

NATIONAL ANTARCTIC RESEARCH PROGRAM

Terra Nova Bay, Antarctica Geomagnetic Observatory

Magnetic Observation Results 2010-2011

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2012

Geomagnetic Observation Results 2010-2011 Terra Nova Bay - Antarctica

Introduction

This report deals with activities undertaken at the Antarctic Italian Geomagnetic Observatory during the austral summer 2010-2011.

The coordinates of the Observatory at OASI are the following:

Geographic latitude:	74.6936°S
Geographic longitude:	164.0975°E
Corrected Geomagnetic latitude (IGRF11):	79.95°S
Corrected Geomagnetic longitude (IGRF11):	306.48°E
Magnetic local time midnight:	08:16 UT

This report describes the activities performed from November 17 to December 03, 2010.

For the present work H, D and Z INTERMAGNET formatted data from the fluxgate magnetometer EDA have been used.

The proton precession magnetometers used to record F total values were Overhauser type; for a description of instruments we refer to geomagnetism text books, for example Parkinson (1983) and Wienert (1970).

Since the total intensity F time variations, at polar latitudes, where values of inclination is almost 90°, are very close to the vertical component Z time variations, the plots of total intensity time variations are not shown. They can however be obtained from the well known equation:

$$F^2=H^2+Z^2$$

Absolute measurements

For the normal absolute measurements-taking at the Observatory, a standard fluxgate magnetometer theodolite for the determination of D, I angles has been used.

At OASI three different azimuth marks are available, for the computation of the Declination (please refer to the 2001/2002 report for details). The coordinates of geodetic points (mark piers and measuring location) were established on the basis of GPS measurements. From these coordinates the azimuth values 152° 44' 04'', 60° 13' 36'' and 338° 07' 59'' were found.

The proton magnetometer recordings, continuously undertaken during the execution of the DI measurements, have allowed the calculation of the absolute intensive elements.

Table 1 shows absolute measurement values for each element; the values of the intensive components H and Z (rounded off to the nT) were computed using the relations:

$$H = F \cdot \cos I$$
$$Z = F \cdot \sin I$$

H₀ and D₀ reference values computation

Since the fluxgate was magnetically oriented in the horizontal plane, as in the previous installations, it was necessary to compute H₀ and D₀ reference values, comparing absolute and relative measurements, at the same time. For the Z component, once the vertical levelling of the sensor was assured, it was assumed that the variations measured by fluxgate were actually the vertical component of the geomagnetic field variations.

In the description the mathematical procedure used for computation of H₀ and D₀, the following symbols are used:

H ₀ , D ₀	Reference values
H _{abs} , D _{abs}	Values of absolute measurements at time t
x,y	Instantaneous variations recorded by fluxgate system at time t

For each absolute measurement, the reference values were computed as:

$$H_0 = H_{abs} \cos(\varphi) - x$$
$$D_0 = D_{abs} - \varphi$$

where

$$\varphi = \arcsin (y/H_{abs})$$

In order to reduce this dispersion in the set, the Chauvenet criterion was used. The method, based on the hypothesis of a Gauss probability distribution for the data, consists in the elimination of measurements whose difference from the average is greater than a multiple of the standard deviation fixed by the sample dimension (in this case a value 2.49 σ , corresponding to a sample of about 40 data elements, was used). This method, however, cannot be applied more than once, since an iterative procedure could exclude most of the values up to the complete elimination of the data (Worthing and Jeffner, 1943).

The average values of H₀ and D₀ are:

$$H_0 = (8019 \pm 8) \text{ nT}$$
$$D_0 = (136.02 \pm 0.07) \text{ deg}$$

Daily base lines computation

After H₀ and D₀ reference values are found, the computation of the base lines in relation to absolute measurements and then the computation of the daily base lines for all days, can follow. The available data are the H, D and Z magnetic element variations recorded by fluxgate system (sampling rate 1 minute) and the absolute measurements recorded from November 17 to December 03, 2010.

The base lines computation was undertaken by two different procedures. In the case of Z, assuming that the fluxgate recordings show the variations of the vertical components, the base line (B_Z) was

computed as the difference between the absolute measurements (Z_{abs}) and the fluxgate measurements (z). On the other hand, in the case of H and D, the magnetic orientation of the fluxgate system axes was taken into account. Using H_0 and D_0 reference values, the H and D base lines were computed for each absolute measurement as:

$$B_H = H_{abs} - [(H_0+x)^2 + y^2]^{1/2}$$
$$B_D = D_{abs} - D_0 - \arctg[y/(x+ H_0)]$$

Mean daily values of the base lines were obtained for those days in which more than one absolute measurement was available.

In order to have a daily base line for each magnetic element, a linear regression analysis using the least squares method has been undertaken. The results are shown in Fig. 1, where the experimental data, as well as the best fit lines are reported.

Using the daily base lines, one minute values for the three field elements H, D and Z were computed as:

$$H = [(H_0+x)^2 + y^2]^{1/2} + B_H$$
$$D = D_0 + \arctg[y/(x+ H_0)] + B_D$$
$$Z = z + B_Z$$

The measurements are reduced to the old site subtracting the following gradient:

$$\Delta H = -1.5 \text{ nT}$$
$$\Delta D = 13.0'$$
$$\Delta Z = 0.7 \text{ nT}$$

In Tables 2, 3, 4 all the hourly and daily averages and the total mean values for the H, D and Z elements on the entire measuring period (from November 16 to December 03, 2009) are reported; the relative plots are shown in Fig. 2. The plots of the one minute data follow in succession.

Geomagnetic field trend (1987-2011)

The availability of a long series of data since 1987 allows to evaluate the geomagnetic field trend. For each antarctic campaign we computed the average value of H, D, Z and F over the time period in which the absolute measurements were performed. In Fig.10 we show these values together with the corresponding IGRF values obtained from the web site: <http://www.geomag.bgs.ac.uk>.

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Table captions

Table 1: Absolute measurement values 2010/2011

Table 2: Horizontal intensity hourly and daily means
(from November 17 to December 03, 2010)

Table 3: Declination hourly and daily means
(from November 17 to December 03, 2010)

Table 4: Vertical intensity hourly and daily means
(from November 17 to December 03, 2010)

Figure Captions

Fig 1: Scatter plot and linear regression for daily H, D and Z^1 base lines.

Fig 2: Hourly means of the H, D and Z^1 elements during the whole campaign.

Fig. 3 – 9: Daily plots of the one minute values of the H, D and Z^1 elements.

Fig. 10: Geomagnetic field trend since 1987.

¹ Z values must be considered negative

TNB Geomagnetic Observatory

Mean values

Campaign	H(nT)	D(deg min)		Z(nT)	F(nT)
1986/1987	7391	136	49	64494	64916
1987/1988	7432	136	54	64452	64879
1988/1989	7444	136	40	64355	64784
1989/1990	7509	136	48	64325	64762
1990/1991	7522	136	45	64254	64693
1991/1992	7564	136	29	64228	64672
1992/1993	7582	136	40	64166	64612
1993/1994	7610	136	41	64148	64598
1994/1995	7643	136	46	64112	64566
1995/1996	7682	136	29	64062	64521
1996/1997	7716	136	33	64018	64481
1997/1998	7756	136	27	63979	64447
1998/1999	7789	136	24	63932	64405
1999/2000	7829	136	14	63886	64364
2000/2001	7861	136	18	63848	64330
2001/2002	7889	136	02	63794	64280
2002/2003	7916	135	58	63761	64251
2003/2004	7929	135	48	63729	64220
2004/2005	7976	135	47	63697	64194
2005/2006	8002	135	40	63624	64125
2006/2007	8027	135	44	63587	64092
2007/2008	8062	135	38	63521	64031
2008/2009	8102	135	20	63467	63981
2009/2010	8136	135	14	63417	63936
2010/2011	8181	135	09	63370	63897

Table 1

Terra Nova Bay Geomagnetic Observatory

Absolute measurements 2010/2011

date julian day	D		(+)	I		(-)	(+)	(+)	(-)
	beg (UT)	end (UT)	D (deg min)	beg (UT)	end (UT)	I (deg min)	F (nT)	H (nT)	Z (nT)
321	20:03	20:07	134 53.4	20:09	20:13	82 38.3	63905	8189	63378
321	20:19	20:22	135 05.0	20:24	20:28	82 40.4	63916	8151	63394
321	20:40	20:44	135 17.9	20:46	20:50	82 40.2	63909	8154	63387
321	20:55	20:58	135 10.9	21:00	21:04	82 41.1	63913	8137	63393
322	08:42	8:46	134 38.1	8:48	8:51	82 35.7	63902	8236	63369
322	08:56	8:59	134 27.0	9:01	9:04	82 36.7	63904	8217	63374
322	09:10	9:13	134 23.0	9:15	9:18	82 37.5	63909	8204	63380
322	09:21	9:24	134 02.6	9:26	9:30	82 39.1	63908	8174	63383
322	21:19	21:22	134 37.3	21:24	21:28	82 41.2	-----	-----	-----
324	02:49	2:52	134 33.3	2:54	2:57	82 37.5	63892	8201	63363
324	02:59	3:02	134 26.9	3:04	3:07	82 37.0	63862	8207	63332
324	03:10	3:13	134 33.7	3:14	3:17	82 36.1	63875	8226	63343
324	03:20	3:23	134 30.3	3:24	3:27	82 35.5	63891	8239	63358
326	04:49	4:52	134 45.3	4:54	4:57	82 32.1	63889	8300	63348
326	05:02	5:05	134 43.9	5:07	5:09	82 32.7	63901	8290	63361
326	05:13	5:15	134 45.6	5:17	5:20	82 33.2	63902	8282	63363
326	05:23	5:26	134 45.0	5:28	5:31	82 33.2	63902	8282	63363
327	05:00	5:03	134 41.5	5:04	5:07	82 34.1	63864	8261	63327
327	05:10	5:13	134 51.6	5:14	5:17	82 32.2	63876	8297	63335
327	05:26	5:29	135 02.8	5:31	5:34	82 32.5	63877	8292	63337
327	05:38	5:41	134 55.8	5:43	5:46	82 32.4	63877	8294	63336
328	03:52	3:54	135 28.4	3:56	3:59	82 37.7	63910	8199	63381
328	04:02	4:04	135 25.4	4:06	4:09	82 37.7	63909	8200	63381
328	04:12	4:14	135 24.8	4:15	4:18	82 37.5	63917	8205	63388
328	04:21	4:23	135 23.5	4:21	4:23	82 37.4	63919	8206	63390
329	04:51	4:54	134 59.2	4:55	4:58	82 35.8	63890	8232	63357
329	05:00	5:03	134 58.2	5:04	5:07	82 35.8	63890	8232	63357
329	05:10	5:13	135 02.0	5:15	5:18	82 35.9	63887	8230	63355
329	05:20	5:23	135 06.0	5:25	5:27	82 35.9	63889	8231	63357
330	09:08	9:12	134 57.3	9:14	9:17	82 38.2	63914	8192	63387
330	09:20	9:23	134 57.7	9:25	9:28	82 38.4	-----	-----	-----
330	09:33	9:36	134 56.2	9:38	9:41	82 38.5	-----	-----	-----
330	09:49	9:52	134 56.7	9:54	9:58	82 38.3	63921	8190	63394
331	06:00	6:03	134 46.2	6:04	6:07	82 36.0	63894	8230	63362
331	06:10	6:13	134 47.6	6:14	6:17	82 36.0	63898	8231	63366
331	06:21	6:23	134 48.8	6:25	6:28	82 35.4	63899	8242	63365
331	06:30	6:32	134 47.4	6:34	6:37	82 35.1	63905	8247	63371
332	23:20	23:24	136 07.1	23:25	23:28	82 40.4	63895	8149	63374
332	23:32	23:35	136 15.1	23:36	23:39	82 40.7	63867	8139	63346
332	23:41	23:44	136 07.6	23:46	23:49	82 40.9	63871	8136	63350
333	09:32	9:35	134 50.9	9:37	9:40	82 36.8	63943	8221	63412
333	09:44	9:47	134 58.3	9:49	9:51	82 36.8	63942	8220	63411
335	09:24	9:27	134 51.9	9:29	9:31	82 37.8	63936	8202	63408
335	09:33	9:36	134 51.6	9:38	9:40	82 37.7	63938	8203	63410
335	09:42	9:44	134 54.3	9:46	9:49	82 37.9	63939	8201	63411
335	09:51	9:54	134 56.1	9:56	9:58	82 38.1	63938	8196	63411
335	23:01	23:04	134 57.3	23:08	23:14	82 30.0	63859	8335	63313
336	09:33	9:36	134 56.7	9:37	9:40	82 38.5	63925	8188	63399
336	09:43	9:46	134 52.9	9:47	9:50	82 38.8	63924	8181	63398
336	09:53	9:56	134 52.6	9:57	9:59	82 39.1	63923	8176	63398
336	10:01	10:04	134 51.5	10:06	10:09	82 38.9	63913	8178	63387

337	09:20	9:23	134	54.6	9:26	9:29	82	38.9	63915	8179	63389
337	09:37	9:39	134	53.4	9:41	9:44	82	39.0	63917	8177	63391
337	09:46	9:49	134	52.9	9:50	9:53	82	39.0	63917	8177	63392

Table 2

Terra Nova Bay Antarctica, Italian Geomagnetic Observatory

Hourly H values (nT) from Nov 17 to Dec 03, 2010

UT	0	1	2	3	4	5	6	7	8	9	10	11	DAILY MEAN
	12	13	14	15	16	17	18	19	20	21	22	23	
julian day													
321	8177	8196	8201	8226	8258	8318	8278	8246	8196	8183	8167	8160	
	8169	8170	8169	8167	8162	8173	8163	8172	8163	8130	8150	8163	8190
322	8174	8199	8209	8261	8319	8275	8253	8243	8239	8177	8161	8158	
	8158	8163	8164	8140	8156	8153	8195	8180	8158	8159	8162	8171	8193
323	8173	8211	8241	8237	8216	8233	8224	8224	8207	8211	8186	8170	
	8171	8169	8169	8170	8175	8185	8190	8191	8178	8157	8164	8176	8193
324	8191	8208	8203	8217	8245	8263	8274	8285	8224	8196	8201	8167	
	8165	8164	8171	8170	8181	8190	8195	8176	8183	8183	8167	8153	8199
325	8154	8146	8180	8209	8225	8215	8214	8215	8229	8207	8198	8173	
	8154	8181	8168	8146	8160	8159	8159	8197	8171	8156	8161	8179	8182
326	8183	8182	8207	8245	8306	8293	8271	8264	8229	8201	8227	8154	
	8147	8145	8156	8149	8152	8146	8140	8155	8218	8206	8169	8160	8196
327	8181	8157	8182	8215	8235	8287	8294	8242	8252	8193	8166	8156	
	8190	8166	8144	8126	8079	8139	8139	8087	8101	8130	8165	8172	8175
328	8217	8235	8215	8201	8213	8252	8243	8198	8178	8175	8196	8191	
	8174	8158	8150	8169	8155	8141	8073	8099	8116	8170	8147	8177	8177
329	8185	8219	8227	8220	8231	8230	8226	8214	8212	8184	8178	8192	
	8164	8159	8161	8161	8167	8164	8173	8176	8196	8181	8168	8175	8190
330	8196	8207	8213	8213	8221	8216	8211	8199	8194	8190	8176	8184	
	8175	8159	8154	8149	8153	8149	8137	8140	8156	8163	8175	8190	8180
331	8205	8216	8215	8224	8215	8227	8237	8222	8206	8197	8191	8183	
	8175	8167	8168	8164	8153	8138	8085	8015	7952	8148	8108	8136	8164
332	8152	8193	8234	8254	8312	8246	8232	8208	8176	8158	8166	8191	
	8194	8167	8165	8143	8138	8147	8134	8095	8069	8084	8110	8142	8171
333	8161	8176	8182	8198	8198	8224	8233	8233	8233	8217	8199	8177	
	8182	8157	8147	8111	8121	8134	8154	8120	8173	8151	8165	8166	8175
334	8172	8159	8176	8204	8227	8228	8234	8220	8213	8220	8196	8179	
	8172	8167	8172	8149	8133	8168	8139	8127	8173	8176	8172	8172	8181
335	8158	8182	8192	8205	8217	8225	8221	8216	8209	8203	8177	8160	
	8155	8161	8162	8163	8143	8115	8071	8093	8097	8158	8133	8155	8165
336	8183	8168	8175	8212	8228	8235	8225	8209	8199	8187	8170	8166	
	8164	8165	8159	8156	8148	8149	8145	8150	8139	8141	8139	8165	8174
337	8190	8194	8195	8200	8215	8246	8242	8228	8201	8180	8165	8177	
	8172	8171	8174	8160	8152	8155	8172	8168	8171	8162	8166	8177	8185

TOTAL MEAN = 8181 nT

Table 3

Terra Nova Bay Antarctica, Italian Geomagnetic Observatory

*Hourly D values from Nov 17 to Dec 03, 2010
(degrees: first three digits, minutes: second two digits)*

UT	0	1	2	3	4	5	6	7	8	9	10	11	DAILY MEAN
	12	13	14	15	16	17	18	19	20	21	22	23	
julian day													
321	13506	13458	13456	13501	13507	13502	13443	13447	13445	13450	13454	13456	
	13452	13452	13452	13447	13449	13438	13445	13435	13508	13459	13438	13449	13452
322	13509	13509	13513	13508	13512	13455	13440	13430	13432	13415	13434	13451	
	13453	13454	13448	13458	13445	13439	13449	13432	13450	13437	13456	13506	13450
323	13507	13513	13516	13503	13503	13457	13454	13448	13446	13451	13457	13460	
	13459	13456	13456	13455	13449	13441	13443	13453	13502	13506	13500	13503	13457
324	13452	13436	13432	13426	13429	13418	13440	13431	13437	13443	13447	13451	
	13454	13454	13449	13447	13436	13435	13431	13430	13427	13434	13426	13503	13439
325	13523	13512	13504	13452	13454	13454	13453	13454	13456	13435	13447	13434	
	13446	13453	13445	13503	13450	13437	13447	13436	13513	13506	13458	13500	13454
326	13511	13516	13503	13511	13451	13443	13442	13441	13441	13438	13441	13436	
	13447	13500	13460	13459	13440	13440	13534	13452	13424	13442	13427	13458	13451
327	13458	13537	13504	13447	13437	13453	13501	13451	13442	13451	13454	13456	
	13450	13448	13456	13440	13503	13450	13444	13457	13455	13444	13520	13512	13455
328	13505	13451	13520	13532	13520	13501	13453	13504	13501	13449	13453	13444	
	13442	13448	13452	13446	13441	13440	13514	13447	13456	13444	13523	13503	13458
329	13505	13452	13502	13521	13510	13506	13504	13500	13460	13451	13454	13457	
	13457	13456	13502	13501	13453	13459	13448	13457	13458	13446	13522	13522	13501
330	13510	13507	13508	13506	13503	13502	13458	13456	13457	13458	13458	13455	
	13458	13460	13459	13504	13506	13504	13504	13508	13504	13504	13456	13446	13501
331	13443	13444	13439	13440	13449	13449	13448	13445	13451	13457	13454	13454	
	13455	13458	13451	13444	13453	13448	13511	13554	13546	13610	13631	13620	13506
332	13610	13510	13409	13401	13405	13524	13521	13508	13454	13455	13456	13456	
	13451	13451	13450	13458	13508	13507	13513	13521	13517	13550	13606	13607	13507
333	13556	13553	13543	13544	13544	13536	13515	13508	13446	13456	13458	13452	
	13454	13455	13503	13514	13514	13459	13501	13527	13518	13530	13539	13554	13519
334	13532	13530	13527	13527	13531	13528	13512	13454	13456	13458	13445	13450	
	13458	13502	13501	13501	13505	13500	13504	13516	13458	13511	13529	13525	13510
335	13532	13520	13509	13458	13500	13504	13502	13502	13457	13452	13454	13455	
	13459	13459	13458	13456	13453	13512	13522	13527	13533	13537	13545	13539	13510
336	13522	13529	13535	13532	13518	13508	13501	13452	13450	13453	13454	13456	
	13456	13458	13460	13500	13503	13504	13508	13504	13504	13515	13517	13513	13507
337	13508	13517	13519	13522	13517	13513	13457	13451	13452	13453	13453	13452	
	13452	13451	13450	13455	13503	13502	13452	13505	13514	13518	13521	13520	13504

TOTAL MEAN = 135° 09'

Table 4

Terra Nova Bay Antarctica, Italian Geomagnetic Observatory

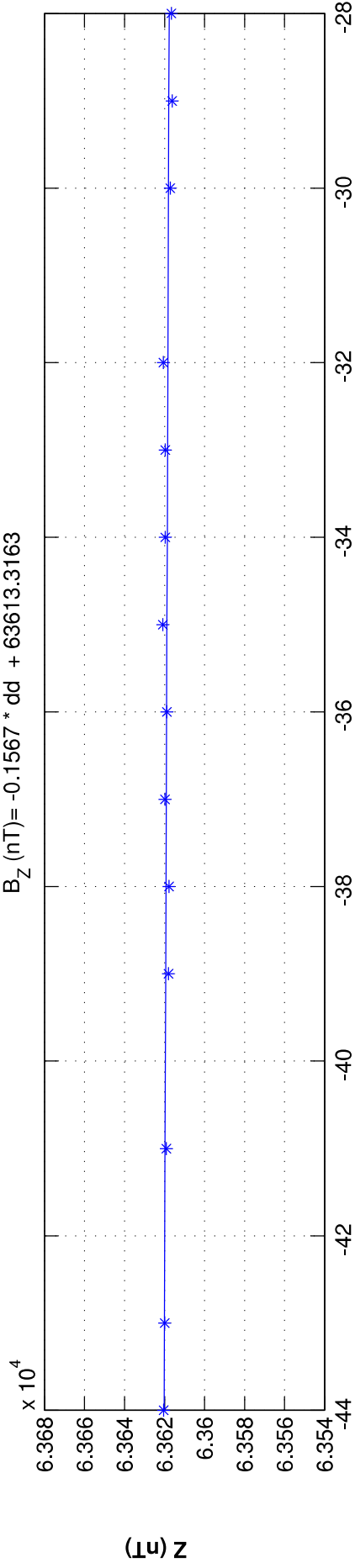
Hourly Z values (nT) from Nov 17 to Dec 03, 2010 (values must be considered negative)

UT	0	1	2	3	4	5	6	7	8	9	10	11	DAILY MEAN
	12	13	14	15	16	17	18	19	20	21	22	23	
julian day													
321	63349	63333	63329	63340	63345	63372	63394	63396	63385	63388	63399	63394	
	63390	63395	63400	63392	63405	63407	63398	63392	63387	63380	63339	63325	63376
322	63324	63326	63333	63333	63351	63338	63352	63362	63365	63382	63395	63396	
	63394	63404	63393	63377	63369	63369	63337	63374	63360	63345	63317	63318	63359
323	63334	63335	63322	63340	63344	63360	63366	63369	63376	63396	63407	63405	
	63397	63395	63398	63396	63397	63392	63404	63411	63434	63410	63396	63371	63381
324	63354	63348	63357	63348	63332	63328	63341	63380	63381	63384	63393	63383	
	63396	63404	63403	63403	63400	63379	63381	63392	63389	63400	63328	63300	63371
325	63313	63319	63322	63320	63349	63360	63374	63375	63381	63406	63402	63431	
	63435	63445	63422	63384	63389	63405	63358	63345	63391	63364	63342	63328	63373
326	63315	63314	63331	63348	63355	63366	63357	63363	63368	63378	63401	63413	
	63408	63391	63398	63380	63399	63350	63319	63360	63384	63444	63339	63319	63367
327	63287	63261	63306	63320	63331	63337	63402	63383	63395	63383	63398	63391	
	63388	63395	63378	63387	63369	63400	63408	63369	63289	63282	63355	63352	63357
328	63323	63317	63333	63369	63391	63393	63371	63389	63401	63404	63400	63393	
	63390	63392	63385	63398	63366	63349	63369	63370	63338	63348	63325	63321	63368
329	63322	63326	63330	63341	63345	63360	63375	63381	63388	63390	63393	63400	
	63406	63404	63414	63396	63394	63382	63410	63392	63415	63401	63349	63319	63376
330	63339	63342	63346	63358	63355	63372	63380	63381	63384	63387	63396	63392	
	63401	63411	63418	63423	63418	63410	63376	63343	63335	63299	63319	63356	63373
331	63350	63338	63323	63334	63351	63352	63366	63373	63386	63388	63389	63384	
	63388	63388	63395	63391	63384	63394	63397	63309	63353	63357	63398	63318	63367
332	63283	63307	63278	63294	63352	63354	63382	63388	63395	63392	63382	63387	
	63382	63384	63382	63386	63385	63379	63374	63359	63353	63362	63366	63359	63361
333	63349	63353	63353	63336	63354	63370	63384	63392	63408	63406	63406	63416	
	63434	63437	63461	63477	63455	63432	63402	63342	63350	63310	63311	63307	63385
334	63308	63305	63323	63338	63362	63379	63378	63376	63381	63391	63402	63396	
	63397	63396	63402	63421	63427	63403	63402	63356	63374	63367	63331	63311	63372
335	63336	63363	63339	63335	63352	63359	63375	63387	63399	63409	63411	63408	
	63394	63392	63396	63407	63417	63383	63406	63390	63359	63350	63317	63336	63376
336	63308	63338	63340	63341	63351	63366	63378	63384	63385	63395	63386	63388	
	63388	63393	63399	63397	63398	63394	63376	63382	63353	63326	63306	63331	63367
337	63347	63341	63332	63340	63352	63357	63368	63376	63386	63392	63387	63385	
	63387	63387	63397	63402	63396	63392	63398	63384	63348	63347	63314	63308	63368

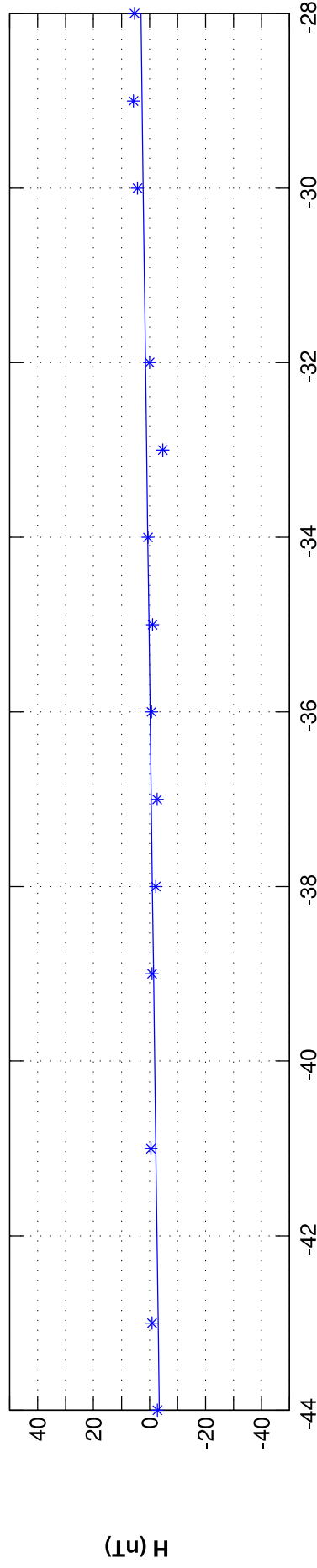
TOTAL MEAN = 63370 nT

Mario Zucchelli Station Z, H and D base lines 2010/2011

$$B_Z \text{ (nT)} = -0.1567 * \text{dd} + 63613.3163$$



$$B_H \text{ (nT)} = 0.4087 * \text{dd} + 14.5383$$



$$B_D \text{ (deg)} = 0.0040968 * \text{dd} + 0.14608$$

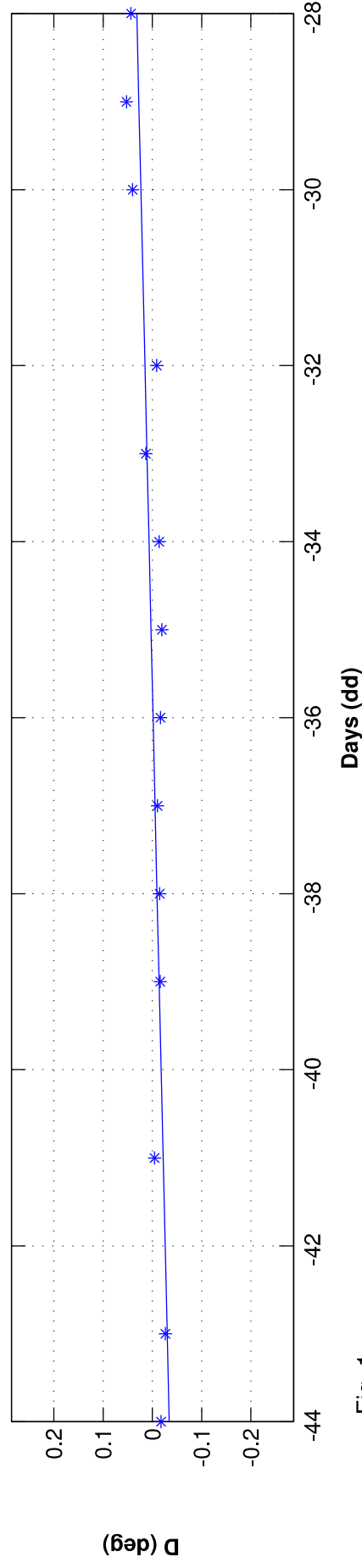


Fig. 1

TNB hourly means 2010/2011

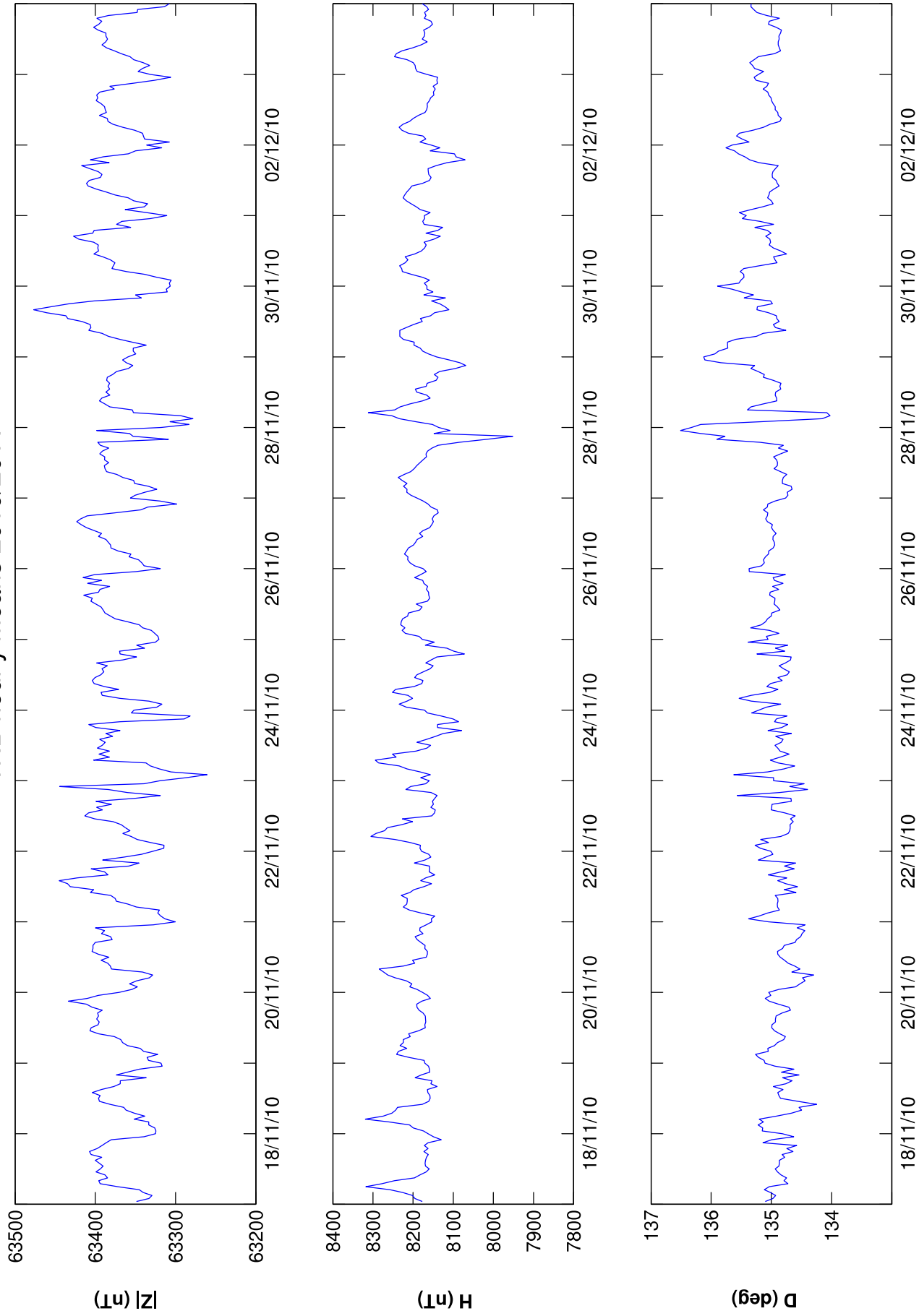
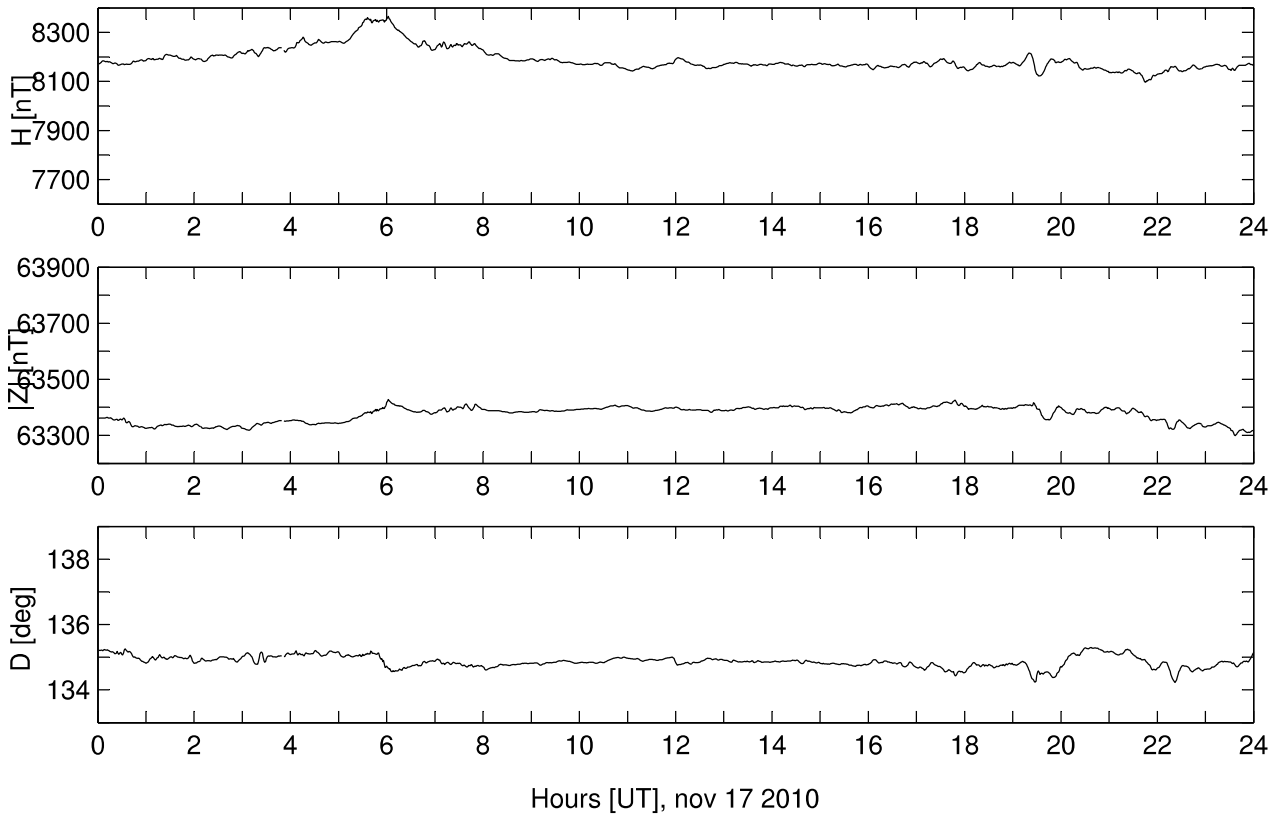


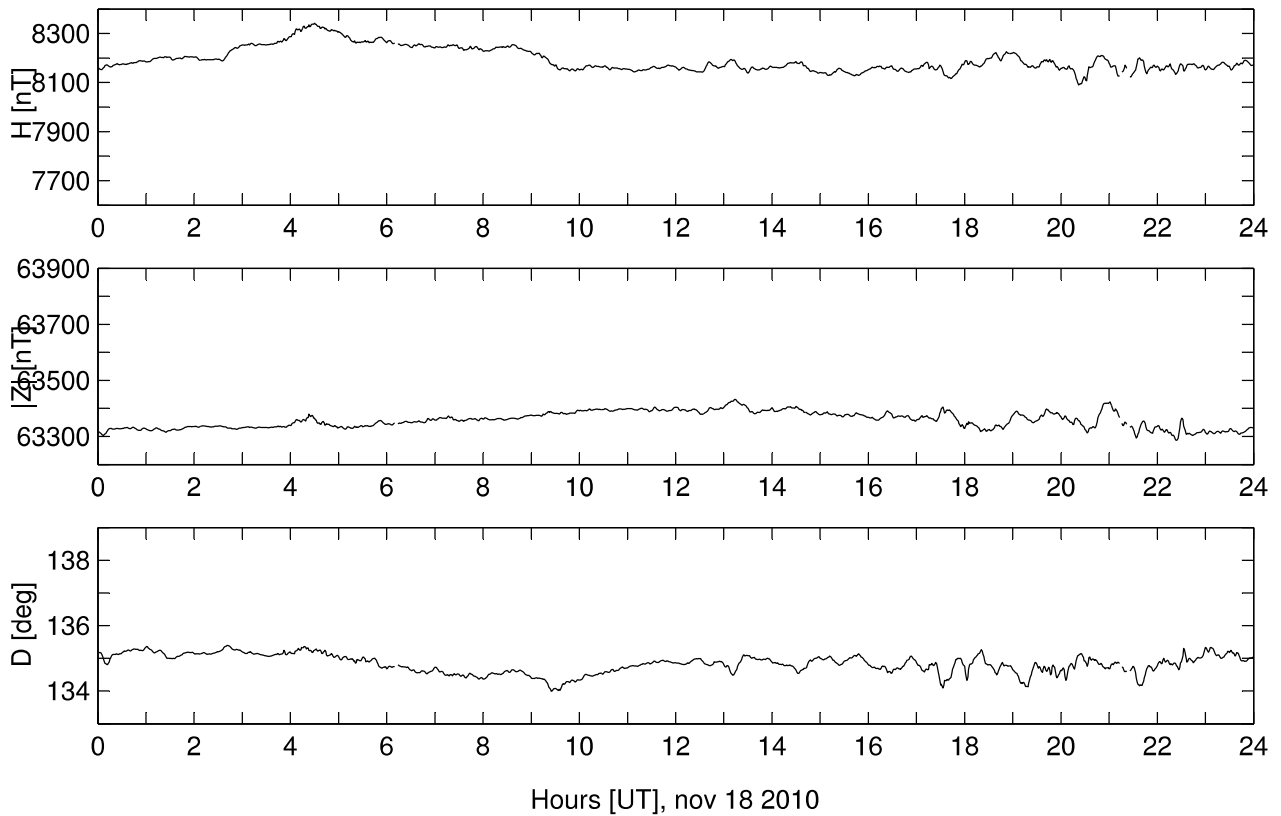
Fig. 2

Fig. 3 - 9

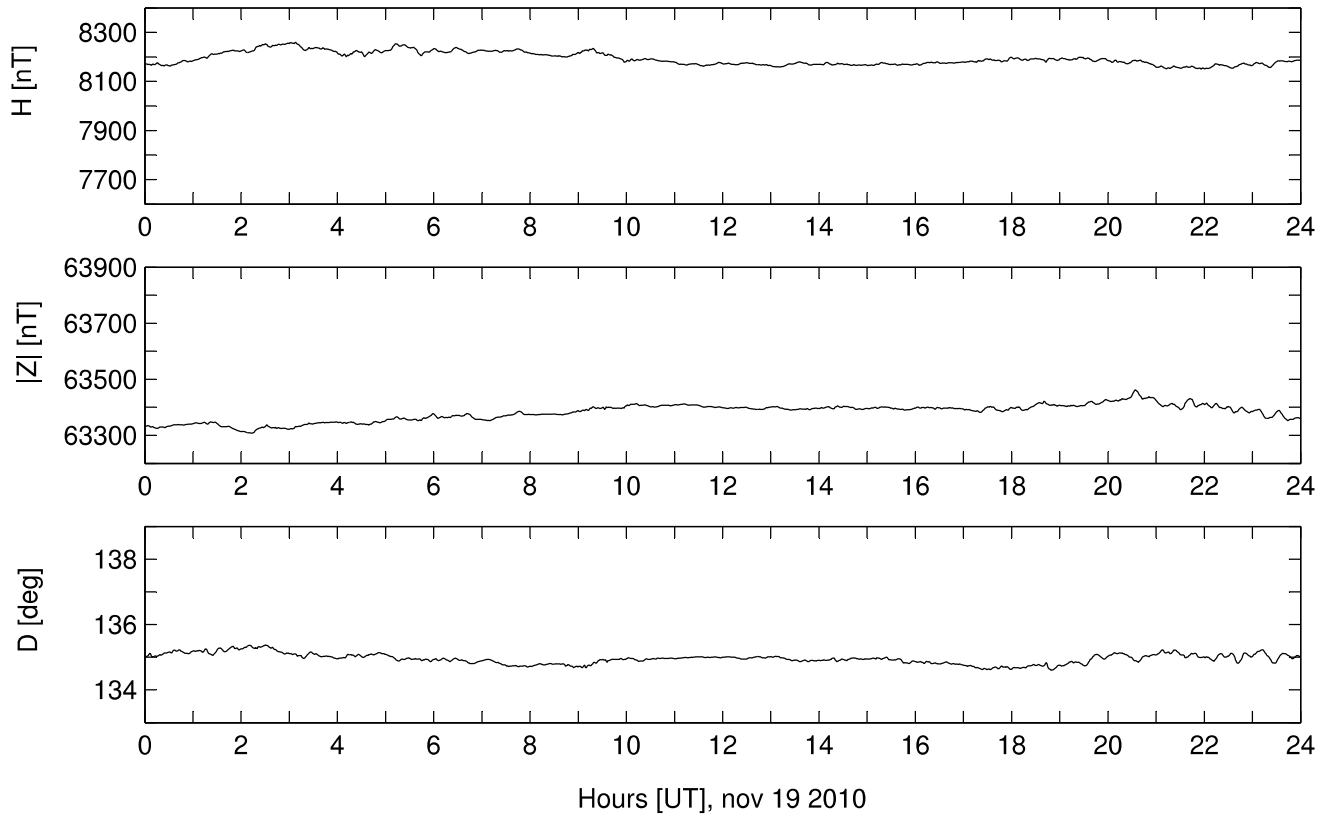
TNB Italian Geomagnetic Observatory, Antarctica



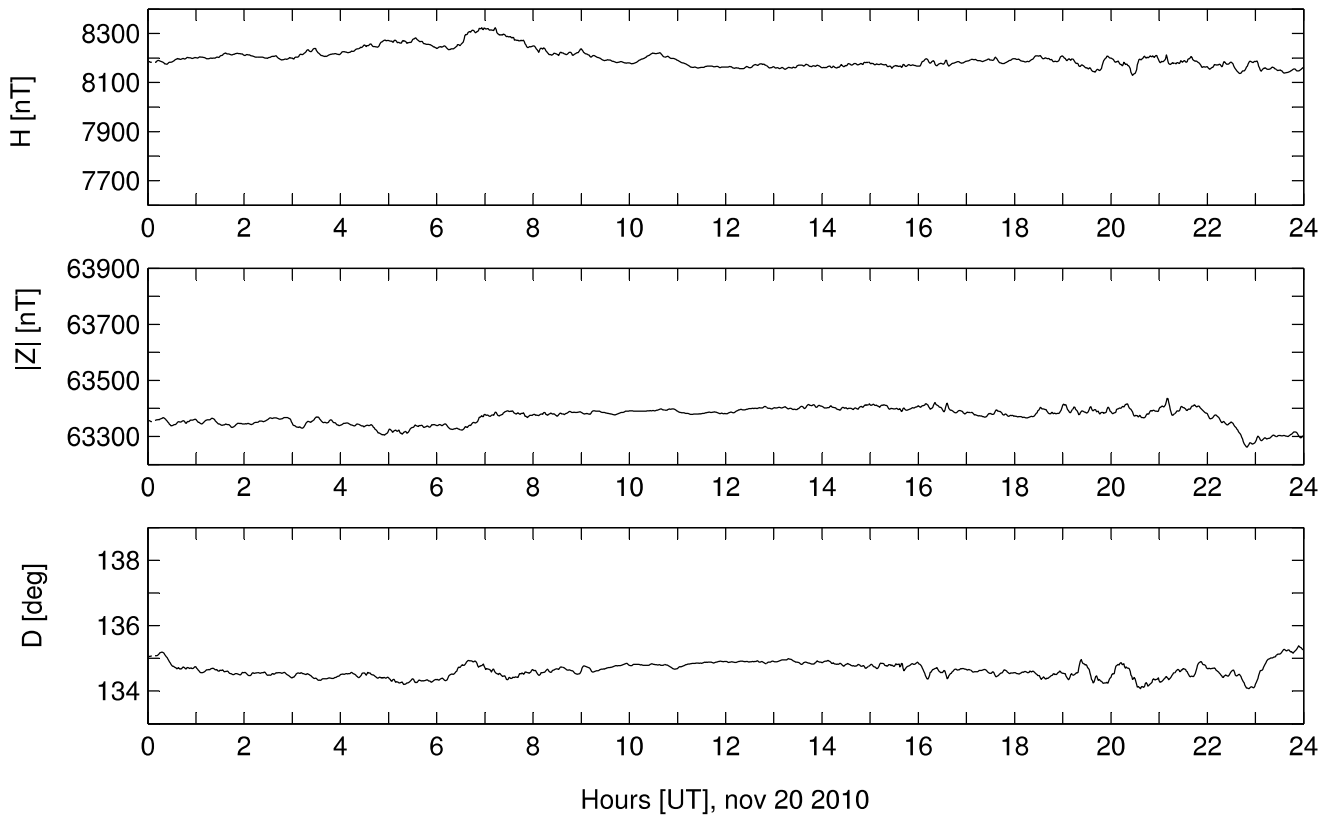
TNB Italian Geomagnetic Observatory, Antarctica



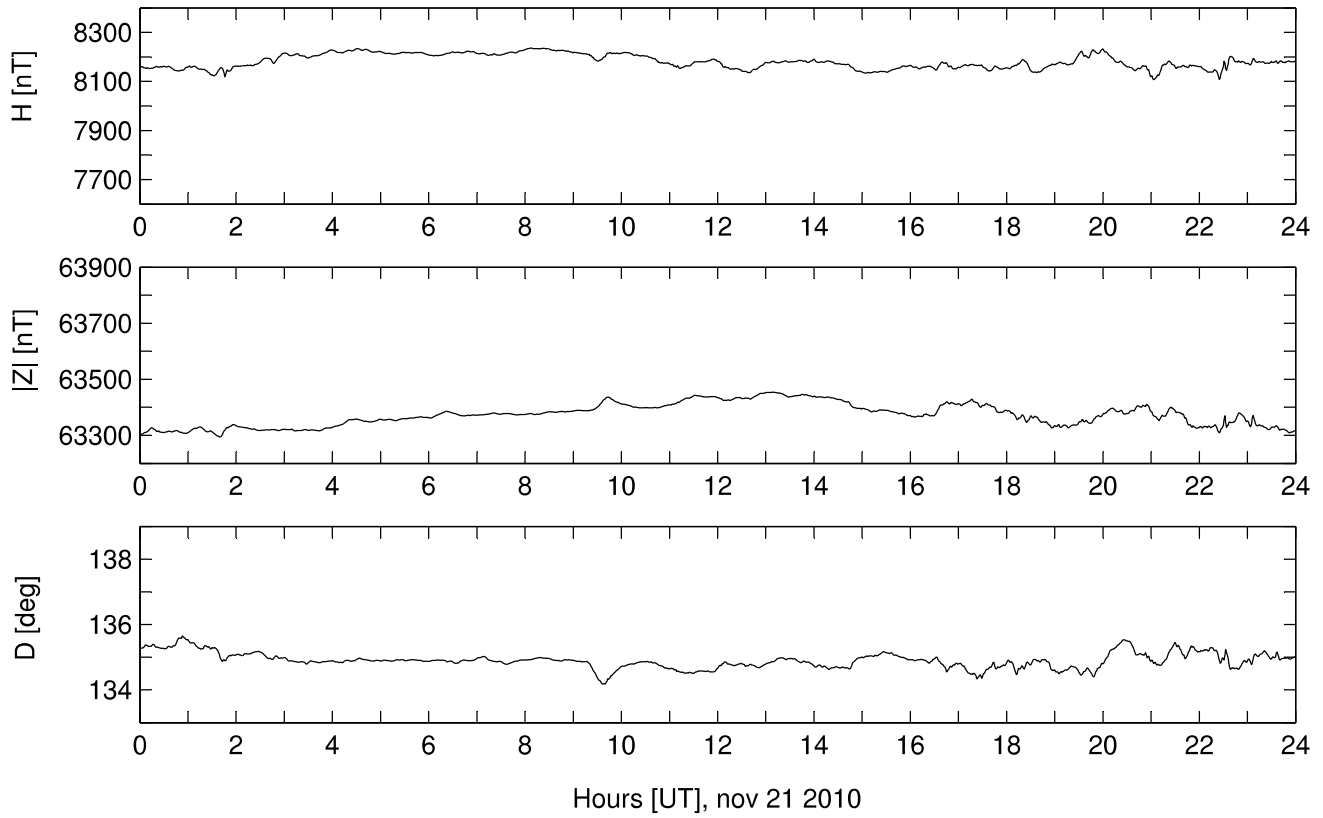
TNB Italian Geomagnetic Observatory, Antarctica



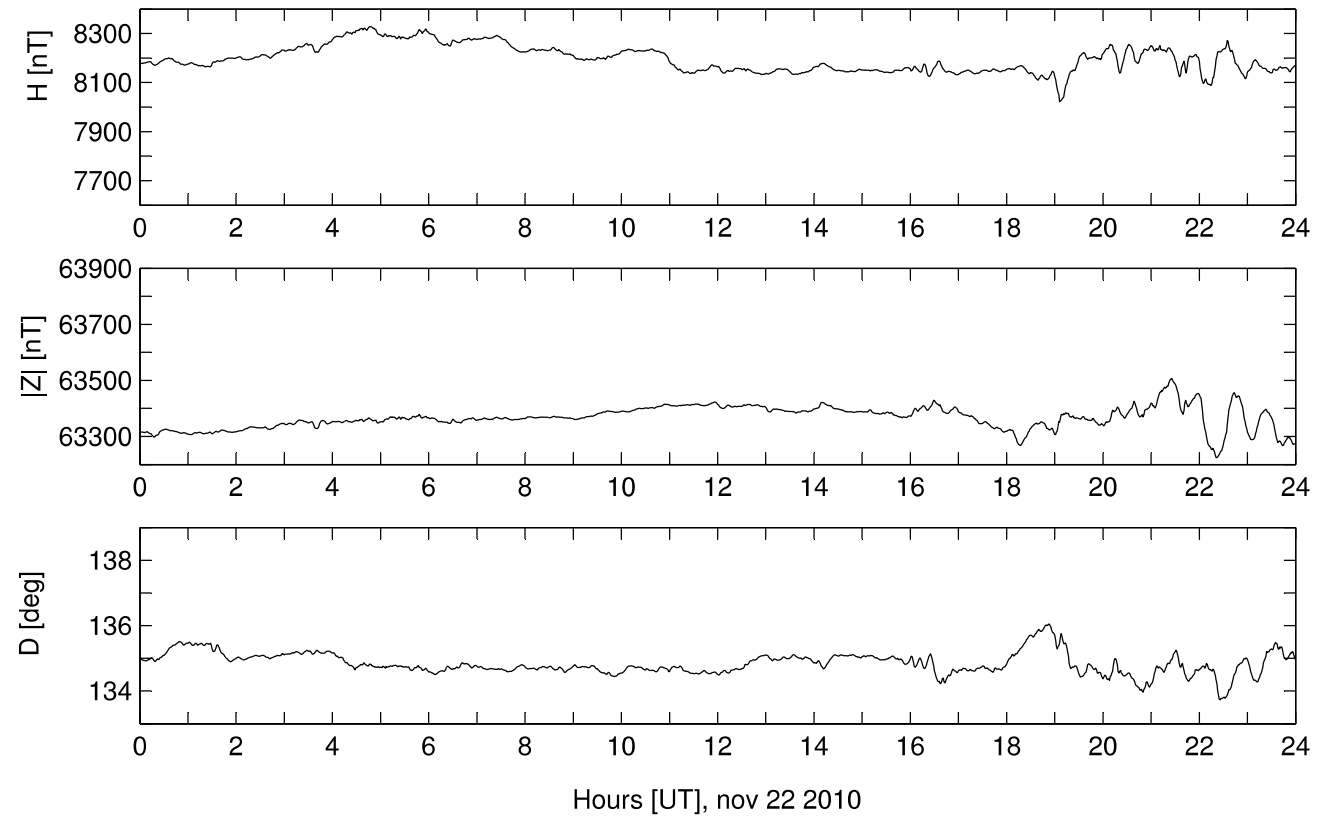
TNB Italian Geomagnetic Observatory, Antarctica



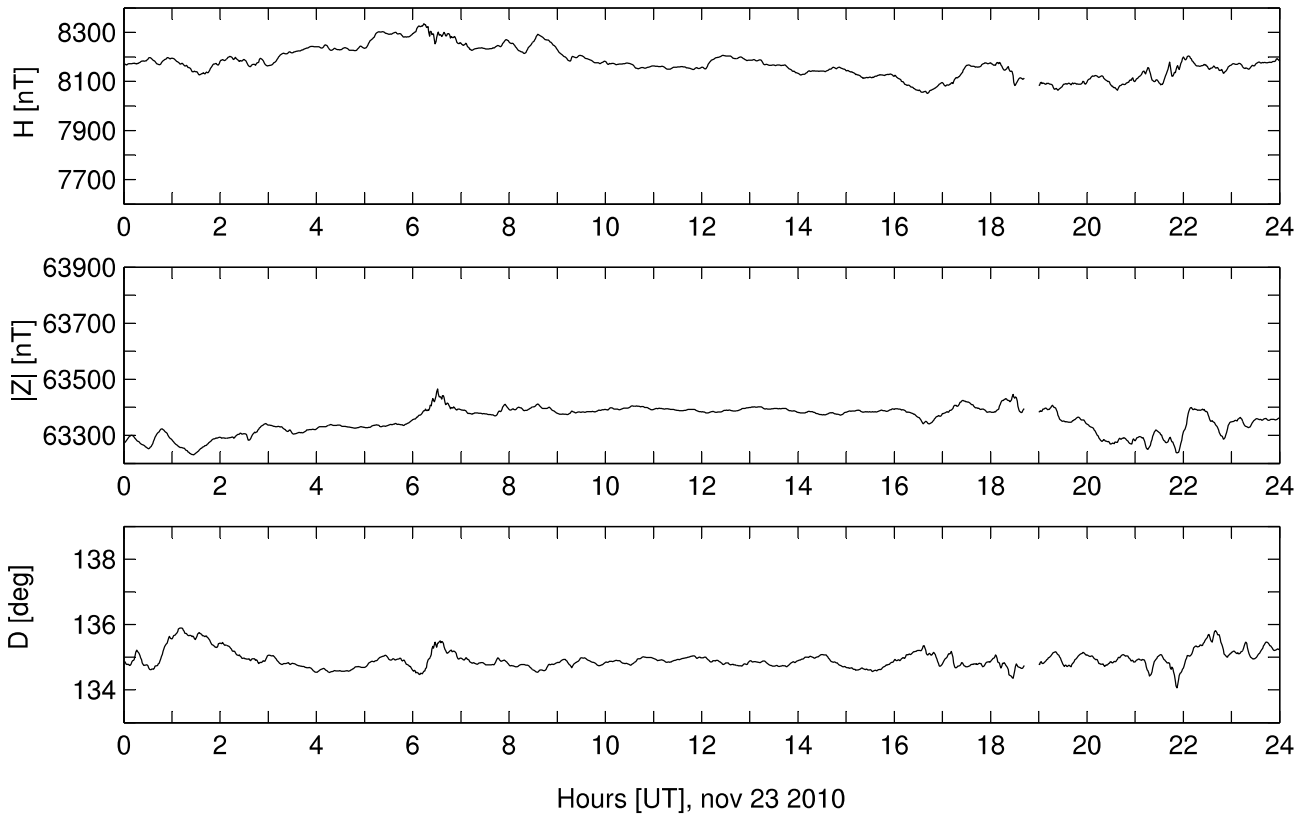
TNB Italian Geomagnetic Observatory, Antarctica



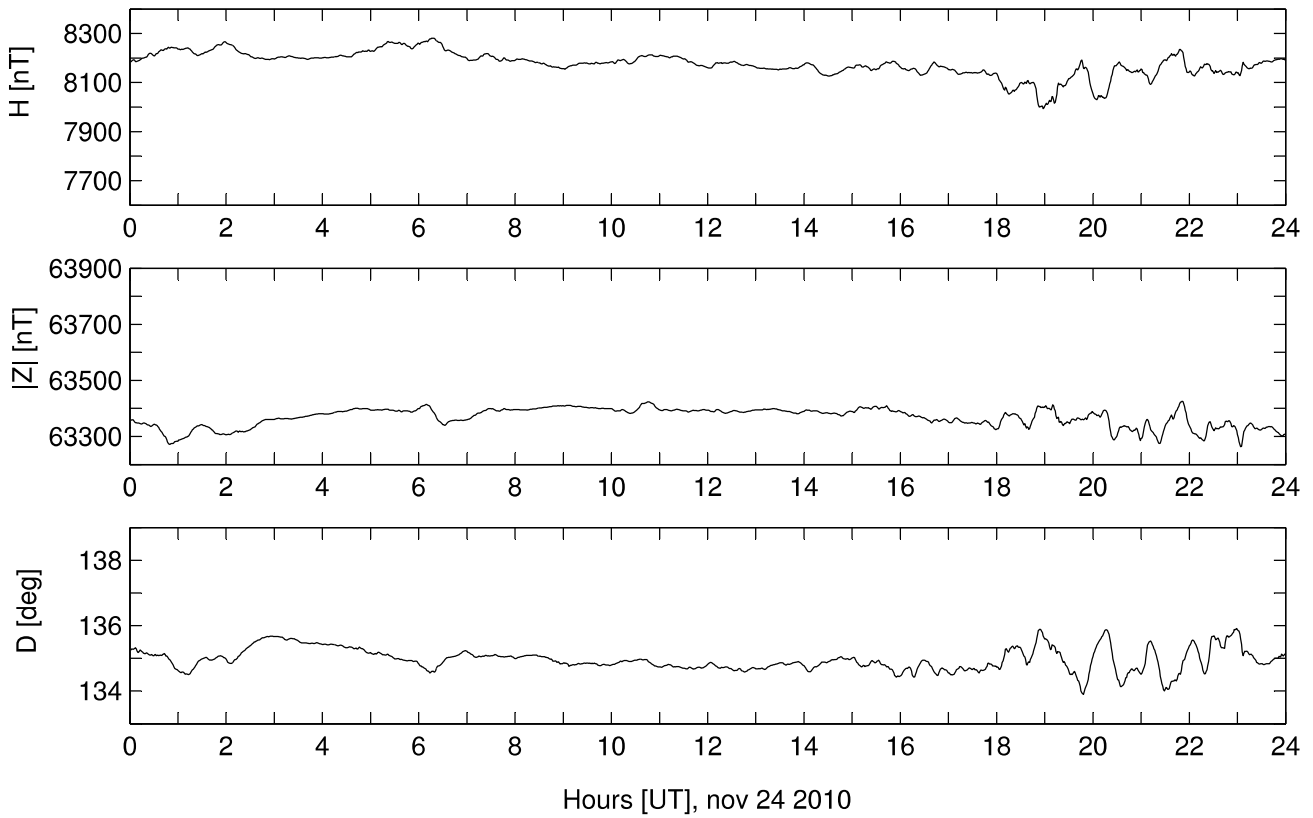
TNB Italian Geomagnetic Observatory, Antarctica



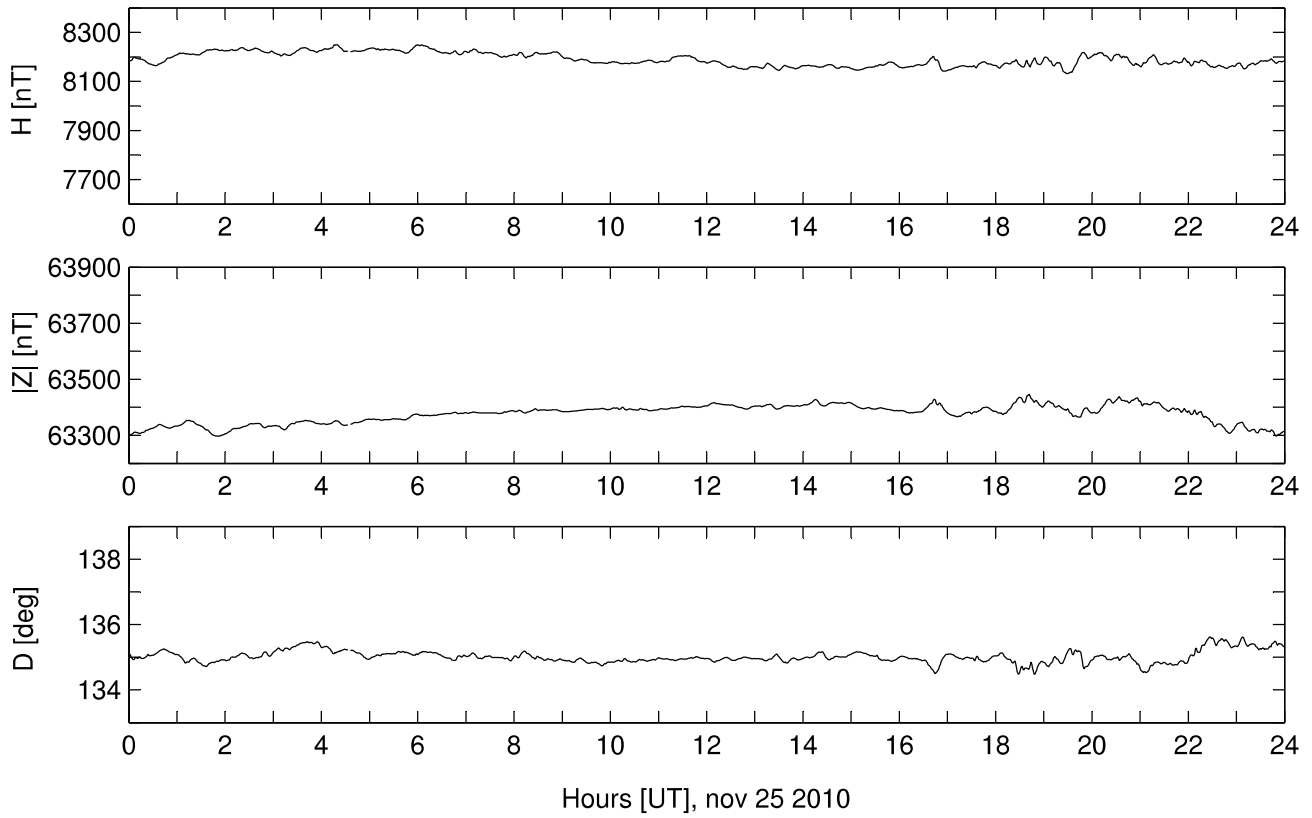
TNB Italian Geomagnetic Observatory, Antarctica



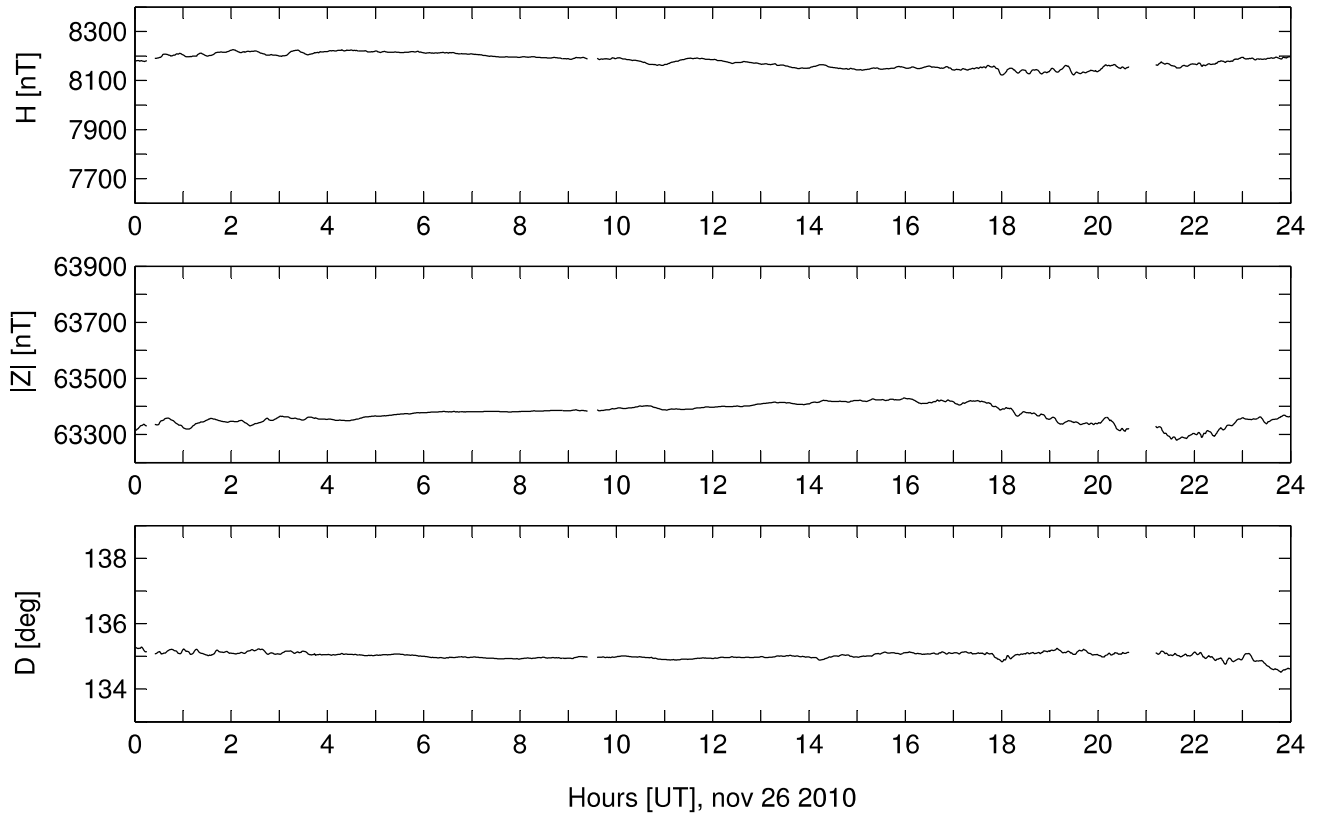
TNB Italian Geomagnetic Observatory, Antarctica



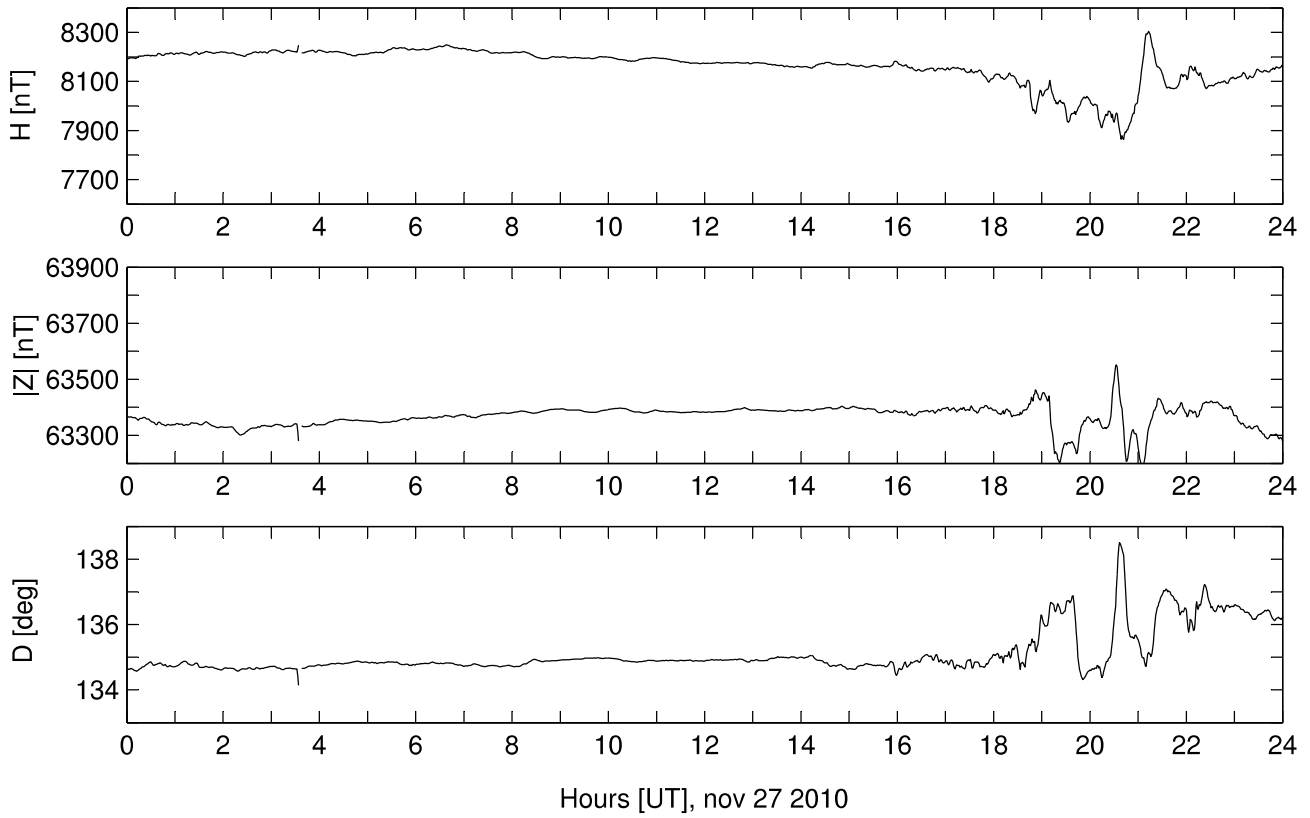
TNB Italian Geomagnetic Observatory, Antarctica



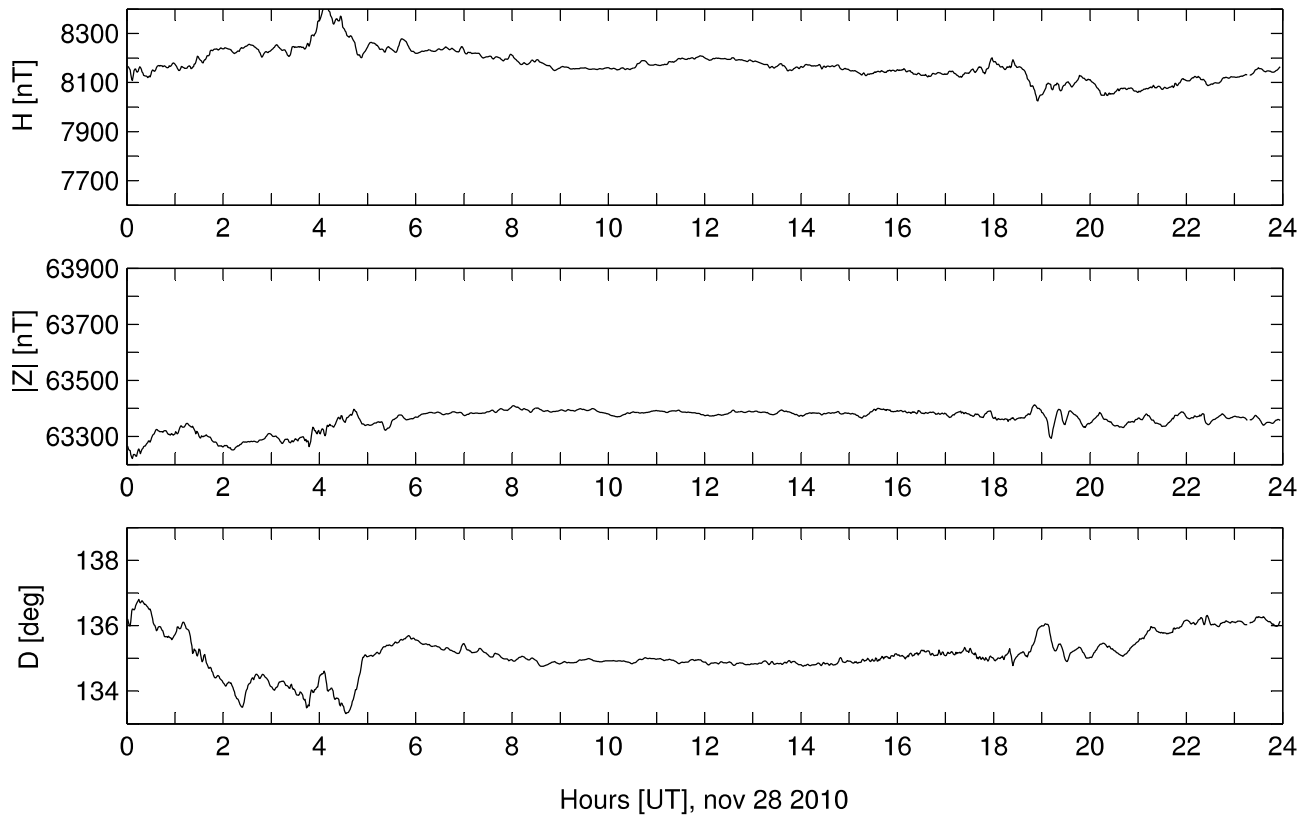
TNB Italian Geomagnetic Observatory, Antarctica



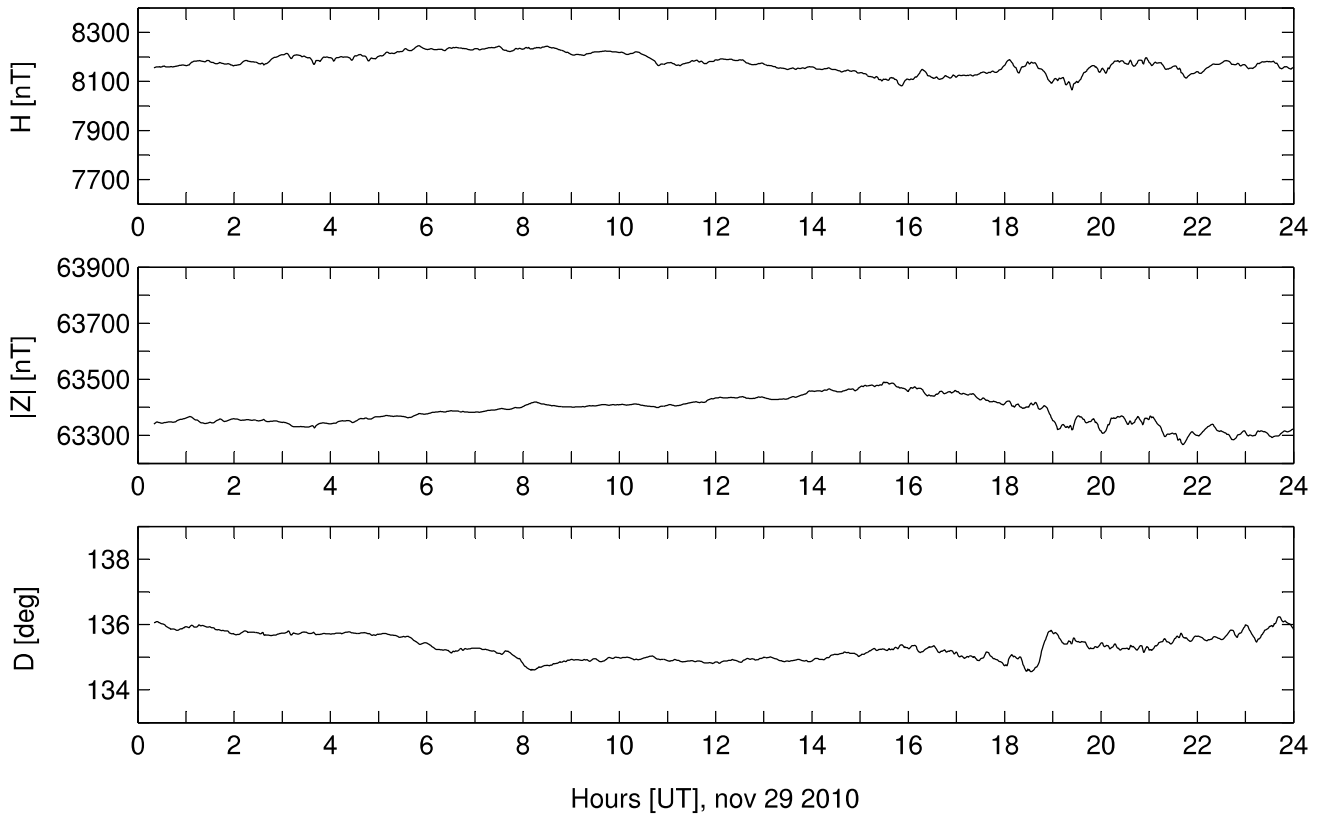
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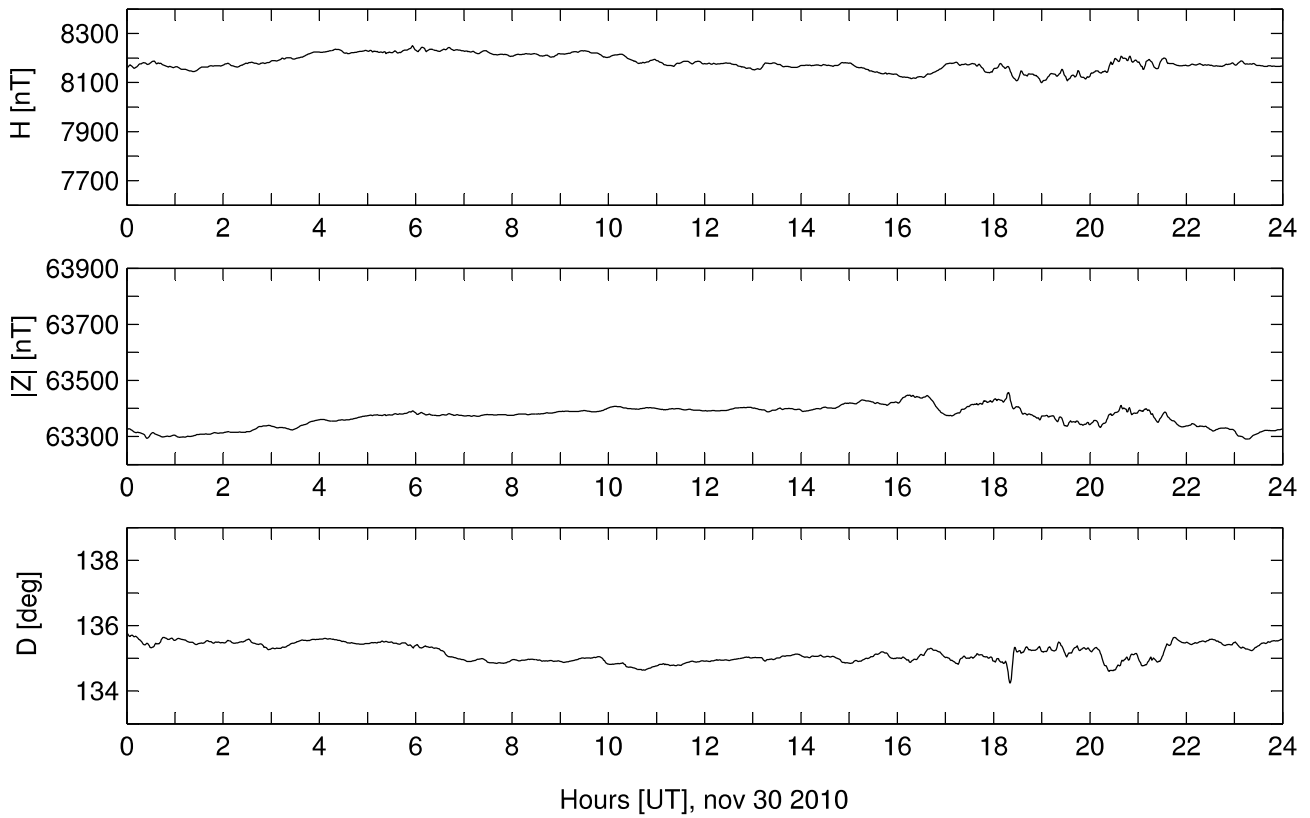
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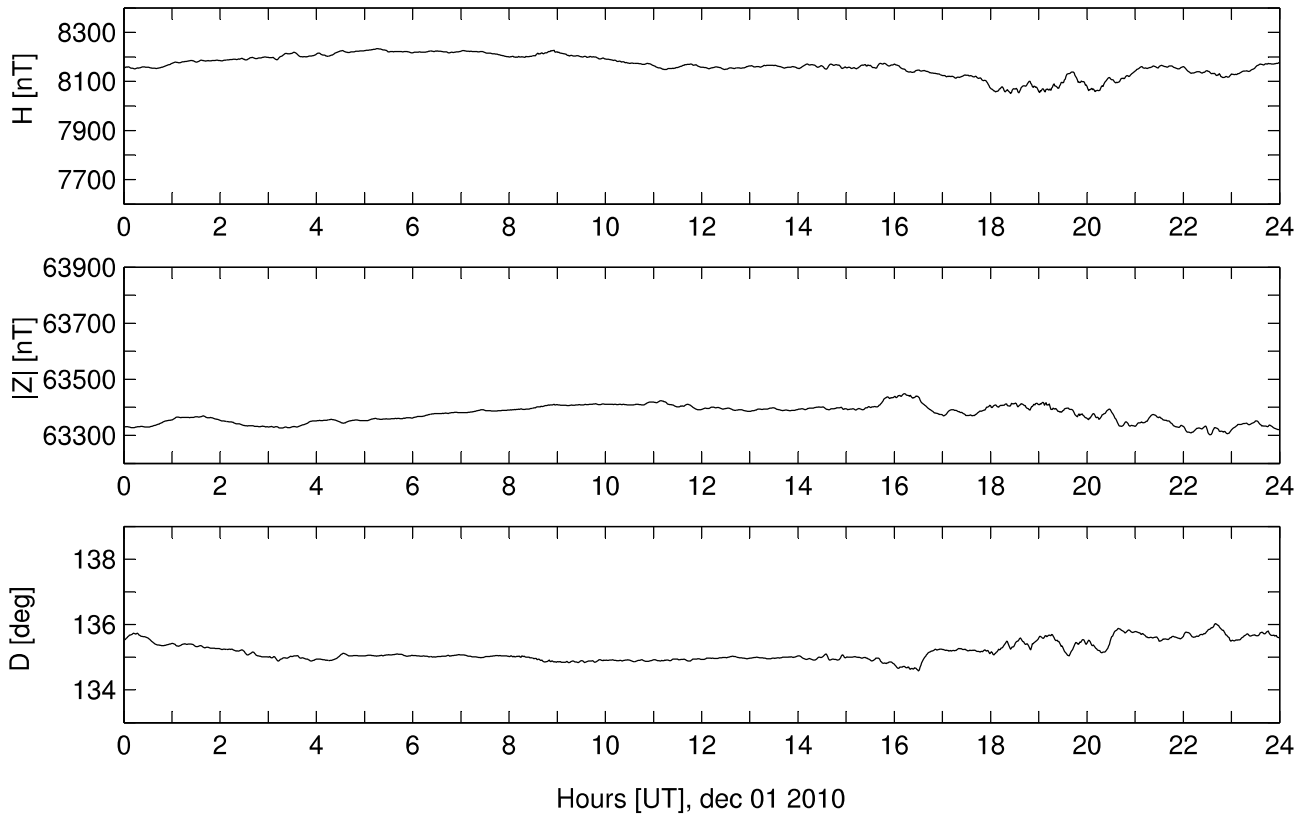
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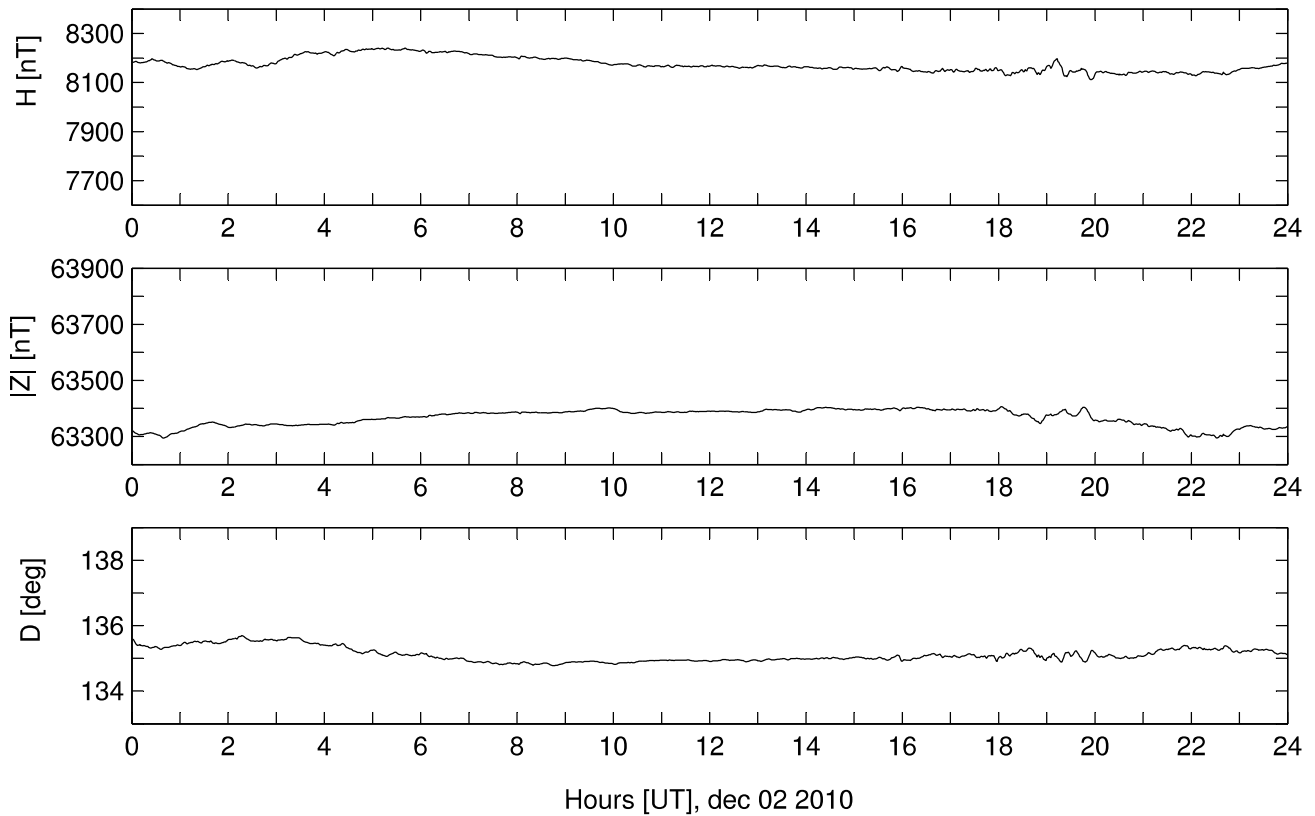
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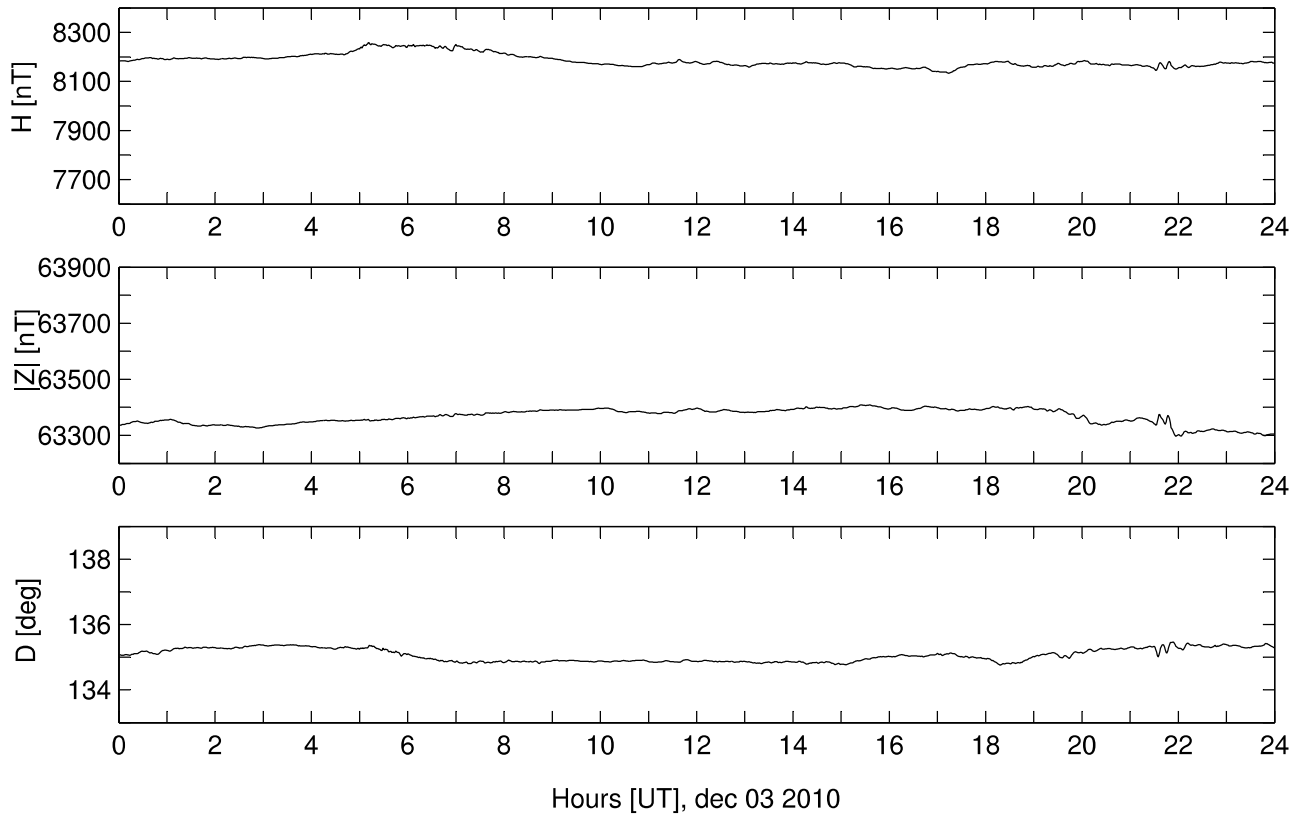
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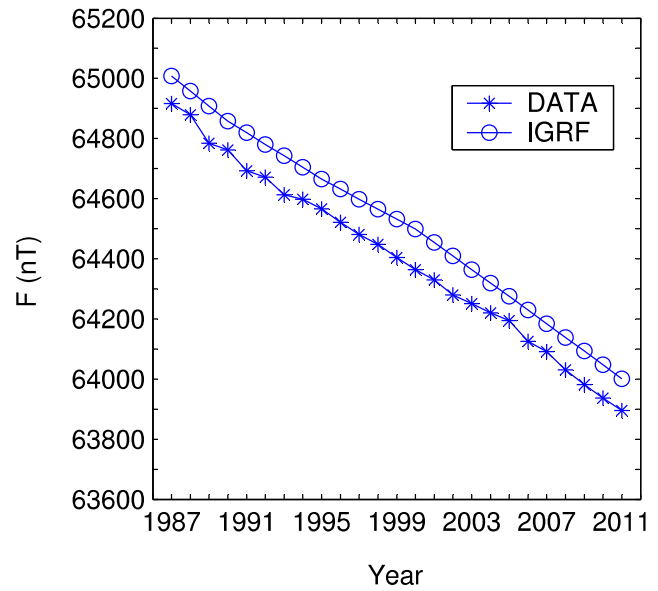
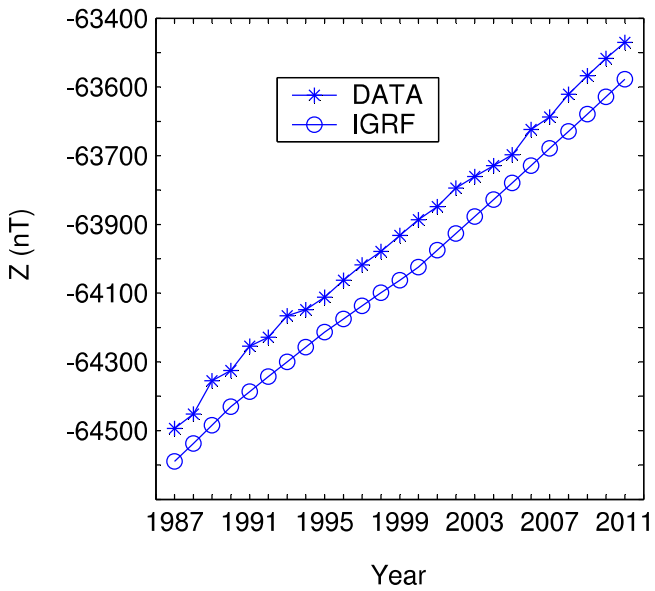
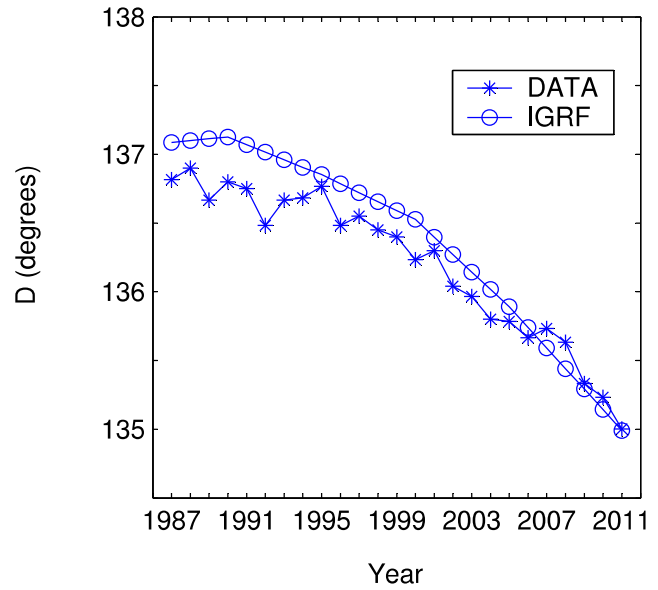
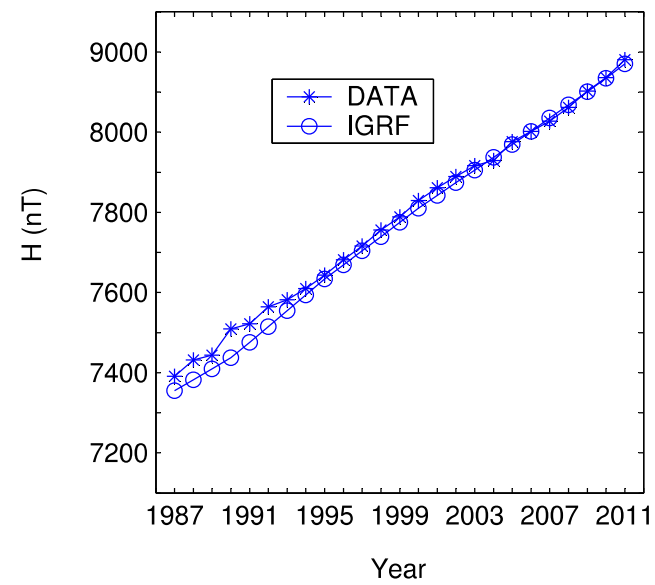


Fig. 10