# Directional Survey Comparison and Data Science

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# Introduction

- Survey comparison of two independent surveys over the same hole interval
  - To evaluate quantitively whether the 2 instruments perform within expectation
  - RIP test: Relative instrument performance
    - Compares sampled inclination and azimuth differences at interpolated depths to the expected relative inclination and azimuth error – generates a numerical result for mean and standard deviation

- Problem: Random errors affect single station comparisons but less effect on overall position error.
  - In inclination comparisons the low angle misalignment of 3° is dominant at higher angles leading to poor RIP test results
  - Current high angle misalignment (0.1° systematic) is systematic and does not encourage refinement of SAG corrections & smaller residual errors. Also not much evidence here.

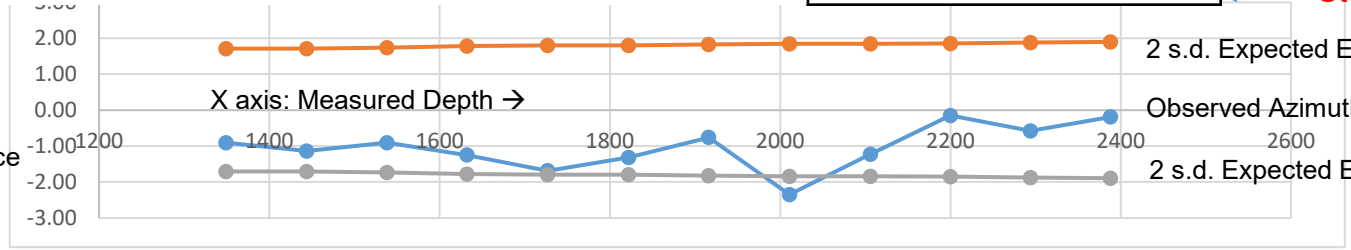
- Data Analysis
  - Look at inclination and azimuth error differences for 3 hole sizes at high angles for a set of wells.
  - Evaluate the behaviour of random misalignment at higher angles, look at DLS effects

# Example of Relative Instrument Performance for azimuth differences

| MD | Comparison Survey azimuth (deg) | | Reference survey azimuth (deg) | | Observed Azimuth | 1 s.d. Expected | Normalised Azimuth |
|---|---|---|---|---|---|---|---|
| (ft) | survey (°) A | Error 1 s.d. (°) B | survey (°) C | Error 1 s.d. (°) D | Difference (°) E = A - C | Error (°) F = SQR(B^2+D^2) | Differences (std.dev) G = E / F |
| 1349 | 135.70 | 0.78 | 136.61 | 0.35 | -0.91 | 0.85 | -1.06 |
| 1444 | 136.40 | 0.78 | 137.54 | 0.35 | -1.14 | 0.85 | -1.33 |
| 1538 | 136.90 | 0.79 | 137.81 | 0.36 | -0.91 | 0.87 | -1.05 |
| 1632 | 137.20 | 0.81 | 138.45 | 0.37 | -1.25 | 0.89 | -1.40 |
| 1727 | 136.90 | 0.82 | 138.59 | 0.37 | -1.69 | 0.90 | -1.88 |
| 1822 | 137.70 | 0.82 | 139.02 | 0.37 | -1.32 | 0.90 | -1.47 |
| 1916 | 138.90 | 0.83 | 139.66 | 0.38 | -0.76 | 0.91 | -0.83 |
| 2011 | 138.10 | 0.84 | 140.45 | 0.38 | -2.35 | 0.92 | -2.55 |
| 2106 | 139.50 | 0.84 | 140.73 | 0.38 | -1.23 | 0.92 | -1.33 |
| 2200 | 141.60 | 0.84 | 141.75 | 0.39 | -0.15 | 0.93 | -0.16 |
| 2294 | 141.60 | 0.85 | 142.18 | 0.40 | -0.58 | 0.94 | -0.62 |
| 2388 | 142.70 | 0.86 | 142.89 | 0.40 | -0.19 | 0.95 | -0.20 |
| | | | | | | **mean** | **-1.16** |
| | | | | | | **std.dev** | **0.65** |

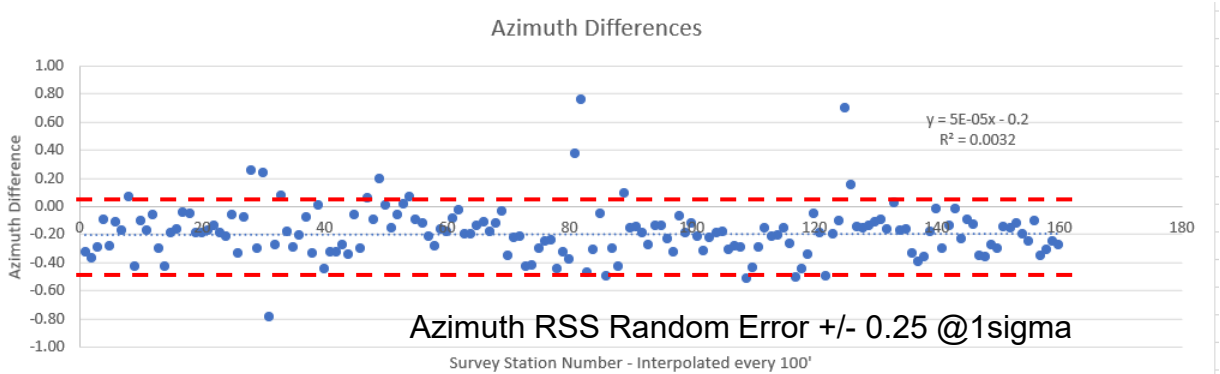
Mean = Systematic

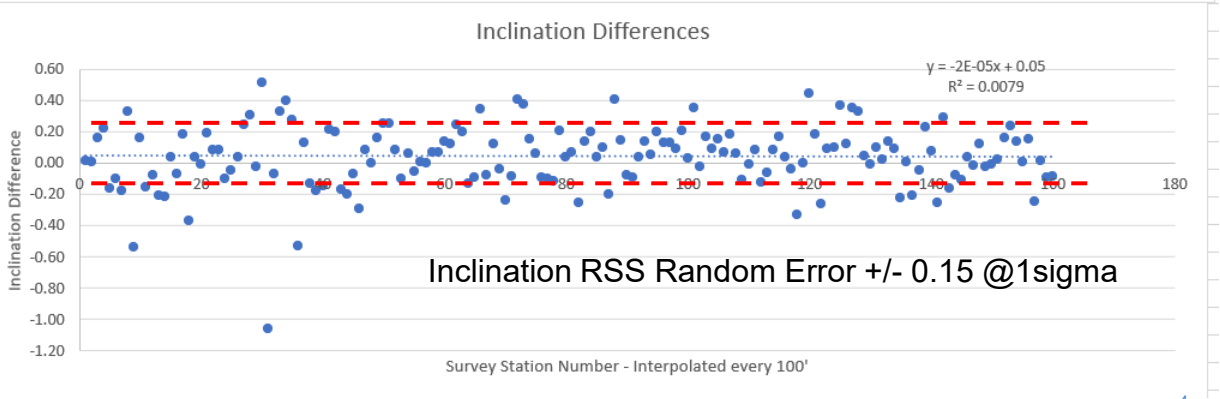
Std.dev = Random



# Survey Analysis

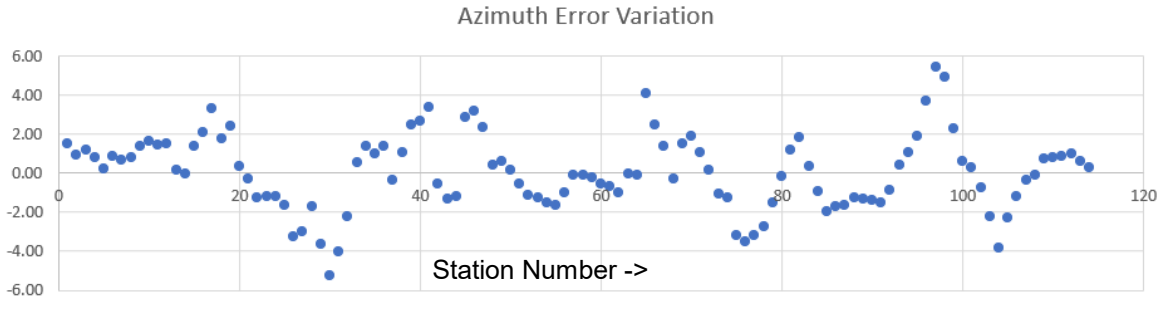
- 8 ½ MWD vs
- DP Gyro 10’
- Interpolated 100’ intervals
- Mean = systematic error
- Std.Dev = random error



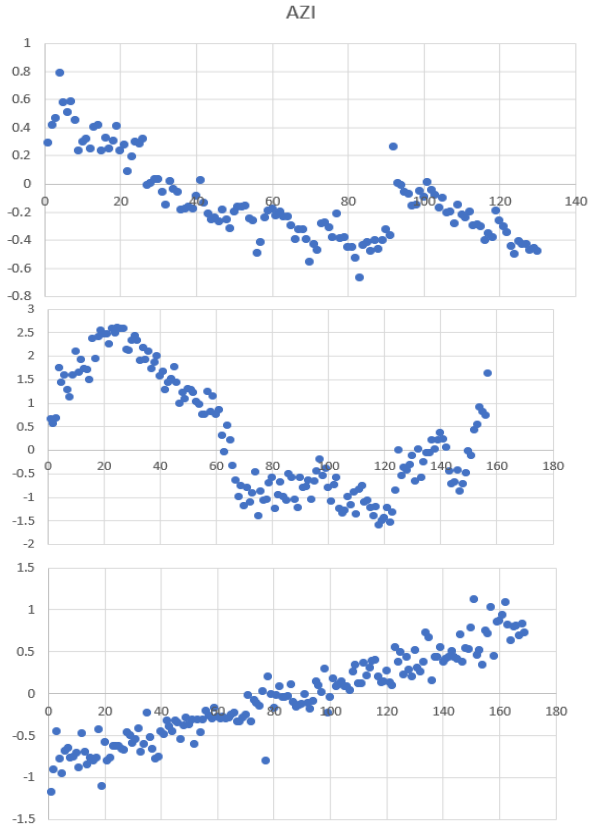



# Azimuth Differences – not reliable

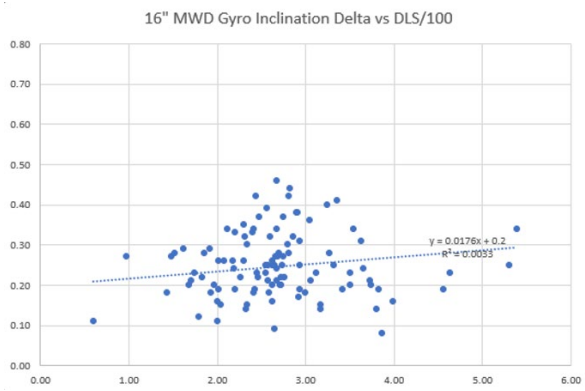
Magnetic Storm? 5-6 Nov 2001, 16-18 stations per day

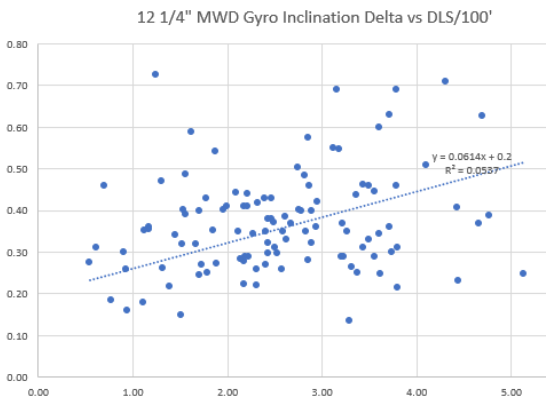


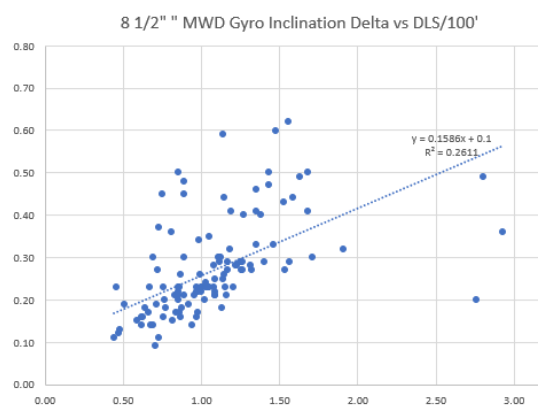

But why is it affecting inclination?



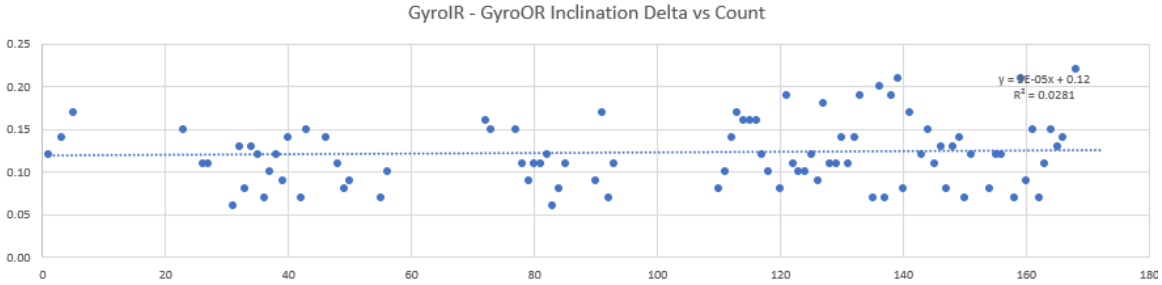
# Comparison Data – Inclination Error Delta for 3 Hole sizes



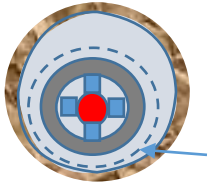

- Mean & SD for each run
- 100-150 per hole section
- Also Gyro Inrun vs Outrun



# 8 ½” Hole Gyro vs MWD – High Angle

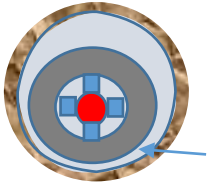
- 2000’ samples, Mean & SD

Gyro Positioning, 10’ stations



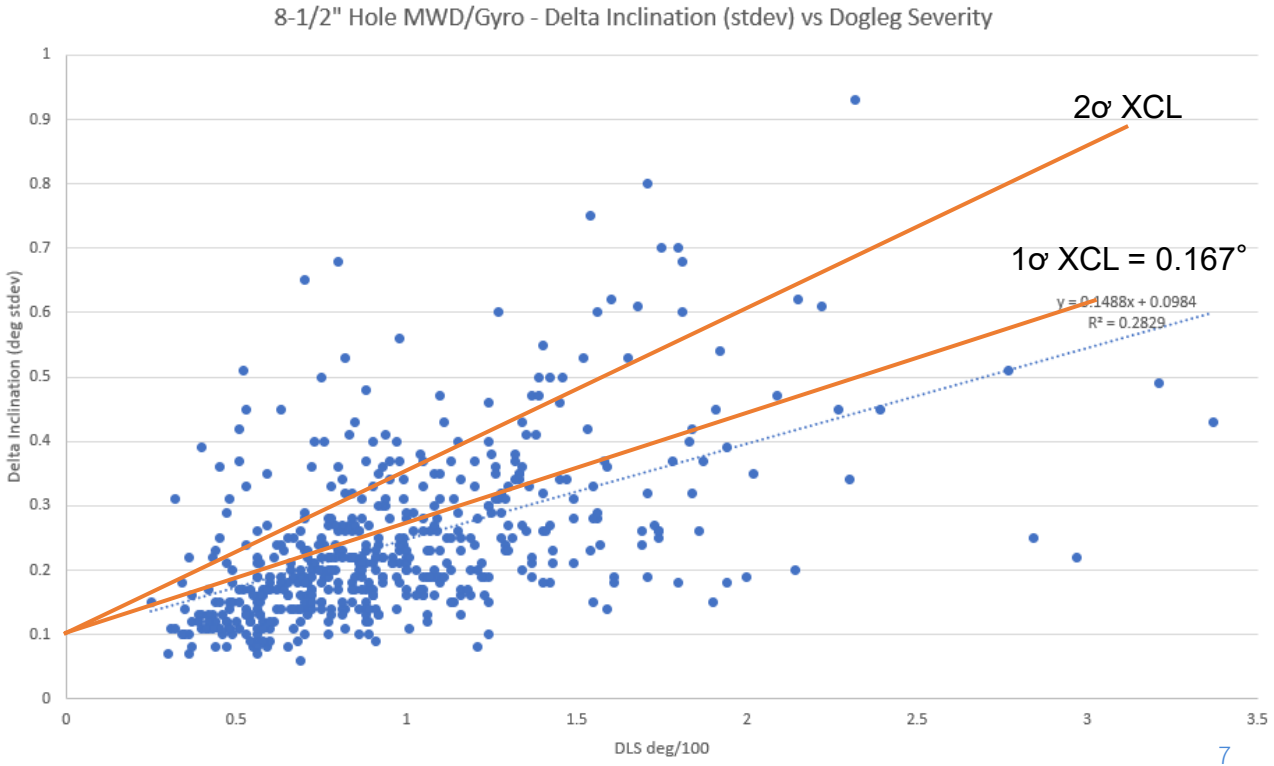
8 ½” Hole
Pipe 5 ½”
Instrument
Tool Joint

MWD Positioning, 90’ stations



8 ½” Hole
Collar 6 ½”
Instrument
Stabilizers

- Observations: Strong DLS effect = XCL, Residual error of 0.1° random



# DP Gyro vs 16” & 12 ¼” MWD

- 1000’ samples

Gyro Positioning, 16” Hole

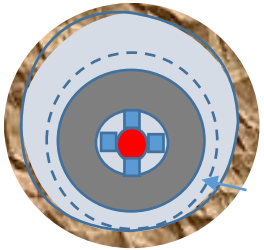
13 3/8” casing
+ 9 5/8” casing

Pipe 5 ½”

Instrument

Tool Joint

MWD Positioning, 90’ stations

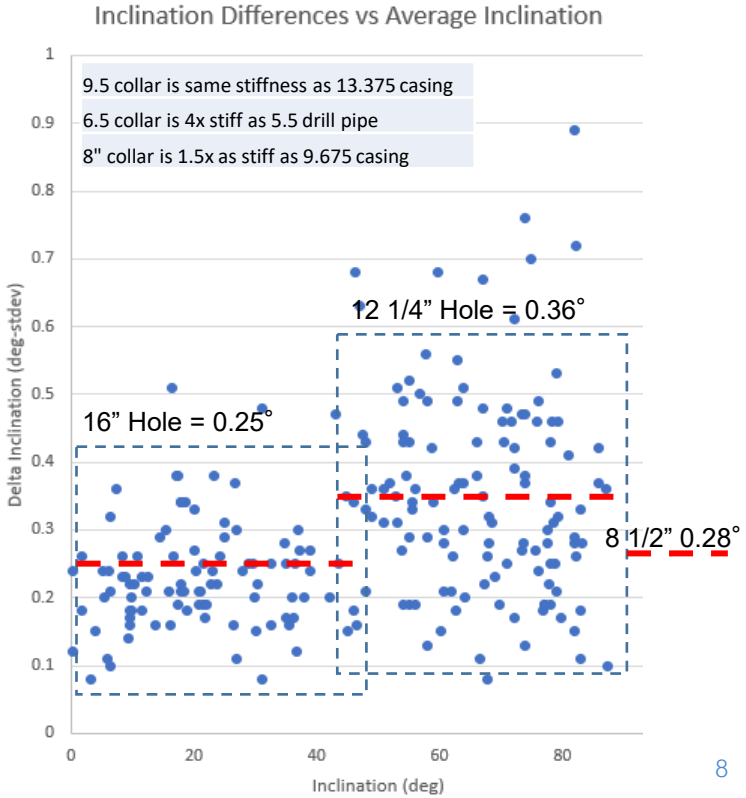


16” Hole

Collar 9 ½”

Instrument

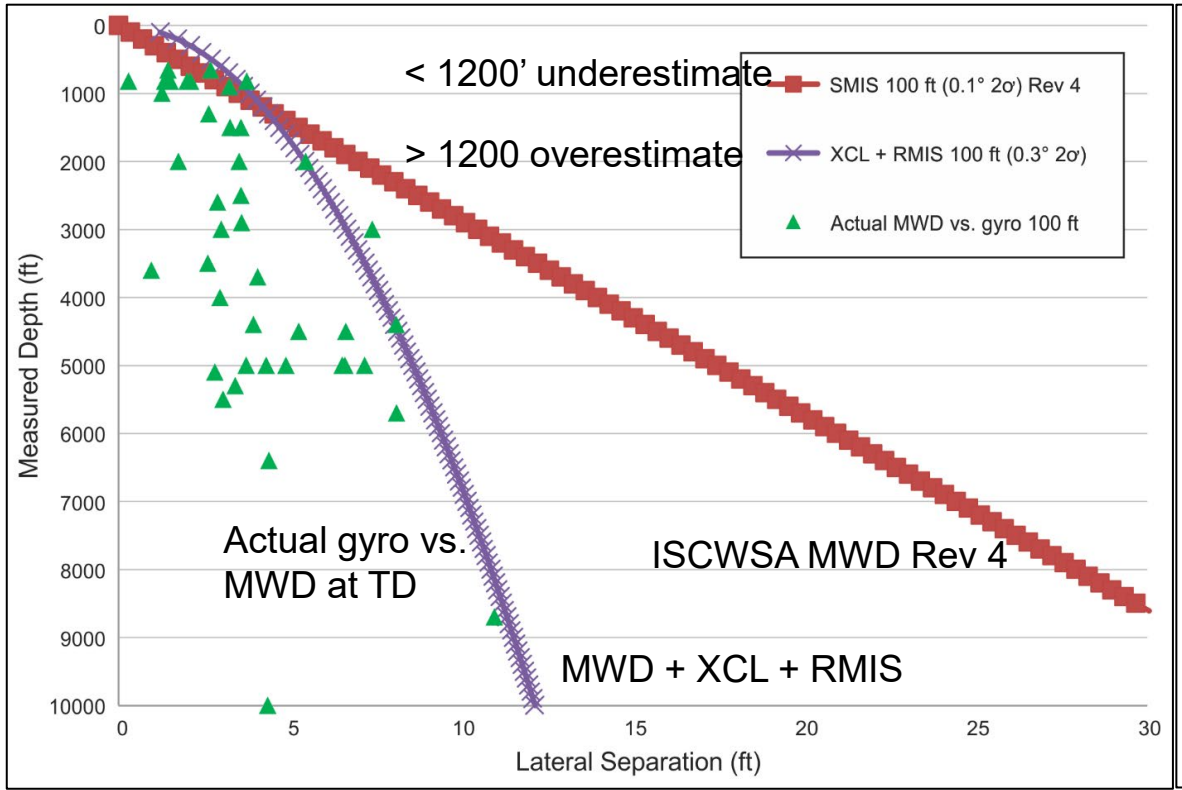
Stabilizers

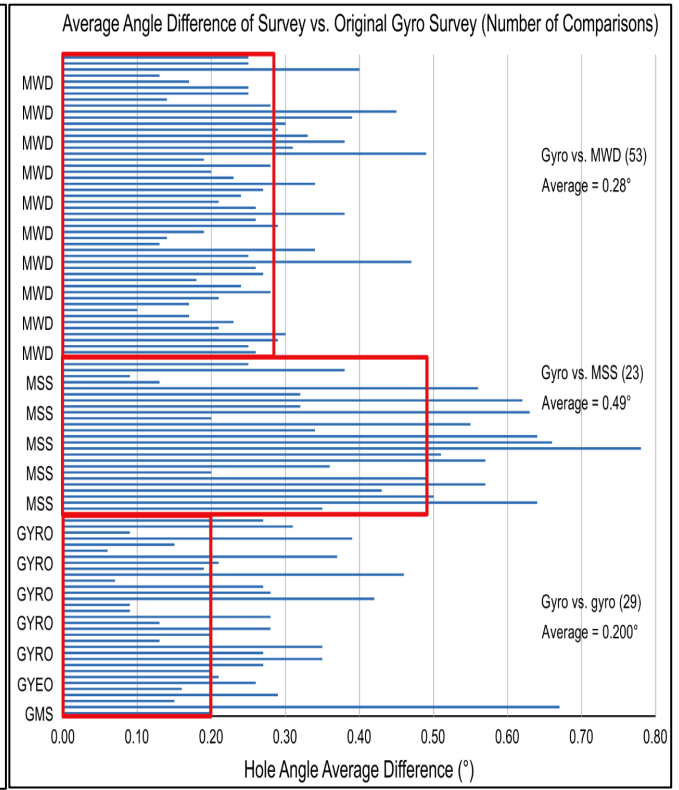




- Observations: More casings remove relative XCL effect

# Low angle Misalignment: Vertical Well Separations

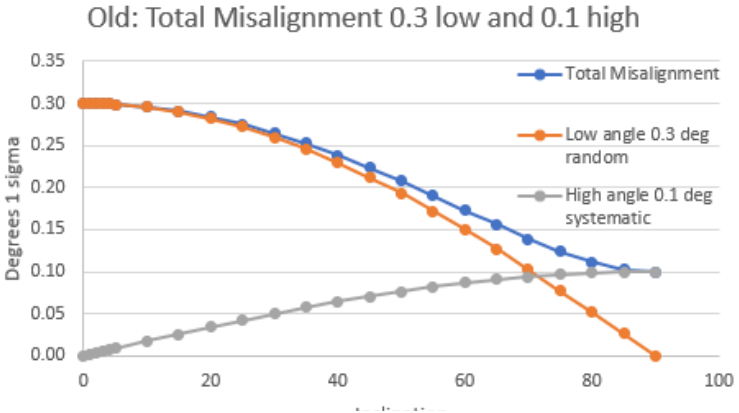
SPE-187073, The Effect of Survey Station Interval on Wellbore Position Accuracy

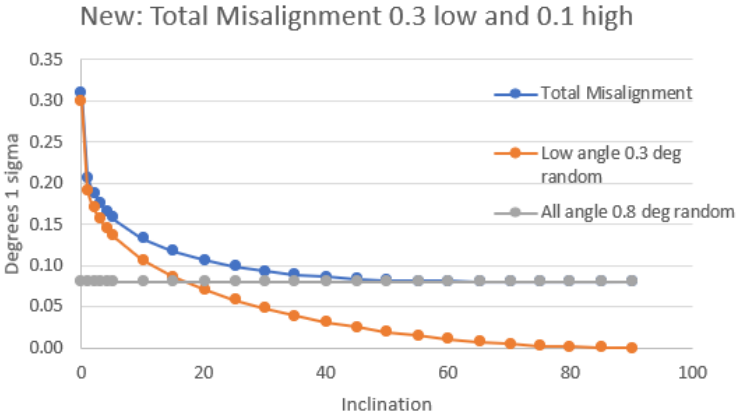


# Old vs. New Misalignment

- Low angle misalignment is weighted differently is like reverse SAG or “floppy BHA” behavior
- High angle misalignment becomes 0.08° and applies at all angles – like roll test values
- ISCWSA rev 0 (SPE67616) is valid except using random not tool face. Weighting is different to in SPE90408



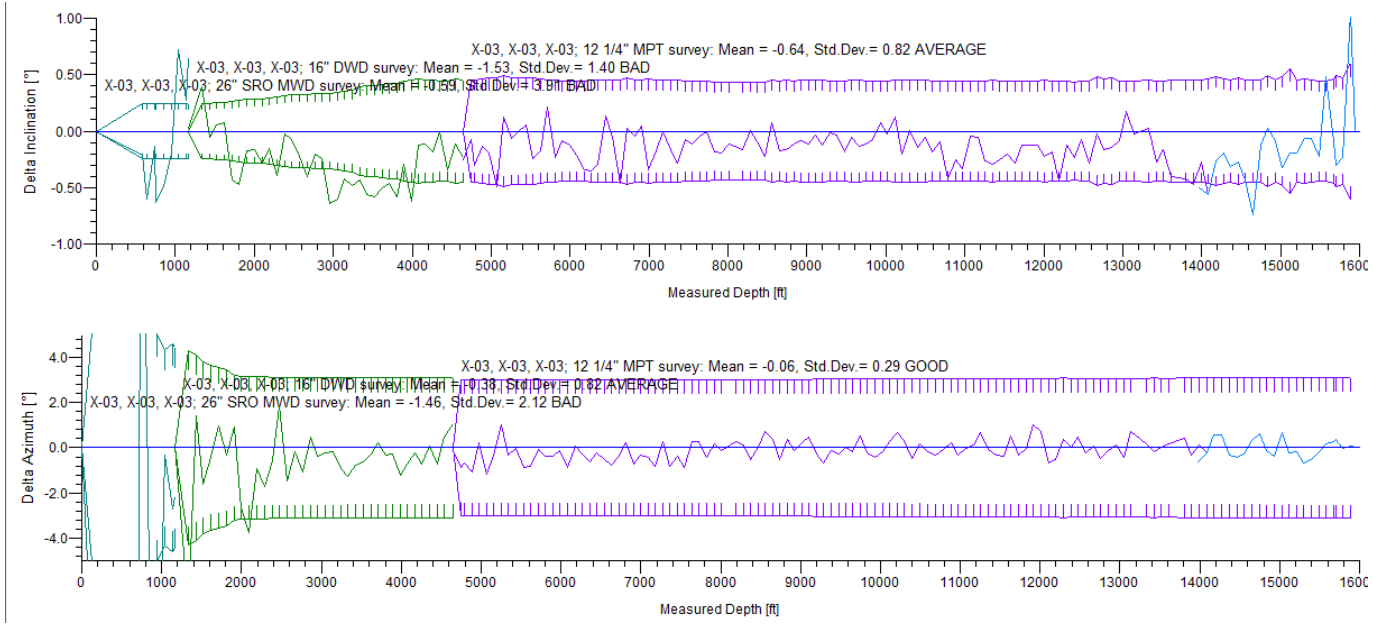

COMPASS IPM Format

| Old Misalignment Rev 5 | | | | | | New Misalignment Rev ? | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Name | Vec | Prop | Unit | Value | Weight | Name | Vec | Prop | Unit | Value | Weight | |
| w_12 | n | n | - | 1 | sin(inc) | w_12 | n | n | - | 1 | 1.0 | High angle |
| w_34 | n | n | - | 1 | sqrt(1-(w_ | w_34 | n | n | - | 1 | 1-(sin(inc))^0.25 | Low angle v |
| xym1 | i | s | d | 0.1 | w_12 | xymr1 | i | r | d | 0.08 | w_12 | High angle |
| xym2 | I | s | d | 0.1 | w_12 | xymr2 | I | r | d | 0.08 | w_12 | |
| xymr3 | i | r | d | 0.3 | cos(azi)*w | xymr3 | i | r | d | 0.3 | cos(azi)*w_34 | Low angle r |
| xymr3 | I | r | d | 0.3 | -sin(azi)*w | xymr3 | I | r | d | 0.3 | -sin(azi)*w_34 | |
| xymr4 | i | r | d | 0.3 | sin(azi)*w | xymr4 | i | r | d | 0.3 | sin(azi)*w_12 | |
| xymr4 | I | r | d | 0.3 | cos(azi)*w | xymr4 | I | r | d | 0.3 | cos(azi)*w_12 | |
| sage | i | s | d | 0.2 | (sin(inc))^ | sage | i | s | d | 0.2 | (sin(inc))^0.25 | SAG Error |

# Conclusions

- Data suggests that low angle misalignment declines rapidly and high angle misalignment is consistent across all angles, there is a DLS effect
- Change means that inclination comparisons in RIP tests are more reliable.
- High angle misalignment and XCL mean that advanced SAG corrections show more value in  vertical wellbore positioning accuracy.
- Hole geometry (sizes and casings) are not considered in the error model because of complexity.
- Low angle misalignment (RMIS) can be ignored when comparing surveys in the same hole/casing. High angle misalignment is valid.

# Thanks……Questions?




RIP Test Example

# RIP Test with Bias