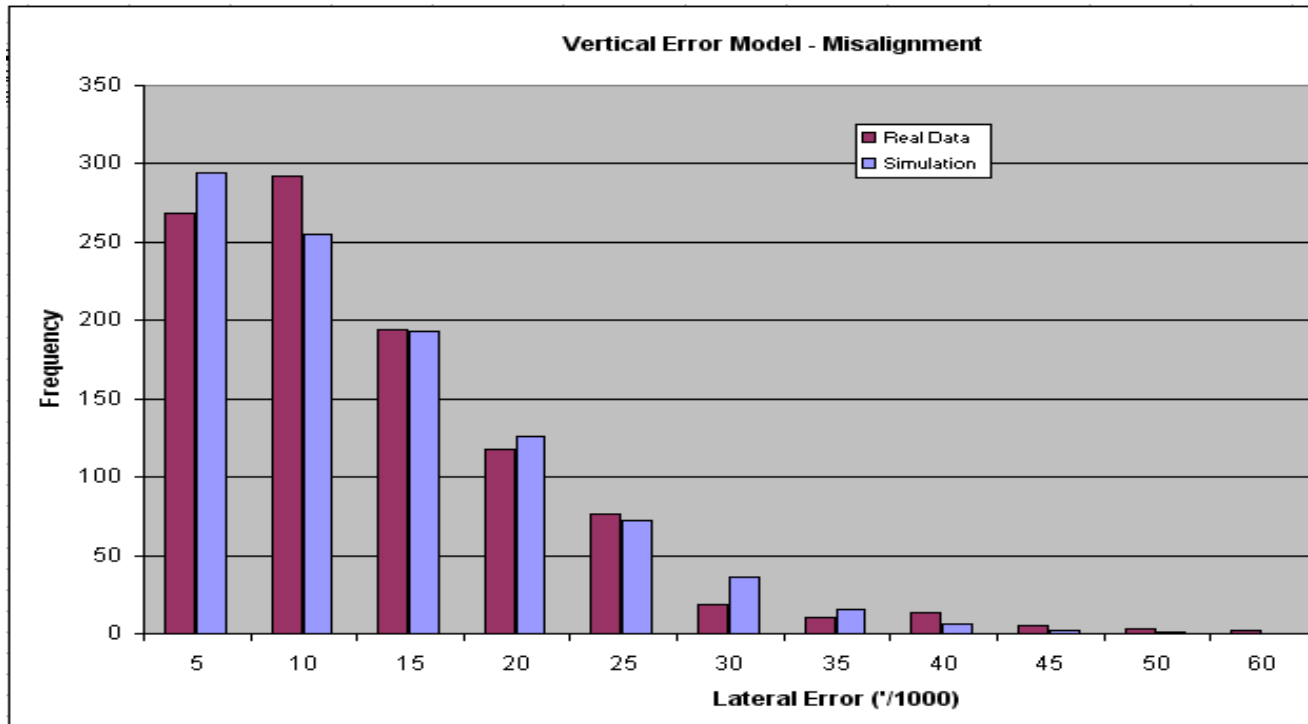
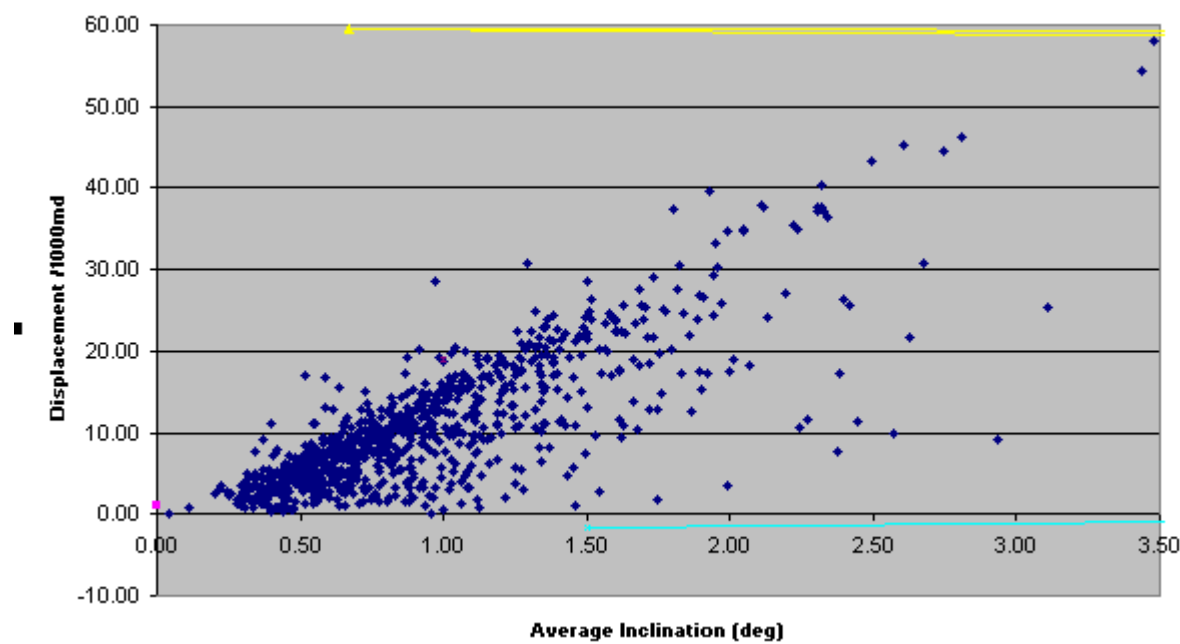


Fig. 2—Histogram showing the distribution of mean angular differences between gyroscopic and MWD surveys for 234 wells drilled in Alaska. Two theoretical distributions are shown for comparison.

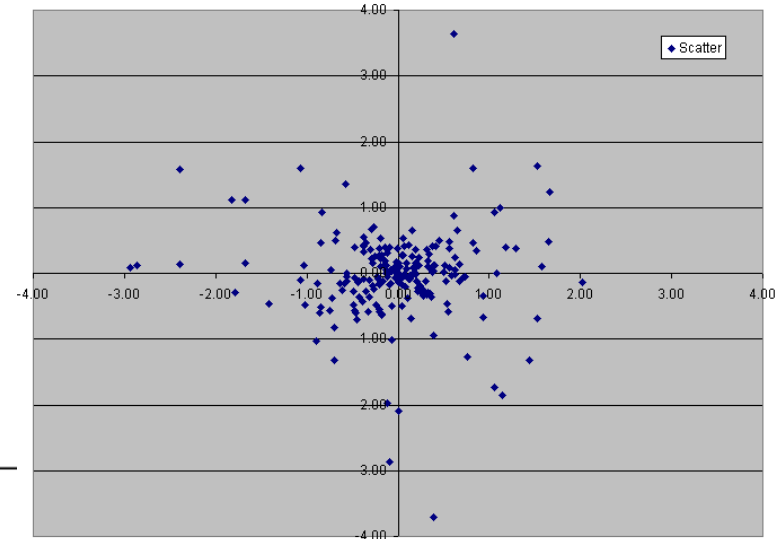
Vertical Model

1000 Vertical Wells
3D Surveyed
Displacement from Centre
13.4'/1000'

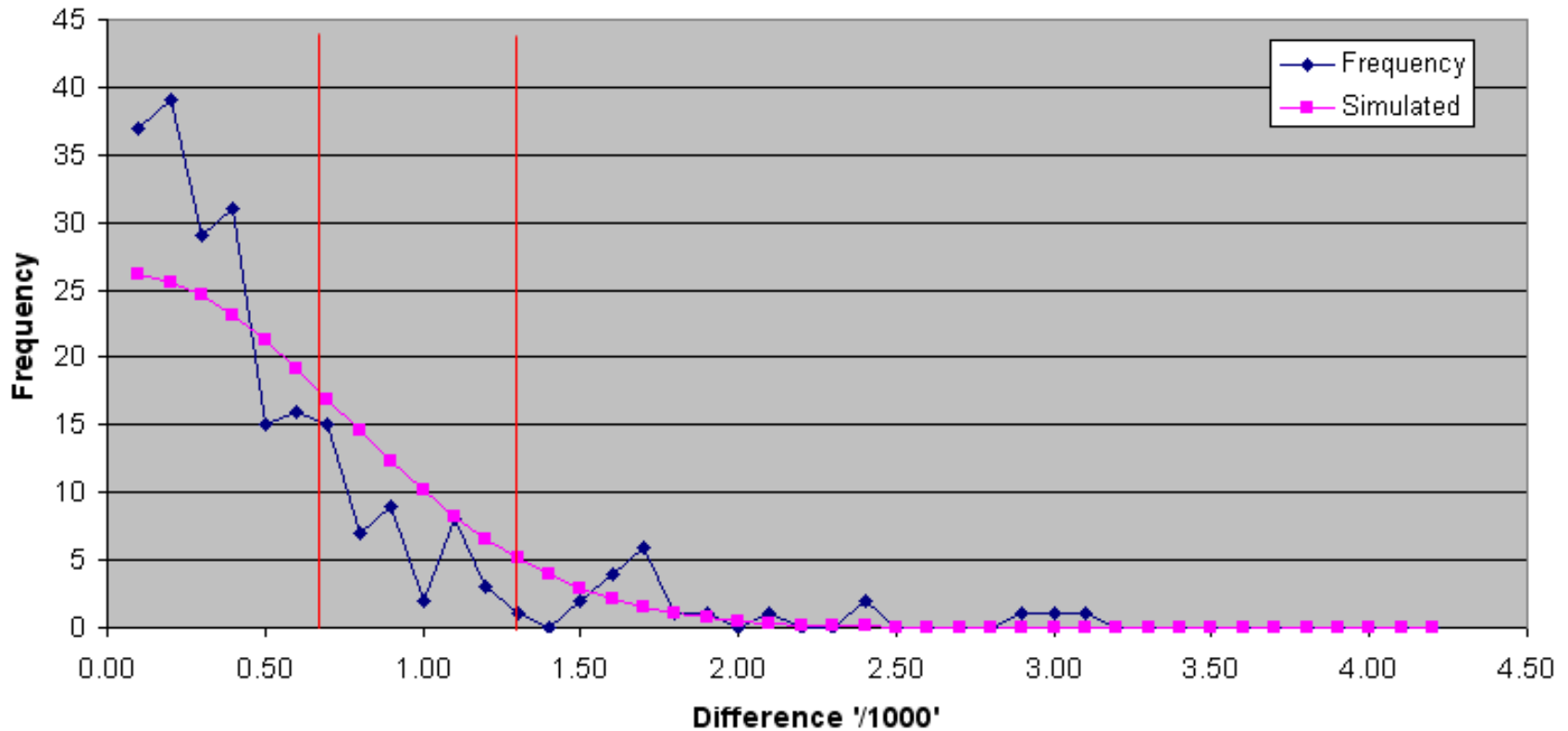


Rate Gyros

High Angle Gyros - Drift
Inrun-Outrun Continuous Gyros
2 Types 230 comparisons

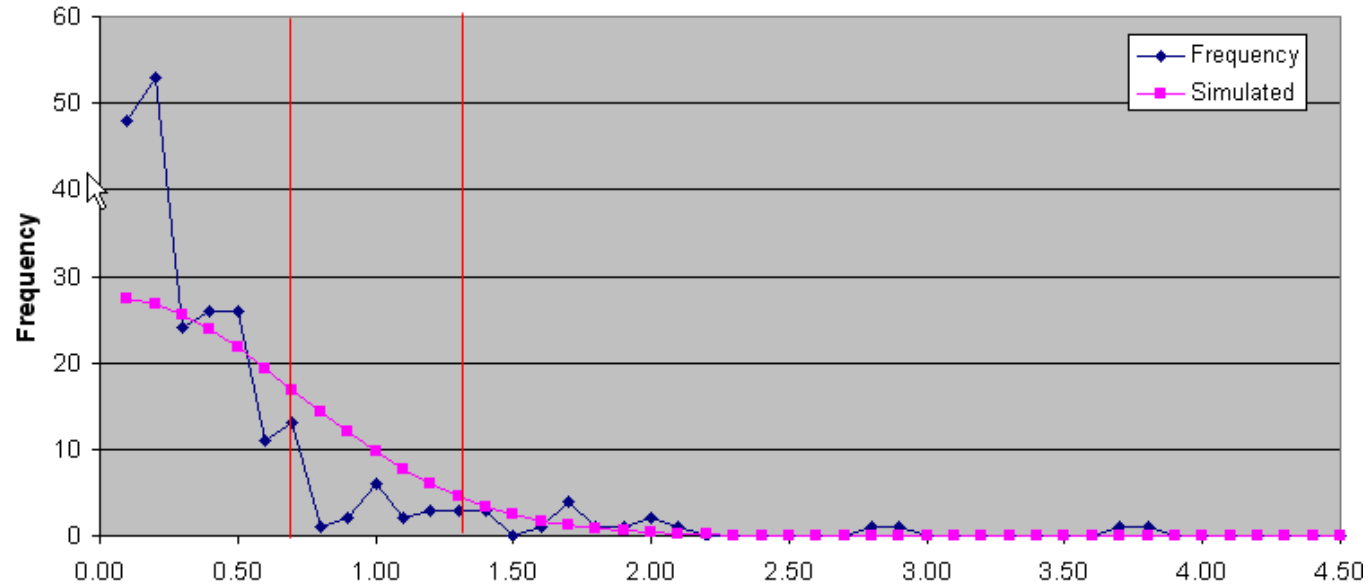


IR/OR Gyro Lateral Error

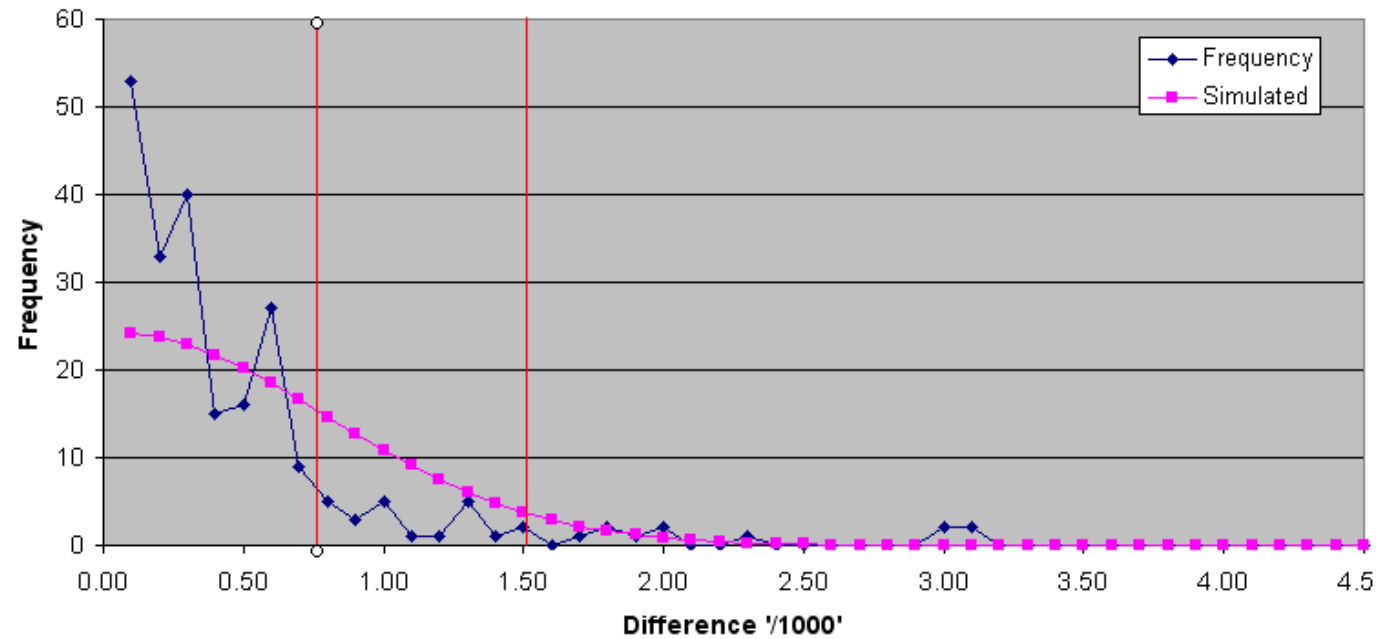


- Gyro Axes
- Highside
- Along Hole

IR/OR Gyro Highside Error

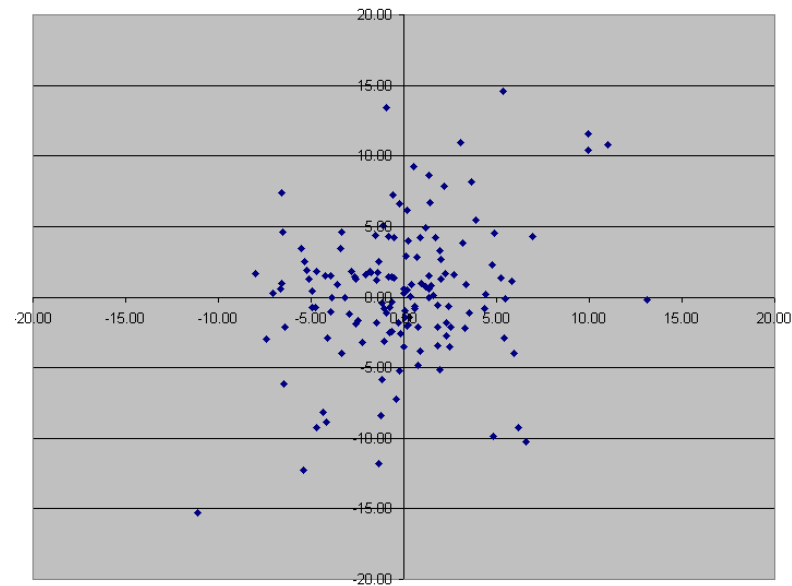


IR/OR Gyro Along Hole Error

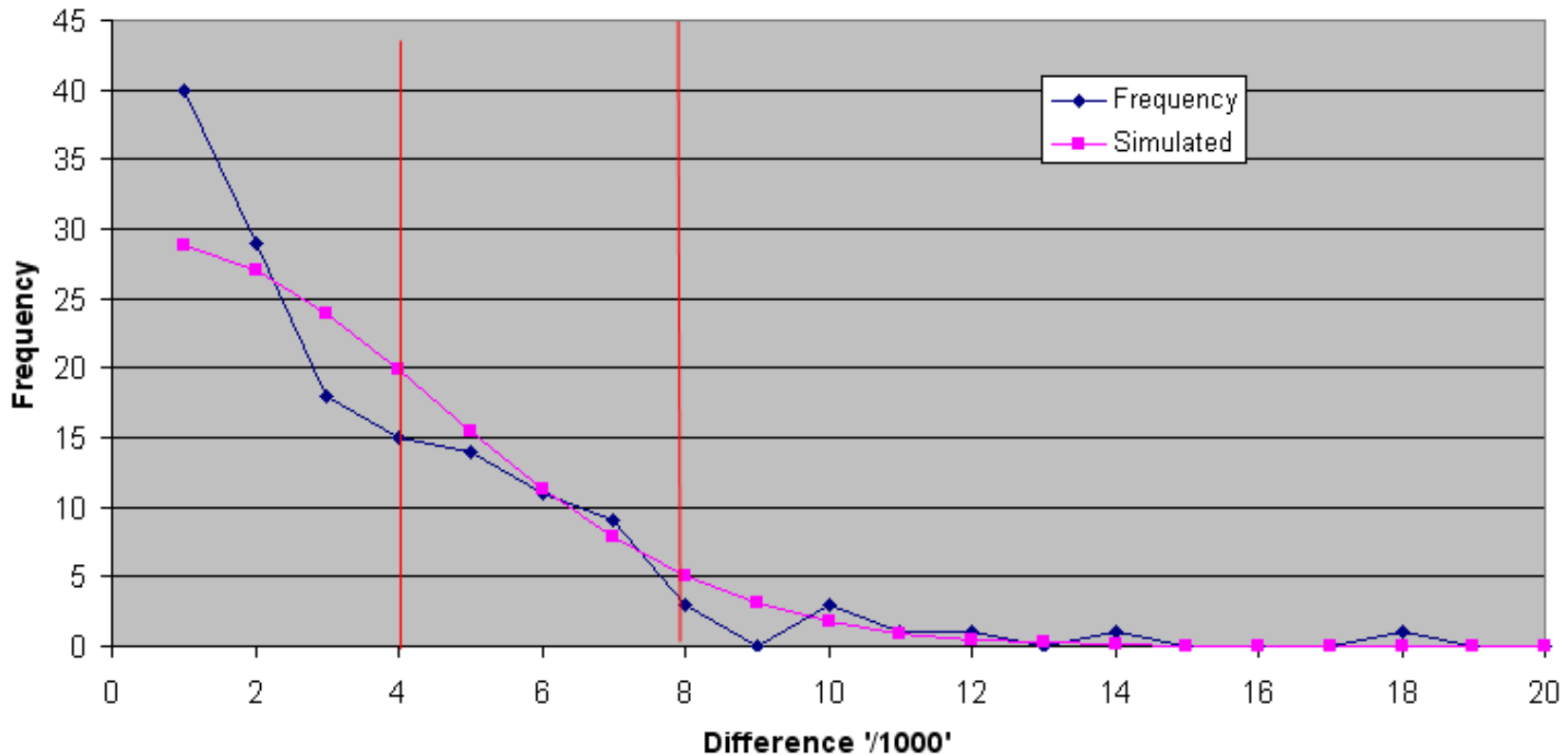


Magnetic EMS/MWD

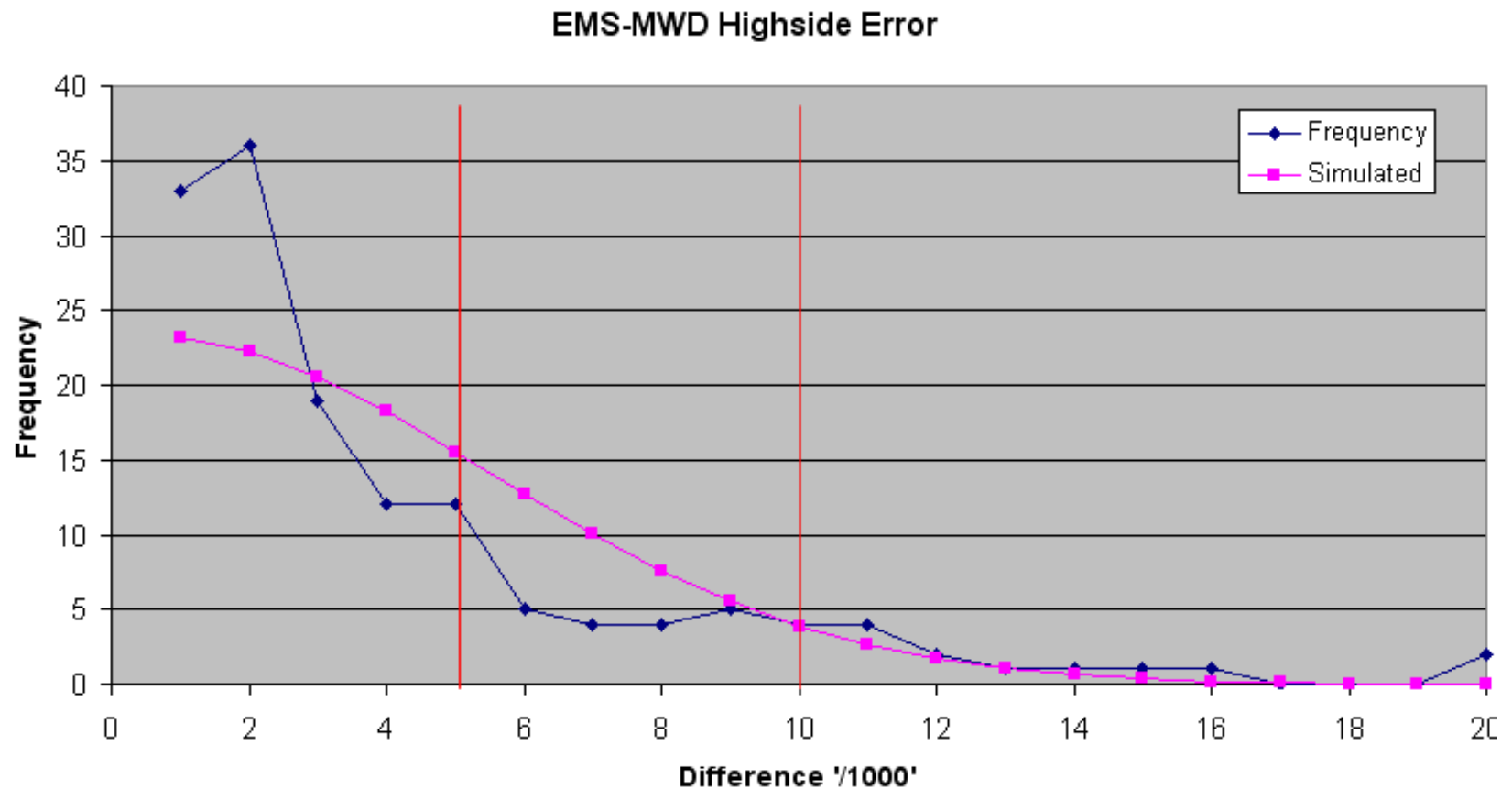
- EMS vs. MWD Comparisons
- 150 Examples
- Lateral = Magnetic Interference
- HighSide = Sag



EMS-MWD Lateral Error

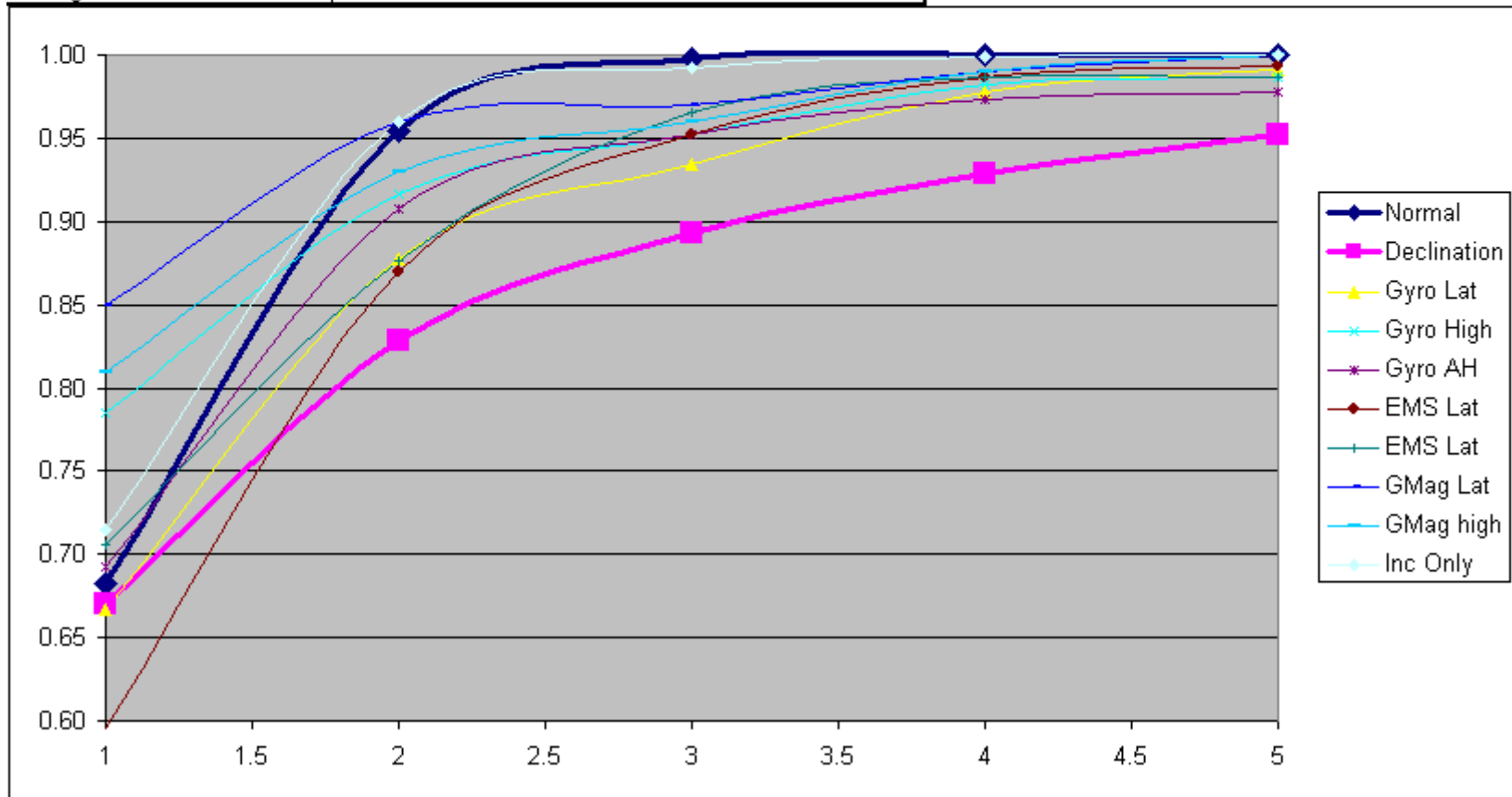


- MWD vs EMS High Side Differences
- Mostly SAG Error



Summary Confidence levels		Standard Deviations (sigma levels)				
Group	Sample Size	1	2	3	4	5
Normal		0.68	0.95	1.00	1.00	1.00
Declination	?	0.67	0.83	0.89	0.93	0.95
Gyro Lat	228	0.67	0.88	0.93	0.98	0.99
Gyro High	228	0.79	0.92	0.95	0.98	0.99
Gyro AH	228	0.69	0.91	0.95	0.97	0.98
EMS Lat	150	0.60	0.87	0.95	0.99	0.99
EMS High	150	0.71	0.88	0.97	0.99	0.99
Gmag Lat	234	0.85	0.96	0.97	0.99	1.00
Gmag High	234	0.81	0.93	0.96	0.99	1.00
Inc Only	1000	0.72	0.96	0.99	1.00	1.00
Average		0.72	0.90	0.95	0.98	0.99

Summary Confidence Levels



Conclusions

- Not many error sources are Gaussian (Normal) distributed
- Mostly have some form of heavy-tail exponential behaviour
- When sources are combined the effect is reduced (central limit theorem) – but still significant
- Confidence levels are lower than predicted with Gaussian, especially at higher sigma levels
- Can we use the same propagation mathematics but use input (1 sigma) based on 99.7% confidence and divide by 3 ?