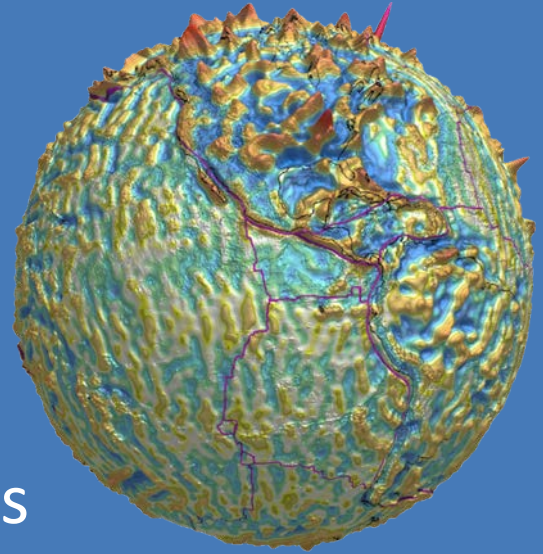# Magnetic Referencing and Survey Accuracy for Horizontal Development in the Permian
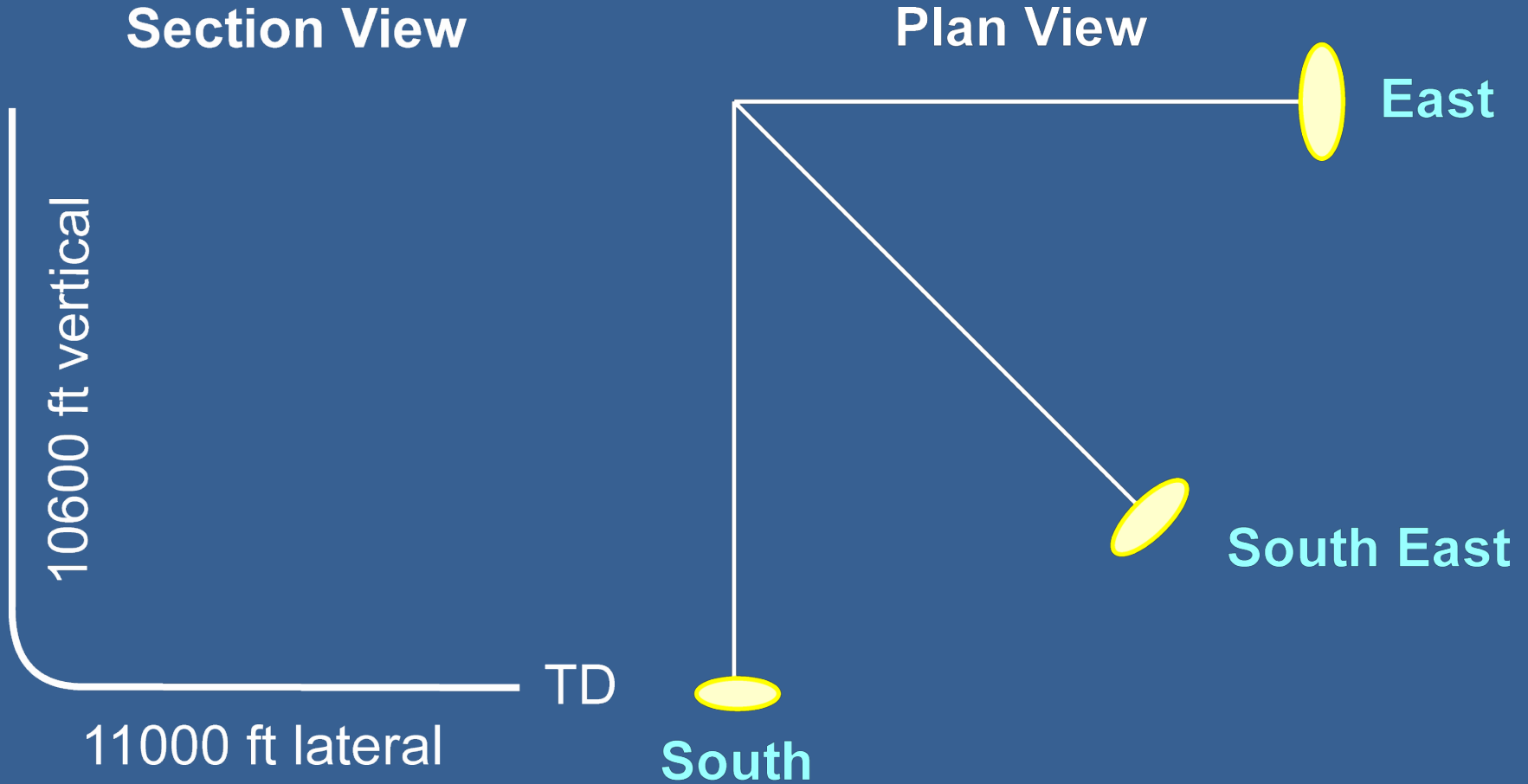
- Wellbore position uncertainty
- Global and local geomagnetic models
- Quality control and advanced corrections
  - Tool code and orientation dependent QC thresholds
  - Multi-Station Analysis (MSA)
- New OWSG tool codes for well planning and AC

Stefan Maus, AADE Luncheon, 02/05/2015

© MagVAR 2015

Positional Uncertainty in MWD

- Largest source of lateral error: Magnetic field
- Accurate geomagnetic models and advanced corrections significantly reduce this error

MWD+IFR1+MS+sag   MWD Only

Halliburton
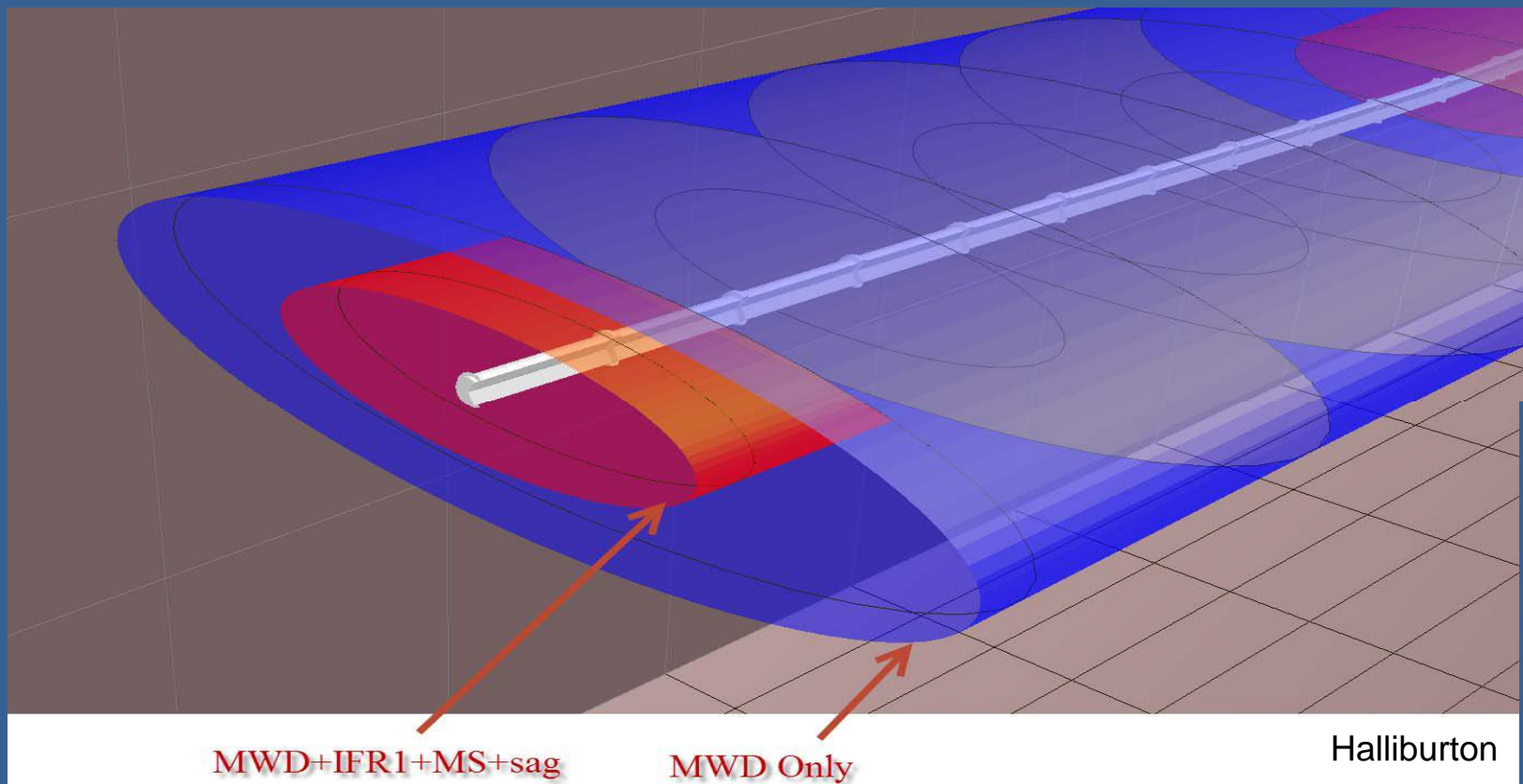
Ellipses of Uncertainty Study

Section View

Plan View

10600 ft vertical

11000 ft lateral

TD

East

South East

South

Uncertainties in West TX

Lateral Uncertainty at TD

Well Azim.	Lateral Length	MWD	MWD +IFR1	MWD +IFR1+MS
	(ft)	(ft)	(ft)	(ft)
E	11000	439	390 (-11%)	173 (-61%)
SE	11000	387	329 (-15%)	160 (-59%)
S	11000	259	161 (-38%)	129 (-50%)

Vertical Uncertainty at TD

TVD	MWD	MWD+IFR1+SAG+MS
10600 ft	119 ft	71 ft (-40%)

3D Ellipsoids given for 95% confidence interval = 2.79 sigma

Error model: ISCWSA OWSG

© MagVAR 2015

What Does the MWD Tool Measure?
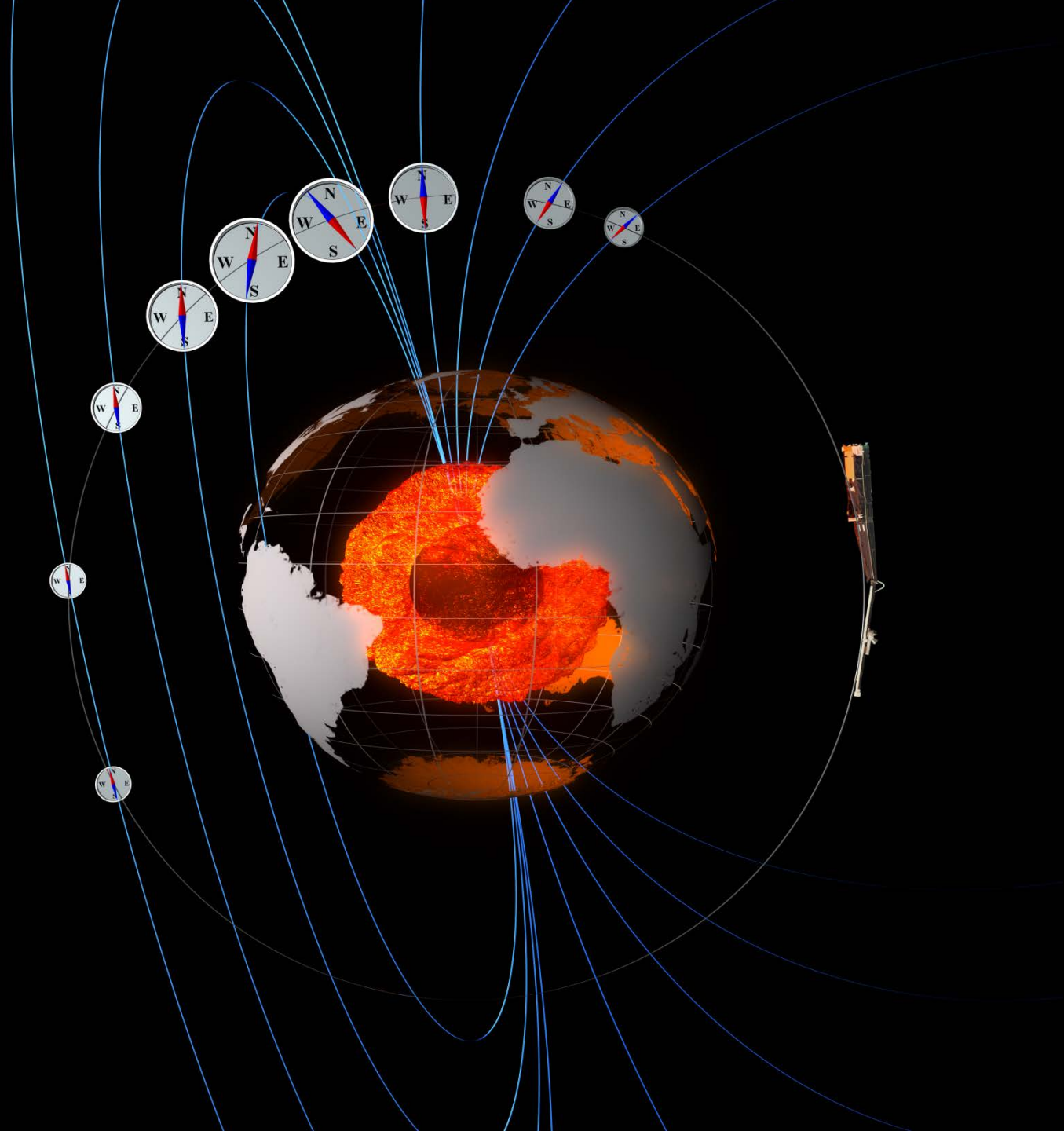
Bx, By, Bz

Gx, Gy, Gz
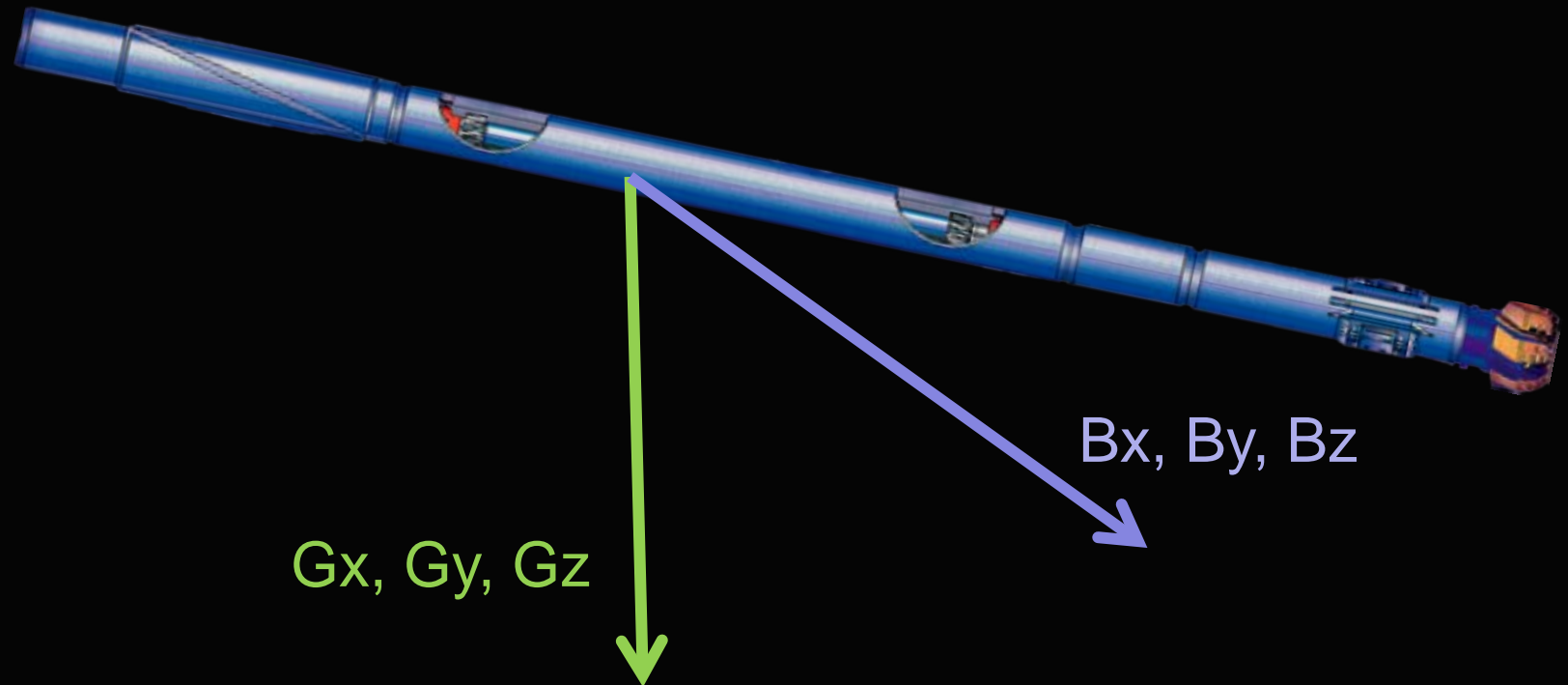
- Compute Inclination, Magnetic Azimuth, Tool Face
- True Azimuth = Magnetic Azimuth + Declination

© MagVAR 2015

Magnetic Elements Given by Model
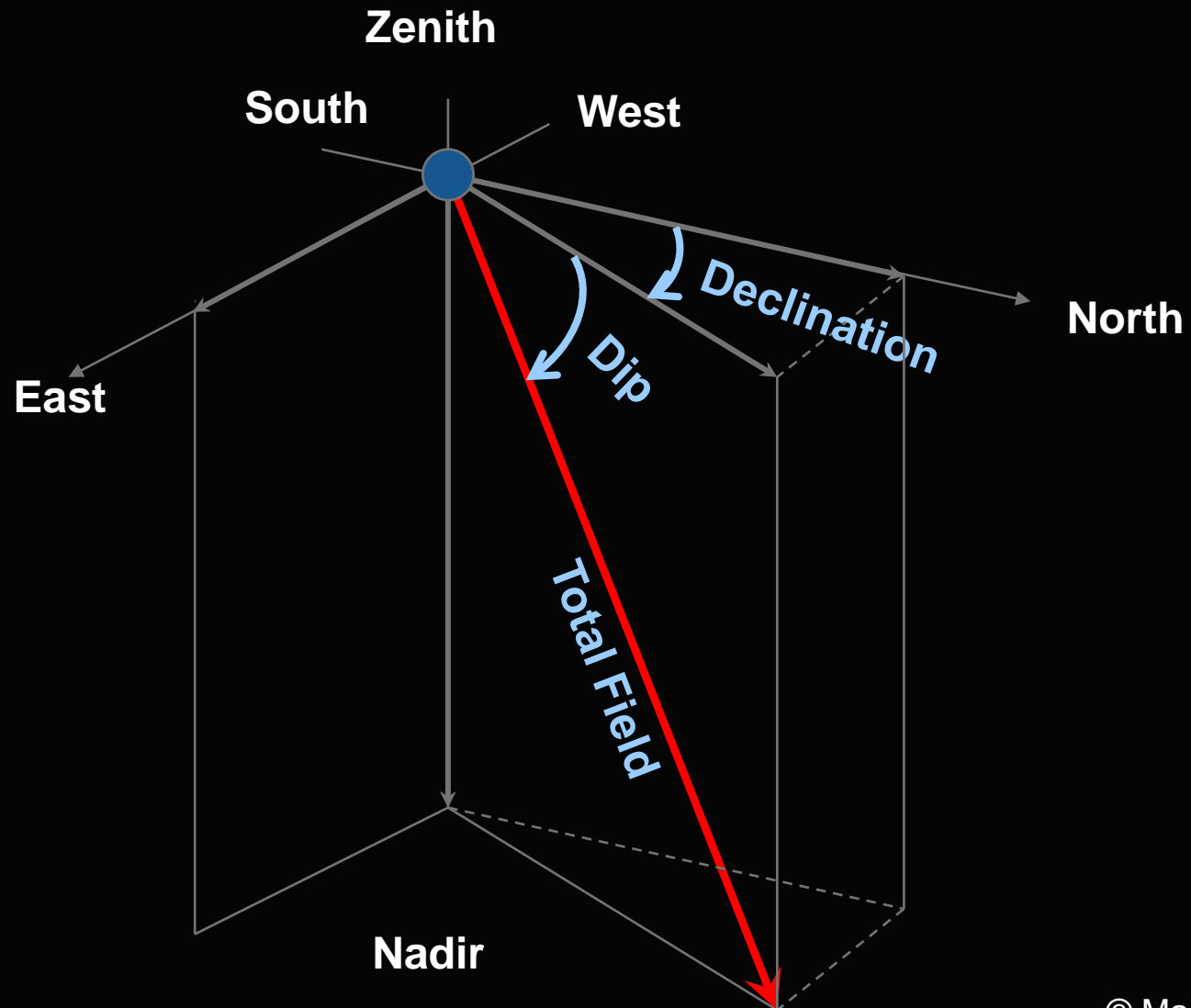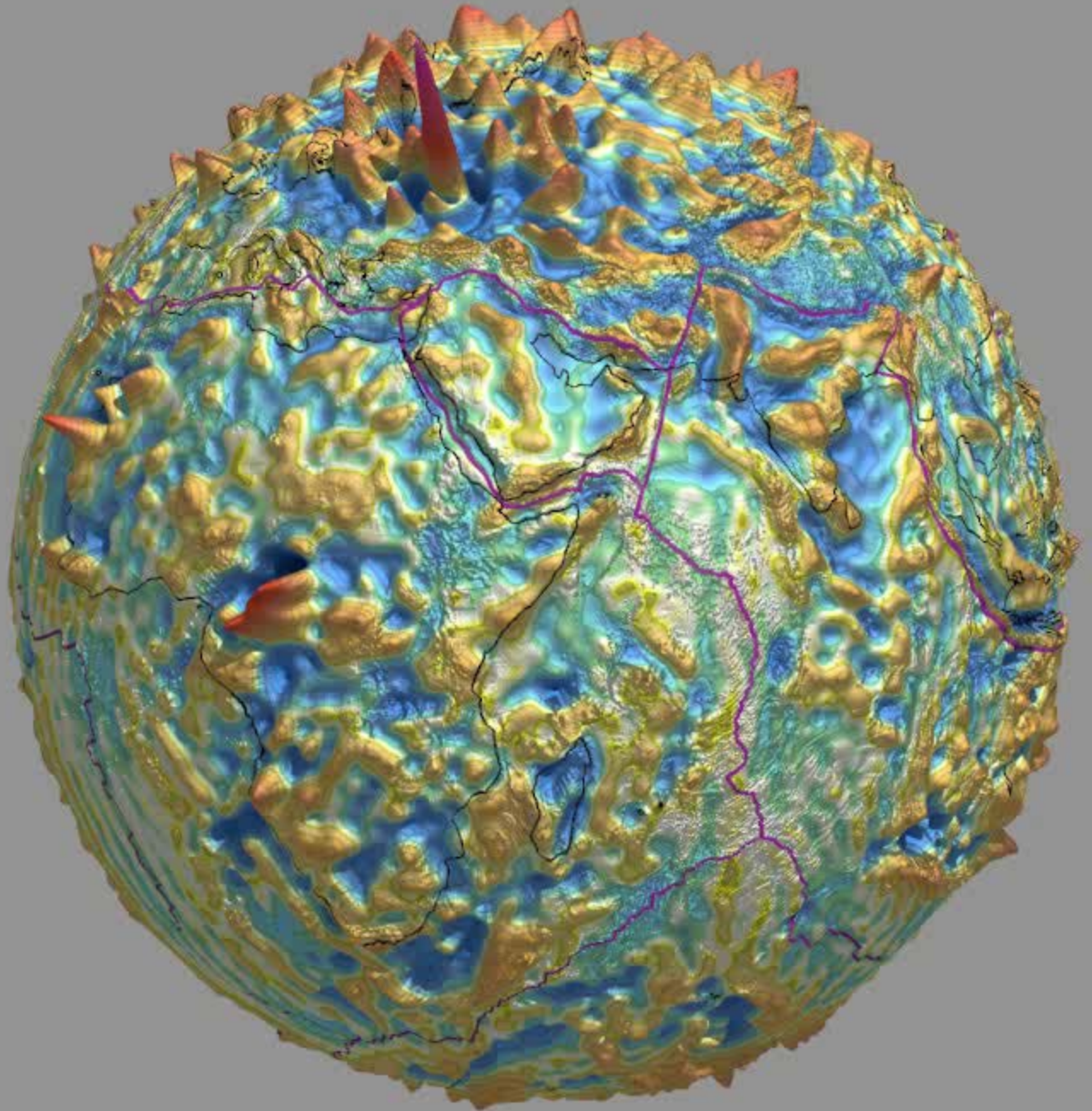
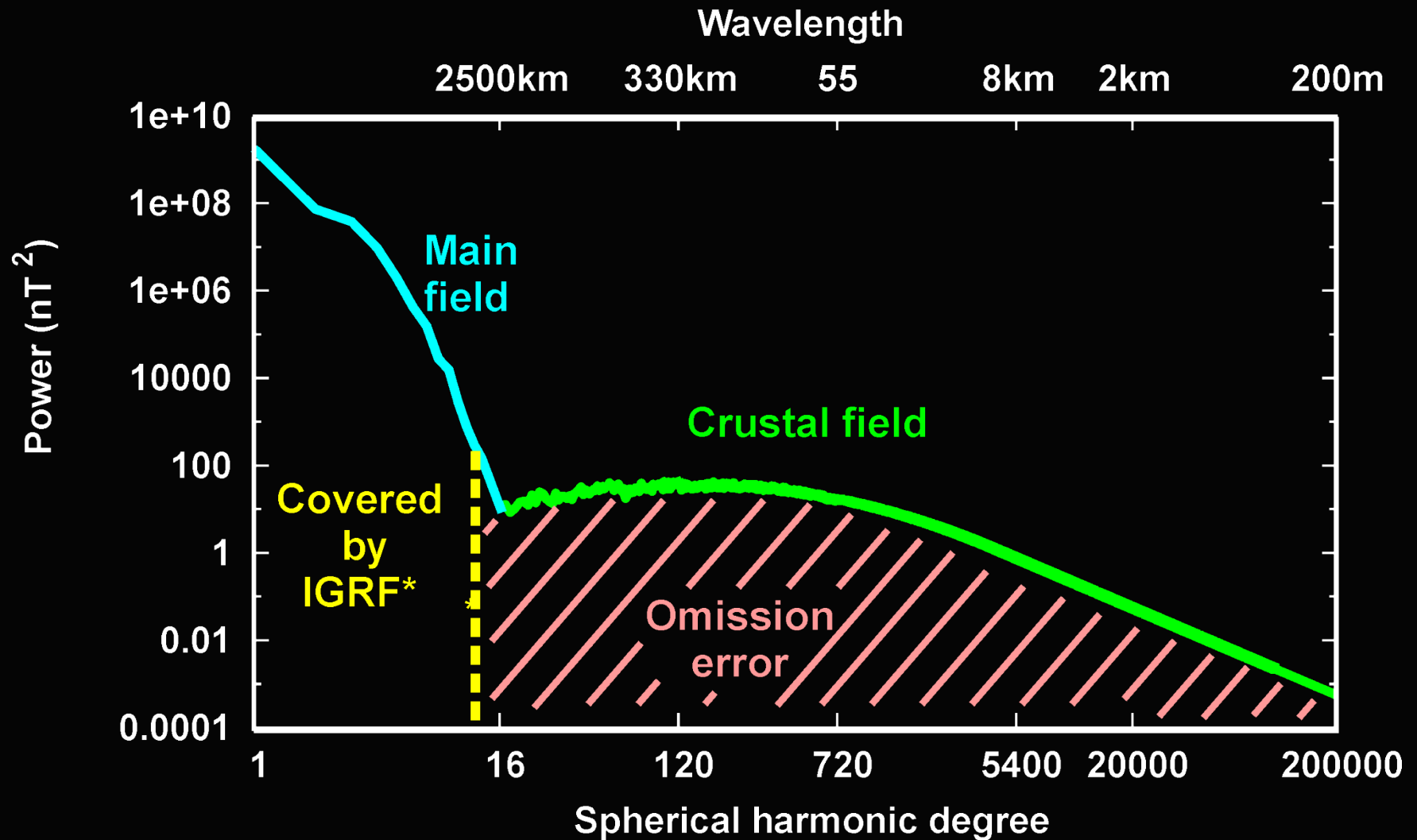Main Field Originating in the Earth's Core

European Space Agency, Swarm project

Crustal magnetic field as seen by CHAMP satellite

Vertical component of the magnetic field
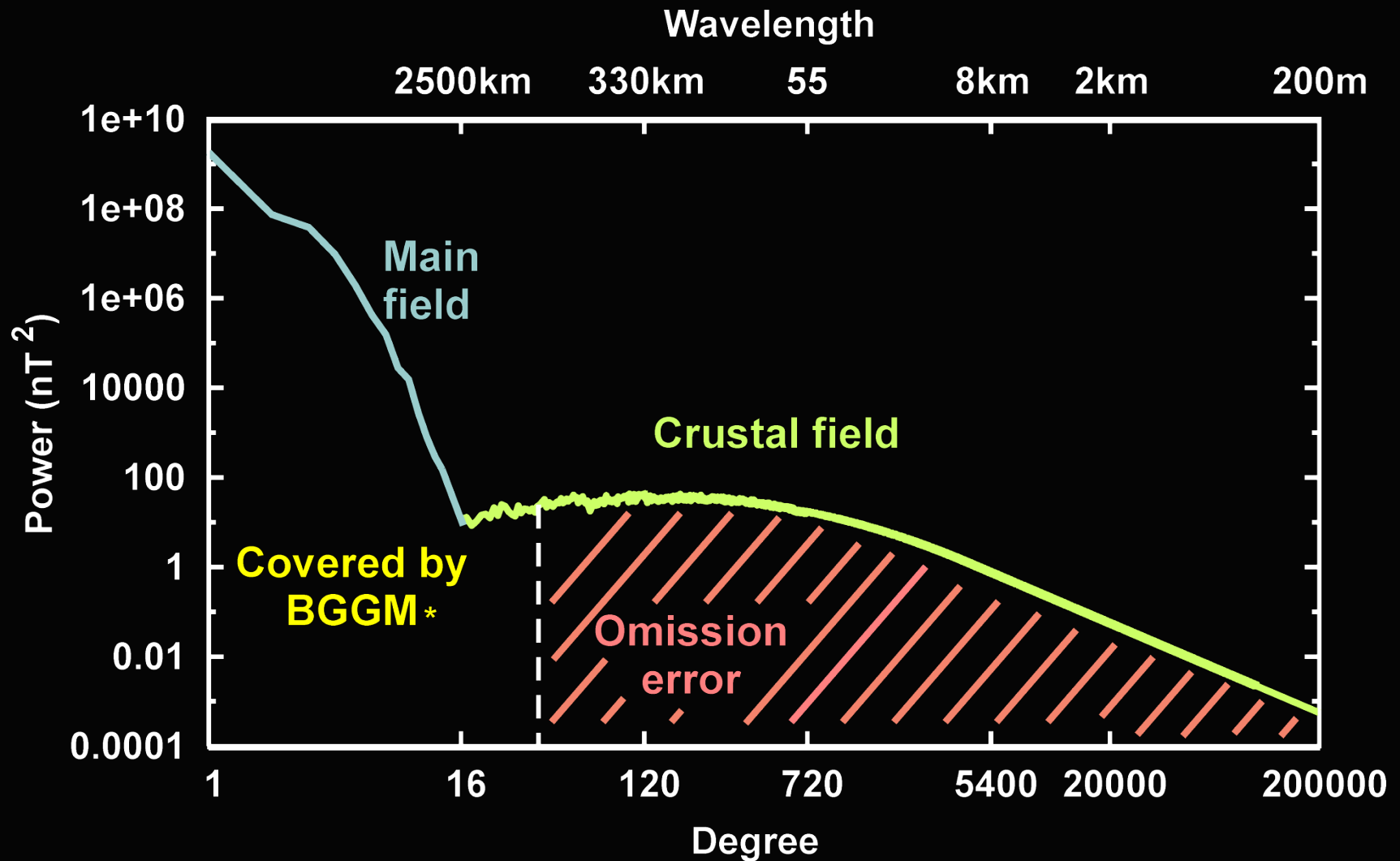
MF7 model
Animation by
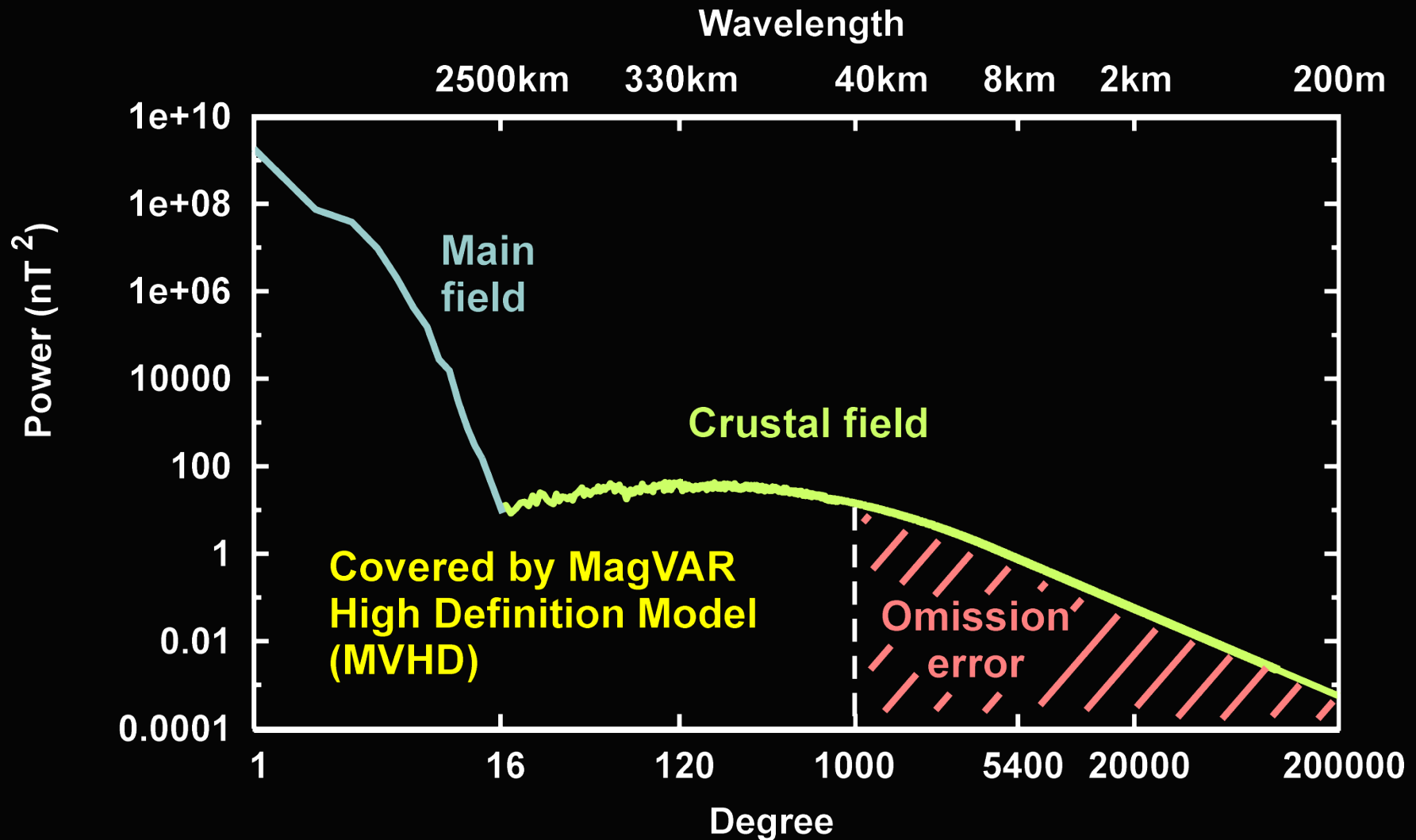Rother and Maus

© MagVAR 2015

Omission Error: IGRF

*IGRF = International Geomagnetic Reference Field

Omission Error: BGGM

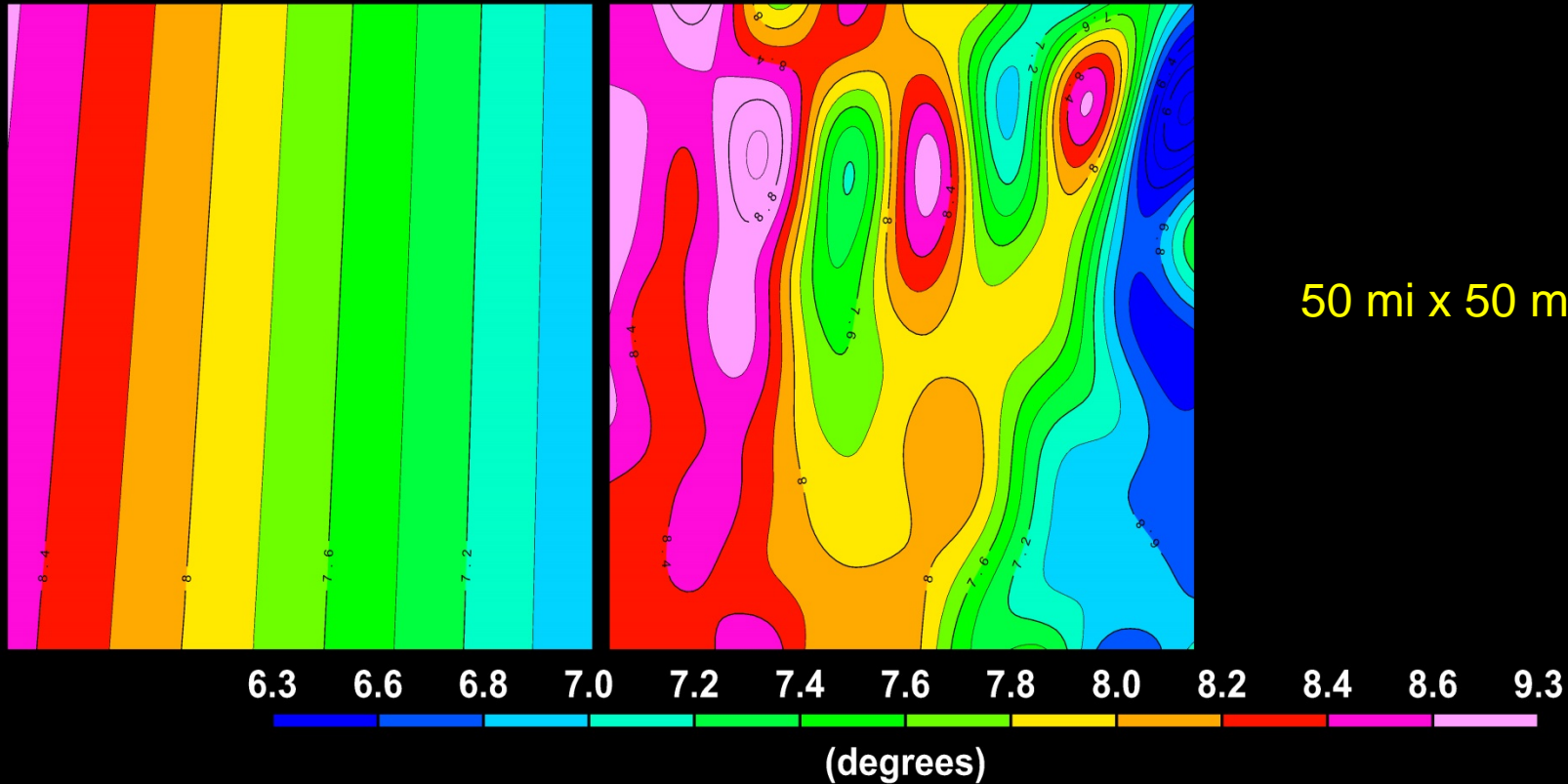*BGGM = BGS Global Geomagnetic Model

Latest High Definition Model (MVHD)

Declination Comparison

Main Field   MVHD

50 mi x 50 mi

6.3   6.6   6.8   7.0   7.2   7.4   7.6   7.8   8.0   8.2   8.4   8.6   9.3

(degrees)

Global Model Calculator

Global Model Calculator

Omission error: MagVAR-IFR
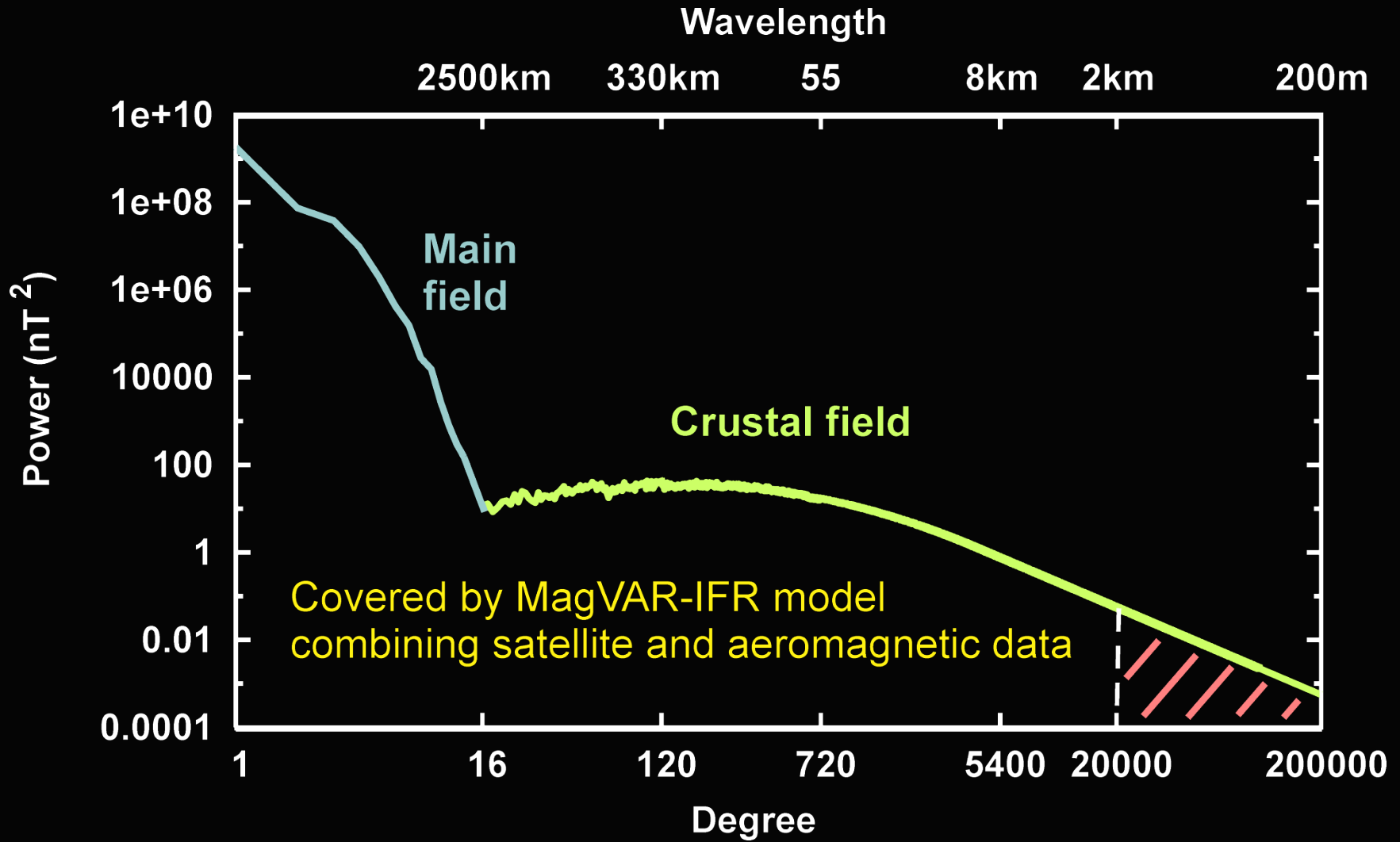
Model Comparison

Main Field   MVHD   MagVAR IFR

6.3   6.6   6.8   7.0   7.2   7.4   7.6   7.8   8.0   8.2   8.4   8.6   9.3

(degrees)
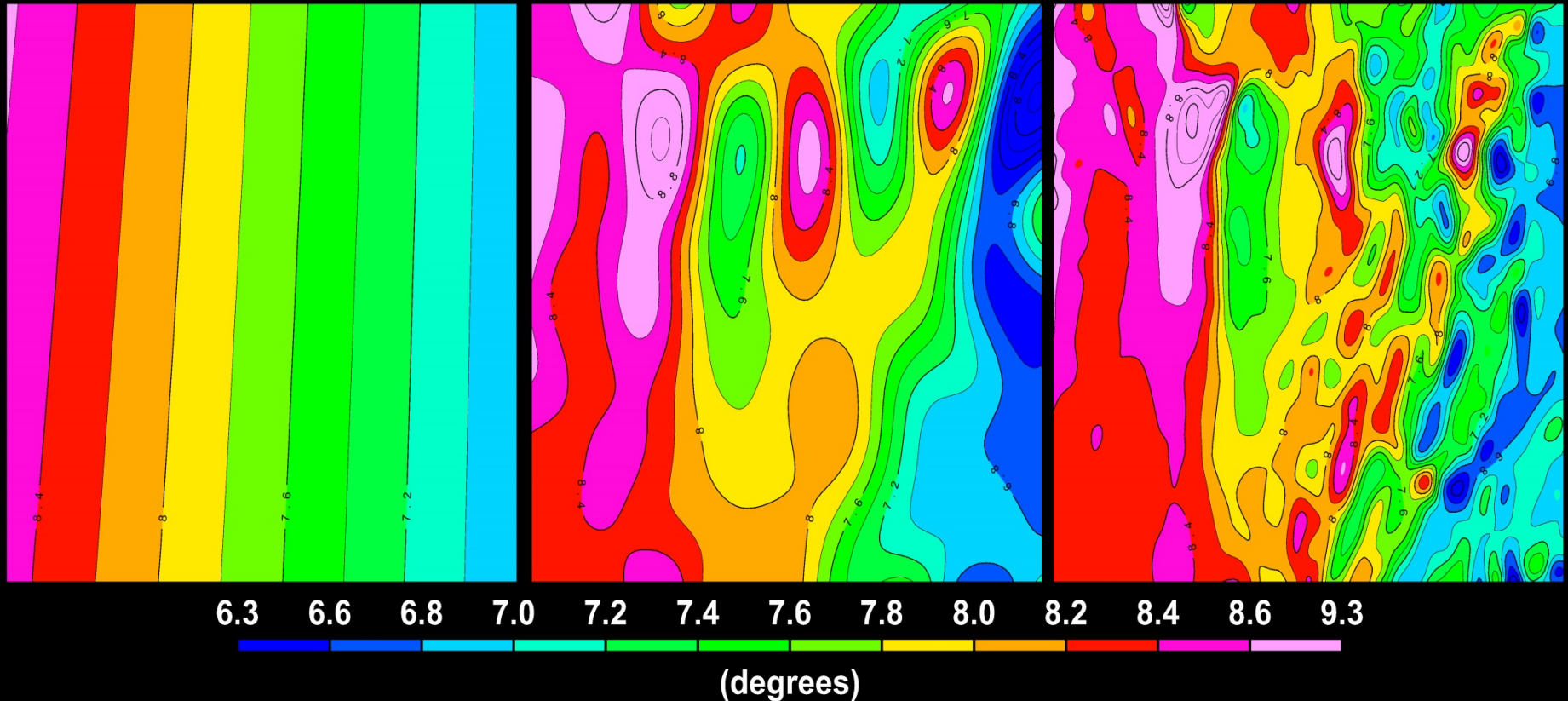
The most detailed magnetic reference is given by In-Field Referencing (IFR)

Permian Basin Aeromagnetic Surveys

450000 500000 550000 600000 650000 700000 750000 800000 850000 900000 950000 1000000

Aeromagnetic Data Coverage
Permian Basin, Texas
Magnetic Variation Services LLC

25000 0 25000 50000 75000
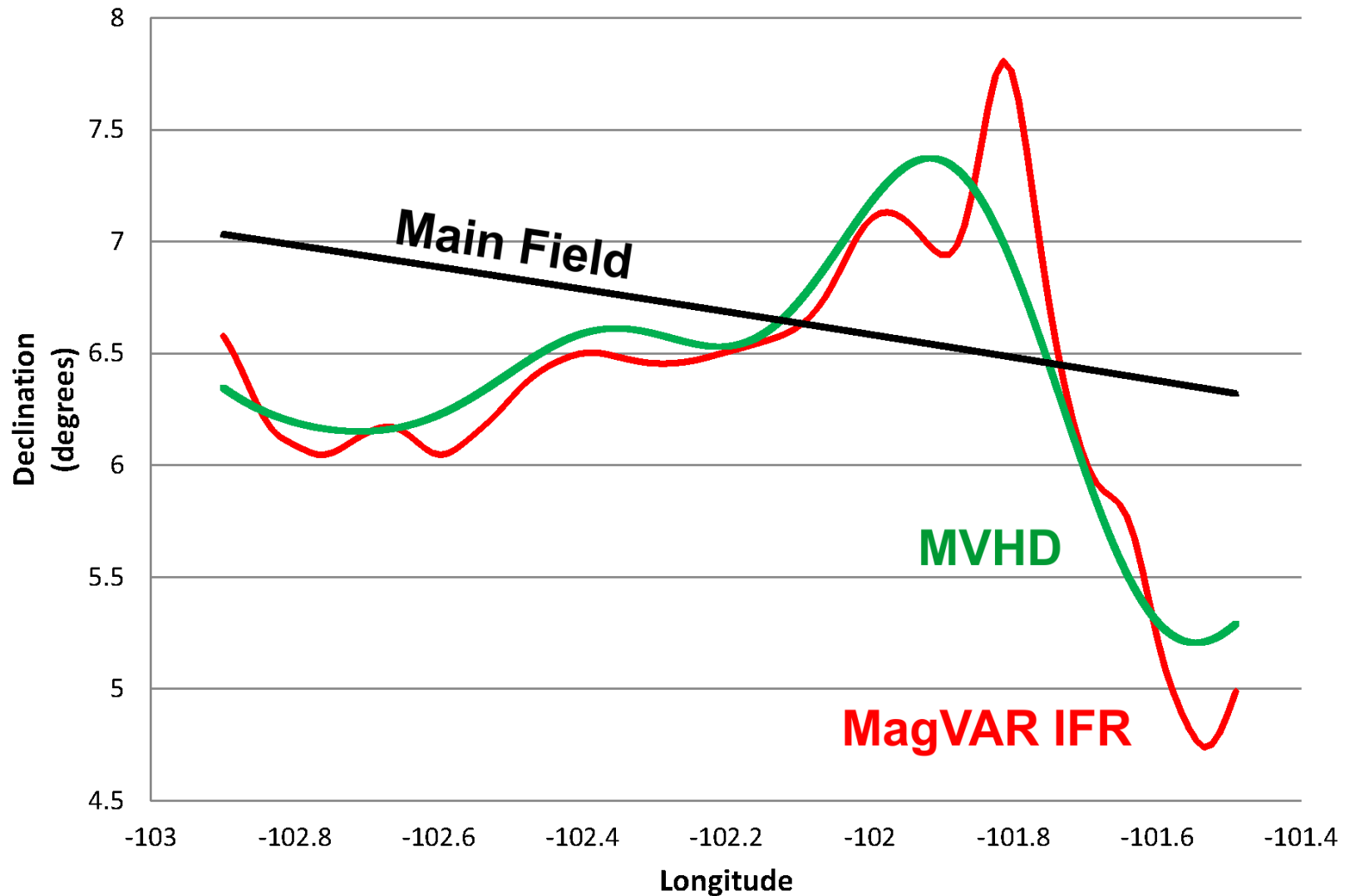(meters)
WGS 84 / UTM zone 13N

-N-
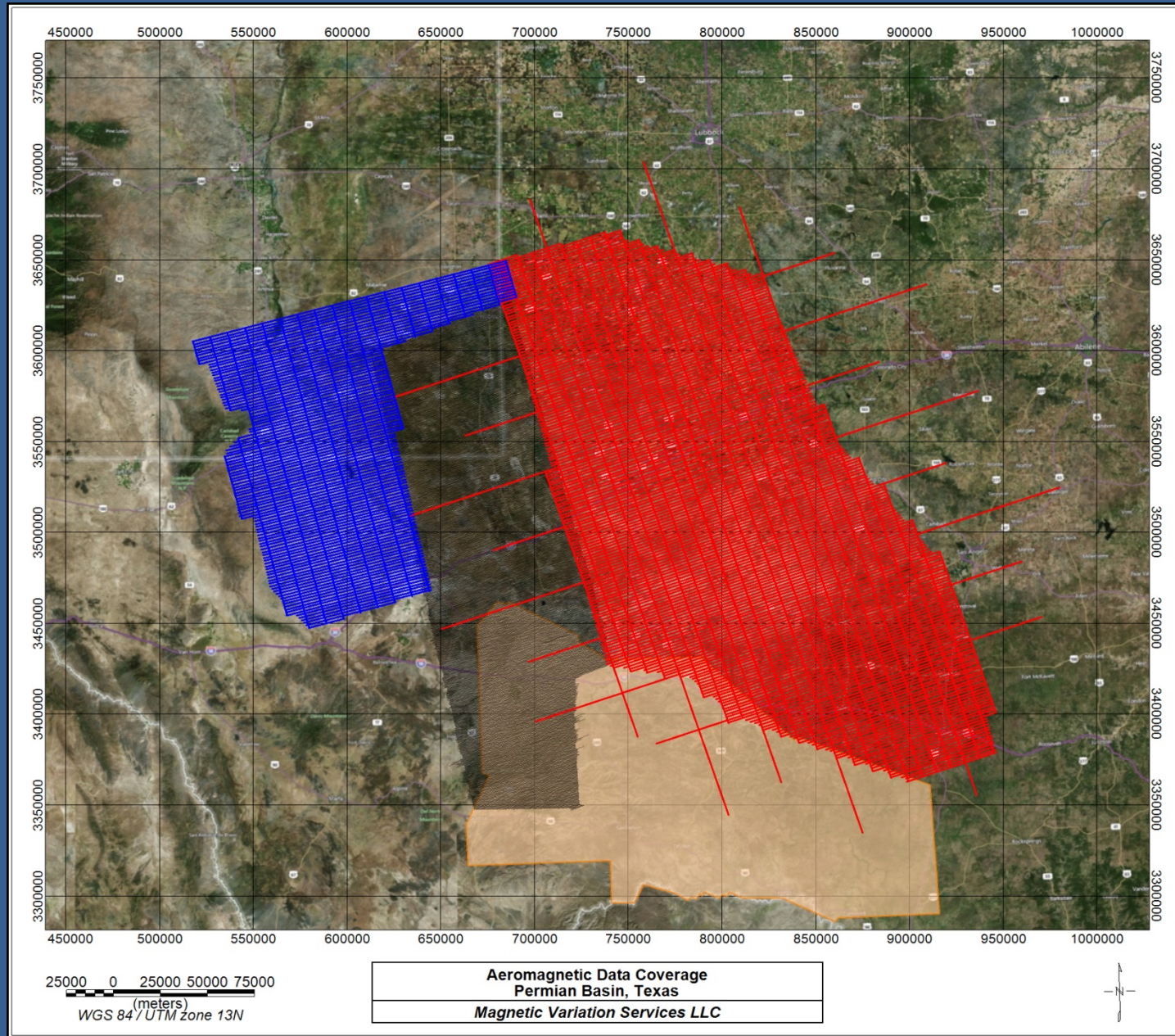
Total Field Comparison
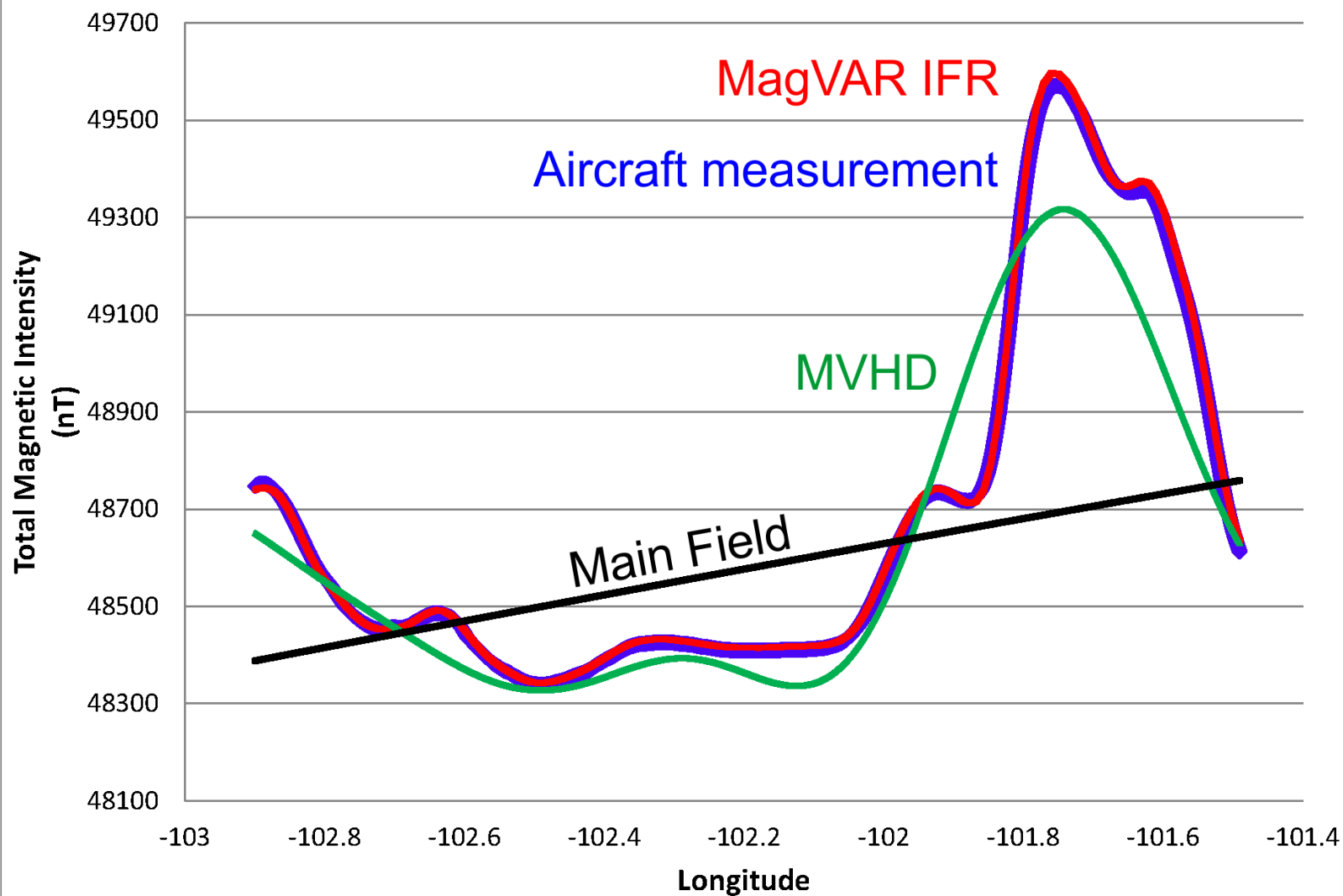
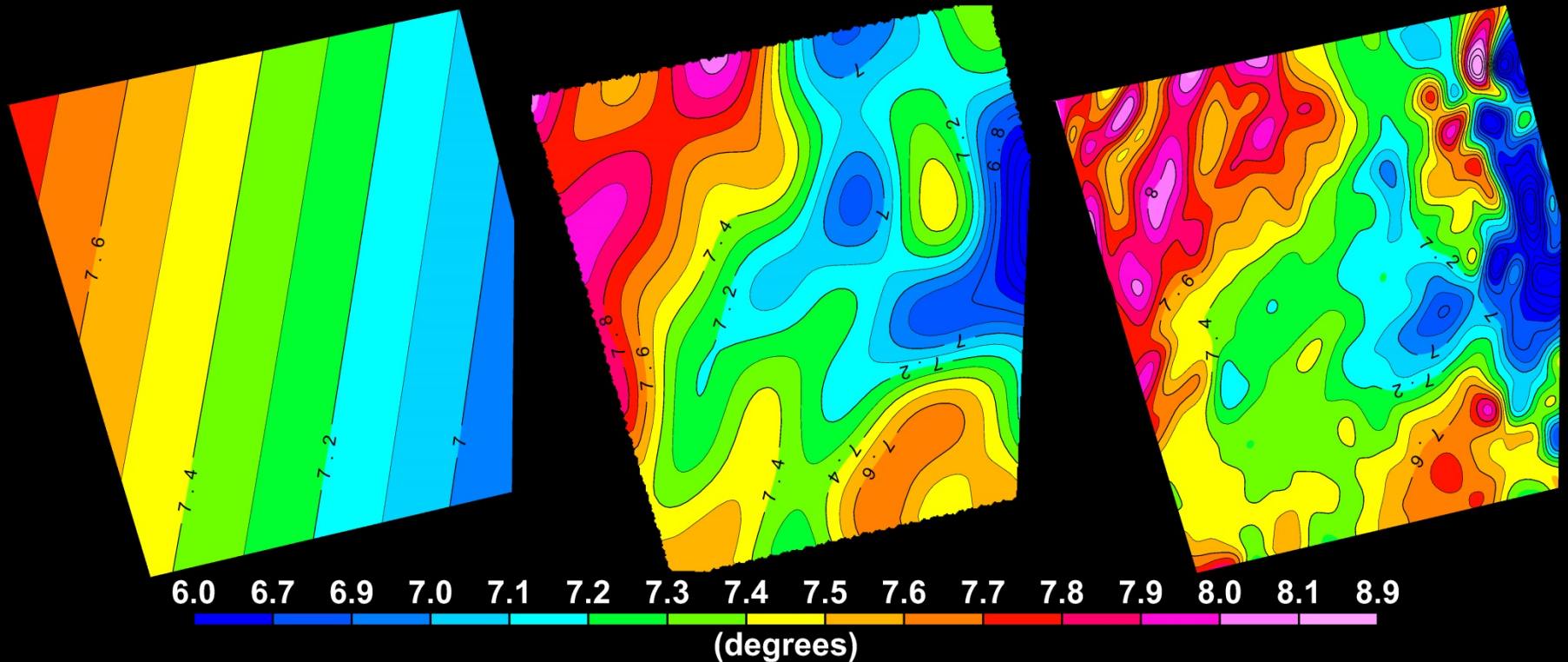Declination Comparison

Declination at 10,000 ft TVD
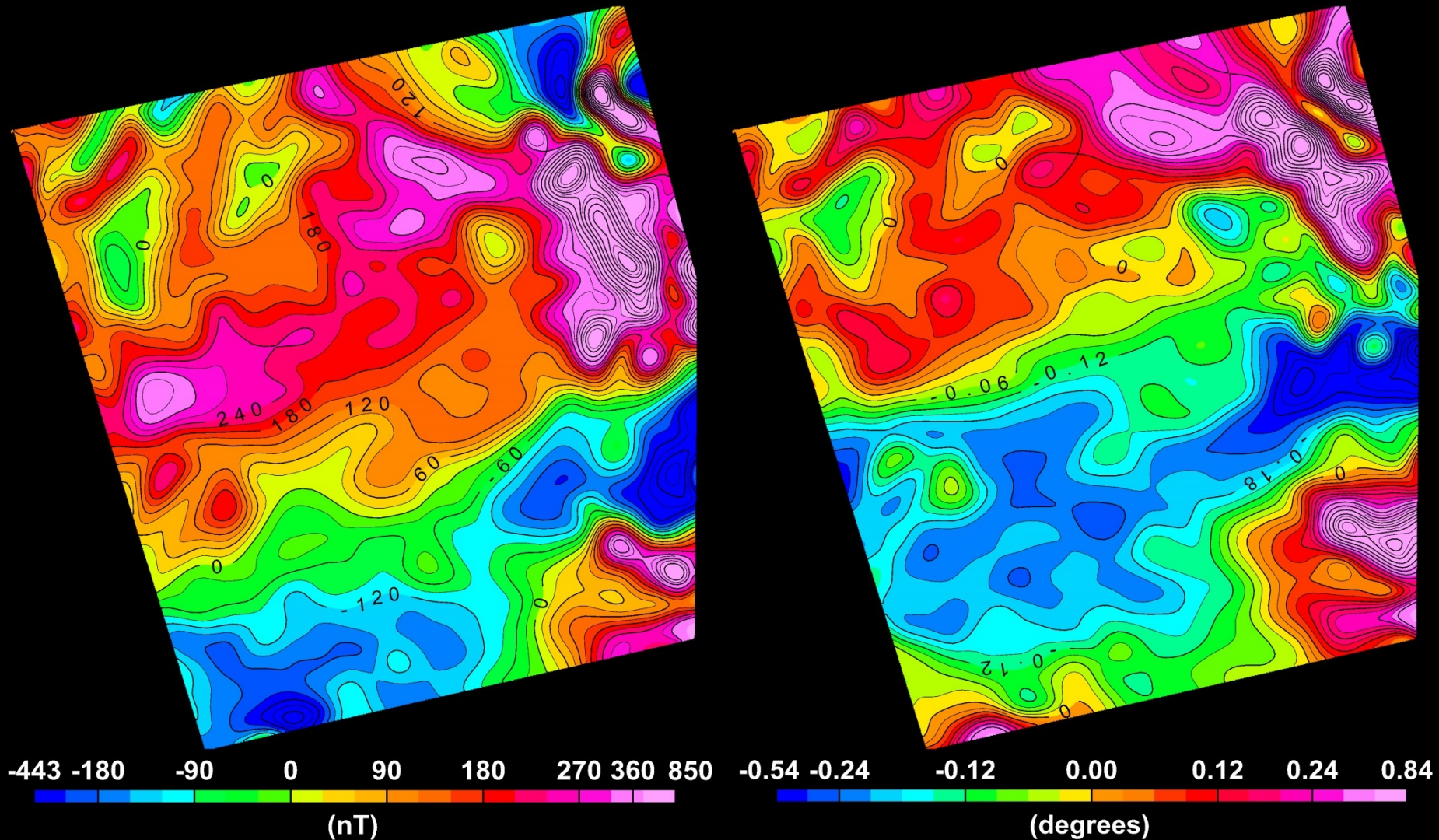

Main Field   MVHD   IFR

Total Field and Dip anomalies (IFR)

MagVAR IFR Calculator

Graphical User Interface provides magnetic reference values and gradients

Export well plan from data base

Auto-generated IFR Values for Sections

Auto-generated IFR Well Segments

Small magnetic gradients
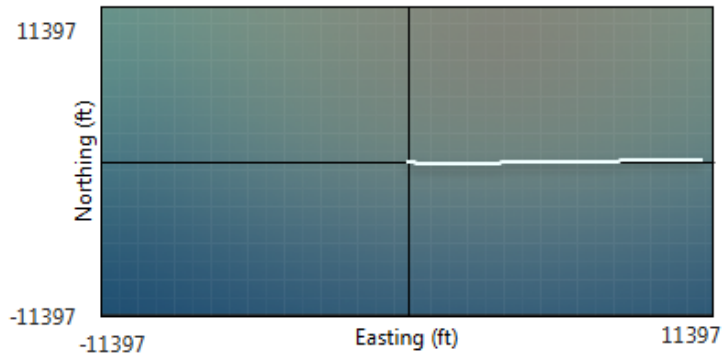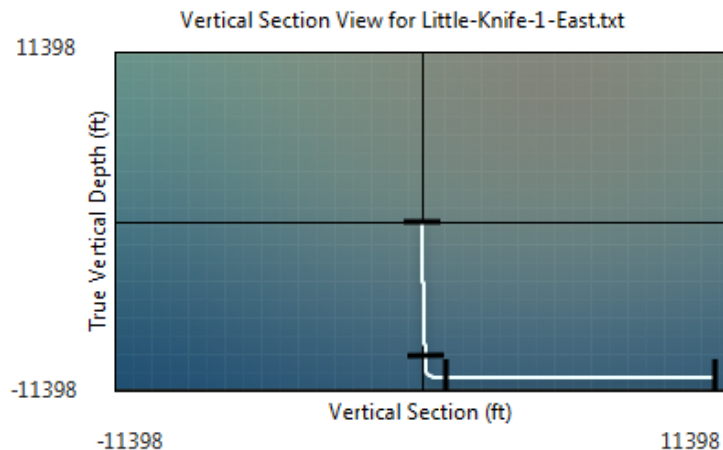
Large magnetic gradients
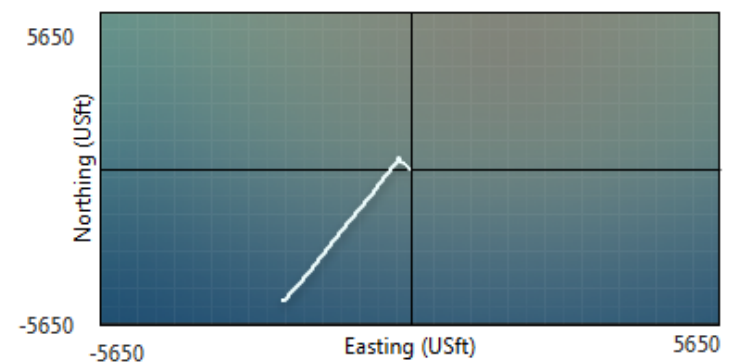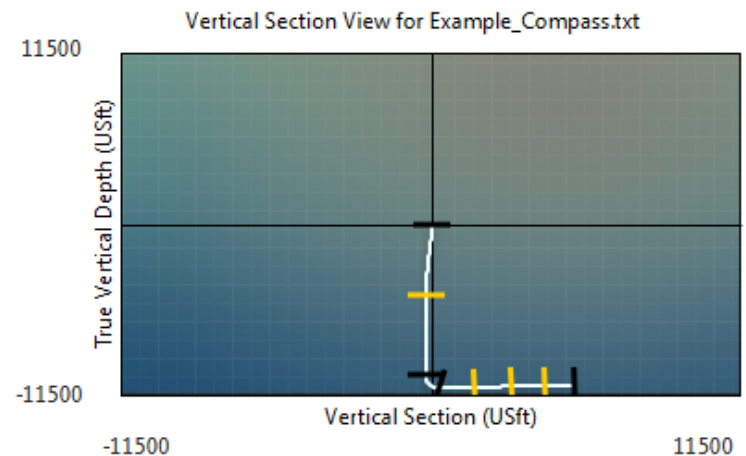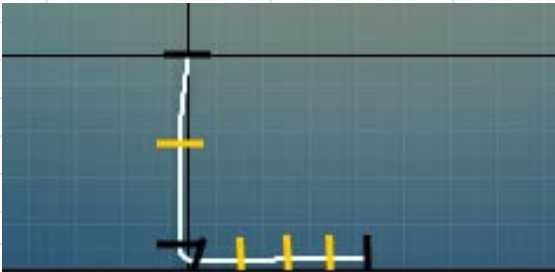
Output File for "auto-generated"

Vertical Section (USft)

	A	B	C	D	E	F	G	H	I
1	MagVAR-IFR Calculator Report								
2	Version:		4.0.2						
3									
4	Lease Block: Permian Basin								
5	Input Data: Aeromagnetic surveys MV-A1, NURE, and CHAMP satellite data								
6	Conditions Of Use: Exclusive license by Pioneer Natural Resources								
7	Coordinate System: NAD27 / Texas SP Central Zone (4203) US feet								
8	Location:								
9	Vertical Reference Point:		0	USft					
10	Report Date:		15-Aug-2014						
11	Location on map								
12	This is the:		Summary						
13	Originator:		MagVAR						
14	Notes:								
15	Summary statistics for the entire well path:								
16			Btotal	Dip	Dec	Grid Convergence	Total Correction	Start MD	End MD
17			nT	degrees	degrees	degrees	degrees	USft	USft
18	Mean:		47949.1	59.86	6.35	-0.78	7.13	0.0	15000.0
19	Range:		51.0	0.06	0.03	0.01	0.02	0.0	15000.0
20									
21	Recommended Segments:								
22	Sec_1_20"_Seg_1:		47930.4	59.88	6.35	-0.78	7.13	0.0	4141.0
23	Sec_1_20"_Seg_2:		47947.6	59.86	6.35	-0.78	7.13	4141.0	8935.0
24	Sec_2_12.5"_Seg_1:		47957.9	59.86	6.36	-0.78	7.14	8935.0	9953.0
25	Sec_3_8"_Seg_1:		47958.3	59.85	6.35	-0.78	7.13	9953.0	11260.0
26	Sec_3_8"_Seg_2:		47962.3	59.85	6.35	-0.78	7.13	11260.0	12640.0
27	Sec_3_8"_Seg_3:		47966.6	59.84	6.34	-0.79	7.13	12640.0	13875.0
28	Sec_3_8"_Seg_4:		47970.8	59.83	6.34	-0.79	7.13	13875.0	15000.0
29									

Example_Compass#_2014-08-15.xls [Compatibility Mode]

Summary / Sec_1_20"_Seg_1 / Sec_1_20"_Seg_2 / Sec_2_12.5"_Seg_1 / Sec_3_8"

Uncertainties in West TX

Lateral Uncertainty at TD

Well Azim.	Lateral Length	MWD	MWD +IFR1	MWD +IFR1+MS
	(ft)	(ft)	(ft)	(ft)
E	11000	439	390 (-11%)	173 (-61%)
SE	11000	387	329 (-15%)	160 (-59%)
S	11000	259	161 (-38%)	129 (-50%)

Vertical Uncertainty at TD

TVD	MWD	MWD+IFR1+SAG+MS
10600 ft	119 ft	71 ft (-40%)

3D Ellipsoids given for 95% confidence interval = 2.79 sigma

Error model: ISCWSA OWSG

QC and Correction of Raw MWD Data

Bx, By, Bz

Gx, Gy, Gz
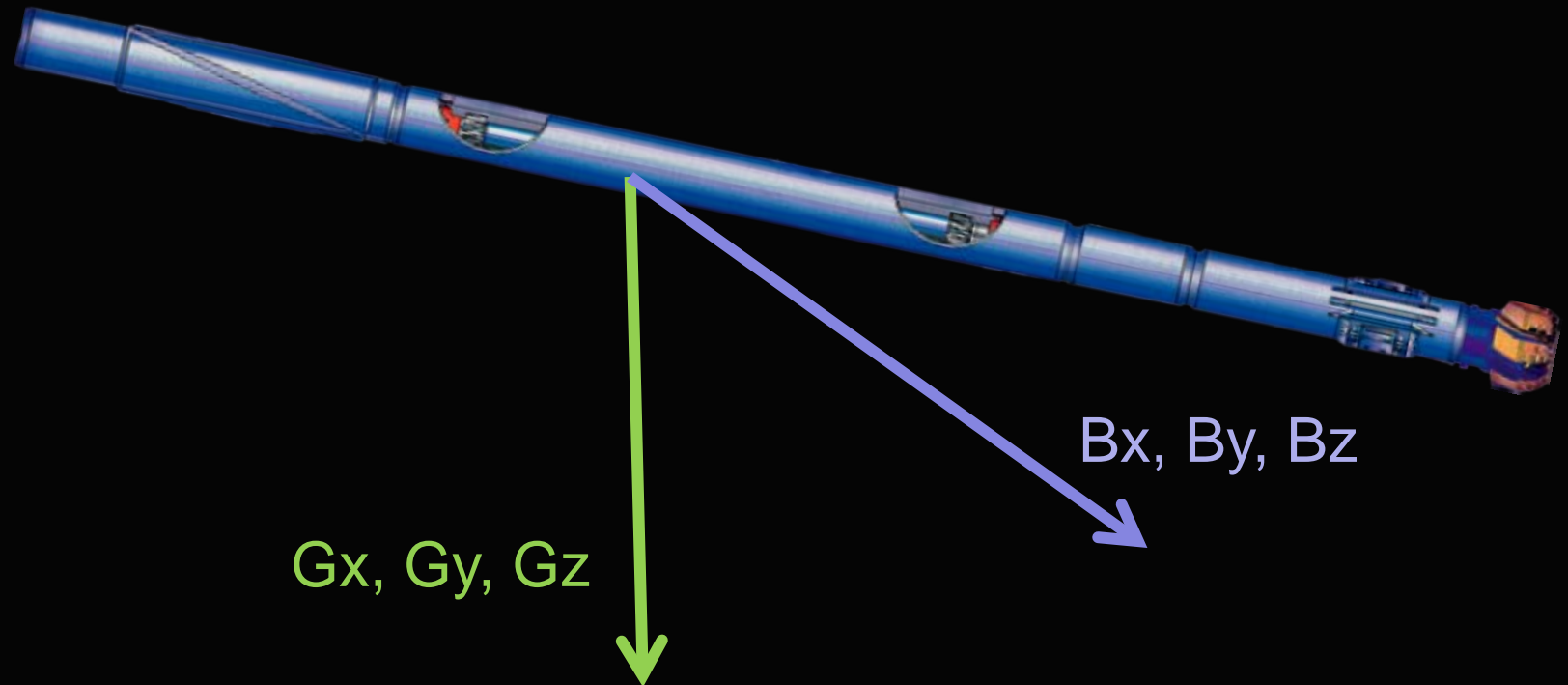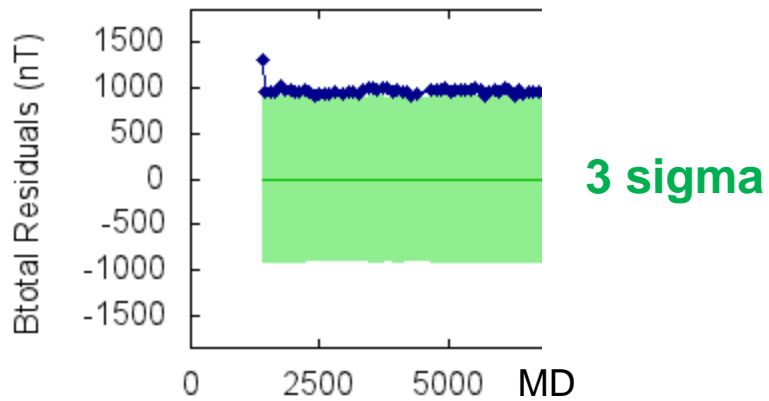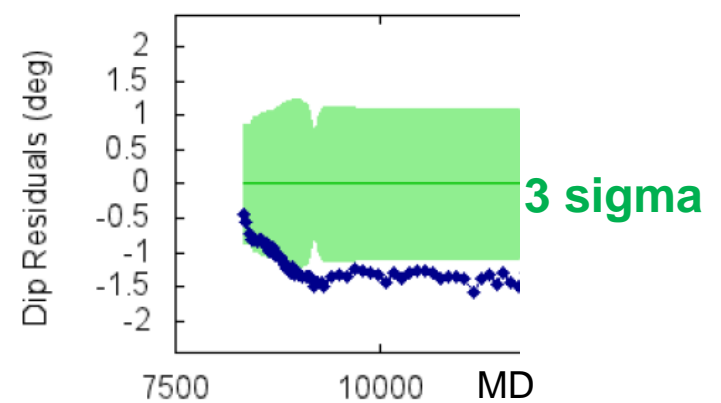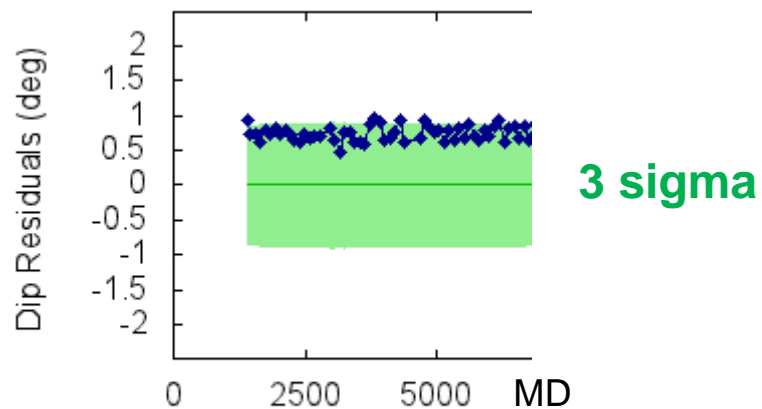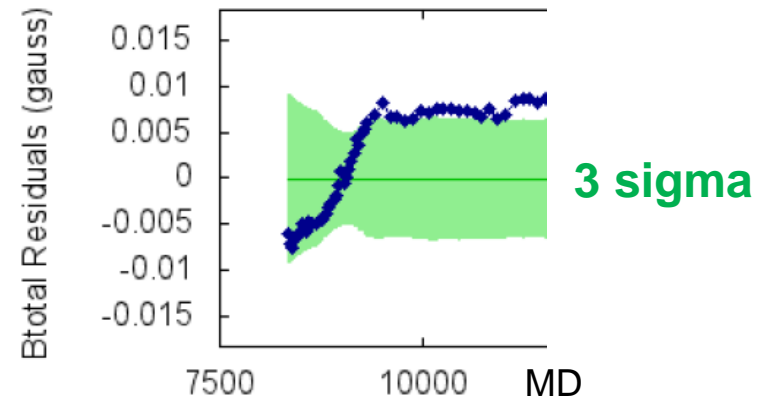
Measure 6 quantities → get 6 parameters:
- Inclination, Magnetic Azimuth, Tool Face (use for steering!)
- Gtotal, Btotal, Dip (use for QC and Corrections!)

Examples of Raw Data QC

Raw data (MWD tool code)

Raw data (MWD tool code)

3 sigma

3 sigma

3 sigma

3 sigma

© MagVAR 2015

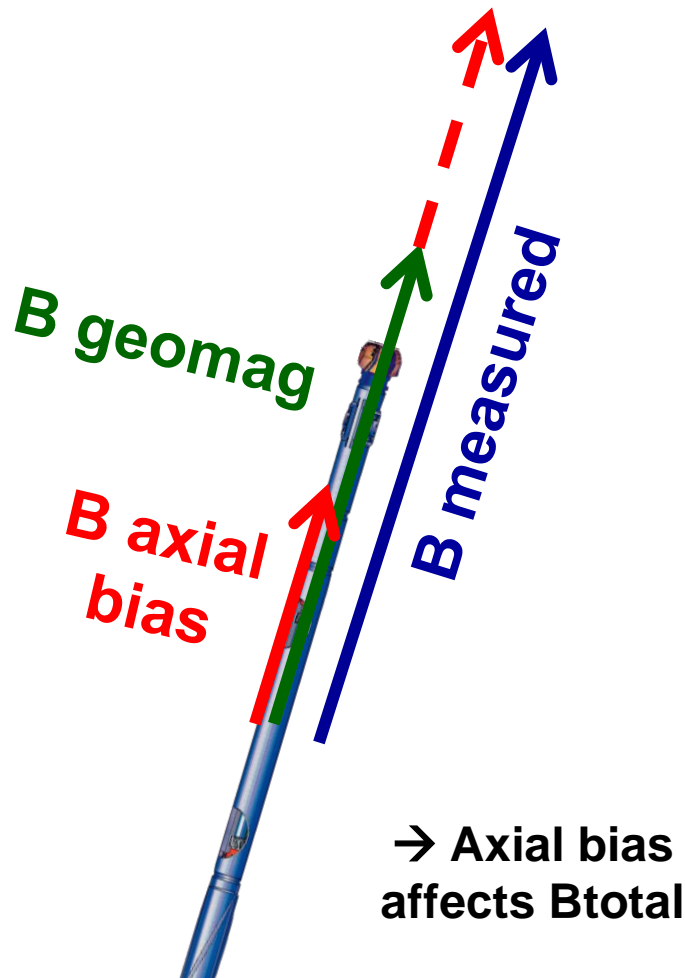# QC Parameter Errors Depend on Wellbore Orientation

Example: Contribution of axial bias to error in Btotal

Wellbore parallel to magnetic field
(plan view)

Wellbore oriented magnetic east
(plan view)

B geomag

B axial bias

B measured

B geomag

B measured

→ **Axial bias affects Btotal**

→ **Axial bias not seen in Btotal**

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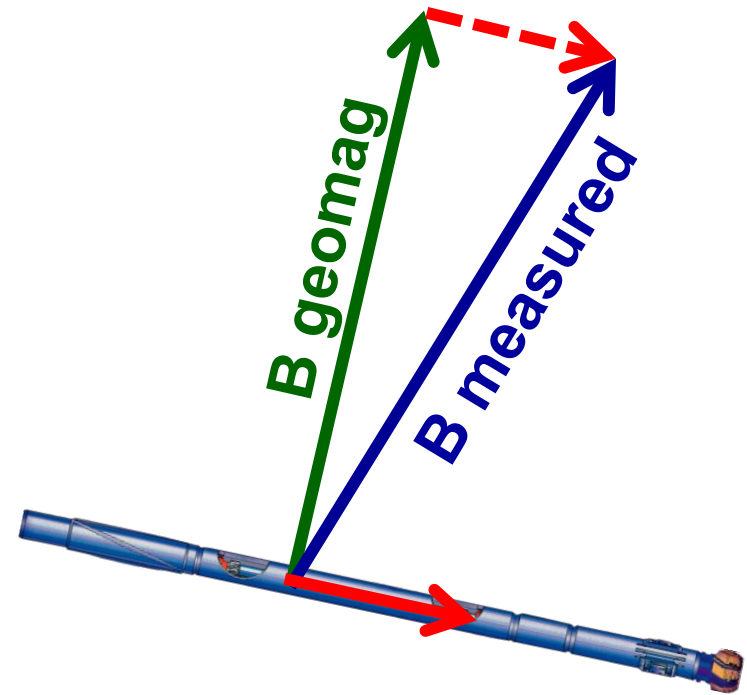
Computing QC Thresholds for Tool Codes

Multi-Station Analysis Correction

Raw data (MWD tool code)
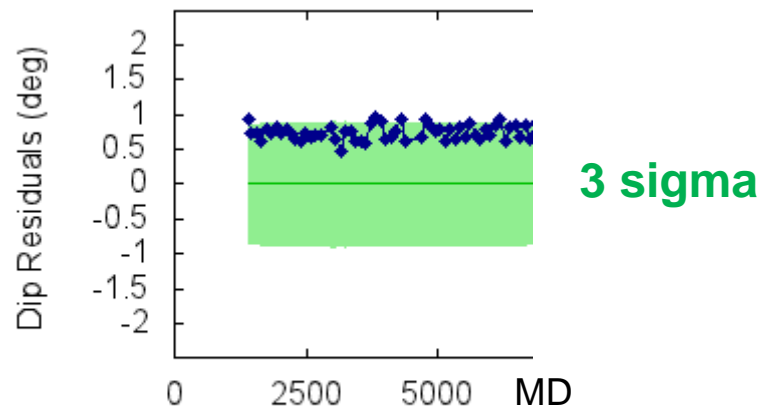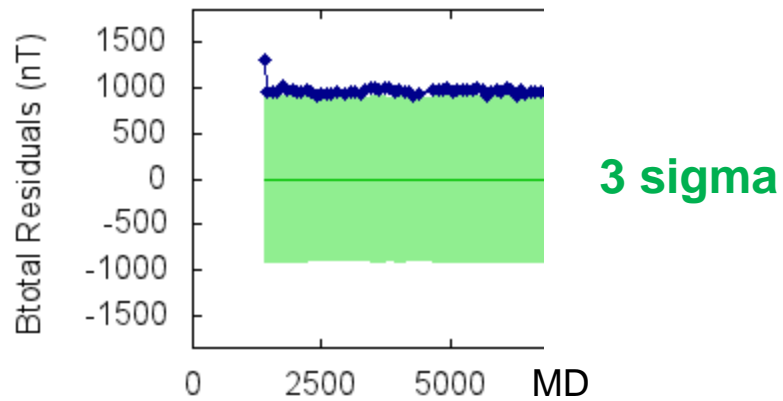
**IFR and MSA corrected data
(MWD+IFR1+MS tool code)**

3 sigma

3 sigma

3 sigma

3 sigma
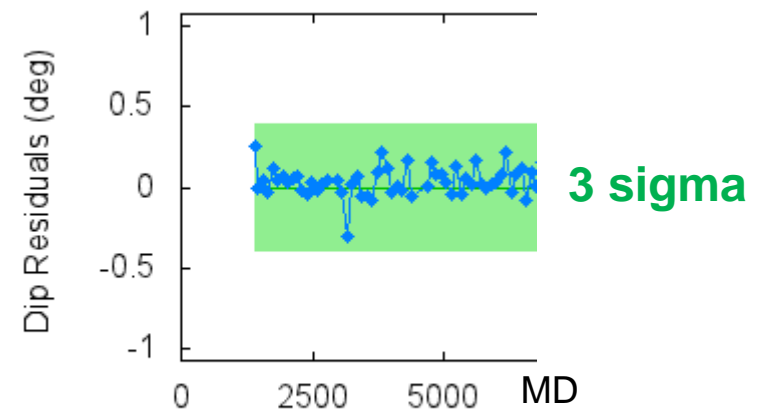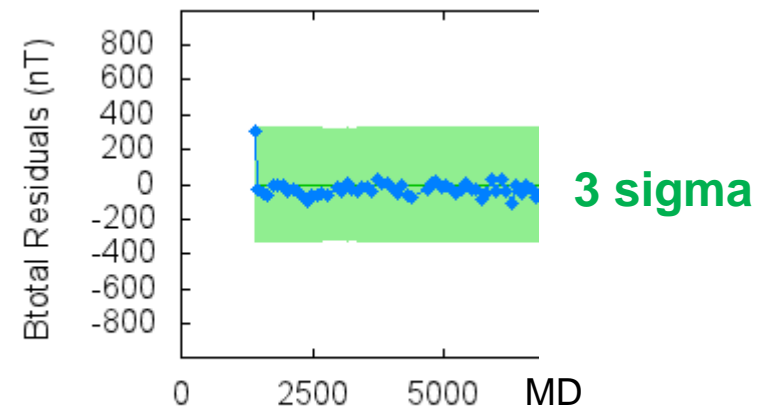
Note the tighter QC thresholds!

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Relevant Tool Codes for Well Planning and Anti-collision Scans

Tool Code	Magnetic reference model	Survey corrections	EOU*
MWD+IGRF	Global IGRF or WMM	-	+10%
MWD	Global BGGM or MagVAR MVSD	-	Standard
MWD+HDGM	Global HDGM or MagVAR MVHD	-	-10%
MWD+IFR1	Local In-Field Referencing (IFR1)	-	-30%
MWD+IFR1+MS	Local In-Field Referencing (IFR1)	Multi-Station	-50%

More Accurate

*Approximate values, actual EOU sizes depend on location and orientation of wellbore

New set of consolidated error models from the Operator Wellbore Survey Group
These are available from Landmark as IPMs for Compass.

Importance of Raw Sensor Data

Record and archive the raw 6-axis sensor data
- With MD, date, time and tool run for each survey
- Sufficient precision (at least 4 significant digits)

The raw data can be read from tool memory
- Needs synchronization with MD

Conclusions

- Wellbore positions have significant uncertainties

- Uncertainties can be reduced by 50%

  - *First step: Produce a local IFR magnetic model*

  - *Second step: Apply Quality Control and use multi-station analysis methods to correct the raw MWD sensor data*

- IFR and survey quality management significantly improve well placement accuracy

For questions about the MagVAR High Definition Model (MVHD), MagVAR IFR and the software shown in this presentation please contact maginfo@magvar.com

Stefan Maus, AADE Luncheon, 02/05/2015

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