Absolute Measurement Session
XIII IAGA Workshop
Boulder Magnetic Observatory

Alan Berarducci and Andy Woods
U.S. Geological Survey
geomag.usgs.gov

Introduction

The absolute measurement session of the XIII IAGA Workshop was held at the Boulder Magnetic Observatory June 10-13, 2008. Approximately 85 people attended this session. The main focus of the session was for observers to make and compare measurements using DIFlux magnetometers. The session also included absolute measurement training, with lectures and practical training. Also included were data processing training, an introduction to solar observations, and a discussion concerning timing for one-second data collection.

Testing and demonstration of three instruments under development was also carried out during the absolute measurement session. The auto DI Flux was demonstrated by Jean Rasson. A triaxial DI Flux was demonstrated by Uli Auster and Anne Hemshorn. A fast delta Declination/delta Inclination (dIdD) magnetometer was tested by Laszlo Hegymegi. Results from the Auto DI Flux and triaxial DI Flux are included in the workshop results presented below.

DI Flux Comparison

Absolute measurements of declination and inclination were made at pillars 1, 2, 3, 4, and 5. Declination (D), inclination (I) and total field (F) were used to calculate D (declination), H (horizontal intensity), and Z (vertical intensity). The location of pillars 1 through 5 (see figure 1) was chosen after extensive total field measurements to determine the lowest gradients. The results from pillars 1 through 5, the auxiliary pillar, and the main pillar were used to compute the session baseline and averages.

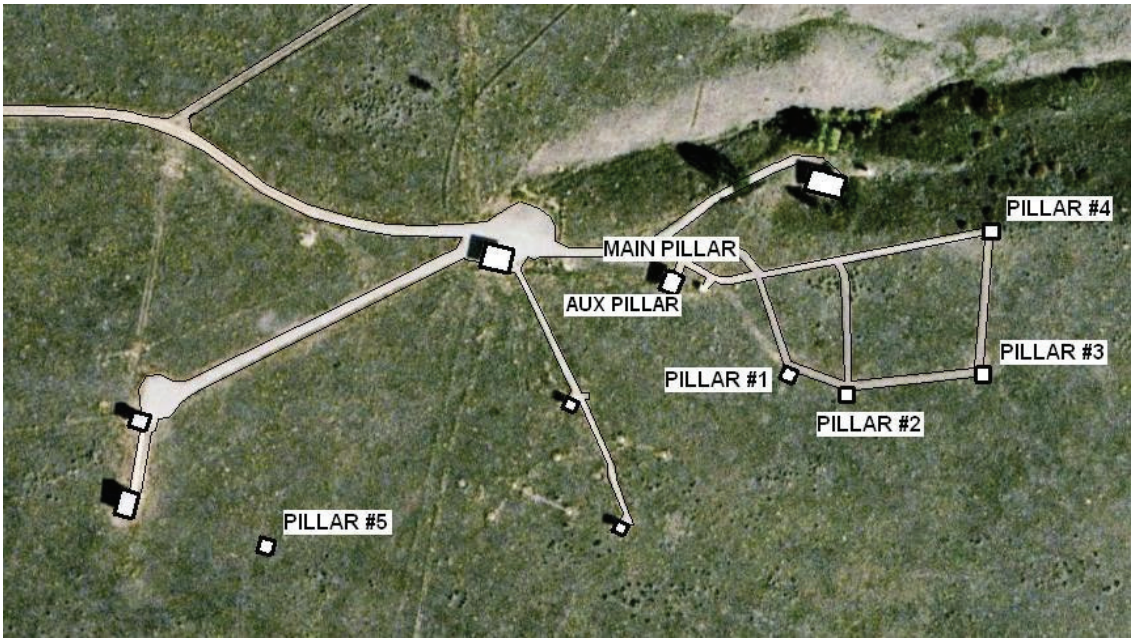

Figure 1. Boulder Observatory.

Approximately 27 magnetometers and 47 observers (including 11 USGS) participated in the absolute measurement session. The DI Flux magnetometers and observers that participated in the absolute measurement session are listed in table 1 below.

Table 1. List of DIFlux instruments and observers.

No.	Observer	Country	Instrument
1	Crosthwaite-Lewis	Australia	Zeiss - 160459 / B0610H
2	Rasson	Belgium	Auto DI
3	Auster	Germany	3-axis Fluxgate/ Zeiss
4	Bayer	Czech Republic	Zeiss 010
5	Brown	United States	Zeiss 020 -616061
6	Calp	Canada	Ziess 010 - 37834 Bartington
7	Camacho	Venezuela	Zeiss 020
8	Cifuentes	Mexico	Zeiss 020
9	Davie	United States	Zeiss 020 - 614379
10	Deshmukh	India	Zeiss 015B
11	Hemshorn	Germany	3-axis Fluxgate/ Zeiss
12	Hernandez	Mexico	Zeiss 020 - 614231
13	Horacek	Czech Republic	Zeiss 010B
14	Kadek	Indonesia	Zeiss 020 - 614379
15	Kaisan	United States	Zeiss 020 - 359137
16	Kampine	Mozambique	Ruska
17	Kuvshinov	Switzerland	Zeiss 020
18	Lim	Korea	Zeiss -15963
19	Linthe	Germany	Zeiss 010
20	Lopez	United States	Zeiss 010
21	Marsal	Spain	Zeiss-Elsec 253101
22	Matzka	Denmark	Zeiss - 151713 (DMI)
23	Minamoto	Japan	Zeiss 010B - 151571
24	Mucusette	Mozambique	Ruska
25	Murtaza	Pakistan	Tavistock - V042717
26	Odell	United States	Zeiss 010
27	Orihuela	Peru	Zeiss 010
28	Pacheco	Colombia	Zeiss 020
29	Pajunpaa-Tero	Finland	Zeiss 010
30	Pedersen	Denmark	Zeiss Theo 010 (DMI)
31	Reda-Neska	Poland	Zeiss Theo 010B / Elsec 810
32	Rosales	Peru	Zeiss 010
33	Schiermeier	United States	Zeiss - 109266
34	Serra	Venezuela	Zeiss 020
35	Shanahan	United Kingdom	Zeiss 010
36	Turbit	United Kingdom	Bartington/ WildT16
37	Uchima	United States	Zeiss 010
38	White	United States	Zeiss 020 - 359137
39	Wu	China	CTM-DI 108
40	Yusuf	Indonesia	Zeiss 020 - 614379
41	USGS Team	United States	Zeiss 010 (USGS Main Pillar)

Extensive measurements were made to determine the pillar differences in D, H, Z, and F. Measurements were made simultaneously on the main pillar, the auxiliary pillars, and pillars 1-5 before, during and after the workshop. The adopted D, H, Z, and F differences are shown in table 2.

Table 2 : D, H , Z and F Differences for Measurement Pillars

	Dcorr to Main (min)	Hcorr to Main (nT)	Zcorr to Main (nT)	Fcorr to Main (nT)
AUX	-1.18	-12.64	2.83	-20.70
Pillar 1	-1.89	-16.52	-11.22	-6.30
Pillar 2	.42	-9.41	-7.34	-12.70
Pillar 3	-3.52	-13.66	-6.50	-11.80
Pillar 4	-3.48	14.64	-14.78	-15.30
Pillar 5	-.42	-18.76	-4.50	-11.60

The observatory baselines were determined on the main pillar in the Absolute Building. Reduction of the measurements was made using the main observatory Narod fluxgate magnetometer and GEM Systems GSM-19, USGS model. The stability of these magnetometers is approximately 9-12 nT/year. During the month of the workshop, June, the stability was between 1 and 3 nT. See figure 2 below.

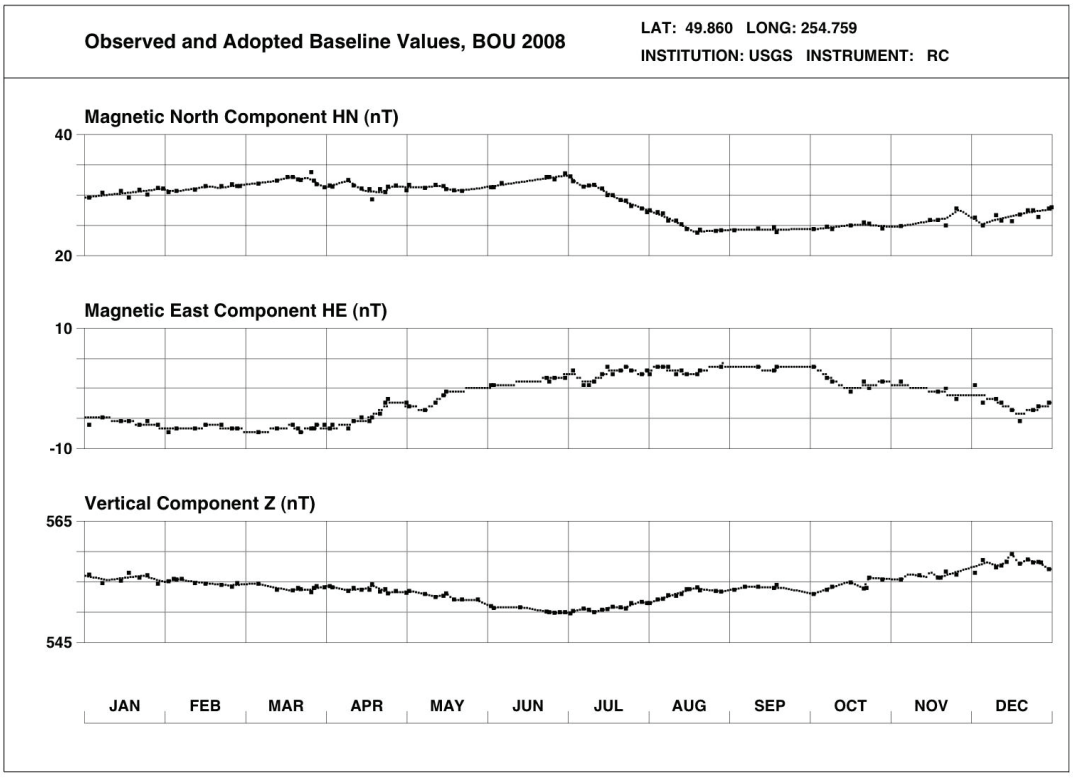

Figure 2. Observed and adopted baseline values for Boulder Observatory, 2008.

The reference levels (zero level) for D, H, and Z are adopted from the mean value of all the measurements made by the session's participants, excluding measurements outside two standard deviations. The reference level for D is 585.85 minutes; H is 30.98nT; Z is 551.87 nT. Two standard deviations for D is 6.84 minutes; for H is 5.73 nT; for Z is 6.84 nT.

Conclusions

The results of the absolute measurement session of D, H, and Z are shown graphically in figures 3, 4, and 5 respectively. The results are shown in tabular form in tables 3, 4, and 5.

The gray cells in tables 3, 4, and 5 show values which were excluded from the session average and individual averages. These values are outside of two standard deviations and are shown for information only.

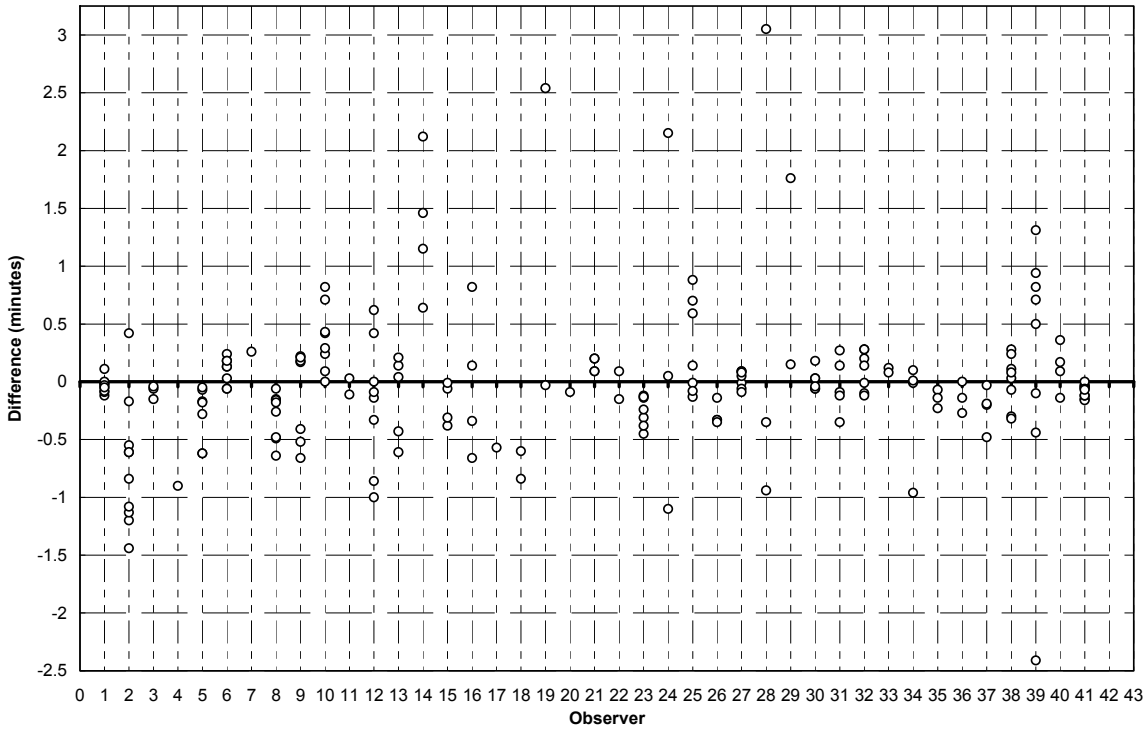

Figure 3. Individual observer difference from workshop average (declination). All measurements outside of two standard deviations have been removed.

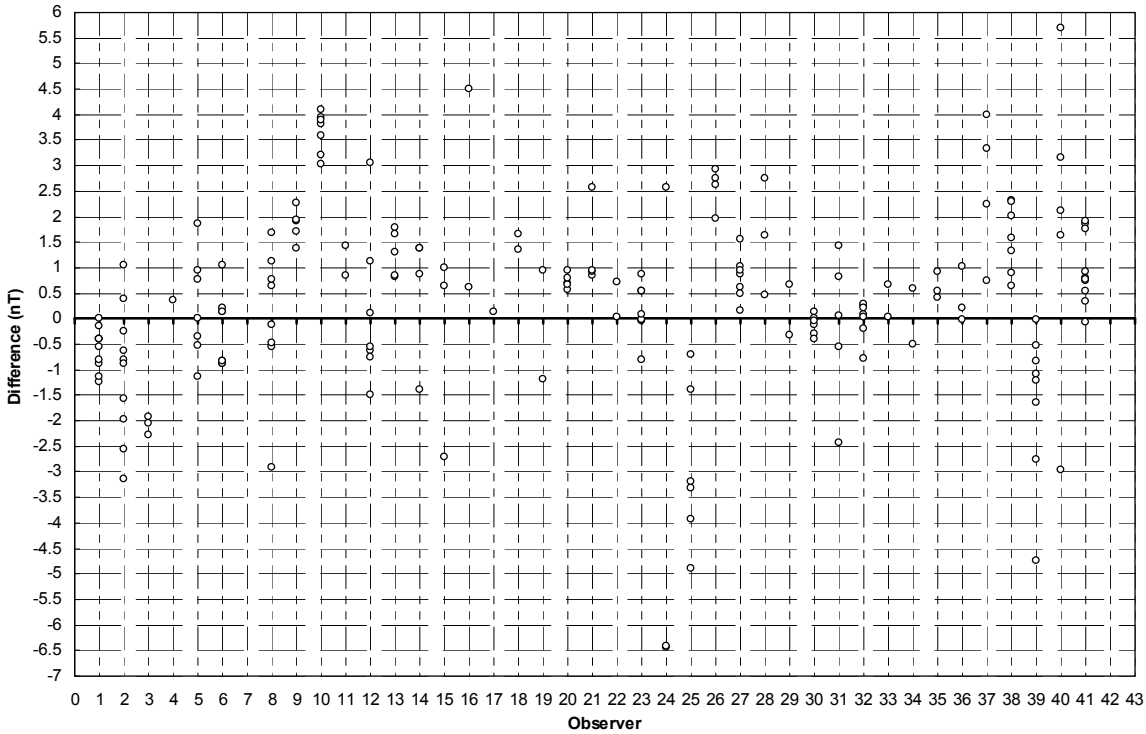

Figure 4. Individual observer difference from workshop average (horizontal intensity). All measurements outside of two standard deviations have been removed.

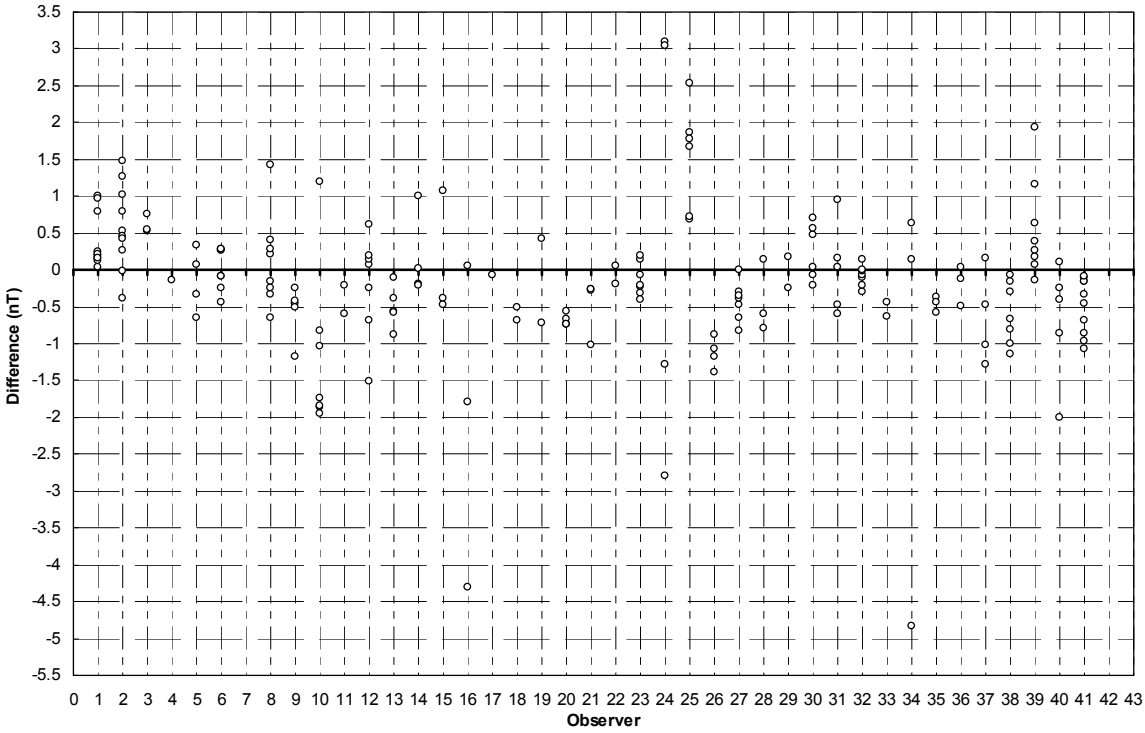

Figure 5. Individual observer difference from workshop average (vertical intensity). All measurements outside of two standard deviations have been removed.

Table 3. Individual difference from workshop average - declination (Min).

Shaded measurements fall outside of 2 standard deviations and were not used in calculating workshop averages.

No	Obs 1 Obs 11	Obs 2 Obs 12	Obs 3 Obs 13	Obs 4 Obs 14	Obs 5 Obs 15	Obs 6 Obs 16	Obs 7 Obs 17	Obs 8 Obs 18	Obs 9 Obs 19	Obs 10 Obs 20	Average	Standard Deviation
1	-0.12 -.03	0.11 -.09	-0.02	-0.01	0	-0.05	-0.03	-0.09	-0.08	-0.05	-0.037	0.059
2	-1.2 .89	-.61 .88	-1.13 -.85	-.84 -.62	.42 -.38	-1.44 -.81	-.55 -.25	-1.08 -.27	-.17	-.61	-.479	.660
3	-.15	-.06	-.04								-.083	.059
4	-.9										-.900	.000
5	-.62	-.62	-.17	-.07	-.18	-.05	-.28				-.284	.242
6	.24	-.06	.13	.18	.03	-.06	.13	.18			.096	.114
7	.26										.260	.000
8	-.64	-.49	-.26	-.48	-.15	-.06	-.16	-.18			-.303	.207
9	-.66	-.41	3.26	-.52	.17	.22	.18	.21			-.116	.395
10	.24	.42	.71	.82	.43	.29	0	.09			.375	.283
11	-.11	.03									-.040	.099
12	-.86	-.33	.42	-1	.62	0	-.14	-.09			-.173	.560
13	.14	.21	-.61	-.43	.04						-.130	.367
14	1.46	1.15	2.12	.64							1.343	.619
15	-.38	-.06	-.31	-.01							-.190	.182
16	.14	.82	-.66	-.34							-.010	.644
17	-.57										-.570	.000
18	-.84	-.6									-.720	.170
19	-.03	2.54									-.030	.000
20	-24.08	-23.98	-23.82	-23.97	-.09						-.090	.000
21	.2	.2	.09	.09							.145	.064
22	-.15	.09									-.030	.170
23	-.14	-.12	-.13	-.45	-.31	-.24	-.38				-.253	.132
24	4.22	2.15	.05	-1.1							1.330	2.350
25	-.01	-.13	-.08	.14	.7	.88	.59				.299	.415
26	-.33	-.33	-.35	-.14							-.288	.099
27	-.01	.09	.09	.05	-.06	-.09	.08				.021	.075
28	11.56	3.05	-.35	-.94							.587	2.154
29	.15	1.76									.955	1.138
30	-.06	.03	.18	-.06	.03	-.04					-.060	.092
31	-.35	-.09	-.12	.14	.27						-.030	.241
32	-.01	.28	-.1	-.12	.2	.14	.28				.096	.172
33	.12	.08									.100	.028
34	-.01	.01	-.96	.1							-.215	.499
35	-.07	-.14	-.23								-.147	.080
36	-.27	0	-.14								-.137	.135
37	-.48	-.2	-.03	-.19							-.225	.187
38	-.3	-.32	-.07	.03	.11	.28	.08	.24			.006	.224
39	.94	-.44	-.1	-2.41	1.31	.71	.5	.82			.166	1.184
40	.17	.09	.36	-.14	-10.49						.120	.207
41	-.03	-.15	-.05	-.04	0	-.06	-.16	-.12	-.12	-.07	-.080	.054

Table 4. Individual difference from workshop average - horizontal intensity (nT).

Shaded measurements fall outside of 2 standard deviations and were not used in calculating workshop averages.

No	Obs 1 Obs 11	Obs 2 Obs 12	Obs 3 Obs 13	Obs 4 Obs 14	Obs 5 Obs 15	Obs 6 Obs 16	Obs 7 Obs 17	Obs 8 Obs 18	Obs 9 Obs 19	Obs 10 Obs 20	Average	Standard Deviation
1	-0.89 .01	-0.8 -.41	-1.23	-1.13	-0.55	-0.39	0.01	-0.41	-0.14	-0.39	-0.539	0.411
2	-.81 -1.33	-.63 -6.78	-.88 -2.12	1.05 -3.13	-1.97 -3.44	-2.56 -2.61	-3.15 -5.34	-1.57 -3.78	.4	-.24	-2.161	1.962
3	-2.05	-1.92	-2.29								-2.087	.188
4	.37										.370	.000
5	.76	-1.14	-.35	.95	.01	-.52	1.85				.223	1.020
6	1.05	-.88	-.84	.13	.22	-.88	-.84	.13			-.239	.726
7	18.28										.000	.000
8	1.13	-.56	-2.92	-.11	1.68	.63	.78	-.47			.020	1.423
9	2.26	-22.17	-21.71	24.68	1.92	1.37	1.95	1.72			1.844	.328
10	3.03	3.81	-130.86	3.21	3.58	3.94	3.89	4.1			3.651	.398
11	.85	1.42									1.135	.403
12	.1	-.62	1.13	3.06	-1.48	-17.73	-.54	-.75			.129	1.526
13	.81	.84	1.3	1.79	1.67						1.282	.455
14	-1.38	1.37	.86	1.39							.560	1.316
15	-136.62	.65	-2.71	1							-.353	2.048
16	75.29	.61	10.28	4.5							2.555	2.751
17	.14										.140	.000
18	1.35	1.65									1.500	.212
19	.95	-1.18									-.115	1.506
20	.57	.69	.67	.79	.95						.734	.144
21	.84	2.58	.91	.95							1.320	.841
22	.04	.73									.385	.488
23	-.05	-.02	.53	.09	-.81	.53	.86				.161	.546
24	-6.44	-6.42	2.56	6.71							2.560	.000
25	-3.93	-78.52	-1.39	-4.88	-.71	-3.33	-3.19				-2.905	1.570
26	2.93	1.96	2.75	2.62							2.565	.423
27	1.03	.61	.49	1.55	.86	.15	.95				.806	.446
28	1.64	.46	2.74	851.62							1.613	1.140
29	.68	-.33									.175	.714
30	-.3	-.11	.13	.01	-.41	-.04					-.120	.201
31	-.55	-2.43	.83	.06	1.43						-.132	1.488
32	-.19	.26	.09	-.77	.28	.2	.03				-.014	.370
33	.03	.68									.355	.460
34	-133.51	12.35	-.51	.58							.035	.771
35	.93	.42	.55								.633	.265
36	1.03	.2	-.02								.403	.554
37	.74	2.24	4	3.33							2.578	1.424
38	-19.66	2.01	2.31	1.59	2.3	1.32	.89	.65			1.581	.664
39	-.02	-.53	-.82	-1.09	-1.21	-4.73	-1.63	-2.77			-1.600	1.504
40	5.7	3.16	2.12	1.64	-2.96						1.932	3.153
41	.54	.8	1.85	.35	.75	1.77	-.08	.78	1.92	.91	.959	.675

Table 5. Individual difference from workshop average - vertical intensity (nT).

Shaded measurements fall outside of 2 standard deviations and were not used in calculating work shop averages.

No	Obs 1 Obs 11	Obs 2 Obs 12	Obs 3 Obs 13	Obs 4 Obs 14	Obs 5 Obs 15	Obs 6 Obs 16	Obs 7 Obs 17	Obs 8 Obs 18	Obs 9 Obs 19	Obs 10 Obs 20	Average	Standard Deviation
1	0.25 .04	0.8 .22	1.01	0.96	0.2	0.16	0.04	0.22	0.12	0.16	0.365	0.356
2	.53 .68	.46 3.01	.42 .65	-.38 1.08	1.02 1.7	1.27 1.34	1.48 2.79	.8 2.12	-.01	.26	1.068	0.905
3	.76	.53	.54								.610	.130
4	-.13										-.130	.000
5	19.65	30.45	30.11	-.34	.08	.33	-.65				-.145	.436
6	-.43	.27	.29	-.08	-.24	.27	.29	-.08			.036	.283
7	-7.49										.000	.000
8	-.33	.4	1.42	.21	-.65	-.16	-.24	.28			.116	.633
9	-1.18	9.29	9.09	-10.84	-.46	-.24	-.5	-.42			-.560	.361
10	-.82	1.2	56.18	-1.03	-1.74	-1.87	-1.84	-1.95			-1.150	1.128
11	-.21	-.59									-.400	.269
12	-.25	.07	-.68	-1.51	.62	7.5	.15	.2			-.200	.704
13	-.56	-.58	-.1	-.39	-.88						-.502	.286
14	1	-.19	.02	-.21							.155	.573
15	58.2	-.39	1.08	-.48							.070	.876
16	-32.16	.05	-4.31	-1.79							-2.017	2.189
17	-.06										-.060	.000
18	-.51	-.69									-.600	.127
19	-.71	.43									-.140	.806
20	-.74	-.74	-.66	-.73	-.56						-.686	.078
21	-.26	-1.02	-.28	-.27							-.458	.375
22	.05	-.2									-.075	.177
23	.15	.19	-.07	-.23	-.21	-.32	-.41				-.129	.229
24	3.09	3.04	-1.29	-2.79							.513	3.010
25	1.86	33.76	.69	2.54	.72	1.77	1.68				1.543	.717
26	-1.39	-.87	-1.18	-1.07							-1.128	.217
27	-.64	-.48	-.38	-.83	-.3	0	-.35				-.426	.264
28	-.6	.14	-.79	-373.64							-.417	.491
29	-.24	.18									-.030	.297
30	.04	-.07	-.21	.47	.7	.57					.250	.377
31	.16	.95	-.48	.03	-.6						.012	.616
32	-.11	-.3	-.21	.15	-.06	-.01	.01				-.076	.149
33	-.44	-.63									-.535	.134
34	57.4	-4.84	.63	.15							-1.353	3.029
35	-.58	-.37	-.43								-.460	.108
36	-.49	-.12	.03								-.193	.268
37	.16	-.48	-1.28	-1.02							-.655	.637
38	8.25	-1	-1.14	-.81	-.67	-.29	-.15	-.07			-.590	.424
39	-.13	.07	.17	.26	.38	1.93	.63	1.16			.559	.680
40	-2	-.86	-.41	-.24	.11						-.680	.816
41	-.34	-.11	-1.07	-.69	-.46	-.97	-.16	-.15	-.86	-.09	-.490	.379