Survey QC, Decision Making, and a Modest Proposal for Error Models

- Marc Willerth, MagVAR

47th General Meeting
April 11th, 2018
Inverness, Scotland

ISCWSA

Speaker Information

- Marc Willerth
- VP of Survey Technologies
- April 11, 2018
- MagVAR

Speaker Bio

- Marc Willerth
  - Magnetic Variation Services, LLC
  - Purdue University / BS Chem / Chem Eng
  - Denver, CO
  - Specializes in:
    - Talking about surveys, survey corrections, and survey quality
    - Talking about error models, & positional uncertainty
    - Honorary “Concerned Dutch Citizen”

Company / Affiliation Information

- High-accuracy Magnetic Models (MVHD, IFR1, IFR2)
- Survey Analysis and Real-time Survey Management
- Free QC Calculator: http://fac.magvar.com/
- Free QC API: https://fac-api.magvar.com/

Two Takeaways

Survey verification should not require expertise in surveying

Error-model-based QC should be possible using the Error model

Expertise Requirement

Most people who drive cars are not mechanics

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CHECK
ENGINE

There are warning signs when you need one

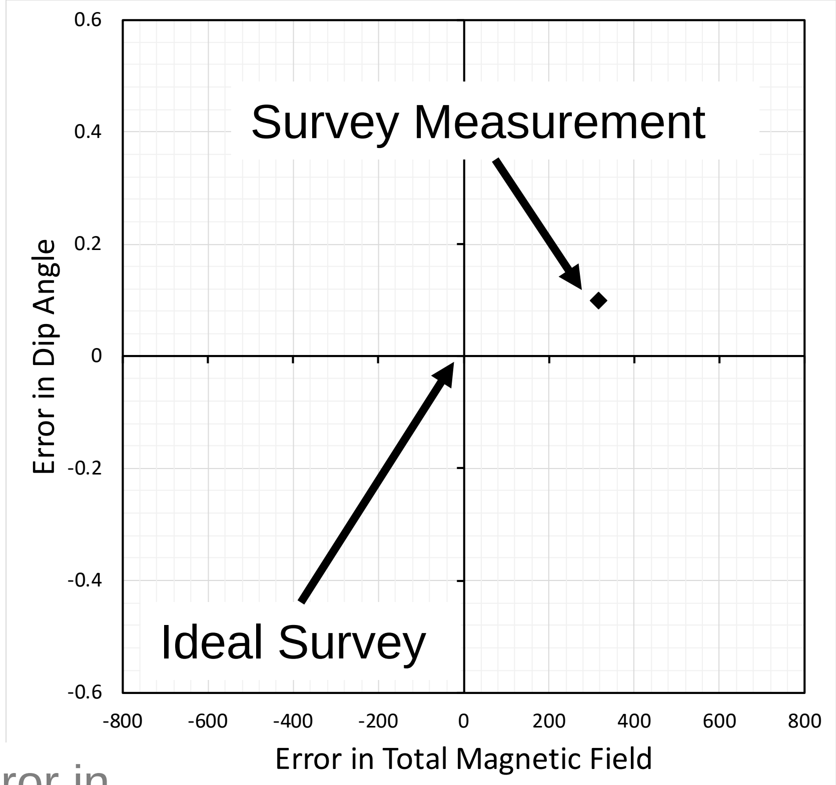
Expertise Requirement

- Most who drill and survey wellbores are not survey experts
- Consumers of the data may be even less of an expert
- How do they know when there is a problem?
- Importance of error-model-based QC

Error-Model-Based QC
A Brief History

Pre-Error Model

- Measure deviation from references
- Many standards, usually fixed thresholds



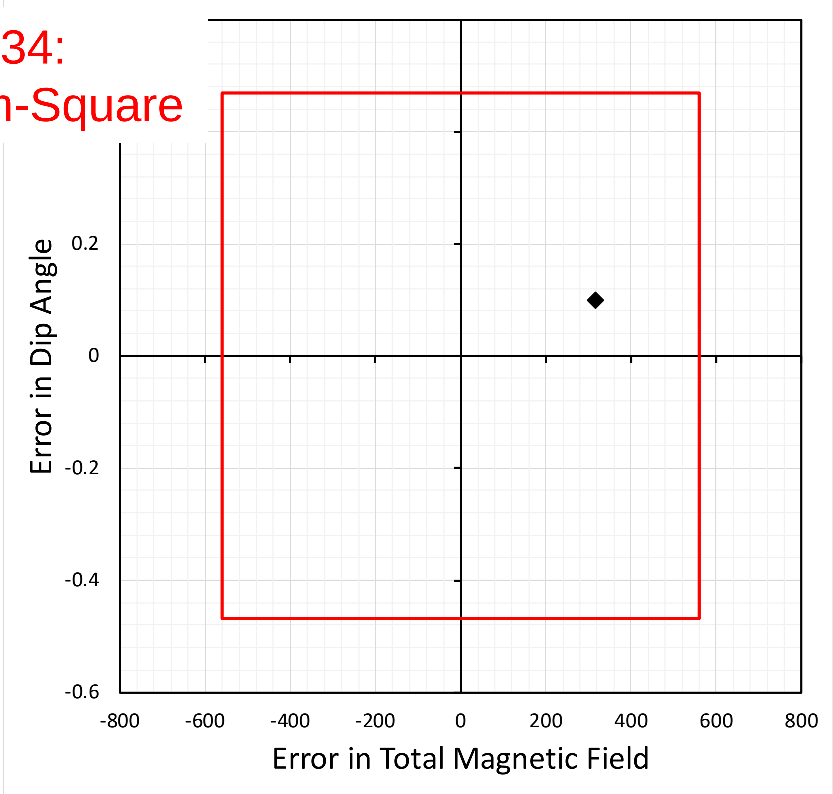
(Not shown – Error in Graviational Acceleration)

Error-Model-Based QC
A Brief History

Pre-Error Model
- Measure deviation from references
- Many standards, usually fixed thresholds

SPE 103734, Ekseth, et al (2006)
- Define weighting functions, Root-Sum-Square
- Dynamic QC – Changes with orientation

SPE103734:
Root-Sum-Square



Error-Model-Based QC
A Brief History

Pre-Error Model
- Measure deviation from references
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SPE 103734, Ekseth, et al (2006)
- Define weighting functions, Root-Sum-Square
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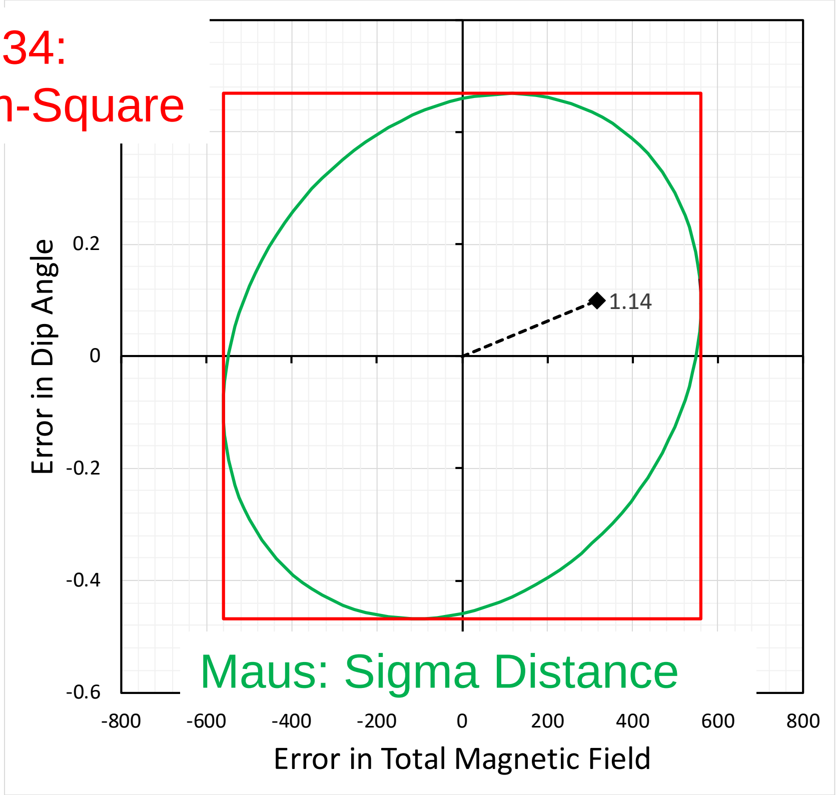
Maus, et al (2017)
- Account for error covariance
- Compute "sigma distance"



Shortcomings of These Methods

Focus on single survey evaluation

- User is interested in the set as a whole
- Exception: MSE in 103734, but use and interpretation requires a knowledgeable user

Real-World workflows can lead to complacency

- Once one survey fails, all the rest will likely fail
- "Drill ahead, this always happens near vertical!"

Escalation procedures often assume some level of expertise

- "If you identify interference from an offset well, notify town"
- Assumes that they already know if the survey is good or bad

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Decision Making With QC

When do I stop drilling?

When do I need to resurvey the well?

How Do We Get There?

Move away from single surveys, towards survey sets

Use Propagation modes to build an expanded error covariance matrix

- Already contained in the Error Model
- Explains how errors should correlate *between* surveys in a set

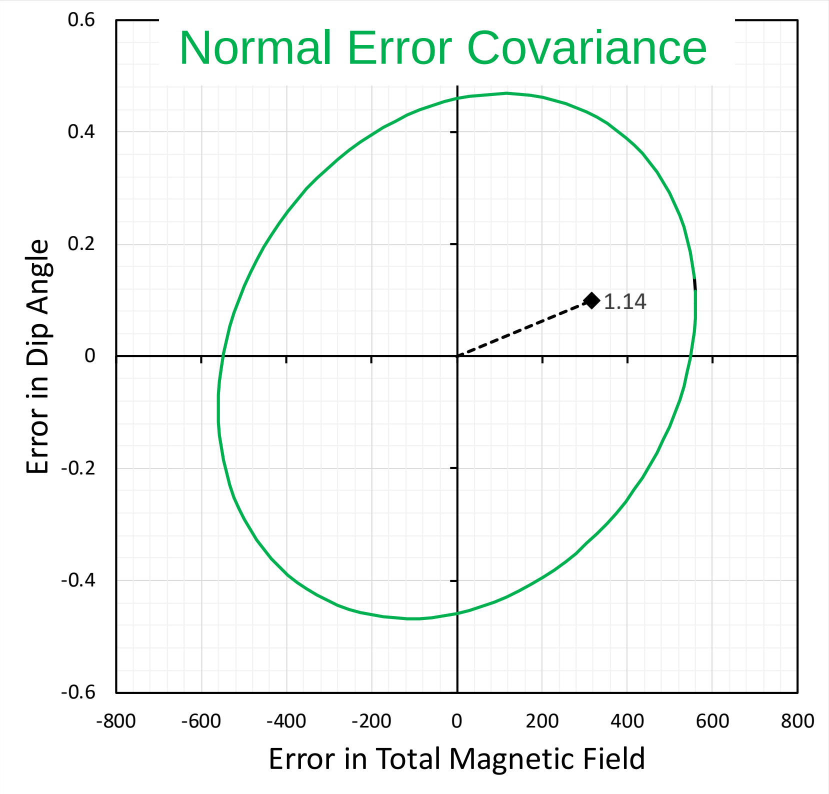
Two New QC Values

- Marginal Sigma Distance
- Total Survey Confidence

Marginal Sigma
Conditional Expectation and Survey QC

First Survey – Normal QC

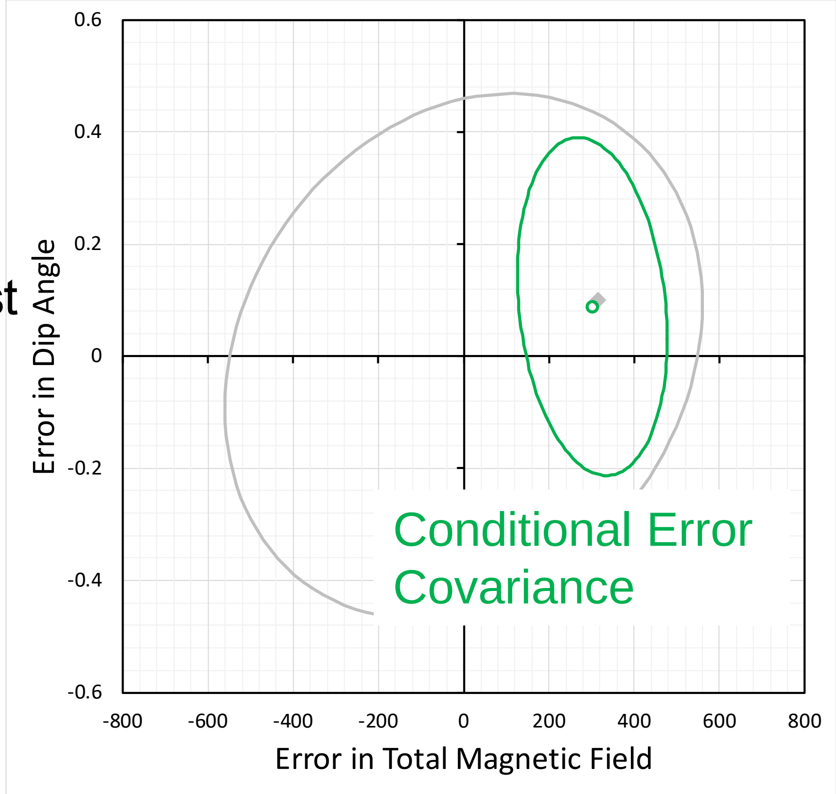
- Acceptable envelope from error covariance



Marginal Sigma
Conditional Expectation and Survey QC

First Survey – Normal QC
- Acceptable envelope from error covariance

Second Survey – Conditional QC based on first
- Drilling straight, large errors are correlated
- Whole ellipse no longer acceptable



Marginal Sigma
Conditional Expectation and Survey QC

First Survey – Normal QC
- Acceptable envelope from error covariance

Second Survey – Conditional QC based on first
- Drilling straight, large errors are correlated
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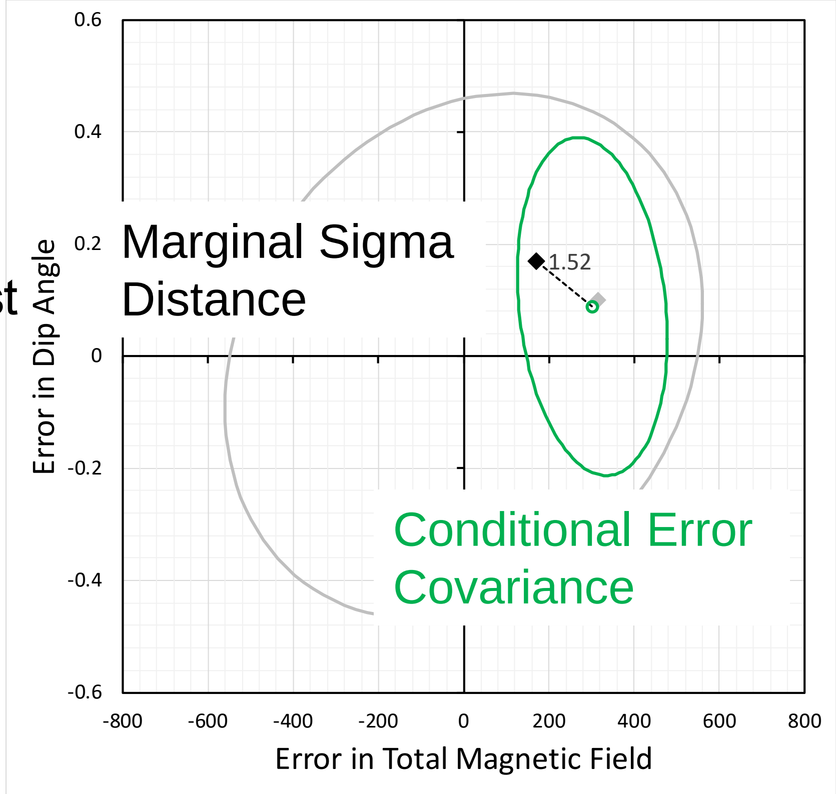
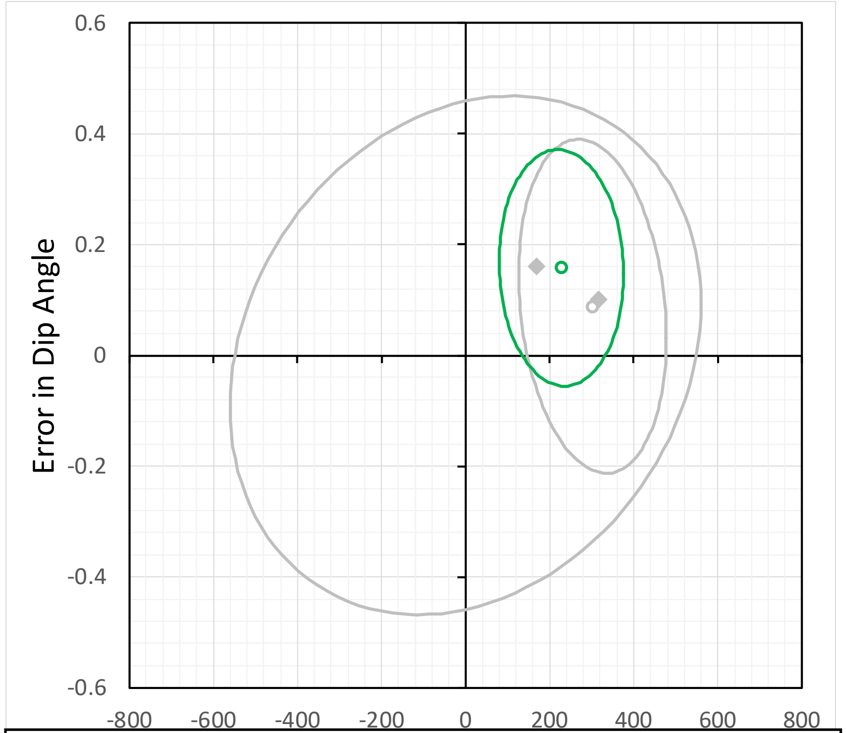
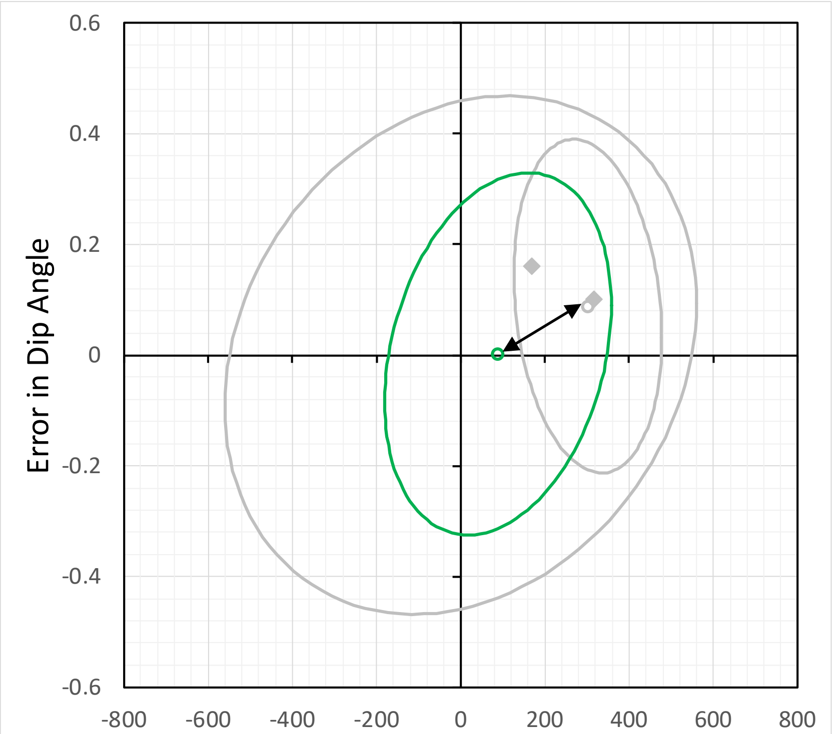
Marginal Sigma
- Sigma Distance from the conditional expectation
- How much “new error” is in this survey?
- Does *this survey* require escalation?



Still Accounts for Orientation Change
Two Possibilities for Survey #3



3rd survey planned at vertical:
Same expectation, QC narrows further



3rd survey planned at horizontal:
Expectation and covariance shift

Evaluating the Whole Survey Set

Sigma distance can be computed for a group of surveys

- With residuals and the expanded covariance matrix

Direct Interpretation is not as straightforward

- Larger survey sets will have a larger “total sigma”

Can convert this sigma distance into a P-value

- Set a threshold for when you should reject a survey as invalid

What is a P-value?

The probability that data at least this extreme would be produced by random chance given a certain set of assumptions

In Other Words…

"If my survey instrument meets the assumptions of the error model, how often do I expect to see data like this?"

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Total Survey Confidence

P-value is a uniform threshold that can apply to all survey sets

- Normalizes for amount and quality of data

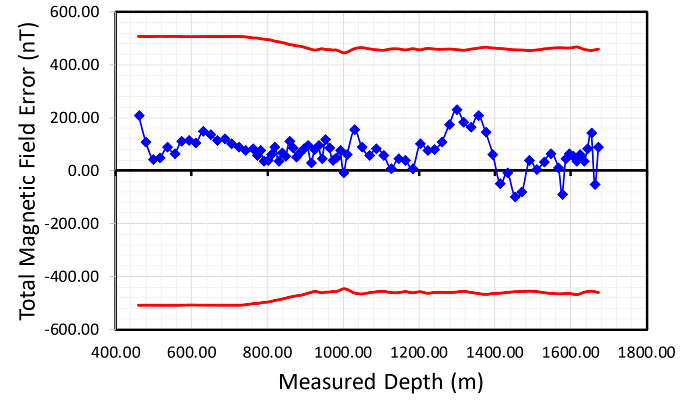
Operators can set their own false positive rate

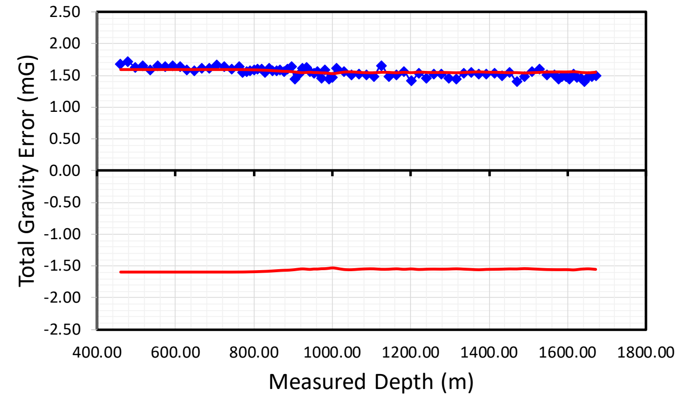
- E.g. if P<= 0.10, escalate for further investigation

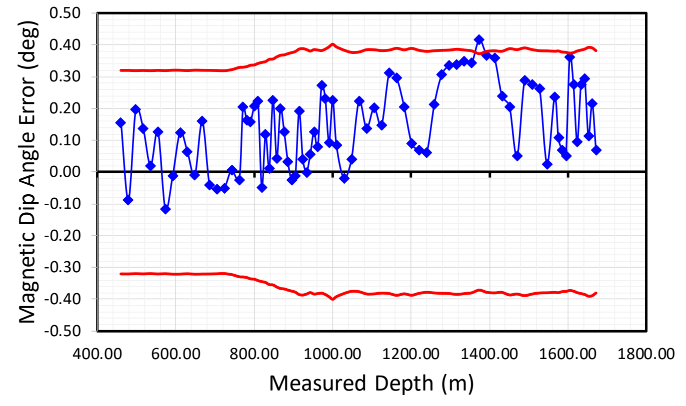
Can analyze arbitrarily large amounts of data

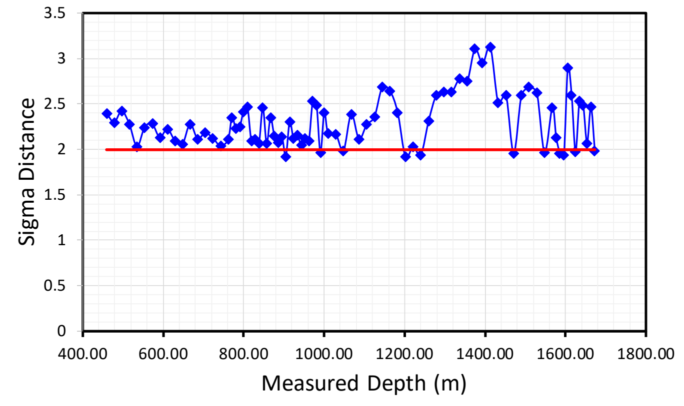
- Single survey, set of surveys, entire pad of wells with surveys, etc

New QC in Action









2-sigma Tolerances

- SPE103734

Sigma Distance plot

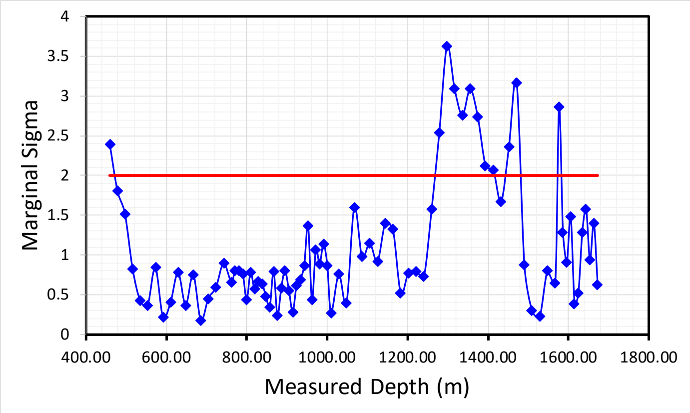
- Threshold of 2

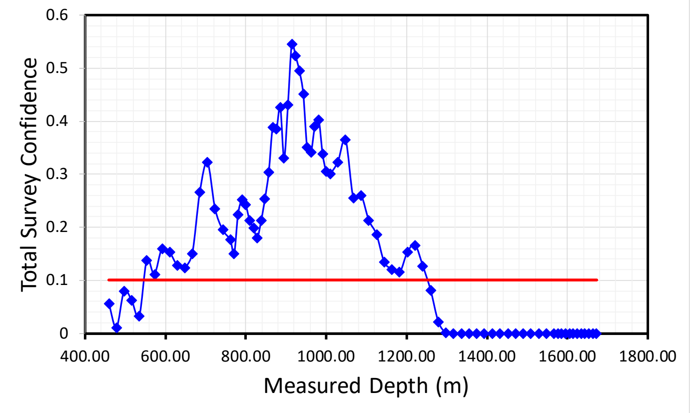
Would you escalate this?

Would you stop drilling?

Is a re-survey needed?

One more time – Same Survey





New QC methods

- Marginal Sigma (<2-sigma threshold
- Total Confidence (P-Value, >0.10 threshold)

Survey passes QC until 1300m

- High confidence, low marginal sigma
- Errors are consistent with the Error-Model

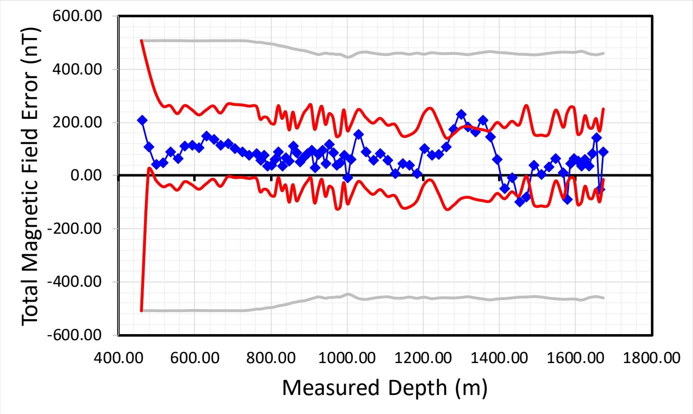
Magnetic storm for ~8 hours

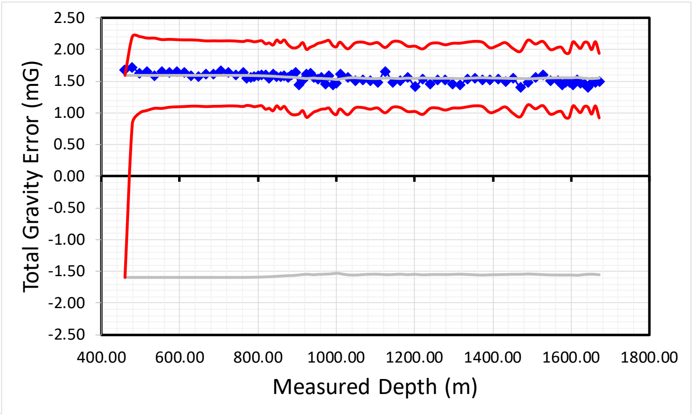
- Affected 10-12 surveys, not just 1
- Accelerometers not a big issue

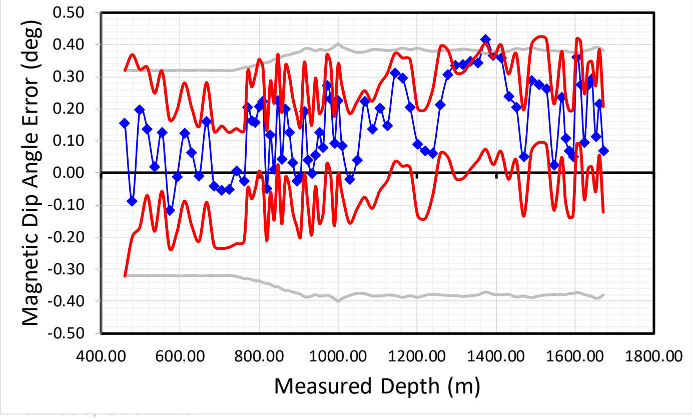
May need to investigate azimuths deeper than 1300m

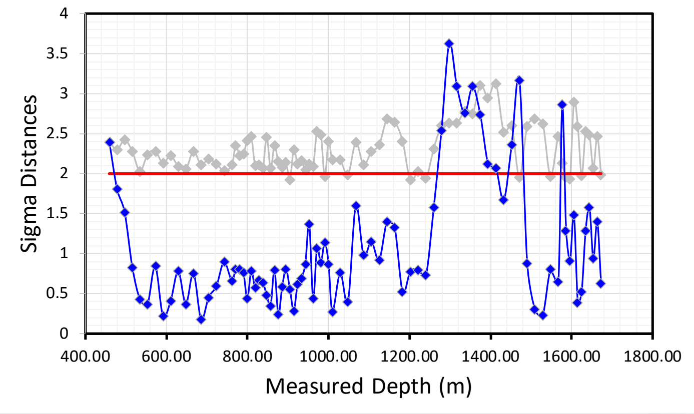
How Does This Work?

Survey QC, Decision Making, and a Modest Proposal for Error Models
presented by Marc Willerth









New QC Approach with Conditional Tolerances

- Tighten as you drill
- Fit data to EM

Mag Storm is not in EM

- Causes QC failure
- Time to escalate

Focus on critical surveys

Build "Expert Knowledge" into the QC process

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Key Takeaway #1

Marginal Sigma and Total Survey confidence remove the expertise requirement to perform error-model based QC on a survey

Corrective action & remediation may still require expert evaluation, but *decision to escalate* does not and should not

A Modest Proposal for Error Models

Why has error-model based QC seemed so challenging up to now?

Why has error-model based QC seemed so challenging up to now?

Because it's not actually in the Error Model!

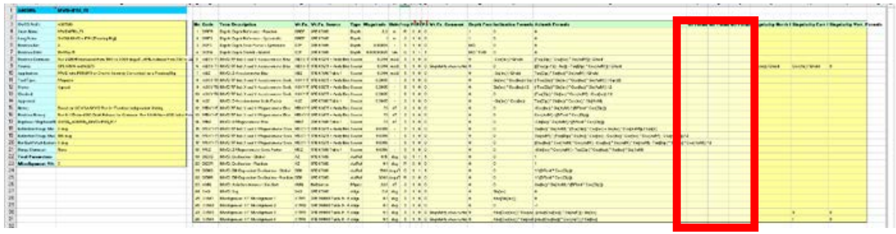
Fixing the Error Models
Enable QC on All Surveys

Step 1: Add fields to the header

- Number of QC Criteria
- Names of the QC Criteria

OWSG Prefix:	A005Mb
Short Name:	MWD+IFR1
Long Name:	OWSG MWD + IFR1
Revision No:	2
Revision Date:	18-May-15
Revision Comment:	Rev 2 DBHR increased from 1500 to 3000 deg.nT. AMIL reduced from 300 to 220
Source:	SPE 67616 and 63275
Application:	MWD with IFR1 (IFR or Crustal Anomaly Correction)
Tool Type:	Magnetic
Status:	Agreed
Checked:	
Approved:	
Notes:	Based on ISCWSA MWD Rev 3 - Toolface Independent Sliding
Revision History:	Rev 0.1 05-Jun-2013 Draft Release for Comment. Rev 1.0 01-Nov-2013 Initial Re
Replaces / Replaced By:	OWSG_A005Ma_MWD+IFR1 /
Inclination Range Min:	0 deg
Inclination Range Max:	180 deg
Hor East/West Exclusior	0 deg
Range Comment:	None
Tool Parameters	
Number of QC Criteria:	3
Q1	Error in Magnetic Field Strength
Q2	Error in Magnetic Dip Angle
Q3	Error in Gravitational Field Strength

Fixing the Error Models
Enable QC on All Surveys



Step 1: Add fields to the header

- Number of QC Criteria
- Names of the QC Criteria

Step 2: Add weighting functions for the QC Criteria

- The same as for Inc, Azi, and Depth
- Relate each error to its relevant QC parameters

No	Code	Term Description	Wt.Fn.	Q1 Formula	Q2 Formula	Q3 Formula
22	AMIL	MWD: Axial Interference - SinI.SinA	AMIL	Bz/Bfield	(cos(Dip)*cos(Inc)-sin(Dip)*sin(Inc)*sin(AzM))/Bfield	0
23	SAG	MWD: Sag	SAG	0	0	0

Fixing the Error Models
Enable Simple QC on All Surveys

Step 1: Add fields to the header
- Number of QC Criteria
- Names of the QC Criteria

Step 2: Add weighting functions for the QC Criteria
- The same as for Inc, Azi, and Depth
- Relate each error to its relevant QC parameters

Step 3: Add errors that impact QC, but not surveys
- Include relevant propagation modes
- Raise awareness of external factors that impact QC

No	Code	Term Description	Wt.Fn.	Wt.Fn. Source	Type	Magnitude	Units	Prop.	P1	P2	P3	V
1	DRFR	Depth: Depth Reference - Random	DREF	SPE 67616	Depth	0.35	m	R	0	0	0	
2	DSFS	Depth: Depth Scale Factor - Systematic	DSF	SPE 67616	Depth	0.00056	-	S	1	0	0	
3	DSTG	Depth: Depth Stretch - Global	DST	SPE 67616	Depth	2.5E-07	1/m	G	1	1	1	
4	ABXY-TI1S	MWD TF Ind: X and Y Accelerometer Bias	ABXY-TI1	SPE 63275 + Andy Brook	Sensor	0.004	m/s2	S	1	0	0	
5	ABXY-TI2S	MWD TF Ind: X and Y Accelerometer Bias	ABXY-TI2	SPE 63275 + Andy Brook	Sensor	0.004	m/s2	S	1	0	0	S
6	ABZ	MWD: Z-Accelerometer Bias	ABZ	SPE 67616 Table 1	Sensor	0.004	m/s2	S	1	0	0	
7	ASXY-TI1S	MWD TF Ind: X and Y Accelerometer Scale Fact	ASXY-TI1	SPE 63275 + Andy Brook	Sensor	0.0005	-	S	1	0	0	
8	ASXY-TI2S	MWD TF Ind: X and Y Accelerometer Scale Fact	ASXY-TI2	SPE 63275 + Andy Brook	Sensor	0.0005	-	S	1	0	0	
9	ASXY-TI3S	MWD TF Ind: X and Y Accelerometer Scale Fact	ASXY-TI3	SPE 63275 + Andy Brook	Sensor	0.0005	-	S	1	0	0	
10	ASZ	MWD: Z-Accelerometer Scale Factor	ASZ	SPE 67616 Table 1	Sensor	0.0005	-	S	1	0	0	
11	MBXY-TI1S	MWD TF Ind: X and Y Magnetometer Bias	MBXY-TI1	SPE 63275 + Andy Brook	Sensor	70	nT	S	1	0	0	
12	MBXY-TI2S	MWD TF Ind: X and Y Magnetometer Bias	MBXY-TI2	SPE 63275 + Andy Brook	Sensor	70	nT	S	1	0	0	
13	MBZ	MWD: Z-Magnetometer Bias	MBZ	SPE 67616 Table 1	Sensor	70	nT	S	1	0	0	
14	MSXY-TI1S	MWD TF Ind: X and Y Magnetometer Scale Fac	MSXY-TI1	SPE 63275 + Andy Brook	Sensor	0.0016	-	S	1	0	0	
15	MSXY-TI2S	MWD TF Ind: X and Y Magnetometer Scale Fac	MSXY-TI2	SPE 63275 + Andy Brook	Sensor	0.0016	-	S	1	0	0	
16	MSXY-TI3S	MWD TF Ind: X and Y Magnetometer Scale Fac	MSXY-TI3	SPE 63275 + Andy Brook	Sensor	0.0016	-	S	1	0	0	
17	MSZ	MWD: Z-Magnetometer Scale Factor	MSZ	SPE 67616 Table 1	Sensor	0.0016	-	S	1	0	0	
18	DECG	MWD: Declination - Global	AZ	SPE 67616	AziRef	0.15	deg	G	1	1	1	
19	DECR	MWD: Declination - Random	AZ	SPE 67616	AziRef	0.1	deg	R	0	0	0	
20	DBHG	MWD: BH-Dependent Declination - Global	DBH	SPE 67616	AziRef	1500	deg.nT	G	1	1	1	
21	DBHR	MWD: BH-Dependent Declination - Random	DBH	SPE 67616	AziRef	3000	deg.nT	R	0	0	0	
22	MDIG	MWD: Magnetic Dip - Global	MDI	SPE 67616 Table 1	Mgntcs	0.1	deg	G	1	1		
23	MDIR	MWD: Magnetic Dip - Random	MDI	SPE 67616 Table 1	Mgntcs	0.08	deg	R	0	0		
24	MFIG	MWD: Total Magnetic Field - Global	MFI	SPE 67616 Table 1	Mgntcs	50	nT	G	1	1		
25	MFIR	MWD: Total Magnetic Field - Random	MFI	SPE 67616 Table 1	Mgntcs	60	nT	R	0	0		
26	AMIL	MWD: Axial Interference - SinI.SinA	AMIL	Halliburton	Mgntcs	220	nT	S	1	0	0	
27	SAG	MWD: Sag	SAG	SPE 67616	Align	0.2	deg	S	1	0	0	
28	XYM1	Misalignment: XY Misalignment 1	XYM1	SPE 90408 Table 9 - Alt. 1	Align	0.1	deg	S	1	0	0	

Benefits of Expanding the Error Model

Removes any ambiguity around "Error-Model-Based QC"

- It's in the error model!

Sets clear data requirements for Error-Model End Users

- To use an error model, you must have the associated QC parameters with the survey

Establishes clear limits on all QC parameters, clearly defines error covariance

- Derived from weighting functions, scaled to the operator's risk management policy

Expedites troubleshooting of survey issues, calls attention to good surveying practices

- Errors with no QC attached cannot be internally verified, require additional procedures

Not Just MWD

Math doesn't care about magnetics – Anything with QC and an error model can do this

Example: Wireline gyro

- Earth-rate measurements, Zero-velocity updates, Pre- & Post- run calibration checks
- If these are in the error model, operators will know to ask for them!

Encourage QC of Depth Measurements

- Example: EDR Depth – Pipe Tally depth, now pipe tally must be stored with surveys

Enable earlier acceptance of new survey tools

- If a vendor provides a model and QC with a mathematical relationship, they are easier to audit

Biggest Benefit
Removal of Barriers to QC

Survey QC becomes routine calculation, like a collision avoidance scan

Lapses in QC procedures are evident at the time they are critical to operations

The users most impacted by a QC failure are empowered to identify issues

Bringing it All Together

Marginal Sigma and Total Survey Confidence enable a non-expert user to quickly validate a survey set against its error models

Adding QC criteria directly into all error models can simplify the survey verification process and promote good surveying practices

Thank You for Your Time!
Any Questions?