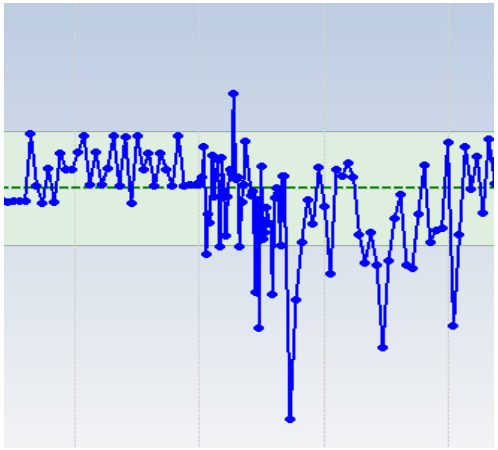
Field Acceptance Criteria Based on ISCWSA Tool Error Models

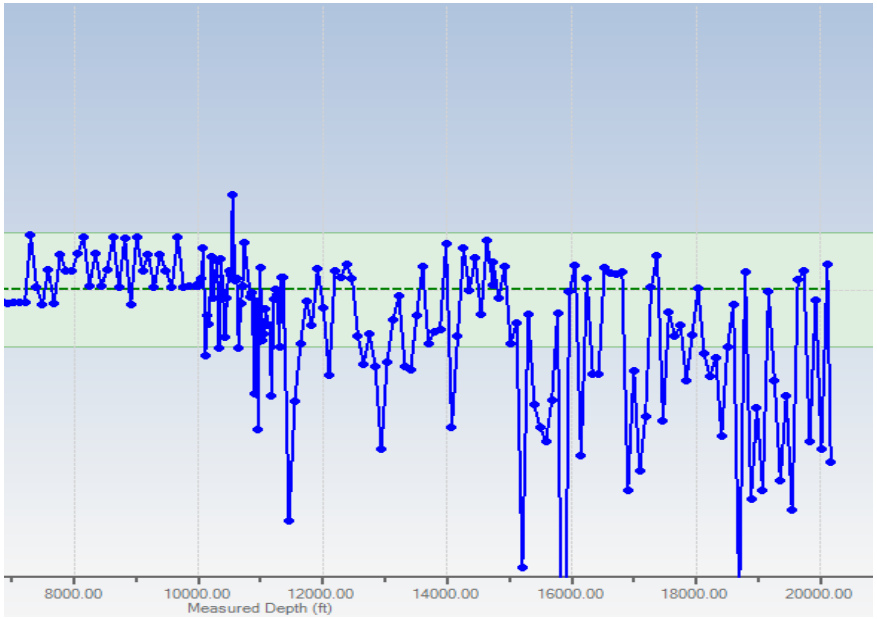


- What are QC parameters?
- Which error sources influence them and how
- ISCWSA example wells and some sample MWD data
- Is there a simple way to define QC criteria?

Stefan Maus, Ryan Croke (MagVAR, University of Colorado)

Motivations for the study

- Operator Wellbore Survey Group (OWSG) has compiled a set of consolidated tool error models, combined effort by COP and CVX
- Tool codes specify 1-sigma error sources and their contribution to the ellipse of uncertainty of the wellbore position
  - → Are the MWD surveys consistent with the tool code?
  - → How to define whether a survey “passes QC?”

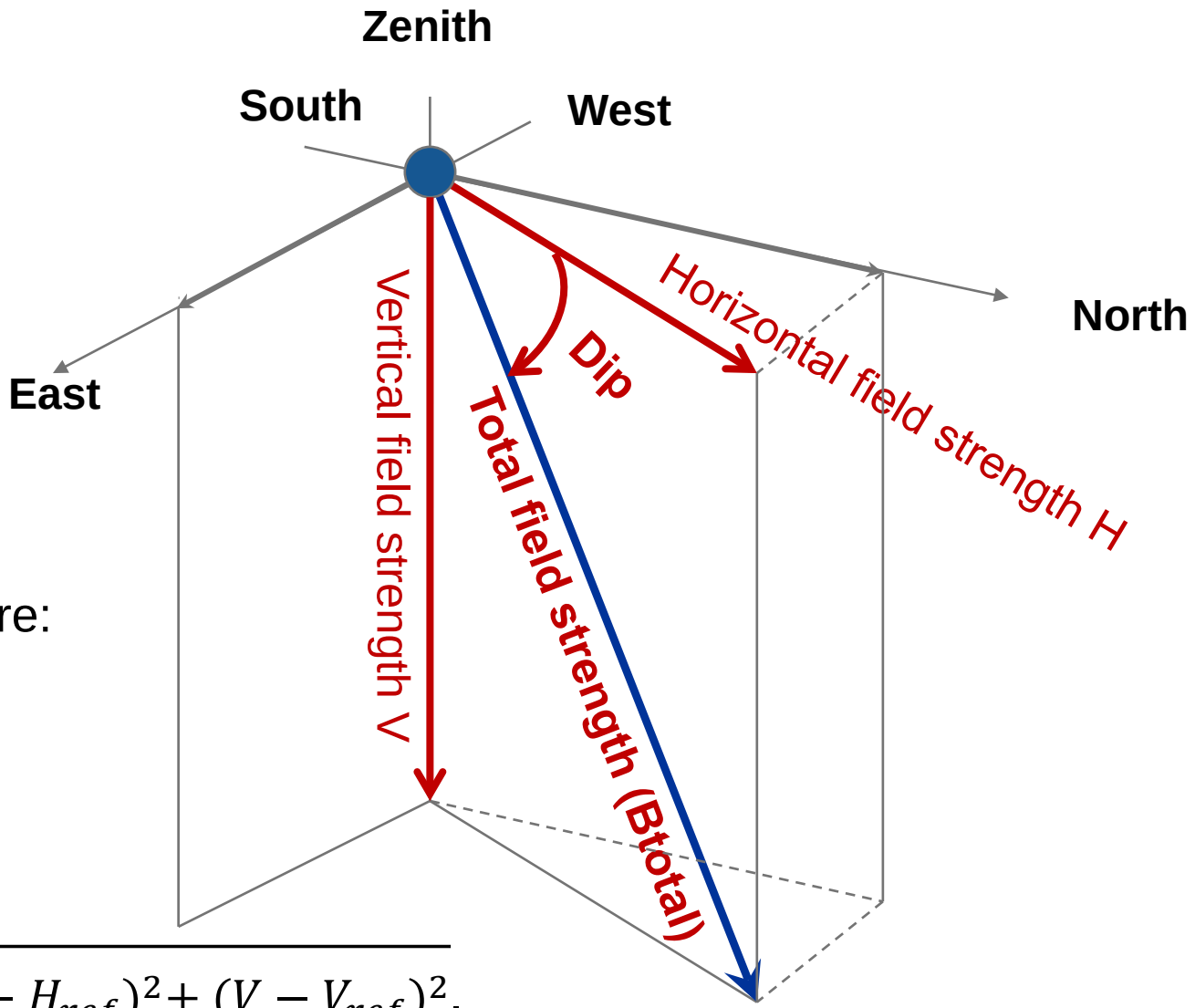


KellyDown Survey Analysis

Relevant Prior Work

- ISCWSA Error Models (Williamson et al.)
- OWSG consolidated tool codes (Steve Grindrod, Son Pham, Pete Clark, Simon McCulloch and others)
- SPE 103734 and SPE 105558 (2006, Roger Ekseth, Kazmir Kovalenko, John Weston, Torgeir Torkildsen, Erik Nyrnes, Andy Brooks, and Harry Wilson) contain many relevant equations and deal with the reliability of directional survey data and methods of eliminating gross errors
  - Scope: How to verify that the various error sources are within the assumptions of the tool code

Magnetic QC Parameters



QC parameters are:
Btotal
Dip

H
V

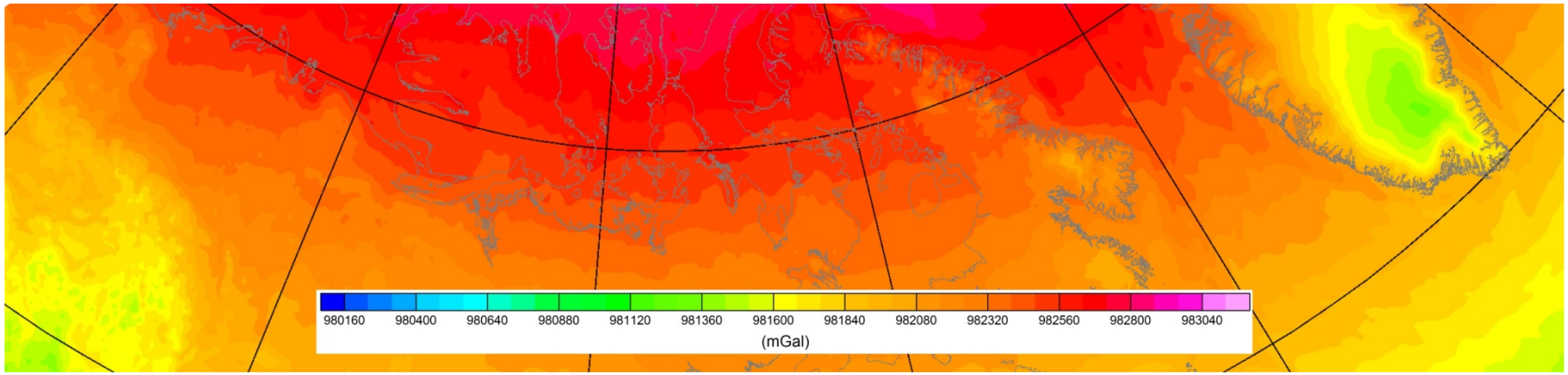
BtotalDip = $\sqrt{(H - H_{ref})^2 + (V - V_{ref})^2}$.

QC Parameter Dependencies

Which error source influences which QC parameter?

Error source	Gtotal	Btotal	Dip	H	V	BtotalDip
Reference model	x	x	x	x	x	x
Accelerometer Bias	x	-	x	x	x	x
Accelerometer Scale Factor	x	-	x	x	x	x
Magnetometer Bias	-	x	x	x	x	x
Magnetometer Scale Factor	-	x	x	x	x	x
Axial interference	-	x	x	x	x	x

Gravity reference errors



- The ISO standard value of gravity is 9.80665 m/s^2
- But: Gravity changes with location and depth
- To find the 1-sigma error of using standard gravity:
  - Averaged difference to Global Acceleration Reference Model (GARM2013)
  - Equal area weighting
  - Depths of 0 to 8000 m:

→ **0.016 m/s^2 (1-sigma)**

Magnetic reference model errors

- Global models: IGRF/WMM, BGGM, HDGM
- Local models: IFR1, IFR2
- Values include systematic and random errors
- From OWSG tool codes (MIFI and MIDI parameters)

Tool code	MFI	MDI
IGRF/WMM	157 nT	0.24°
BGGM	130 nT	0.20°
HDGM	107 nT	0.16°
IFR1	50 nT	0.10°
IFR2	used 40 nT here	Used 0.08° here

There is a need to define the random and systematic errors for IFR2

Why no mis-alignments?

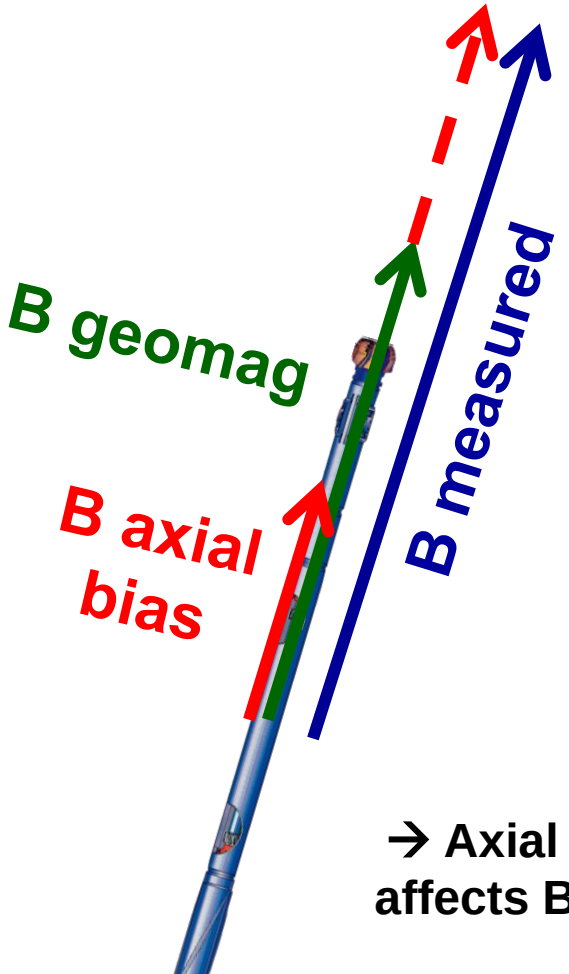
- Tool mis-alignment (XYM, SAG):
  - →The survey will give inclination & azimuth errors
  - →But these are not detectable in the QC parameters
- Sensor mis-alignment between grav and mag:
  - This will result in a detectable residual in dip
  - But: The ISCWSA tool codes lump these into the Magnetometer biases (based on a study by Andy Brooks)

→ There is no direct mis-alignment term affecting the errors in the QC parameters

Parameter errors depend on wellbore orientation

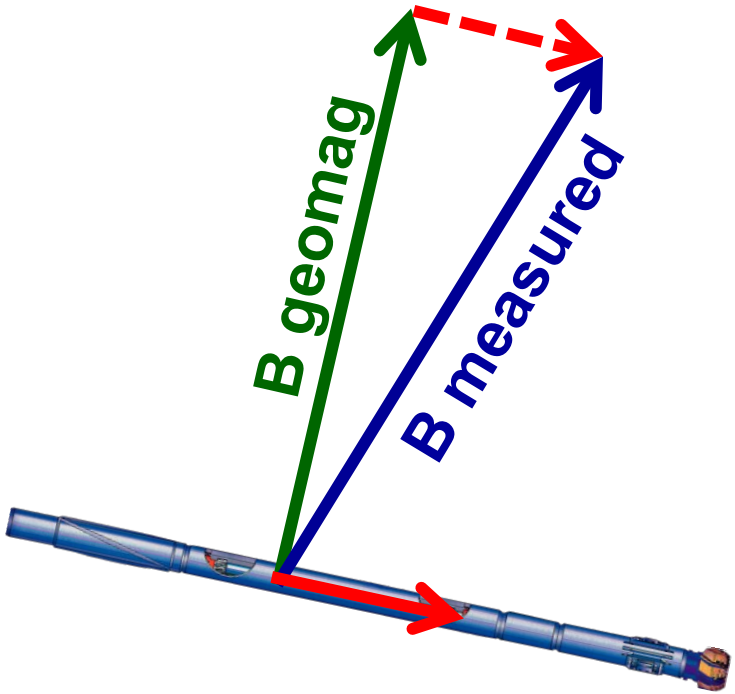
Example: Contribution of axial bias to error in Btotal

Wellbore parallel magnetic field
(plan view)



→ **Axial bias affects Btotal**

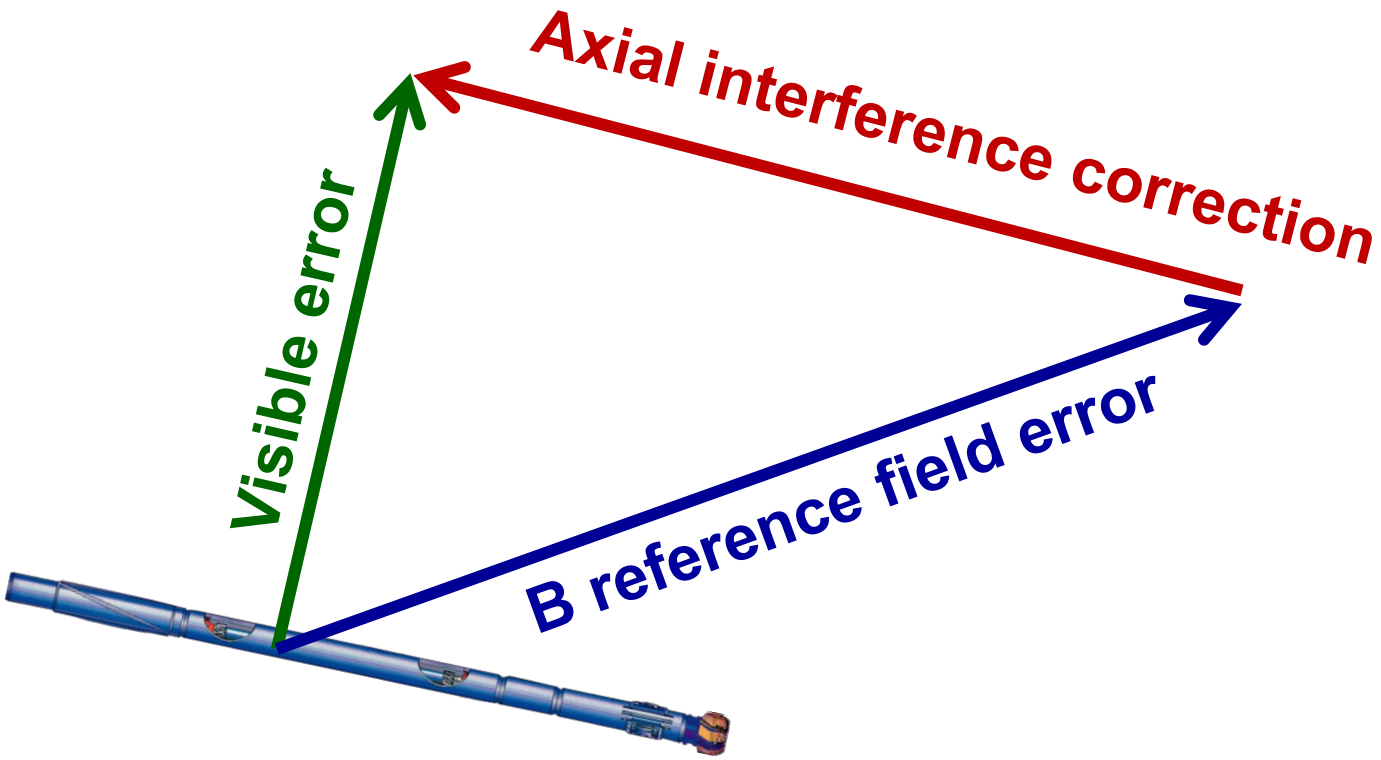
Wellbore oriented magnetic east
(plan view)



→ **Axial bias not seen in Btotal**

Axial interference correction

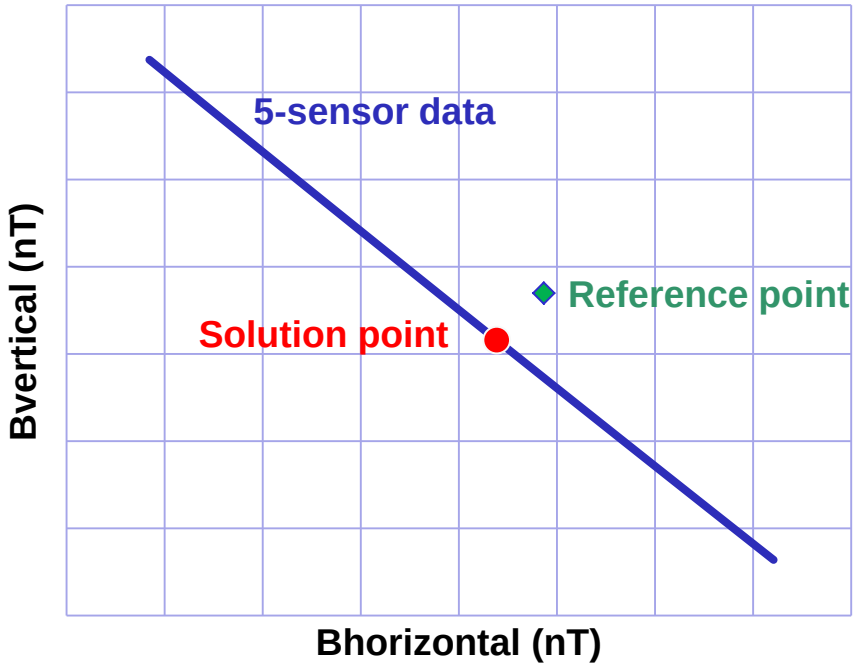
- Removes axial interference by adjusting the Bz bias
- Also reduces the effect of reference model errors!



→ Axially corrected data need much smaller QC limits

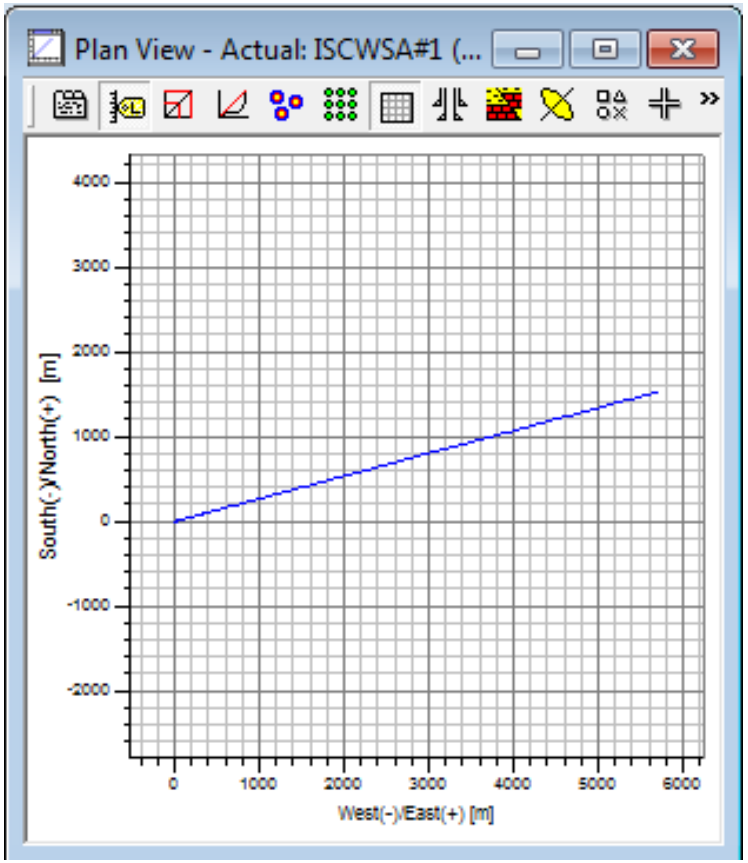
Btotal and Dip errors are correlated for axially corrected data

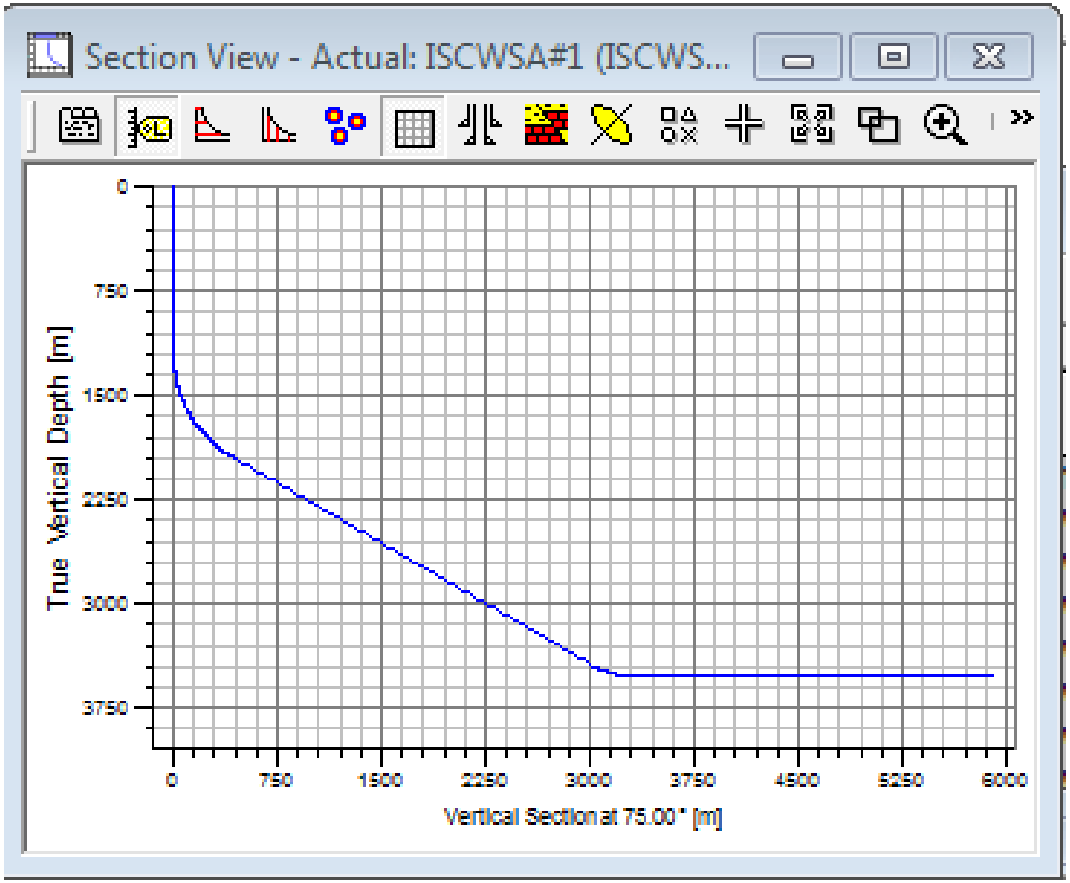
- Changing axial Bz changes BH, BV
  - Slope depends on Inc and Az of wellbore
- AX solution is closest to reference point
  - →Error vector ⊥ slope
- δBH, δBV correlated
  - → δBt, δDip correlated



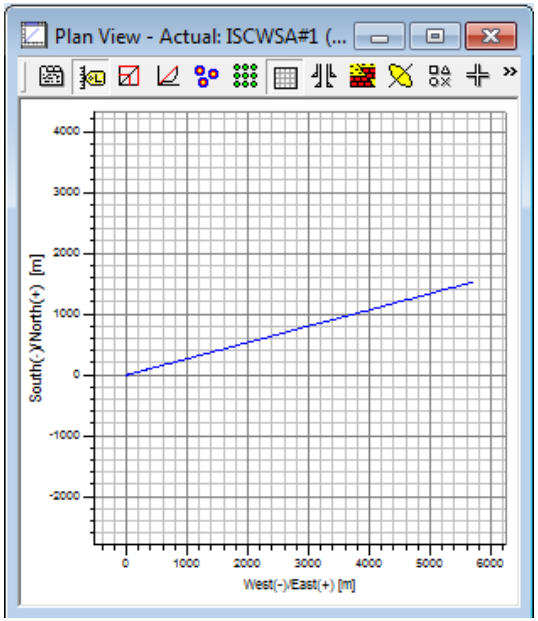
Sketch by Andy Brooks

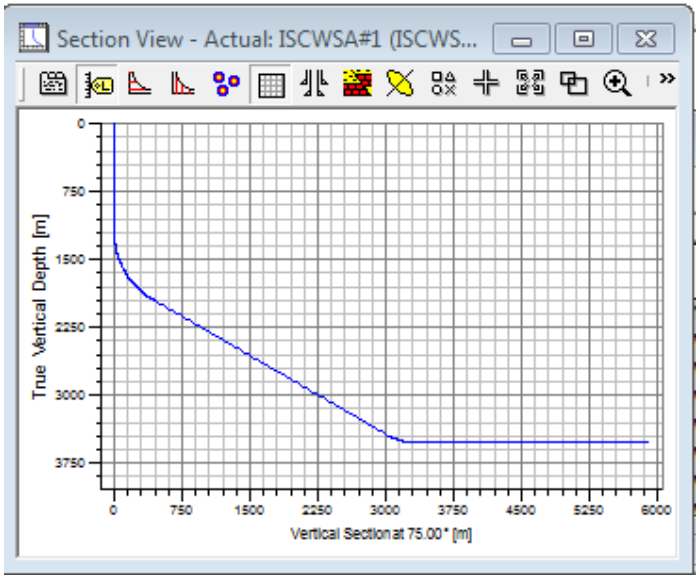
Example 1: ISCWSA Test Well #1

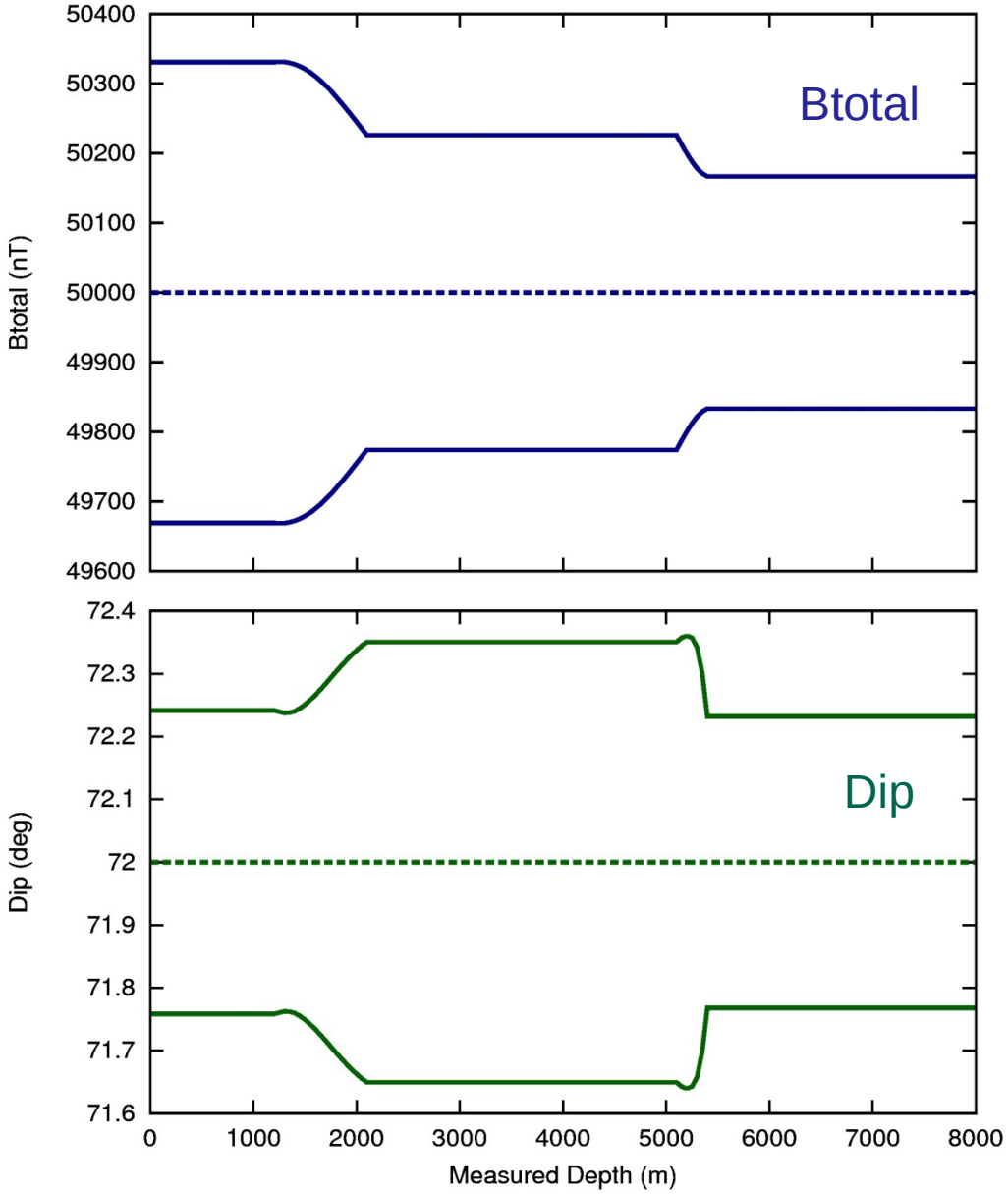




ISCWSA Test Well #1: MWD tool code (1σ)







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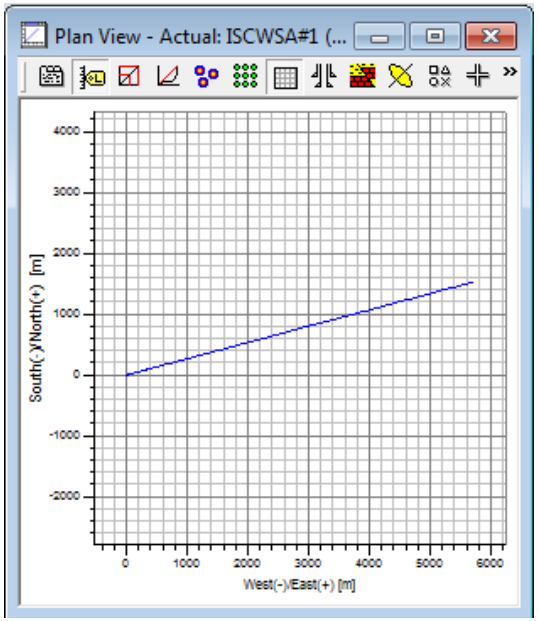
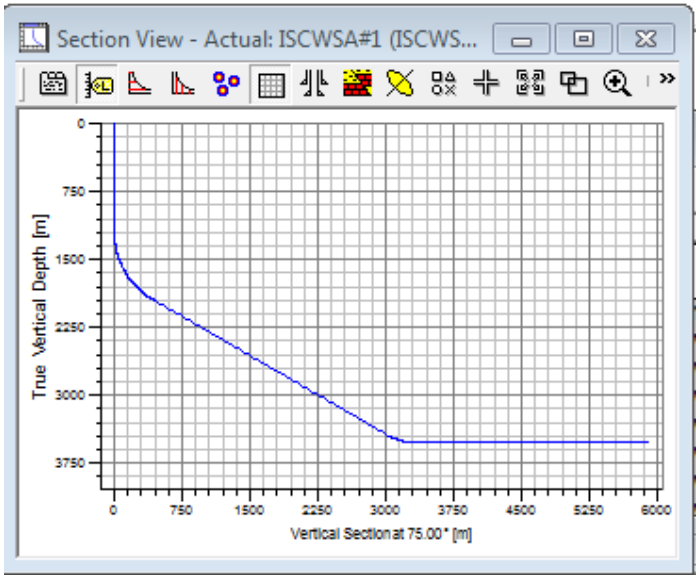
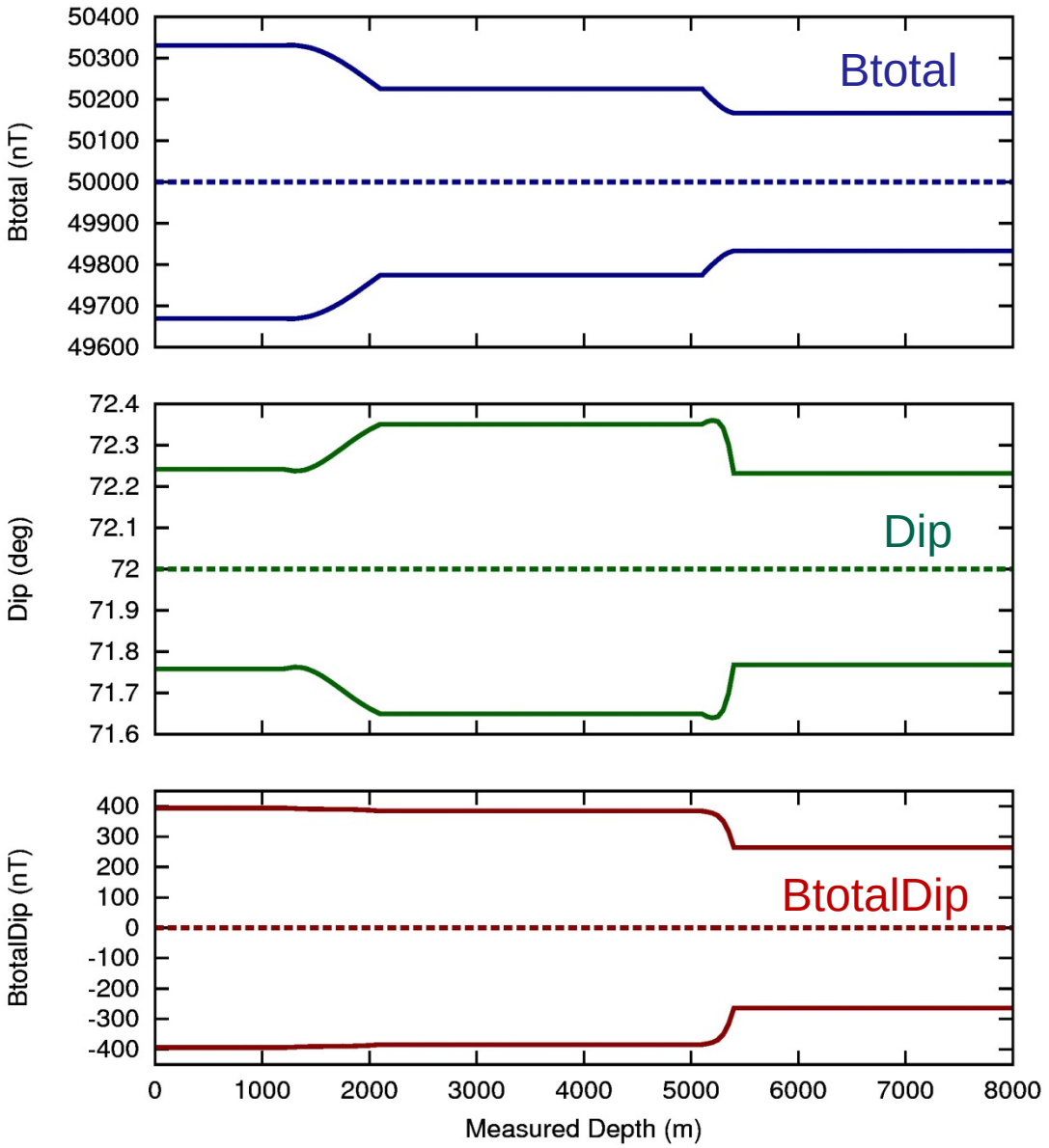
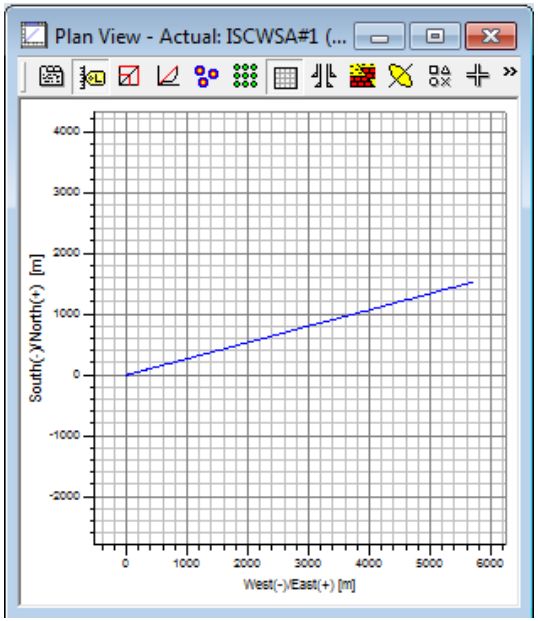
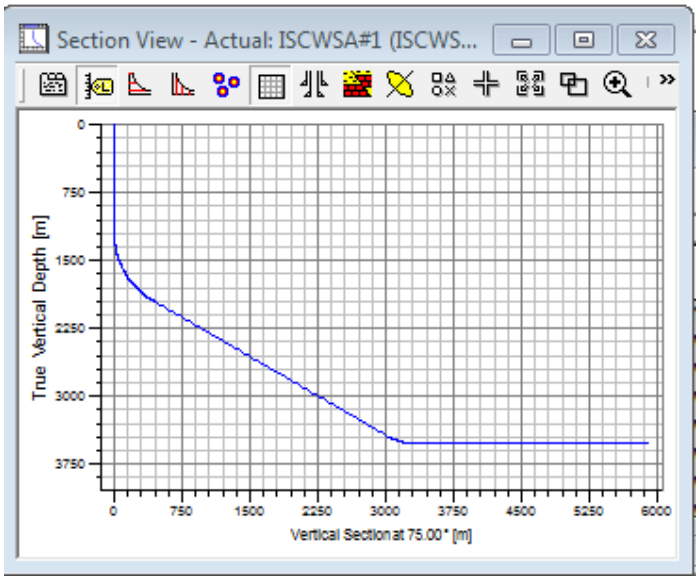


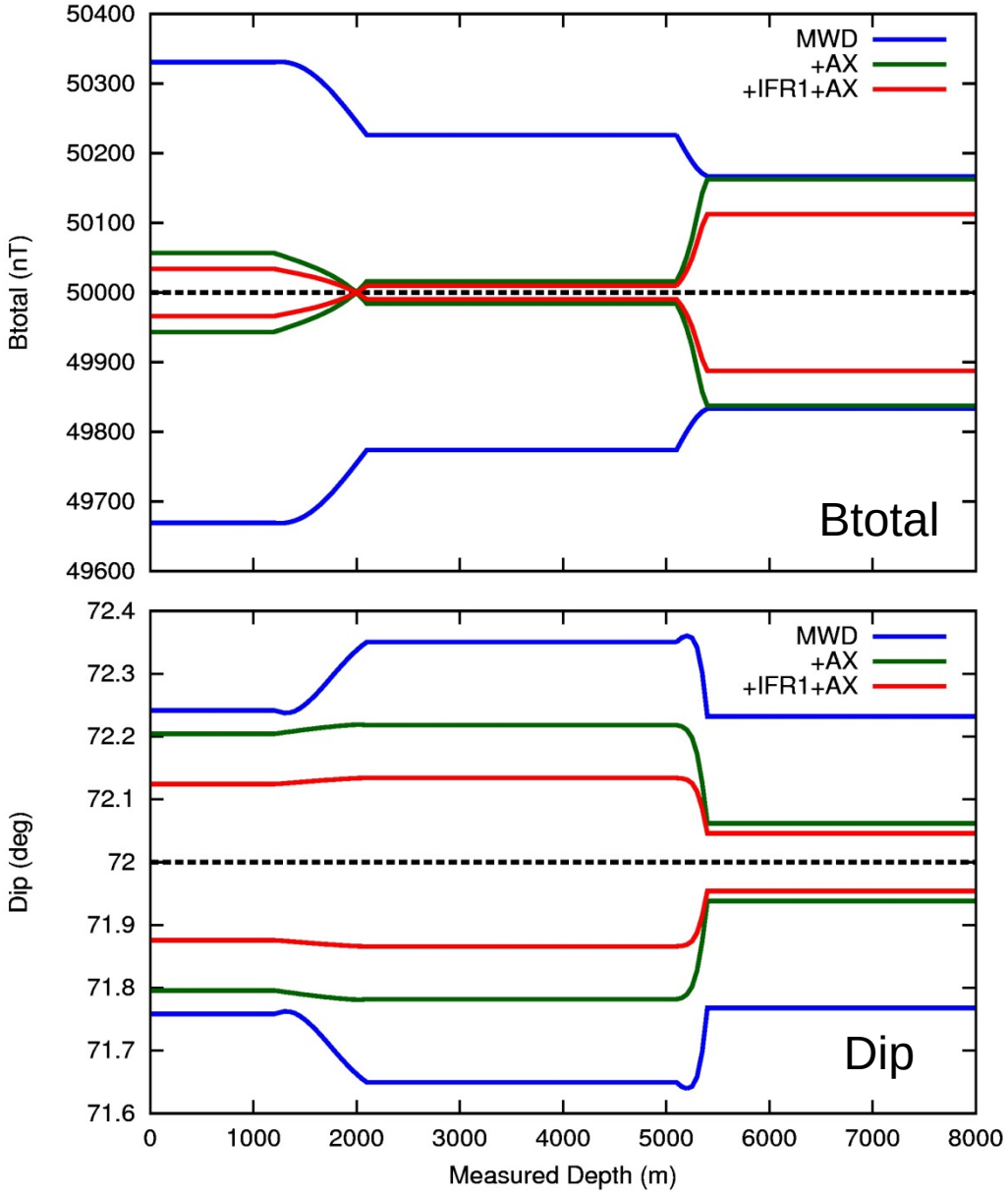




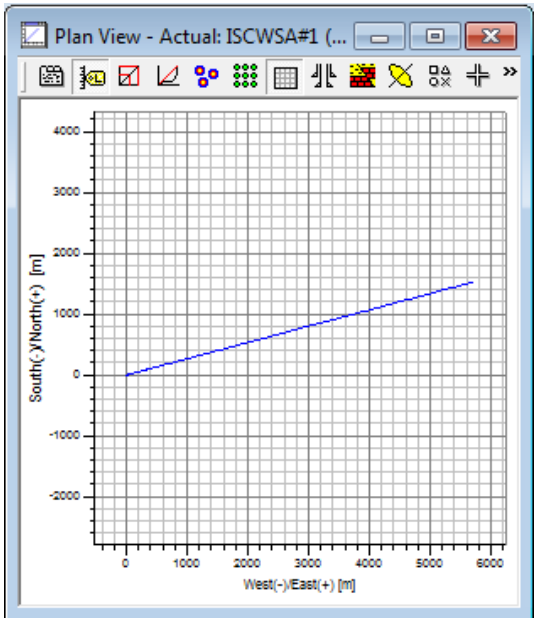
ISCWSA Test Well #1: Axial correction

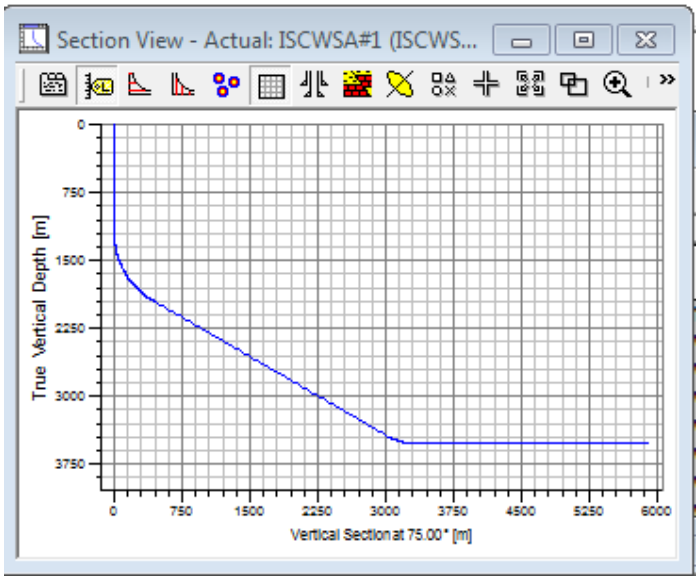


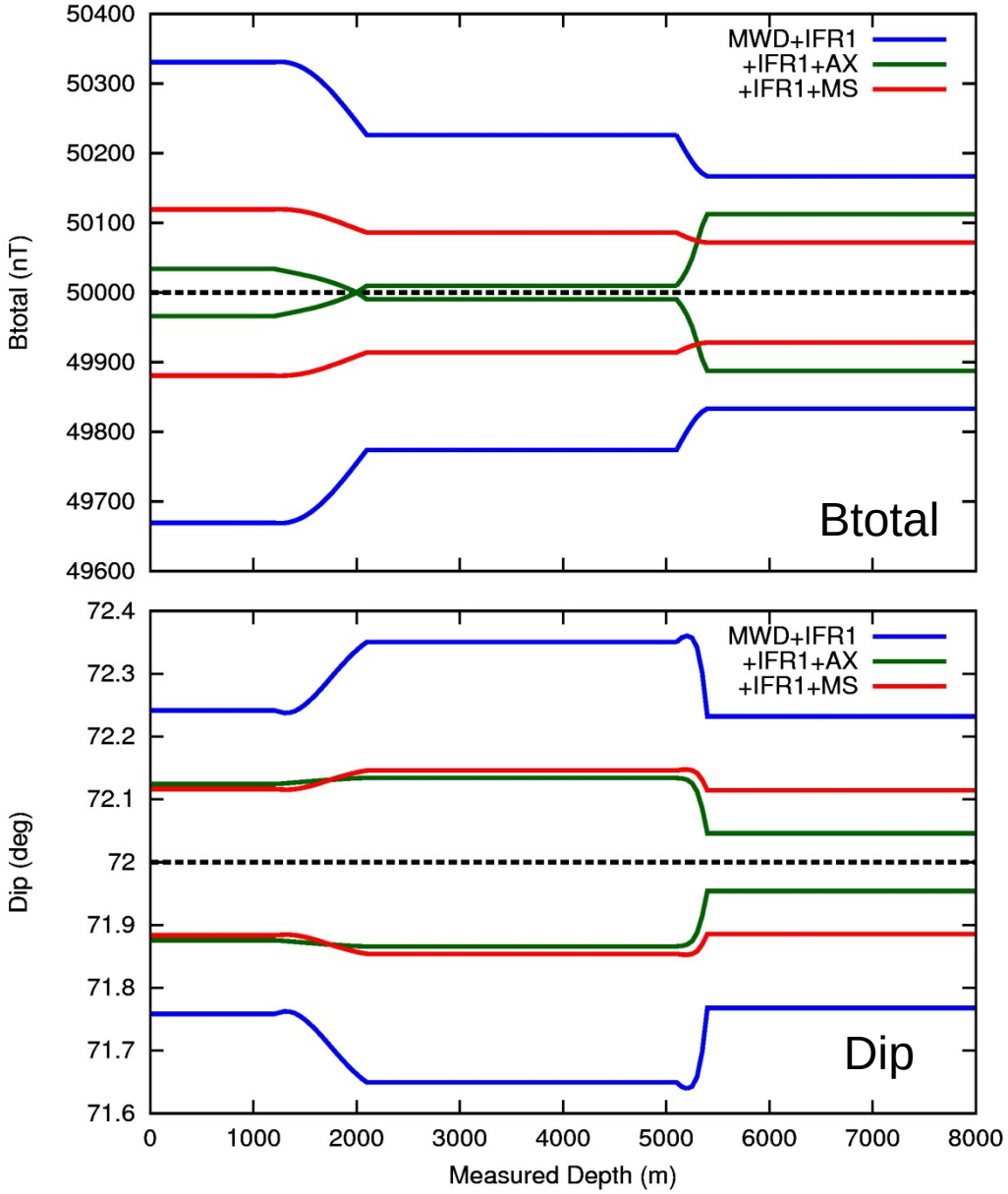




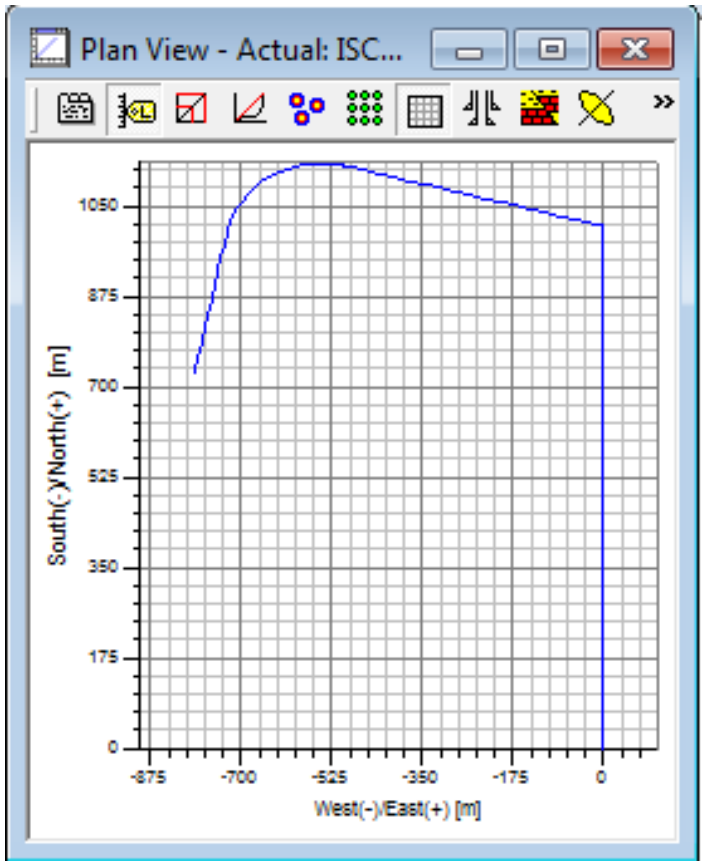
ISCWSA#1: Axial versus Multi-Station Analysis

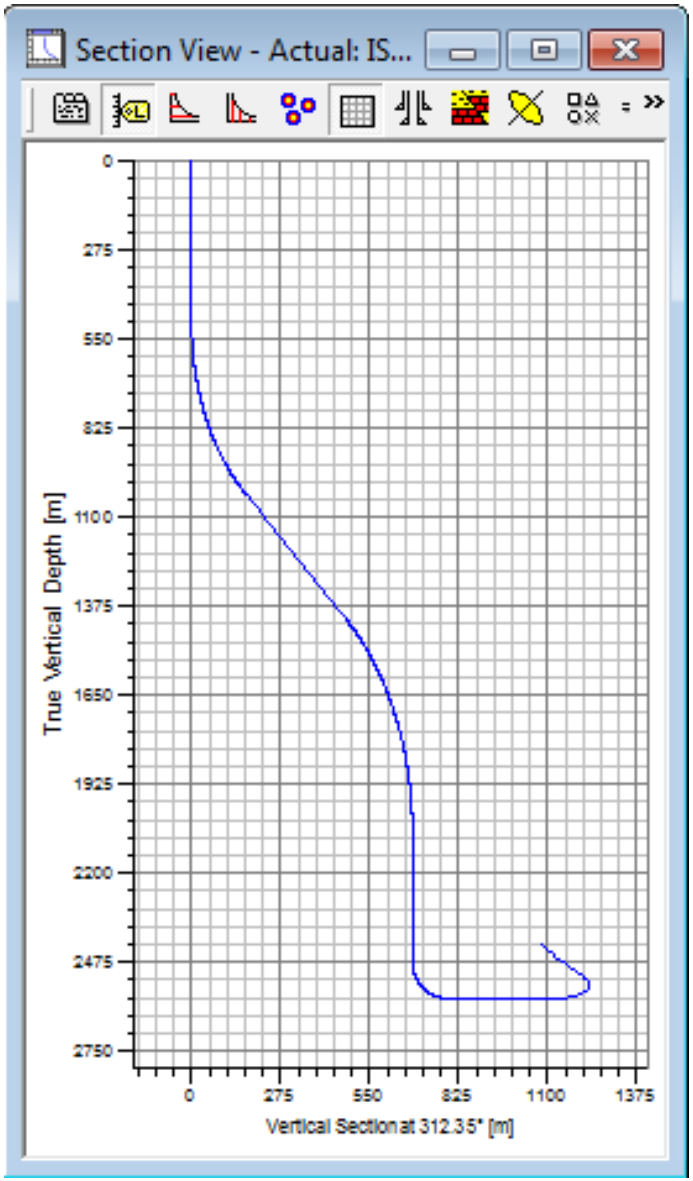




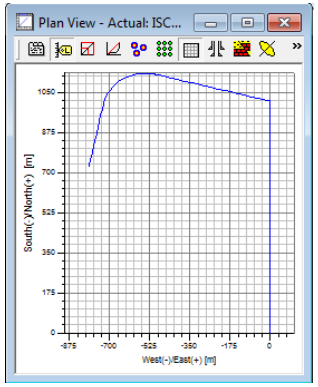


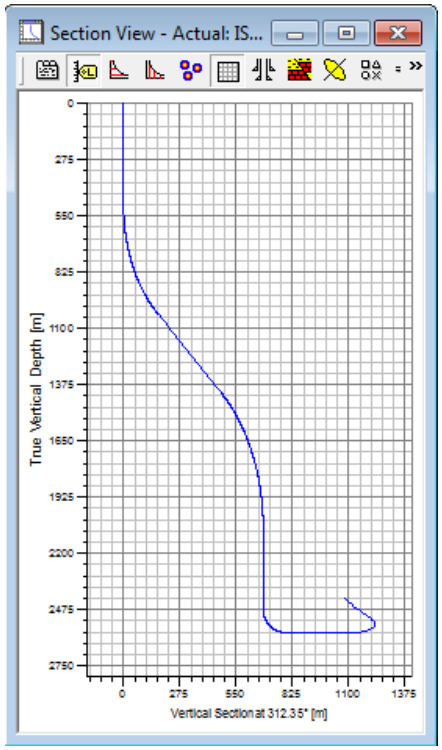
Example 2: ISCWSA Test Well #3

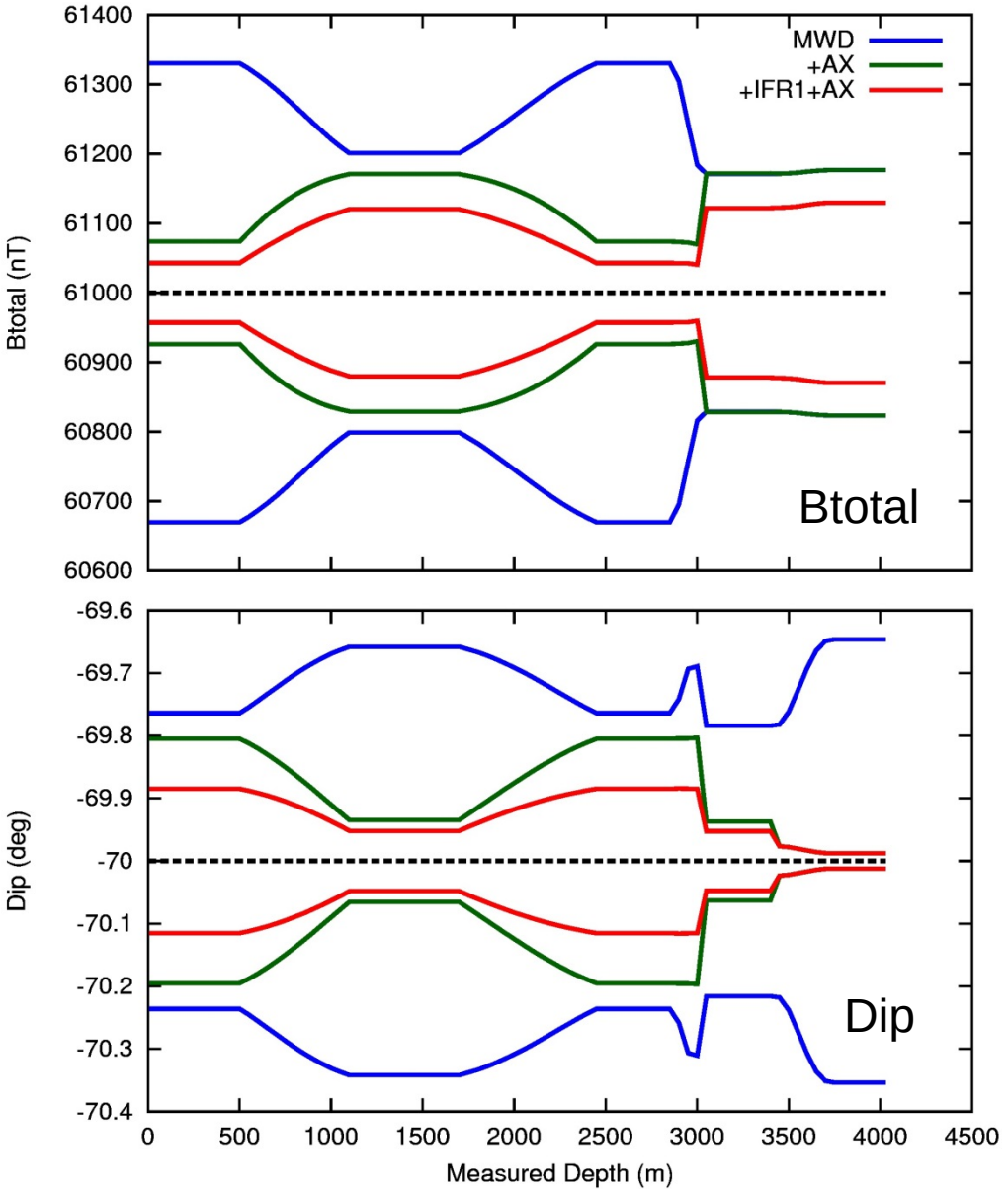




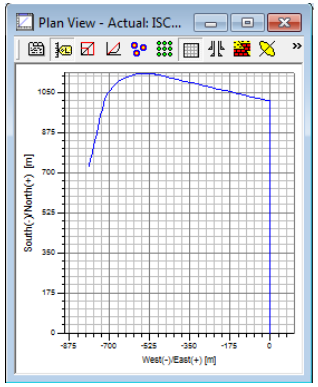
ISCWSA#3: Axial correction (1σ)

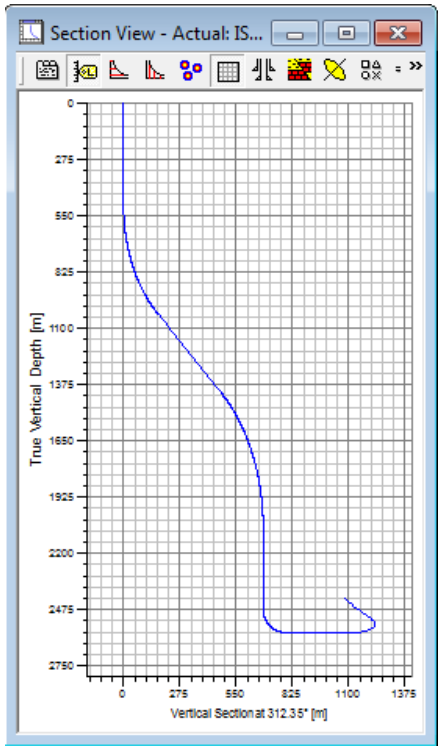


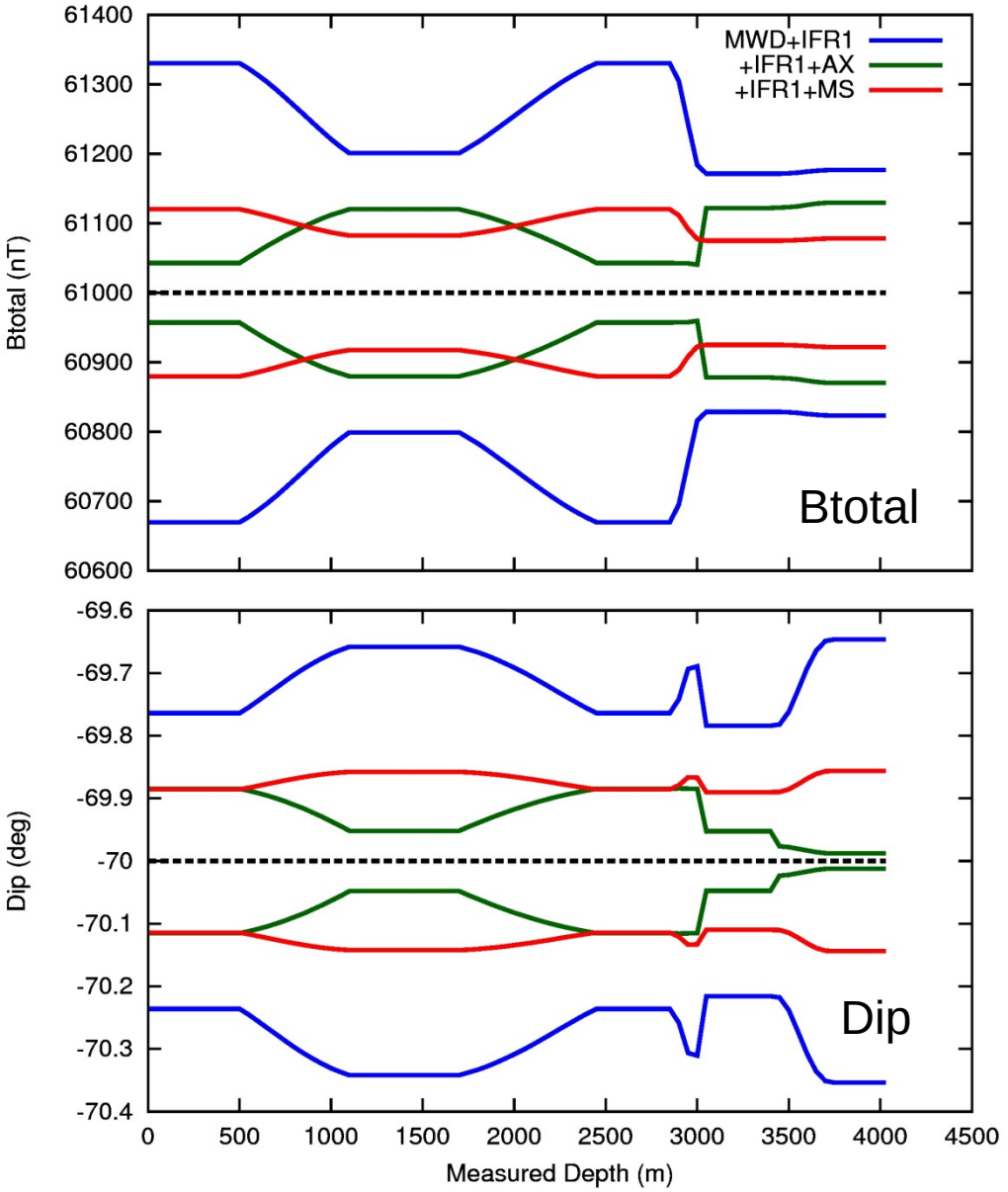




ISCWSA#3: Axial versus Multi-Station Analysis

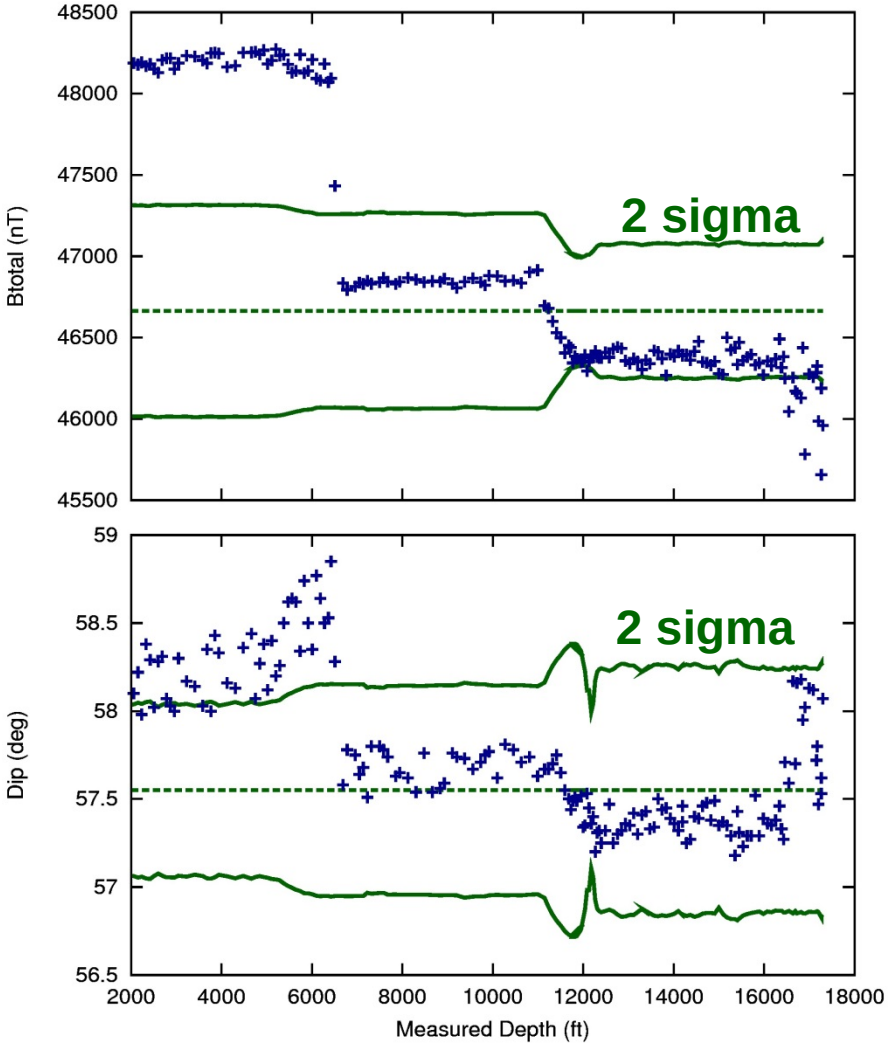




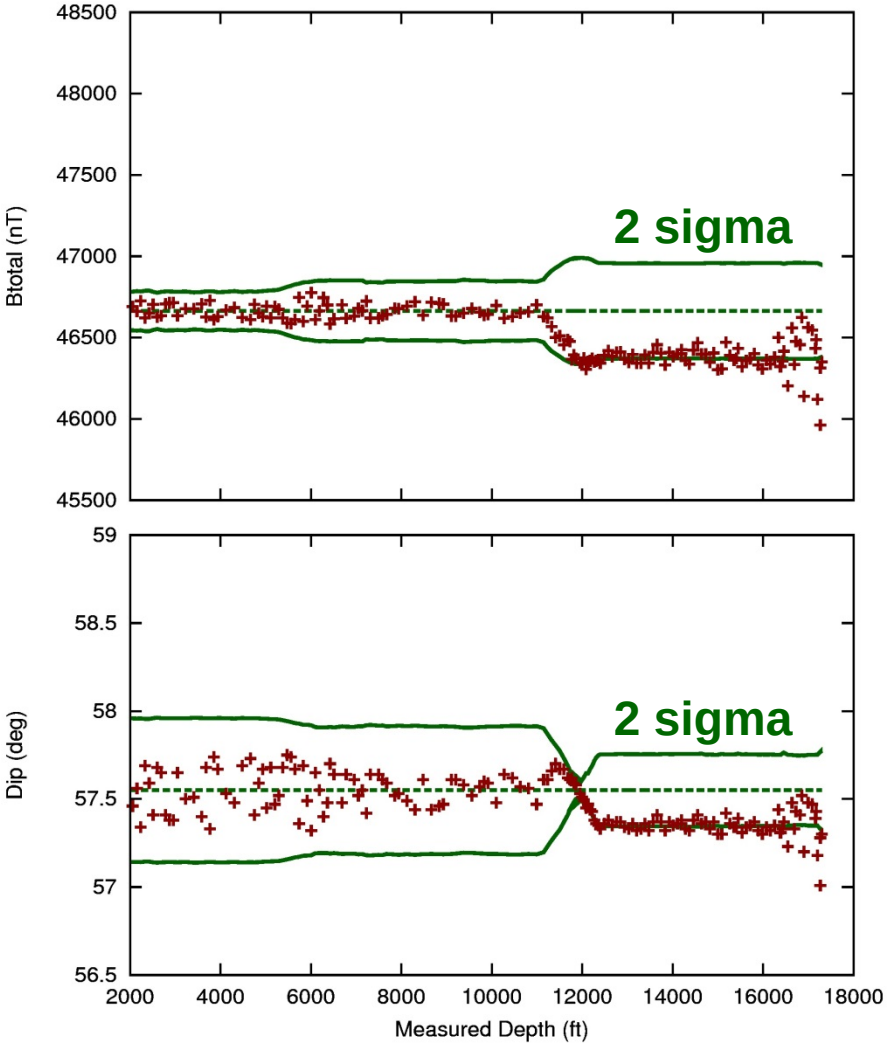


Looking at some real MWD data

Raw data (MWD tool code)



Axially corrected data (MWD+AX tool code)



Implementation: Point value calculator

MagVAR IFR Calculator point processing window

Processing a well trajectory file

MagVAR IFR Calculator well trajectory file processing window

Global average of 1-sigma errors

Linear average over:

- All locations (equal area weighting)
- All well directions (equal angular area weighting)

OWSG Tool Code	Gtotal (m/s^2)	Btotal(nT)	Dip	BTotalDip (nT)	
MWD	**0.017**	**217**	**0.33°**	**343**	**default**
MWD+AX	0.017	103	0.15°	164	
MWD+IFR1	0.017	180	0.28°	292	
MWD+IFR1+AX	0.017	66	0.09°	107	
MWD+IFR1+MS	0.017	83	0.14°	138	
MWD+IFR2	0.017	178	0.28°	287	
MWD+IFR2+AX	**0.017**	**62**	**0.09°**	**100**	**smallest**
MWD+IFR2+MS	0.017	78	0.13°	127	

How to define QC criteria?

If a tool meets the assumptions of the tool code:

- 95.4% of the surveys within ±2 sigma
- Chance that within ±2σ for both grav and mag:

  0.954 x 0.954 = 0.910, say 90%

→ Just under 10% of surveys will be outside of ±2σ

Possible criterion:

"Not more than 10% of surveys should fail QC criteria corresponding to 2 sigma of the selected tool code"

- Sets an ambitious 2 sigma goal
- Robust definition: Non-Gaussian distributions have 95% percentile near 2σ

Conclusions and Outlook

- OWSG tool codes → 1σ errors in Gtotal, Btotal Dip
  - Some missing parameters: GFI, MFI, MDI
- Errors depend on the location and orientation of well
- Application 1: To analyze MWD tool performance
- Application 2: To define QC criterion

Suggestion: “Not more than 10% of surveys should fail QC criteria corresponding to 2 sigma of the selected tool code”

Helpful discussions with Son Pham, Neil Bergstrom and Andy Brooks are gratefully acknowledged