UPDATE
ERROR MODEL GROUP

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Tech21

Speaker Information

- Andy McGregor
- Chairman Error Model Maintenance Workgroup
- Survey Management – Domain Champion
- Tech21/Weatherford
- 22nd September 2016

Speaker Bio

- Introduction
  - With Tech21 Weatherford
  - 10 years in survey management
  - Degree in Physics & Astronomy, University of Glasgow
  - PhD Space Engineering, Cranfield University
  - Based in Inverness, Scotland
  - Specialized in
    - Survey Management, multi-station analysis, IFR and error modelling

Error Model Documentation

Document first draft complete – to be reviewed

Accompanied by:

- The MWD error model definitions – in spreadsheet
- Example implementation spreadsheets on gyro test cases

- Derivation of singular case of accel biases
- Note on lumped misalignments and scalefactors

Diagnostic Data Sets

Will create further validation data sets for

- Inclination only
- MWD-MWD tie-ons with latest Rev4 models
- Gyro-MWD tie-on

Clarifying particular gyro test results from SPE paper

Correlation of Error Sources

- Anti-collision method will use combining covariances
- Current combined methods simply add covariance matrices and implicitly assume all errors are uncorrelated.
- Noted that this was not strictly correct for geo-magnetic reference terms

Correlation of Error Sources

- Current practice generally the conservative option

Previously decided to

- Evaluate correlation values
- Evaluate effect – is this important?
- Determine how they could be handled

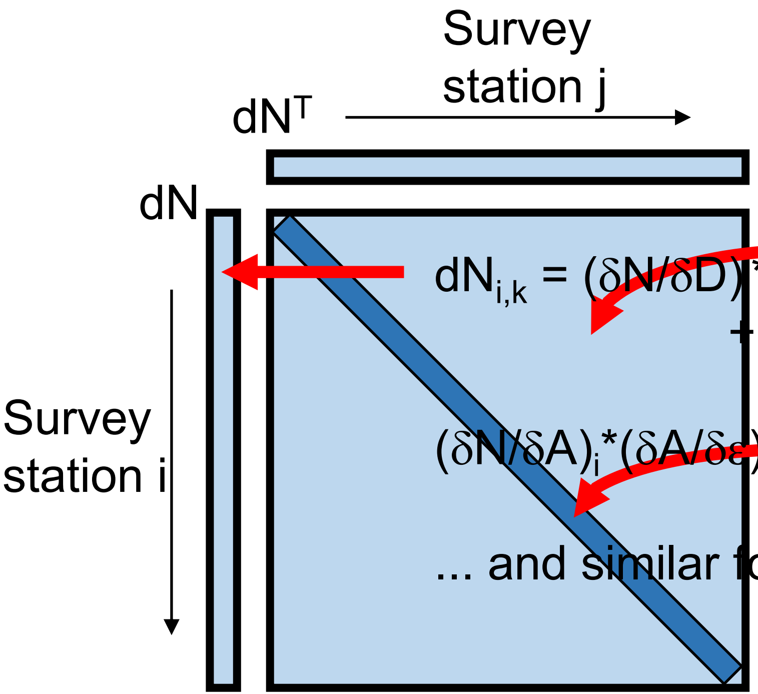
Correlation of Error Sources

- Stefan Maus estimated correlations between declination error if two surveys depending on geomagnetic model in

Estimate of average actual correlation (Stefan's analysis)

	IGRF	Standard	HD #1	HD #2	IFR1 #1	IFR1 #2	IFR2 #1	IFR2 #2
IGRF	0.55	0.66	0.34	0.34	0.03	0.03	0.03	0.03
Standard		0.79	0.40	0.40	0.03	0.03	0.03	0.03
HD #1			0.68	0.49	0.04	0.04	0.04	0.04
HD #2				0.68	0.04	0.04	0.04	0.04
IFR1 #1					0.39	0.08	0.39	0.08
IFR1 #2						0.39	0.08	0.39
IFR2 #1							0.44	0.09
IFR2 #2								0.44

$dN*dN^T$ matrix

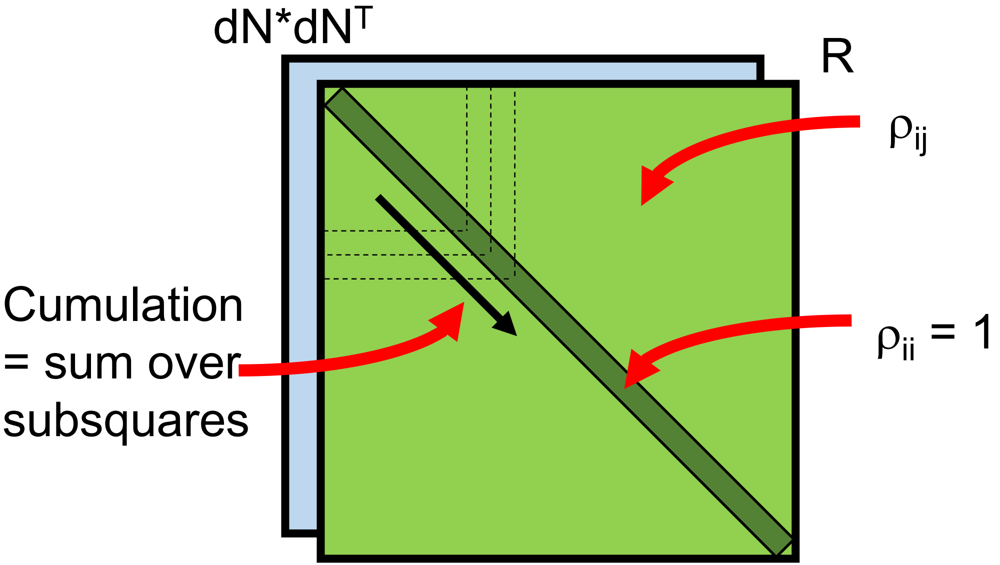


$dN_{i,k} = (\delta N/\delta D)_i*(\delta D/\delta\varepsilon)_i*d\varepsilon_k$
$+ (\delta N/\delta I)_i*(\delta I/\delta\varepsilon)_i*d\varepsilon_k$
$+$
$(\delta N/\delta A)_i*(\delta A/\delta\varepsilon)_i*d\varepsilon_k$

... and similar for dE and dV

- Similar matrices for:
  - $dN*dN^T$
  - $dE*dE^T$
  - $dV*dV^T$
  - $dN*dE^T$
  - $dN*dV^T$
  - $dE*dV^T$
- One matrix for each error term

Correlation coefficient matrix



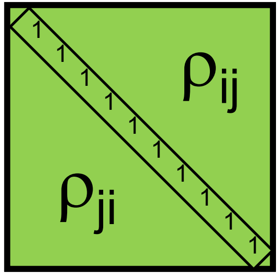
R = matrix containing correlation coefficients (of the particular error term)

Procedure:

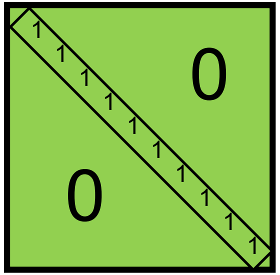
- Multiply R onto ($dN*dN^T$), element by element
- Cumulate from upper left corner

Correlation coefficient matrix

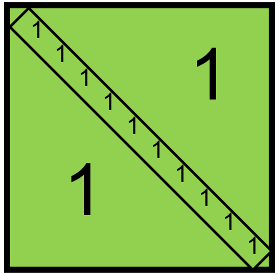
General



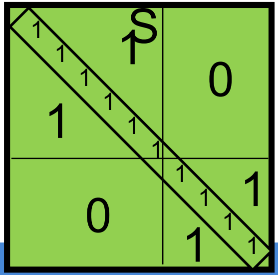
Random



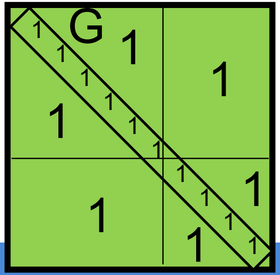
Systematic



Two surveys:



W or



Results for Partial Correlations

- Correlation seems to be important for global mag models
- In more extreme cases ellipses overestimated (parallel) or under-estimated (opposing) by ~25%
- Less so for IFR
  - Less impact of geomag ref errors
  - Lower correlation
- Some further work needed to check results and look at oblique cases

Simplifying Considerations

- Only need to consider four mag ref terms
  - DECG, DBHG, MFI, MDI
- No need to consider vertical terms
  - Hence 3 nev-covariance elements
- Likely reduced analytical equations will be determined.

Towards new model uncertainties

Confidence Level	Original Declination Limit (degrees)	New Declination Limit (degrees)
68.3% (1σ if Gaussian)	0.148	0.140
90%	0.419	0.411
95%	0.823	0.676
95.4% (2σ if Gaussian)	0.874	0.717
99%	1.641	1.149
99.7% (3σ if Gaussian)	2.613	1.249

(Using vector survey data 1985 and onwards only in both cases)

Locations of oil fields with local magnetic data

- Objective is one new error look-up table (scalable 1-sigma values) for annually revised high-degree global models, ideally with all-party agreement

Long Survey Intervals

- Jerry Codling presented details of further work on effect of survey interval on well position
- Candidate method of handling this
- Based on survey interval and angle changes across that interval
- Needed to be evaluated in an error model

Example
Importance of Long Interval Models

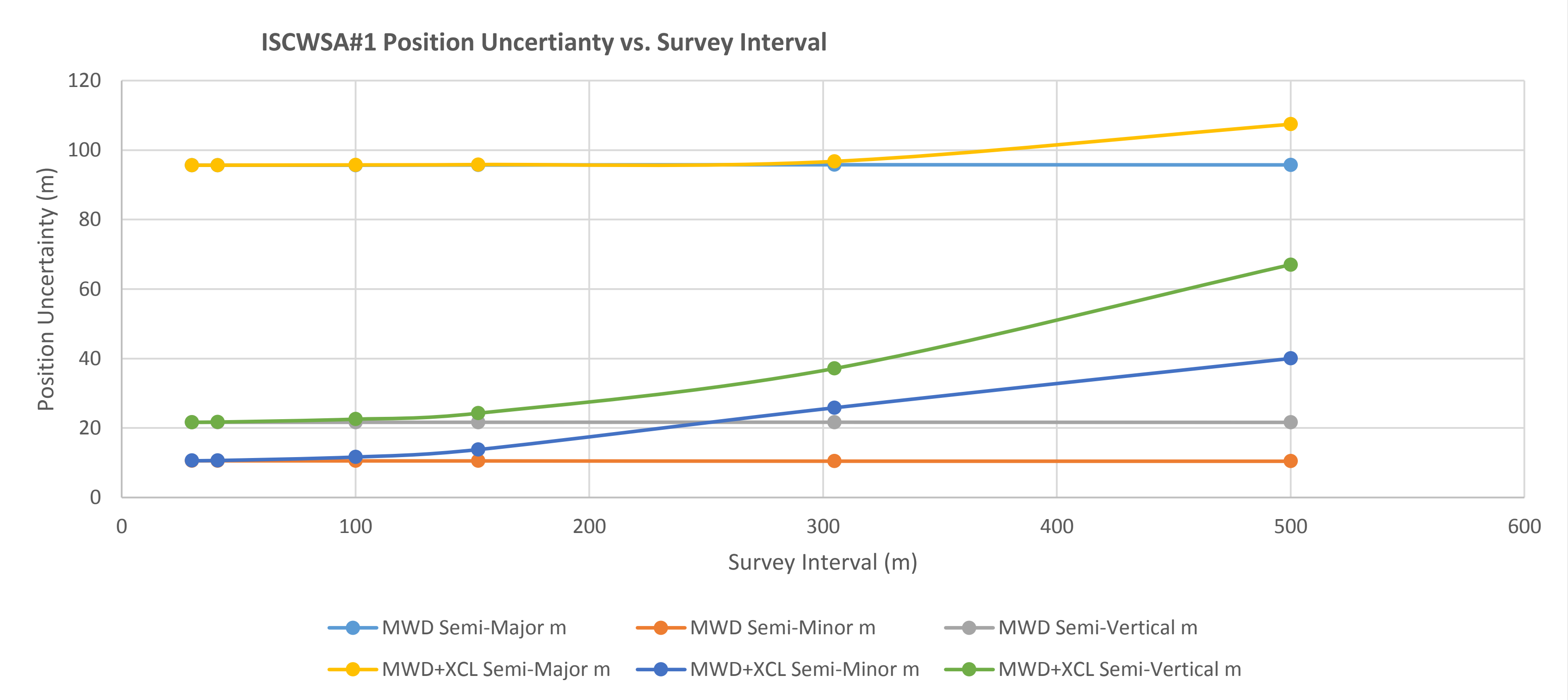
		Standard toolcode		Survey Interval > 1000ft	
Number of Stations	Total Md	Md Fail (ft)	% fail	Md Fail (ft)	% fail
BLIND	1,793,287	1,768,232	99%	752,903	42%
MWD	15,616,069	4,807,024	31%	1,581,828	10%
MWD_SC	47,990,277	3,698,504	8%	1,166,129	2%
CBMAG	2,323,544	1,824,353	79%	698,870	30%
Total	67,723,177	12,098,113	18%	4,199,730	7%

Long Survey Intervals

- Steve Grindrod looked at effect of survey interval on the ISCWSA test wells and compared to error model results
- Using Compass IPM with these terms added

#Name	Vector	Tie-On	Unit	Value	Formula
DLS	i	r	-	0.167	max(abs(din), 0.0033*smd)
DLS	a	r	-	0.167	max(abs(daz), 0.0033*smd/sin(inc+0.00001))

Effect on Test Wells



Validation of Tool Models

Policy that tool provider supplies error model

What evidence should back that up?

- QA\QC Criteria
- Process Documentation
- Repeatability of test stand data
- Assessment of downhole environmental factors
- Multiple runs/tools downhole
- Comparison with independent surveys downhole

Hole Misalignments

- Rev4 + OWSG increased misalignment terms
  - 0.06° to 0.1° - Operators wanted more conservative values
- Previously drilled wells violating a-c
- Systematic or random propagation
  - Random not common
- Big difference in top hole
- Doubly conservative
- Dependent on BHA type
- Split terms