



Chained Multi-Single Station MWD Calculation

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Thinking



Accelerometer: $A_x = g_x = g \cos(\text{HTF})\sin(I)$
 $A_y = g_y = -g \sin(\text{HTF})\sin(I)$
 $A_z = g_z = -g \cos(I)$

Magnetometer: $H_x = B_x = (B_h \cos(Az)\cos(I) - B_d \sin(I)) - B_h \sin(Az)\sin(\text{HTF})$
 $H_y = B_y = -B_h \sin(Az)\cos(\text{HTF}) - (B_h \cos(Az)\cos(I) - B_d \sin(I))\sin(\text{HTF})$
 $H_z = B_z = B_h \cos(Az)\sin(I) + \cos(I)$

Linear solution for B_d , $B_h \cos(Az)$ and $B_h \sin(Az)$
 g measured at surface, global model, local model, compare with solution
 B_h , B_d (equivalent to B_{total} , dip) monitored, local and global models, QC



$$\begin{bmatrix} H_x + B_d \sin(I) \cos(\text{HTF}) \\ H_y - B_d \sin(I) \sin(\text{HTF}) \end{bmatrix} = \begin{bmatrix} \cos(I) \cos(\text{HTF}) & -\sin(\text{HTF}) \\ -\cos(I) \sin(\text{HTF}) & -\cos(\text{HTF}) \end{bmatrix} \begin{bmatrix} B_h \cos(Az) \\ B_h \sin(Az) \end{bmatrix}$$

$$\begin{bmatrix} H_x \\ H_y \\ H_z \\ B_d \\ 0 \end{bmatrix} = \begin{bmatrix} \cos(I) \cos(\text{HTF}) & -\sin(\text{HTF}) & -\sin(I) \cos(\text{HTF}) & 0 \\ -\cos(I) \sin(\text{HTF}) & -\cos(\text{HTF}) & \sin(I) \sin(\text{HTF}) & 0 \\ \sin(I) & 0 & \cos(I) & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} B_h \cos(Az) \\ B_h \sin(Az) \\ B_d \\ M_z \end{bmatrix}$$

$M_z=0$ only at high inclination E/W, but no algorithm
“fail”



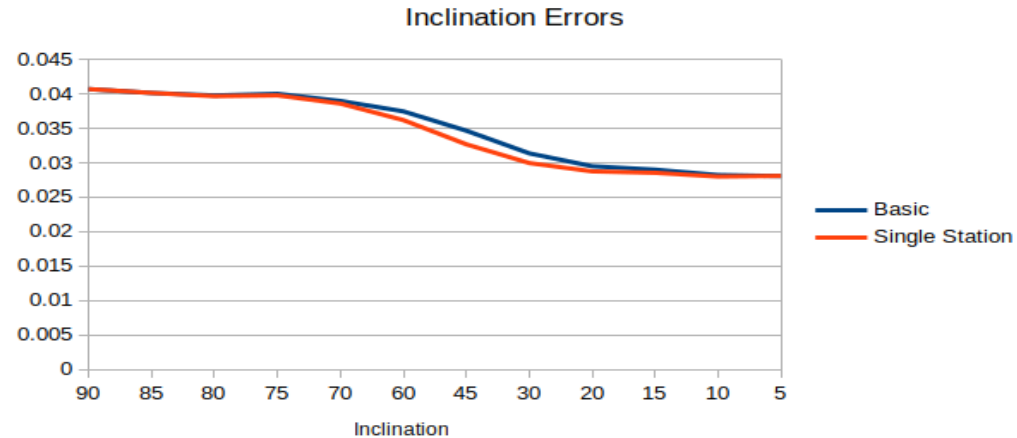
Wellbore Positioning Technical Section



The Industry Steering Committee on
Wellbore Survey Accuracy (ISCWSA)

$$\begin{bmatrix} g_x - A_x \\ g_y - A_y \\ g_z - A_z \\ g - g^* \end{bmatrix} = \begin{bmatrix} -g_l \sin(\text{HTF}) & \cos(\text{HTF}) & 0 \\ -g_l \cos(\text{HTF}) & -\sin(\text{HTF}) & 0 \\ 0 & 0 & 1 \\ 0 & g_l/g & g_z/g \end{bmatrix} \begin{bmatrix} d\text{HTF} \\ dg_l \\ dg_z \end{bmatrix}$$

Errors	Regular	Optimizing
Inclination	0.035°	0.035°
Highside	0.115°	0.115°
Gtotal	0.62mg	0.07mg





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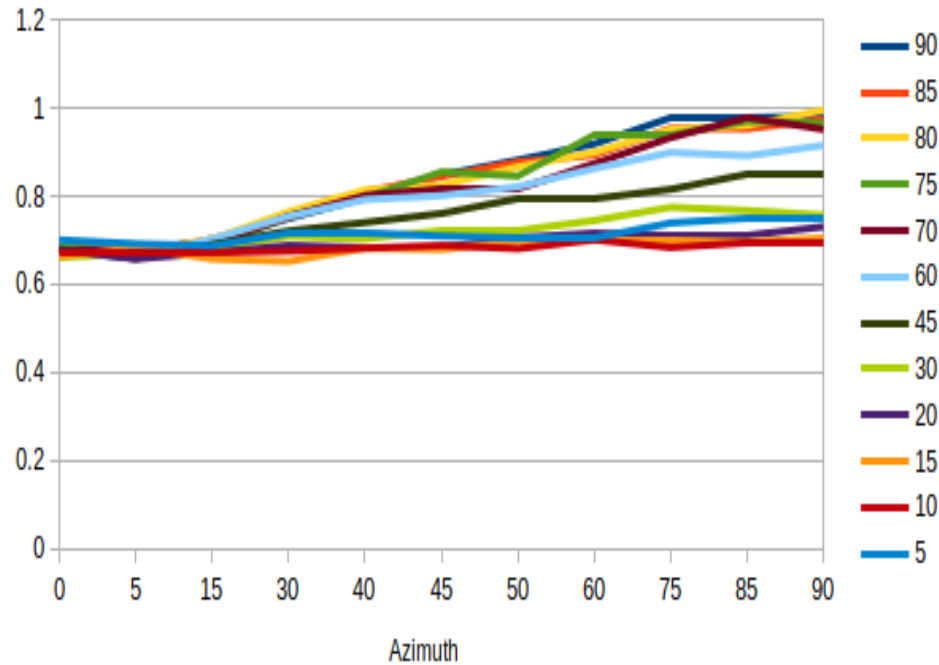
$$\begin{bmatrix} B_x - H_x \\ B_y - H_y \\ B_z - H_z \\ B_h - B_h^* \\ B_d - B_d^* \end{bmatrix} = \begin{bmatrix} \cos(I)\cos(HTF) & -\sin(HTF) & -\sin(I)\cos(HTF) \\ -\cos(I)\sin(HTF) & -\cos(HTF) & \sin(I)\sin(HTF) \\ \sin(I) & 0 & \cos(I) \\ \cos(Az) & \sin(Az) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} dB_h \cos(Az) \\ dB_h \sin(Az) \\ dB_d \end{bmatrix}$$

Avg
“worse”
Azimuth
=0.82°

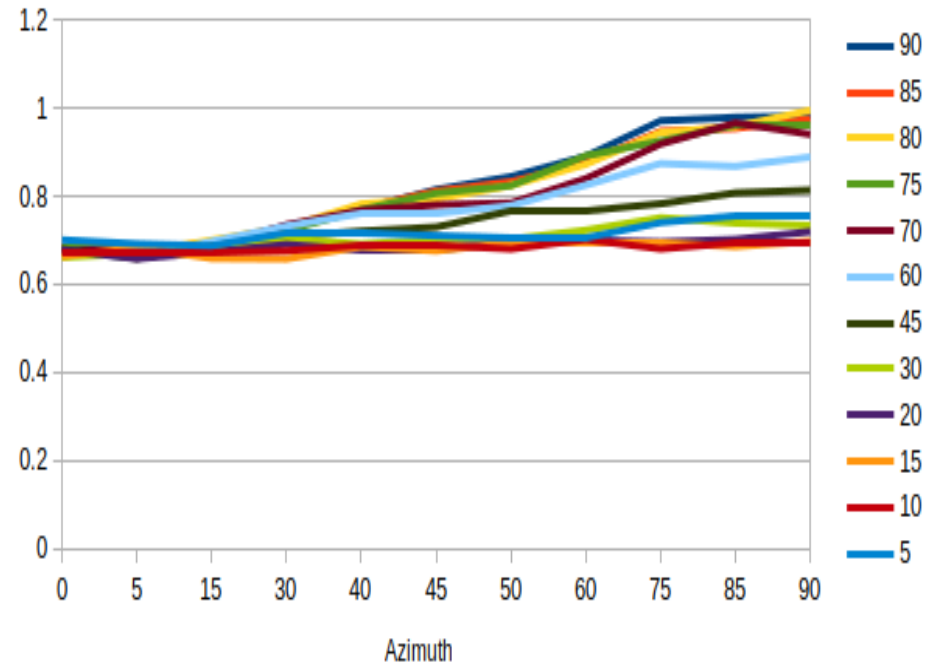
Errors	Regular	Optimizing
Azimuth	0.82°	0.80°
B _h	198nT	25.6nT
B _d	207nT	23.6nT



Azimuth Errors, Basic Computation



Azimuth Errors, Single Station





$B_{total}=50,000nT$; Dip = 75° ; 18 stations

Expected Offset (“XO”) Instance = Random Value plus random walk effect (approx)

Gravity:

$s_{xh}=0.3mg$; $DBias_{xh}=0.2mg$; $XO_{xh}=0.6mg$; $s_{dh}=0.3mg$; $DBias_{dh}=0.2$; $XO_{dh}=0.6mg$
 $s_{gtot}=0.1mg$; $DBias_{gtot}=0.02mg$; $XO_{gtot}=0.11mg$

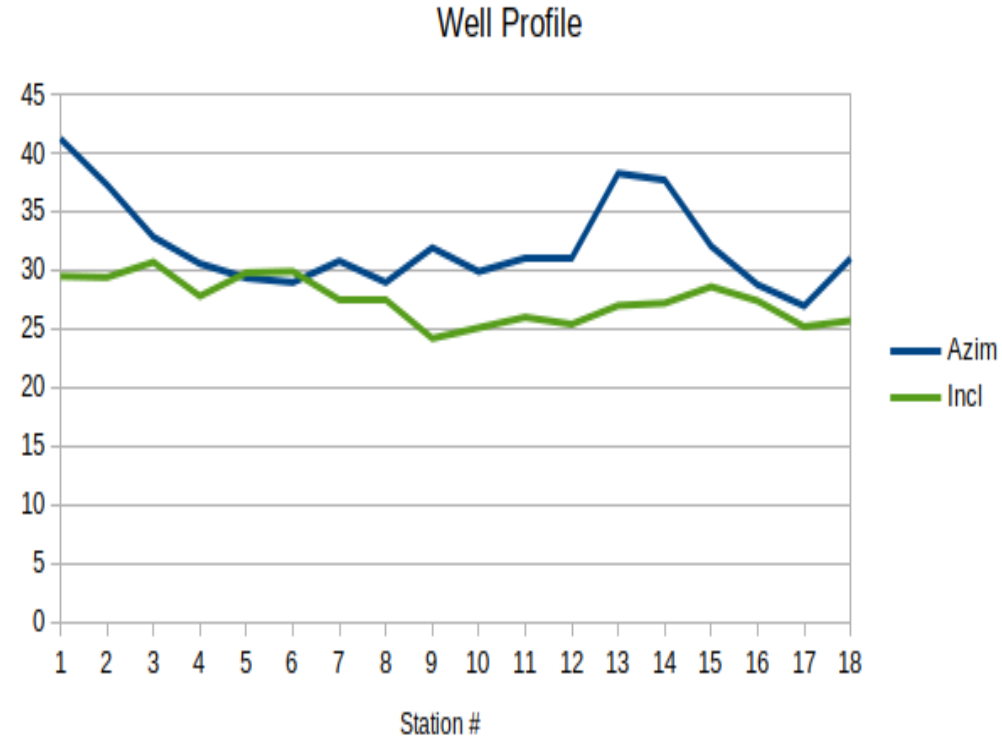
Magnetics:

$s_{xh}=80nT$; $DBias_{xh}=50nT$; $XO_{xh}=150nT$; $s_{dh}=80nT$; $DBias_{dh}=80nT$; $XO_{dh}=220nT$
 $XO_{xh}(ms)=90nT$ $XO_{dh}(ms)=130nT$
 $s_{Bref}=80nT$; $DBias_{Bref}=20nT$; $XO_{Bref}=95nT$; $XO_{BrefH}(ms)=82nT$; $XO_{BrefV}(ms)=87nT$;



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RMS Error	Single Station	Multistation
Azimuth	0.80	0.43
Inclination	0.051	0.037
HTF	0.107	0.079
gravity	0.06mg	0.09mg
Bhoriz	53nT	54nT
Bdown	52.8nT	49.7nT



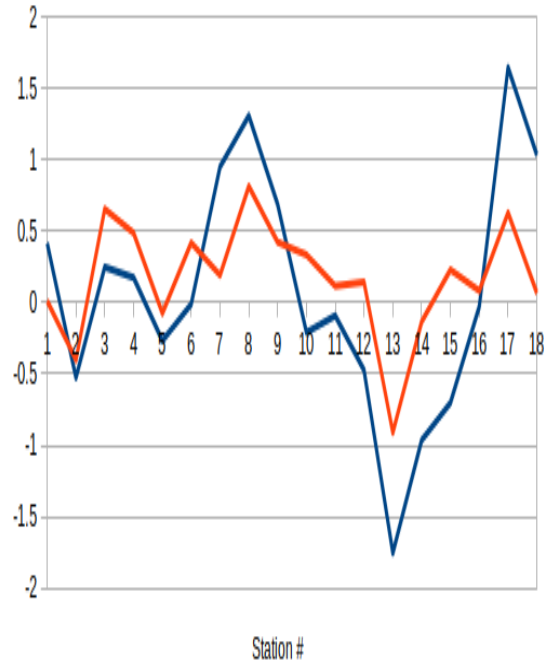


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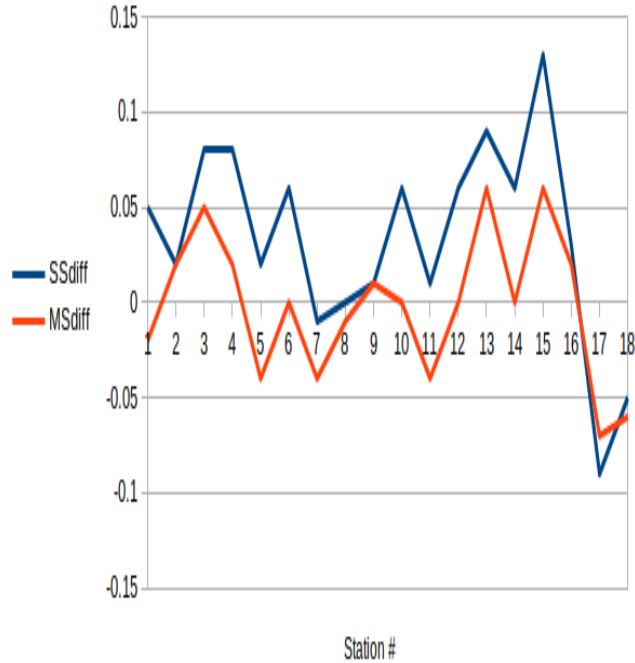


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Azimuth Errors



Inclination Errors



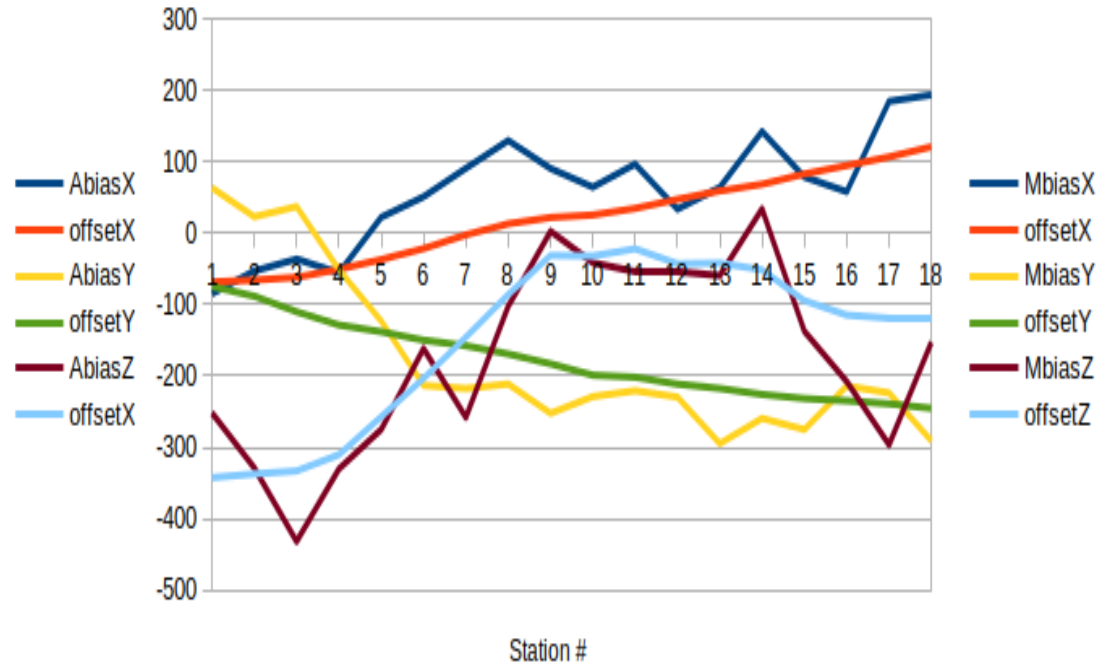
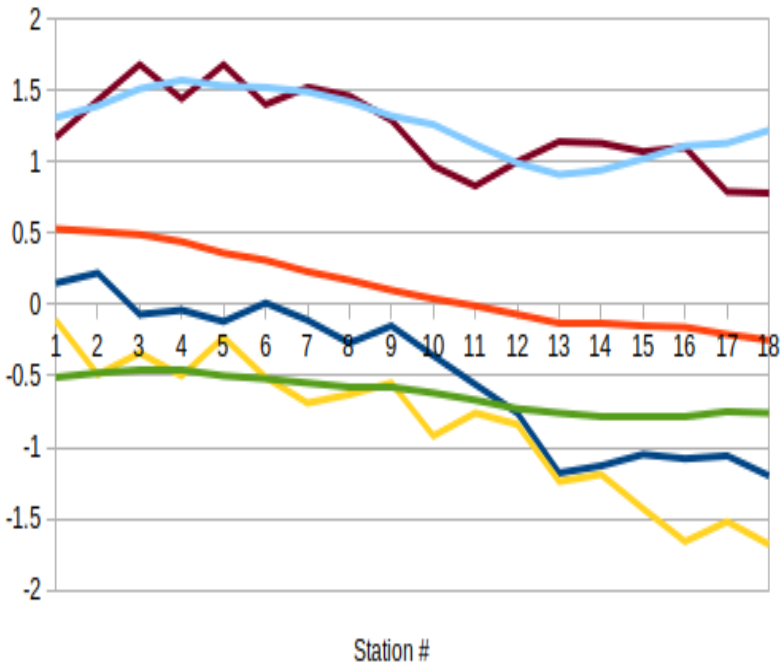
HTF Errors



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Accelerometer Biases and Estimates

Magnetometer Biases





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RMS Error 2000 Runs	Base	Single Station	Multi- Station
Azimuth	1.15	1.12	0.66
Inclination	0.051	0.051	0.035
HTF	0.13	0.13	0.12
g	0.89mg	0.86mg	0.84mg
Bhoriz	268nT	82nT	82nT
Bdown	309nT	83nT	87nT

Worse Azim = 274
(out of 2000)
Avg worse Azim = 0.88

Worse Incl = 365
(out of 2000)
Avg worse Incl = 0.050

Worse HTF = 285
(out of 2000)
Avg worse Incl = 0.047

Unstarts: Mag=14, Acc=5



Future work:

- 1.Solve “unstart” issue with Simplex sub-search
- 2.Enable outlier determination
- 3.Add external interference model