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First observations of **irregular surface of** interplanetary shocks at ion scales by Cluster

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1. CONTENTS

This file contains supporting information for the paper "First observations of irregular interplanetary shocks at ion scales by Cluster". In the Section 2 we show wavelet spectra of magnetic field fluctuations observed by Cluster 1 spacecraft upstream of the four interplanetary (IP) shocks studied in our publication. In the Section 3 we show ion spectrogram and energy fluxes around two of the shocks for which the data were available. In the Section 4 we show the results of our high-M_A, low-β run. In the Section 5 we provide information on our novel one-spacecraft method for determining shock normals. We first provide the description, then we discuss the sources of errors and in the end we provide figures of B-field profiles of the shocks in the shock-normal coordinate system.

2. WAVELET SPECTRA OF UPSTREAM WAVES

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Figure 1 shows magnetic field data and the corresponding wavelet spectra for the four IP shocks observed on 17 Januar 2001, 5 April 2010, 26 February 2012 and 3 March 2012. Panels i) show B-field magnitude data as black lines, while $B_{x,GSE}$ or -$B_{x,GSE}$ component is represented by the blue line. Panels ii) and iii) exhibit B and $B_{x,GSE}$ wavelet spectra, respectively. We can see that compressive and/or transverse B-field fluctuation in the frequency range 10^{-2}-10^{-1} Hz are present upstream of all four shocks. In general, there is more power in the transverse component of these fluctuations than in the compressive component.

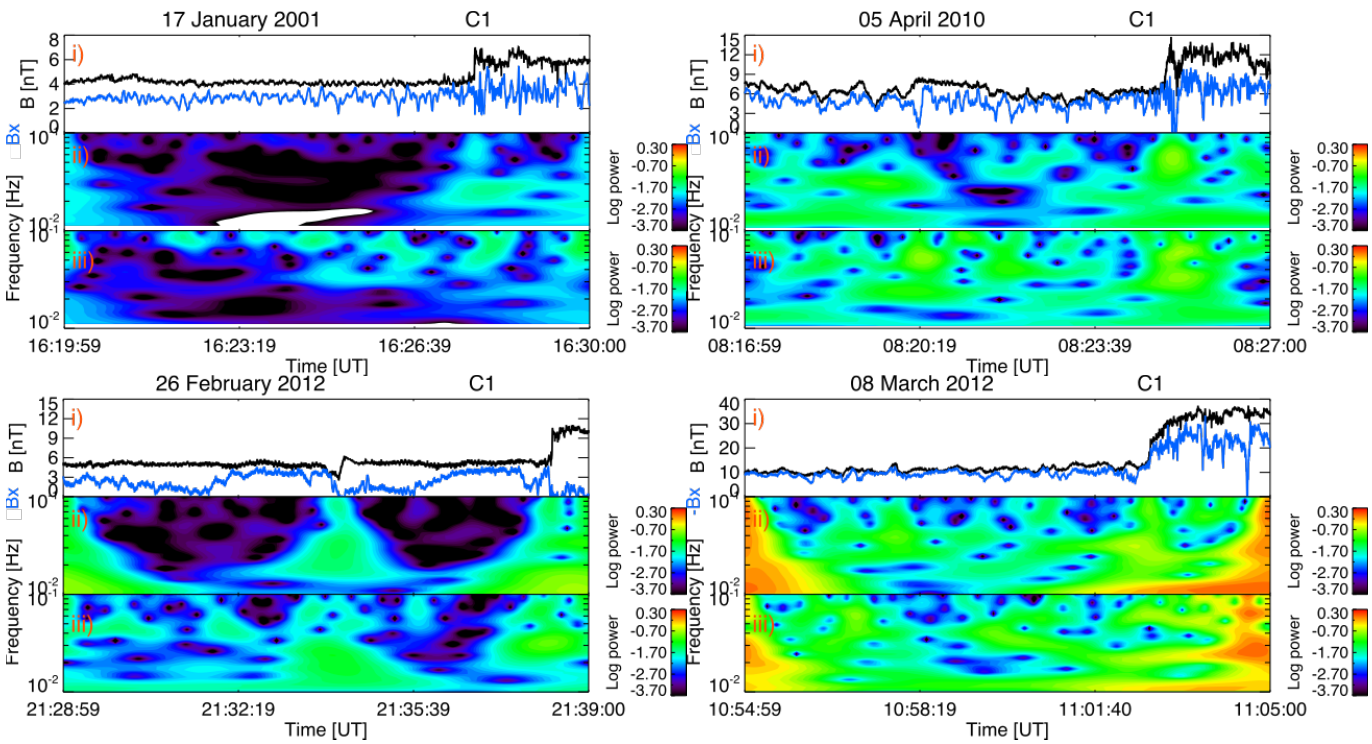


Figure 1. Magnetic field data and wavelet spectra during time periods when the four IP shocks were observed. Black traces on panels i) represent the magnetic field magnitude. Blue traces on panels i) show $B_{x,GSE}$ or -$B_{x,GSE}$ magnetic field component. Panels ii) and iii) exhibit wavelet spectra of the B and B_x, respectively.

3. PARTICLE DATA

Figure 2 shows magnetic field, particle spectrogram and particle energy fluxes at time when a) 17 January 2001 and b) 5 April 2010 shocks were observed. In both cases the suprathermal ion energy fluxes in units (in units of keV/(s·cm^{-2}·sr·keV)) start increasing before the shock arrival and peak at shock transition, suggesting they are accelerated by the shocks. The suprathermal ion energy flux (and magnetic ULF fluctuations) in the case of the 5 April 2010 could partially arrive from the Earth's bow-shock, since the ion spectrogram suggests that prior to and possibly during the shock encounter, the Earh's foreshock has been observed intermittently.

4. SIMULATION RESULTS FOR HIGH-M$_A$, LOW-β RUN.

Figure 3a shows results from our high-M$_A$ (=6.5), low-β (=0.2) run at time t=112.5 Ω_i^{-1}) with x = [-25,25] d$_i$ and y = [40, 120] d$_i$. x=0 is the average shock position obtained from the averaged (in y direction) B-field profile. The colors represent the B-field magnitude. The white curve marks the shock front and blue arrows show the directions of local shock normals.

Figure 3b shows four B-field profiles for y=46 d$_i$ (black), 50 d$_i$ (red), 97 d$_i$ (cyan) and 115 d$_i$ (magenta). Animations for this run can be found at
http://usuarios.geofisica.unam.mx/primoz/IPShockRipplingSupplement/ and are titled BfieldLowBeta.gif, BfieldHighLowShort.gif.

Figure 3c shows the distribution of θ_{BN} angles at time t=112.5 Ω_i.

Figure 3d shows the time evolution of the θ_{BN} for the point on the shock surface at y=97 d$_i$.

Figure 3e shows θ_{NN} angles for pairs of normals shown on panel a).

5. ONE-SPACECRAFT METHOD FOR DETERMINING SHOCK NORMALS

Determining the geometry (θ_{BN}) of observed collisionless shocks is fundamental for understanding the physical processes that govern particle acceleration at these shocks as well as their evolution in time. In order to determine θ_{BN}, one needs to find the shock normal and the upstream B-field direction. Obtaining the latter is straightforward, while determining precise shock normal vectors not so much. Common methods used for calculating the normal vectors can be divided into multi-spacecraft and one-spacecraft methods. The first relay on determining accurate shock crossing times for at least four spacecraft. This can be hard if the shock transition is highly structured and if time

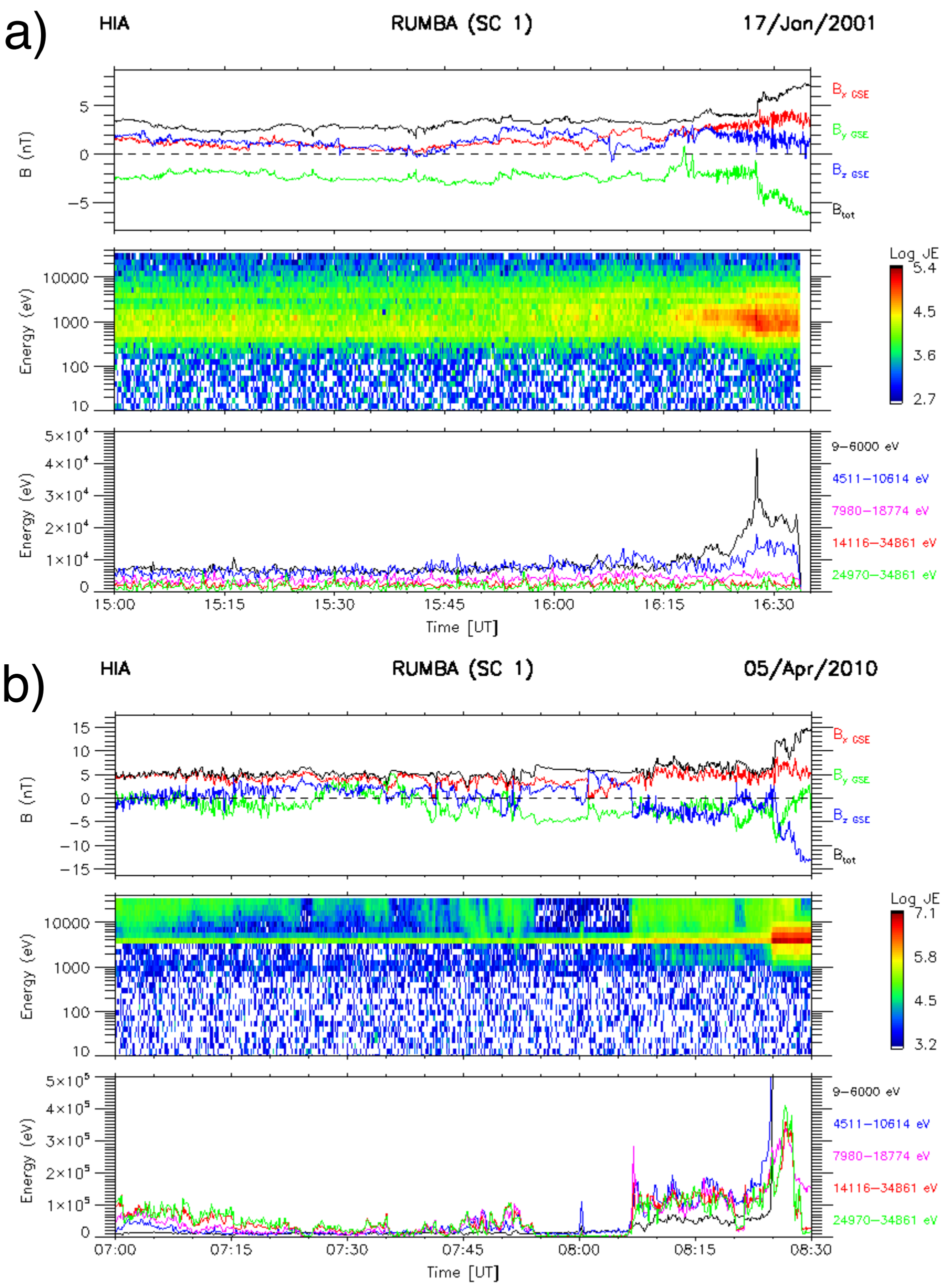


Figure 2. Panels a) and b) show magnetic field data from FGM and particle spectrograms and fluxes for 17 January 2001 and 5 April 2010 shocks.

differences between pairs of spacecraft are of the order of time periods during which the shocks are observed.

The most common one-spacecraft method involves the magnetic coplanarity theorem. This requires averaging of upstream and downstream fields during chosen time intervals (but exclude the shock

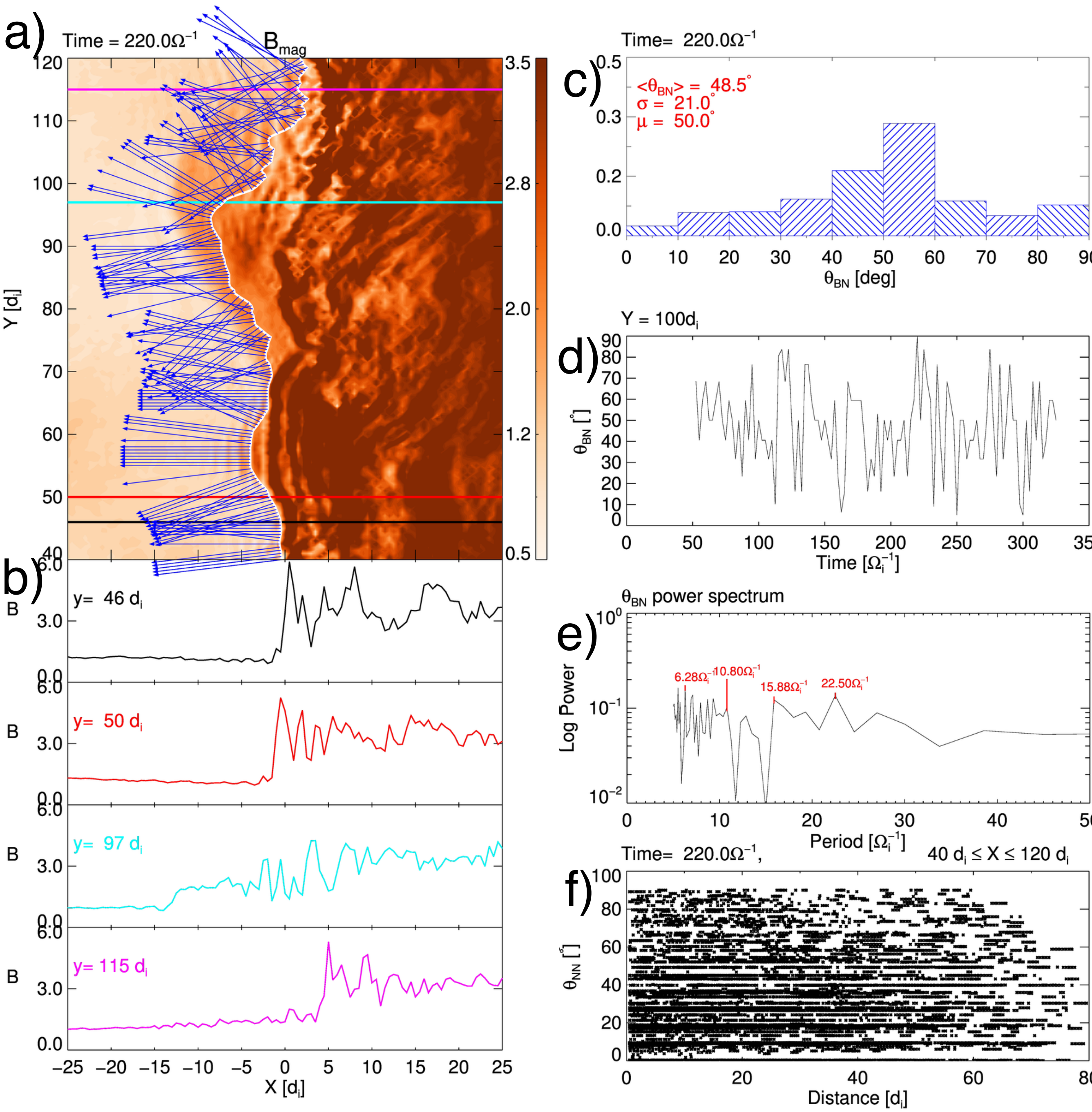


Figure 3. Results from our high-M$_A$, low-β run.

transition) which are then used to calculate the shock normal and θ_{BN}. Thus one obtains some time-averaged values. When multiple inter-spacecraft separations are small ($\lesssim$100 d$_i$), one would expect the shock normals calculated this way to coincide within the margin of error. This is because self-reformation is a cyclic process so local shock normals and θ_{BN} vary in time around some average value which should be similar at small spacecraft separations.

In order to study shock irregularity, we need local shock normals at the times when the shocks were observed by each spacecraft and see how they vary as a function of inter-spacecraft separation. Here we use a one-spacecraft method based on shock normal coordinate system (SNCS). The latter contains three perpendicular axes, n, l and m. The n-axis is parallel to the shock normal, the l-axis contains a projection of the upstream B-field on the shock plane, while the m-axis completes the right-hand coordinate system. When crossing a shock, the B_n component is constant at some finite value, the B_m-component is zero, while the B_l component changes from upstream to downstream.

This is of course strictly true only for MHD shocks. In the case of collisionless shocks there exist out-of-plane component of the magnetic field produced in the shocks's foot and overshoot. Still we expect to find a unique direction of the maximum variance of the B-field (l-axis) and another direction in which the B-field oscillates around zero (m-axis). The third direction that completes the right-hand coordinate system is thus the n-axis along which the B_n component varies around some average value.

In order to find the SNCS using given interval, we first smooth the B-field data by using a 4-second sliding window in order to remove the upstream whistlers. We then perform minimum variance analysis (MVA, Sonnerup & Scheible 1998) of the B-field across the shock and postulate that the direction of maximum variance gives us the l-direction. We also obtain two more vectors, perpendicular to l. We then rotate one of them around the l-axis and calculate the absolute value of the mean of the B-field projection along it. Once this value reaches its minimum close to 0, we take the corresponding vector to point along the m-axis and the remaining vector has to point along n.

5.1. *Sources of error*

This method is not without errors. There are two main sources that distort our calculations. The first is the error of the MVA method itself which depends on the number of measurement points and the calculated eigenvalues (Sonnerup & Scheible 1998):

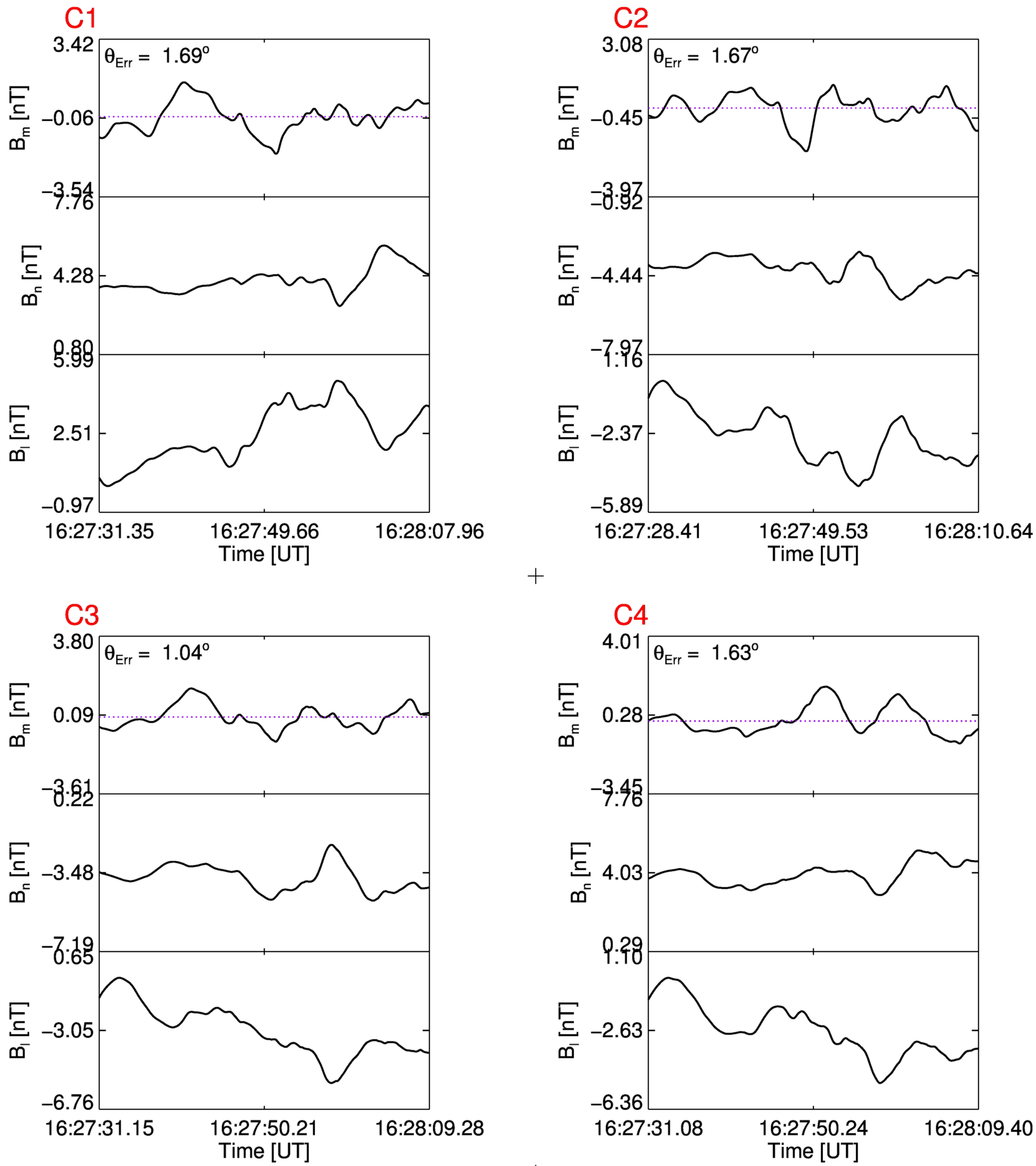
$$\theta_{Err} = \sqrt{\frac{\lambda_3}{M-1}\frac{\lambda_2}{\lambda_2-\lambda_3}}. \tag{1}$$

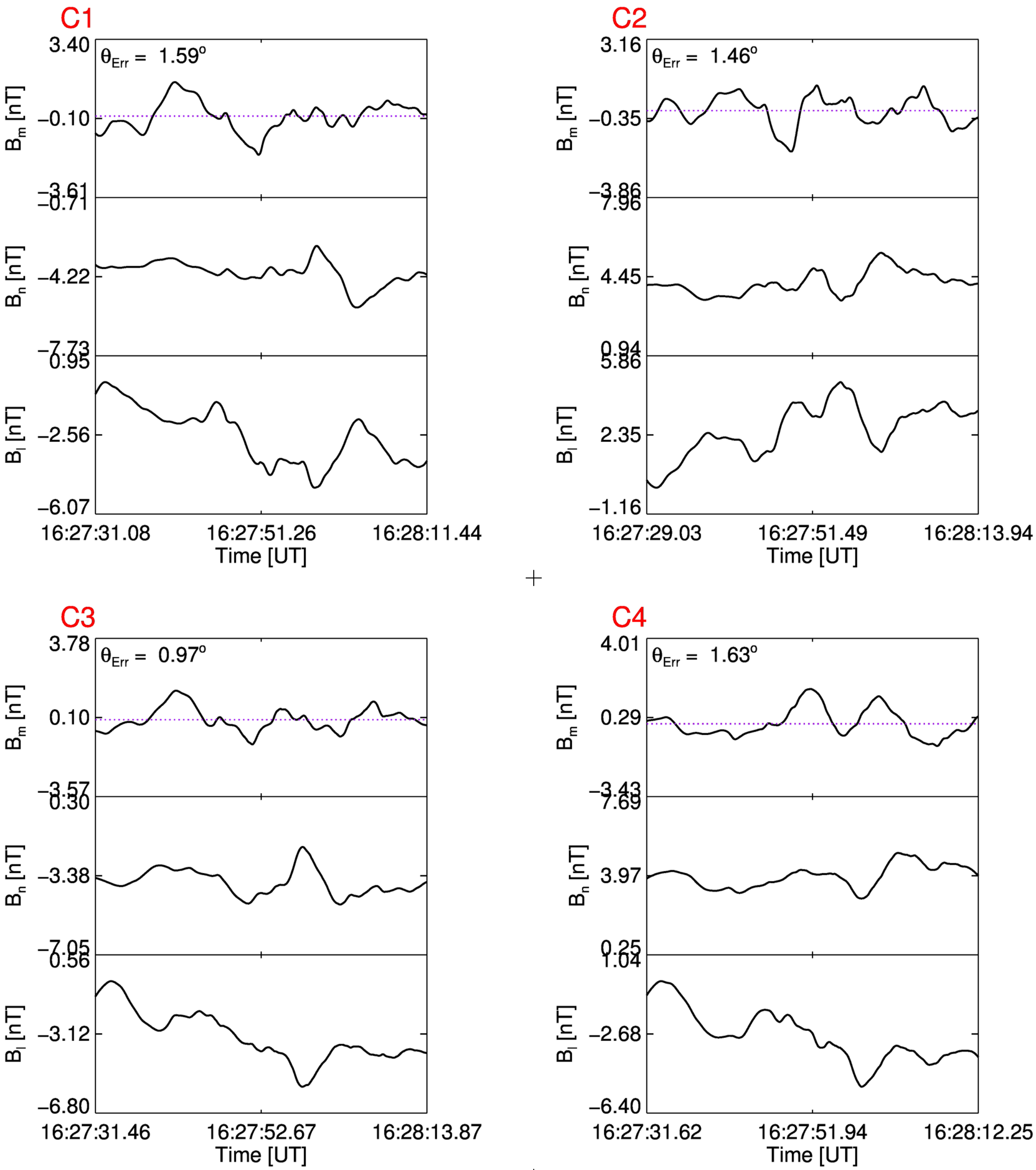
Here λ_2, λ_3 and M are the intermediate and minimum eigenvalues and the number of measurement points, respectively. In the figures below we show this error for each case.

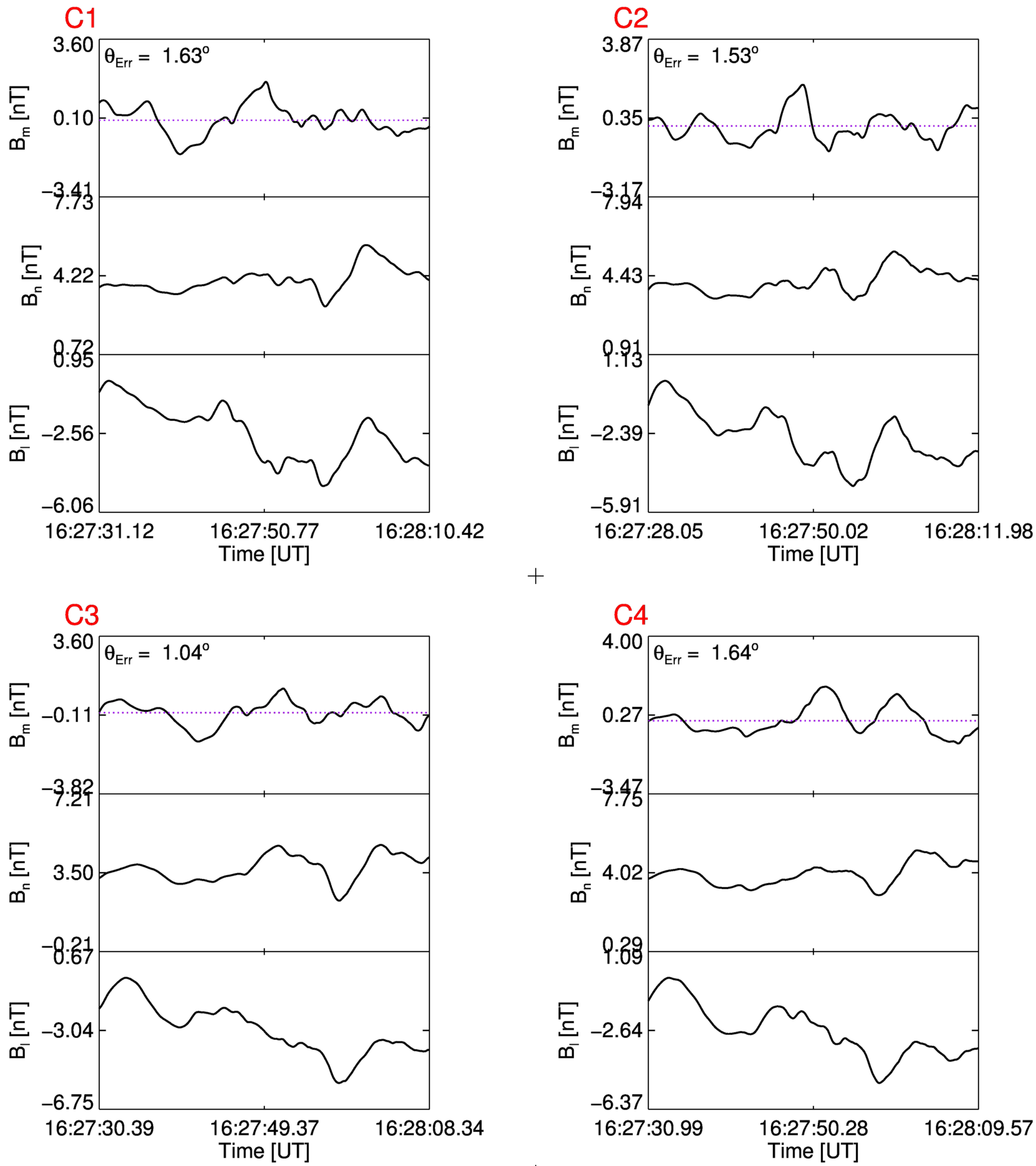
The second source of errors comes from determining time intervals which are used for the MVA. These intervals need to include the shock transition but also some upstream and downstream regions. One needs to select the intervals carefully so not to include large B-field rotations that are not associated with shocks and could affect the the determination of the direction of maximum variance. We select the time intervals by hand. We repeat the process for each shock and spacecraft ten times. We then proceed to calculate angles between pairs of normals from different spacecraft (θ_{NN}) and calculate the the average angles and the error of the mean. We then sum this error with θ_{Err} in order to estimate the total error of our method. The latter is shown in Table 1 and in Figure 2 in form of error bars.

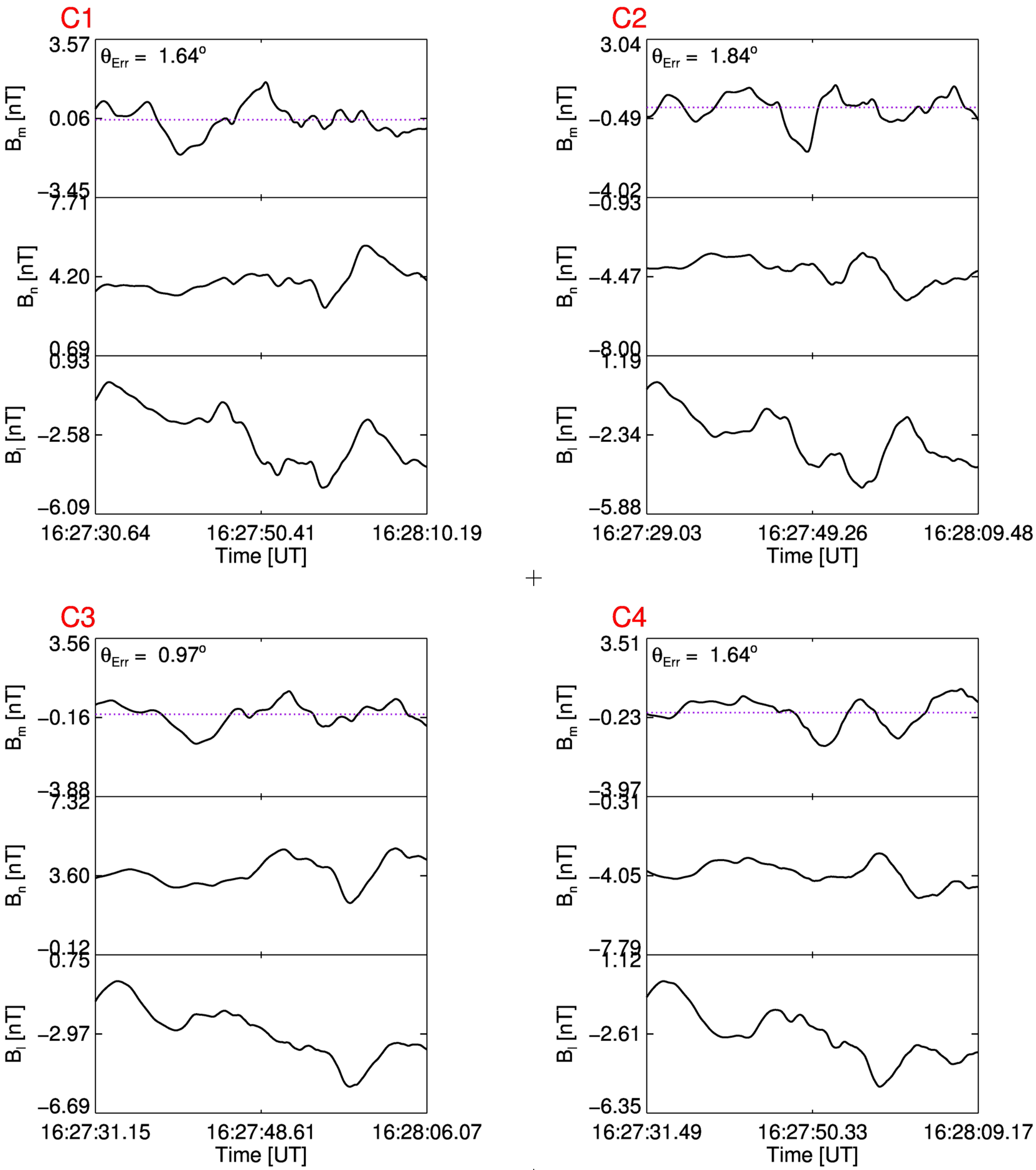
5.2. *Plots*

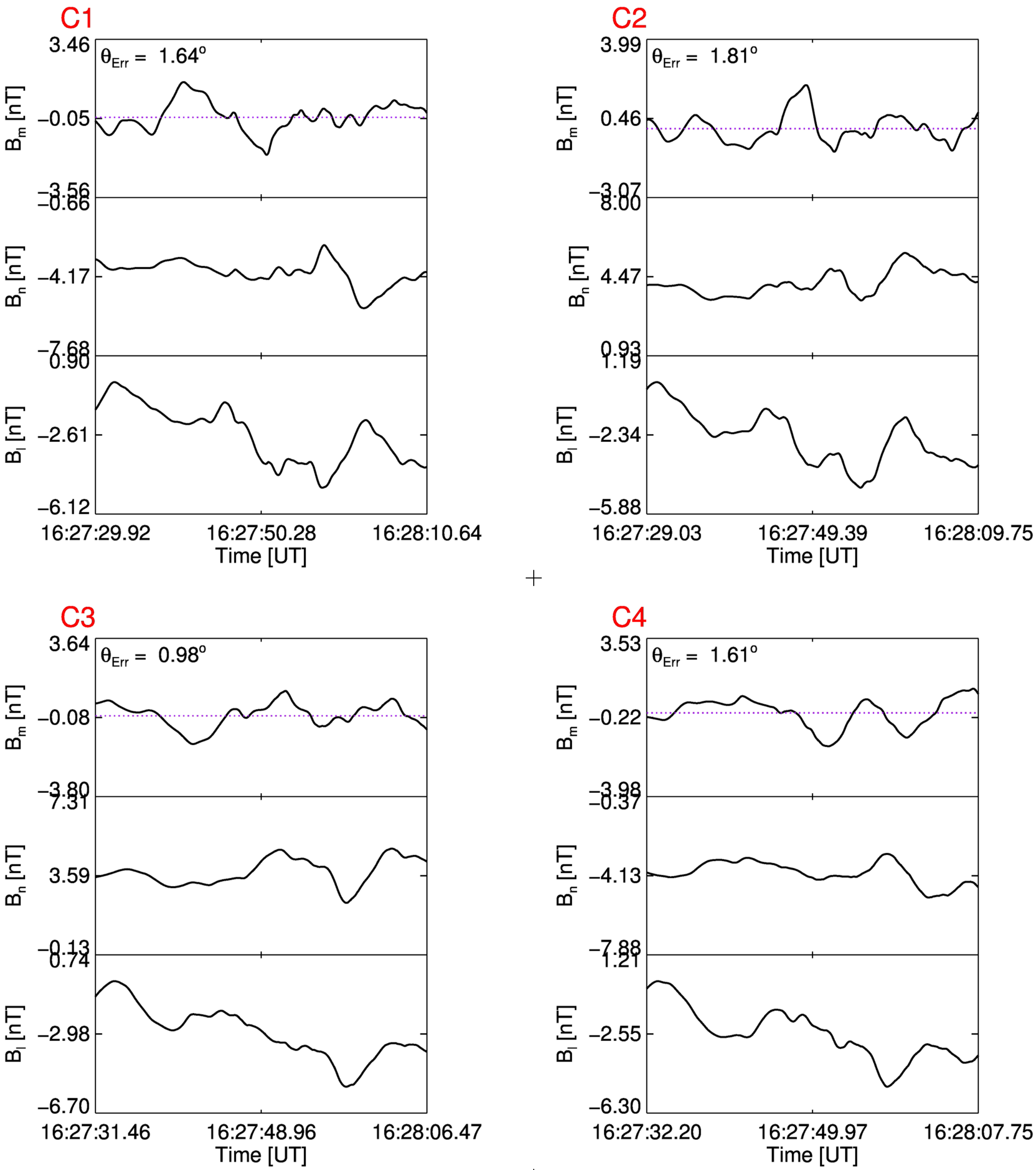
5.2.1. **17 January 2001**

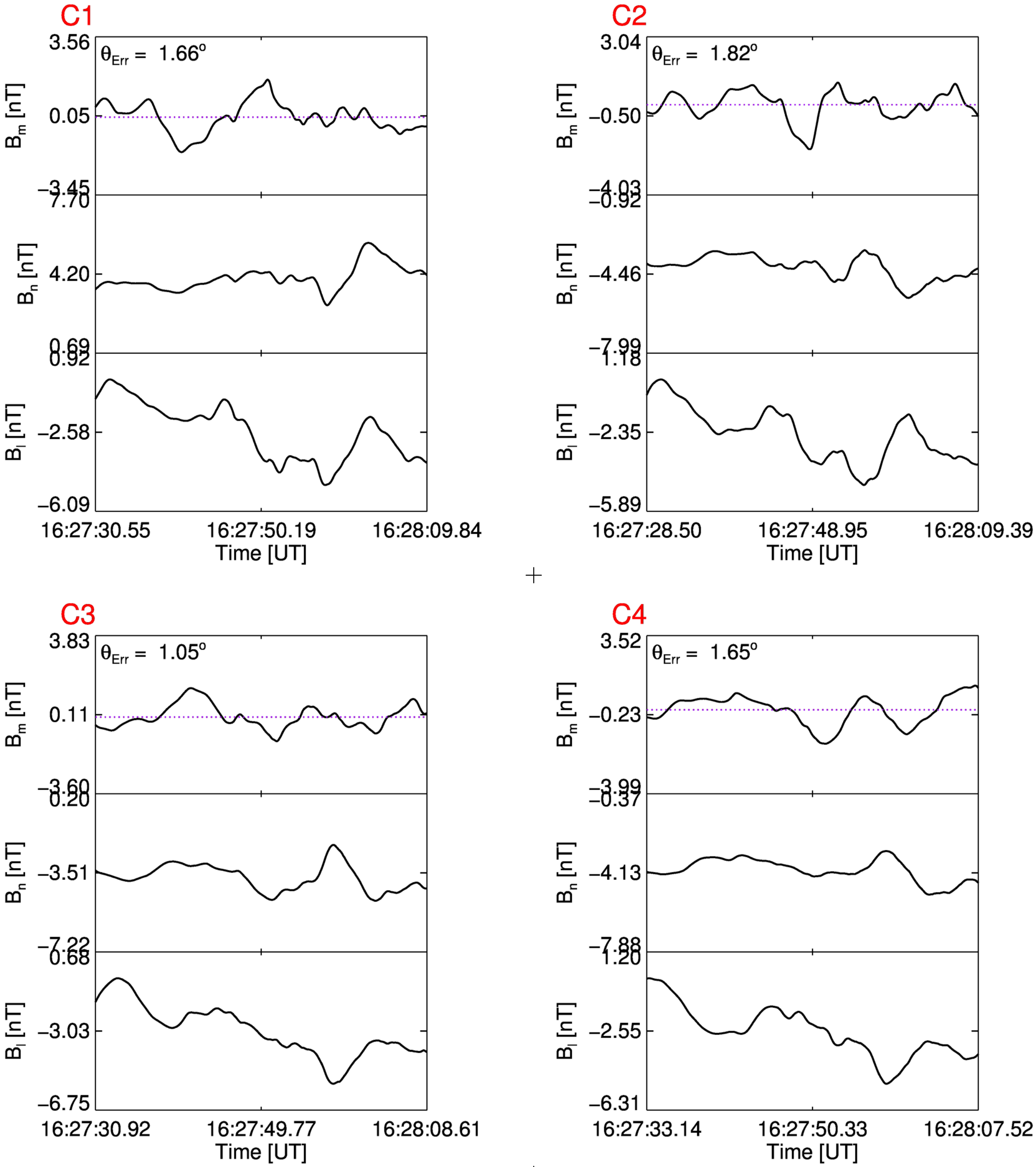

C1
θErr = 1.69°
3.42
−0.06
−3.54
Bm [nT]
7.76
4.28
0.80
Bn [nT]
5.99
2.51
−0.97
Bl [nT]
16:27:31.35
16:27:49.66
16:28:07.96
Time [UT]
C2
θErr = 1.67°
3.08
−0.45
−3.97
Bm [nT]
−0.92
−4.44
−7.97
Bn [nT]
1.16
−2.37
−5.89
Bl [nT]
16:27:28.41
16:27:49.53
16:28:10.64
Time [UT]
C3
θErr = 1.04°
3.80
0.09
−3.61
Bm [nT]
0.22
−3.48
−7.19
Bn [nT]
0.65
−3.05
−6.76
Bl [nT]
16:27:31.15
16:27:50.21
16:28:09.28
Time [UT]
C4
θErr = 1.63°
4.01
0.28
−3.45
Bm [nT]
7.76
4.03
0.29
Bn [nT]
1.10
−2.63
−6.36
Bl [nT]
16:27:31.08
16:27:50.24
16:28:09.40
Time [UT]

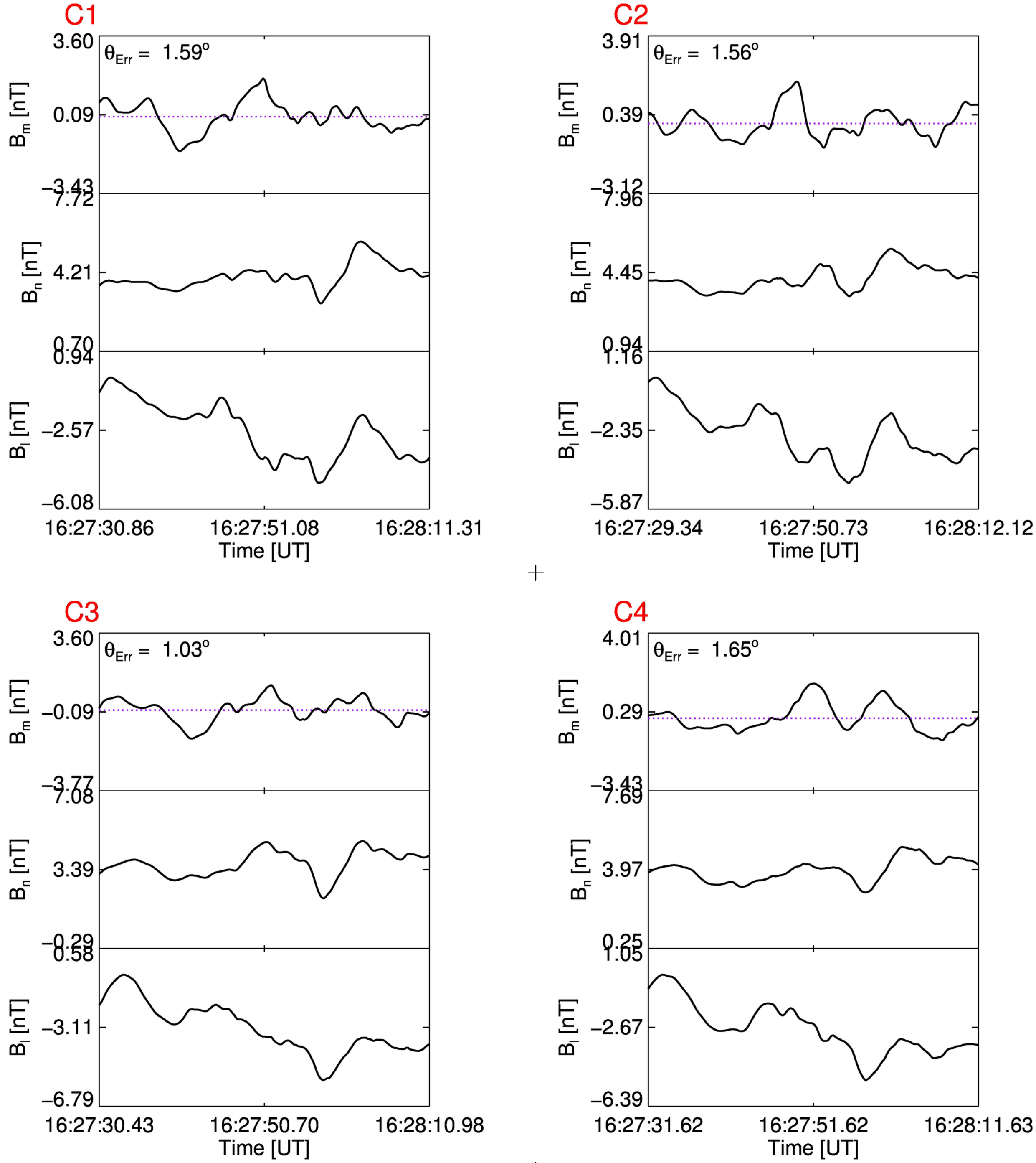

C1
θErr = 1.59°
3.40
−0.10
−3.61
−0.71
−4.22
−7.73
0.95
−2.56
−6.07
Bm [nT]
Bn [nT]
Bl [nT]
16:27:31.08
16:27:51.26
16:28:11.44
Time [UT]
C2
θErr = 1.46°
3.16
−0.35
−3.86
7.96
4.45
0.94
5.86
2.35
−1.16
Bm [nT]
Bn [nT]
Bl [nT]
16:27:29.03
16:27:51.49
16:28:13.94
Time [UT]
C3
θErr = 0.97°
3.78
0.10
−3.57
0.30
−3.38
−7.05
0.56
−3.12
−6.80
Bm [nT]
Bn [nT]
Bl [nT]
16:27:31.46
16:27:52.67
16:28:13.87
Time [UT]
C4
θErr = 1.63°
4.01
0.29
−3.43
7.69
3.97
0.25
1.04
−2.68
−6.40
Bm [nT]
Bn [nT]
Bl [nT]
16:27:31.62
16:27:51.94
16:28:12.25
Time [UT]


C1
θ_{Err} = 1.63°
3.60
0.10
−3.41
7.73
4.22
0.72
0.95
−2.56
−6.06
B_m [nT]
B_n [nT]
B_l [nT]
16:27:31.12
16:27:50.77
16:28:10.42
Time [UT]
C2
θ_{Err} = 1.53°
3.87
0.35
−3.17
7.94
4.43
0.91
1.13
−2.39
−5.91
B_m [nT]
B_n [nT]
B_l [nT]
16:27:28.05
16:27:50.02
16:28:11.98
Time [UT]
C3
θ_{Err} = 1.04°
3.60
−0.11
−3.82
7.21
3.50
−0.21
0.67
−3.04
−6.75
B_m [nT]
B_n [nT]
B_l [nT]
16:27:30.39
16:27:49.37
16:28:08.34
Time [UT]
C4
θ_{Err} = 1.64°
4.00
0.27
−3.47
7.75
4.02
0.29
1.09
−2.64
−6.37
B_m [nT]
B_n [nT]
B_l [nT]
16:27:30.99
16:27:50.28
16:28:09.57
Time [UT]

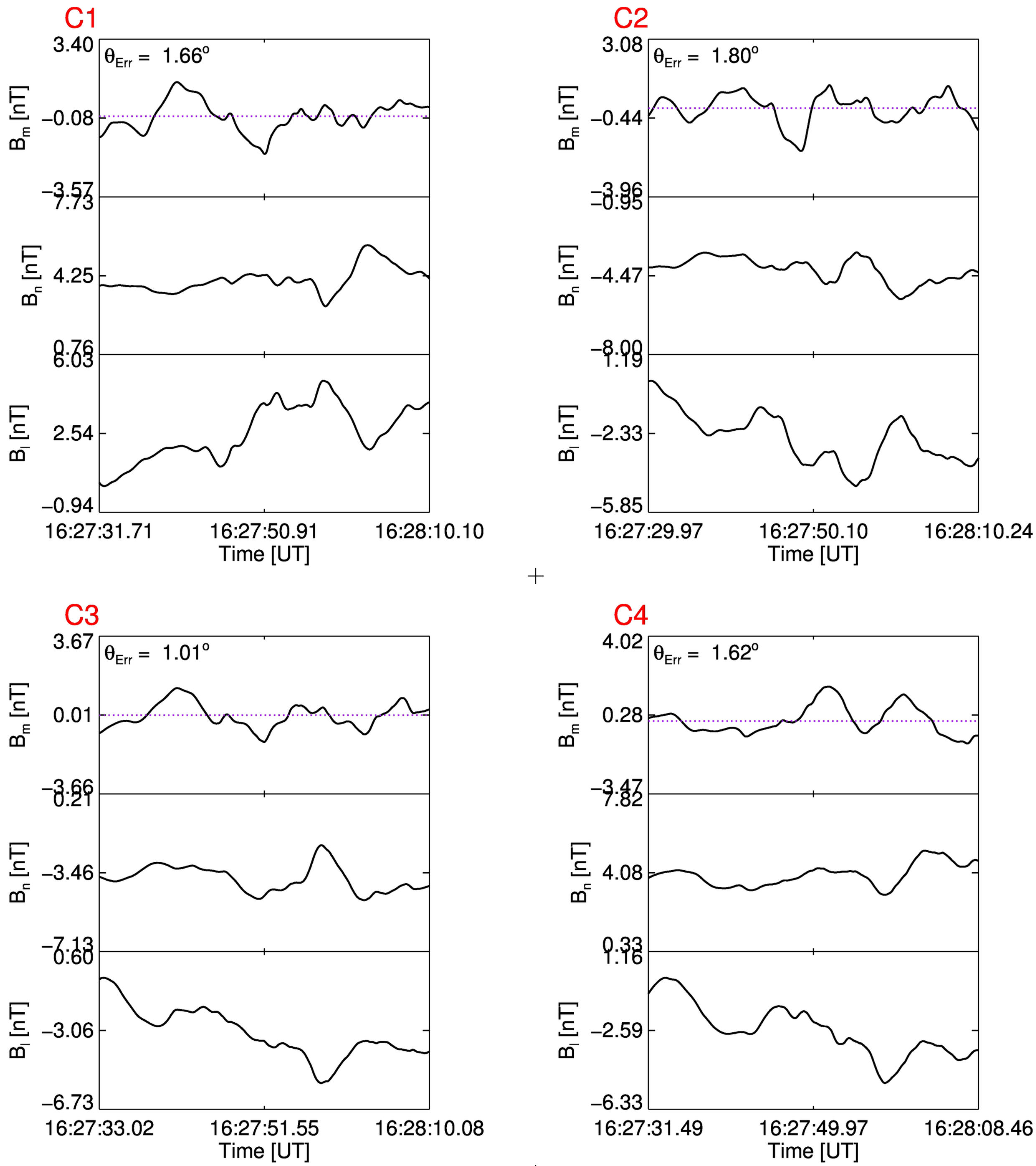

C1
θErr = 1.64°
3.57
0.06
−3.45
7.71
4.20
0.69
0.93
−2.58
−6.09
B_m [nT]
B_n [nT]
B_l [nT]
16:27:30.64
16:27:50.41
16:28:10.19
Time [UT]
C2
θErr = 1.84°
3.04
−0.49
−4.02
−0.93
−4.47
−8.00
1.19
−2.34
−5.88
B_m [nT]
B_n [nT]
B_l [nT]
16:27:29.03
16:27:49.26
16:28:09.48
Time [UT]
C3
θErr = 0.97°
3.56
−0.16
−3.88
7.32
3.60
−0.12
0.75
−2.97
−6.69
B_m [nT]
B_n [nT]
B_l [nT]
16:27:31.15
16:27:48.61
16:28:06.07
Time [UT]
C4
θErr = 1.64°
3.51
−0.23
−3.97
−0.31
−4.05
−7.79
1.12
−2.61
−6.35
B_m [nT]
B_n [nT]
B_l [nT]
16:27:31.49
16:27:50.33
16:28:09.17
Time [UT]

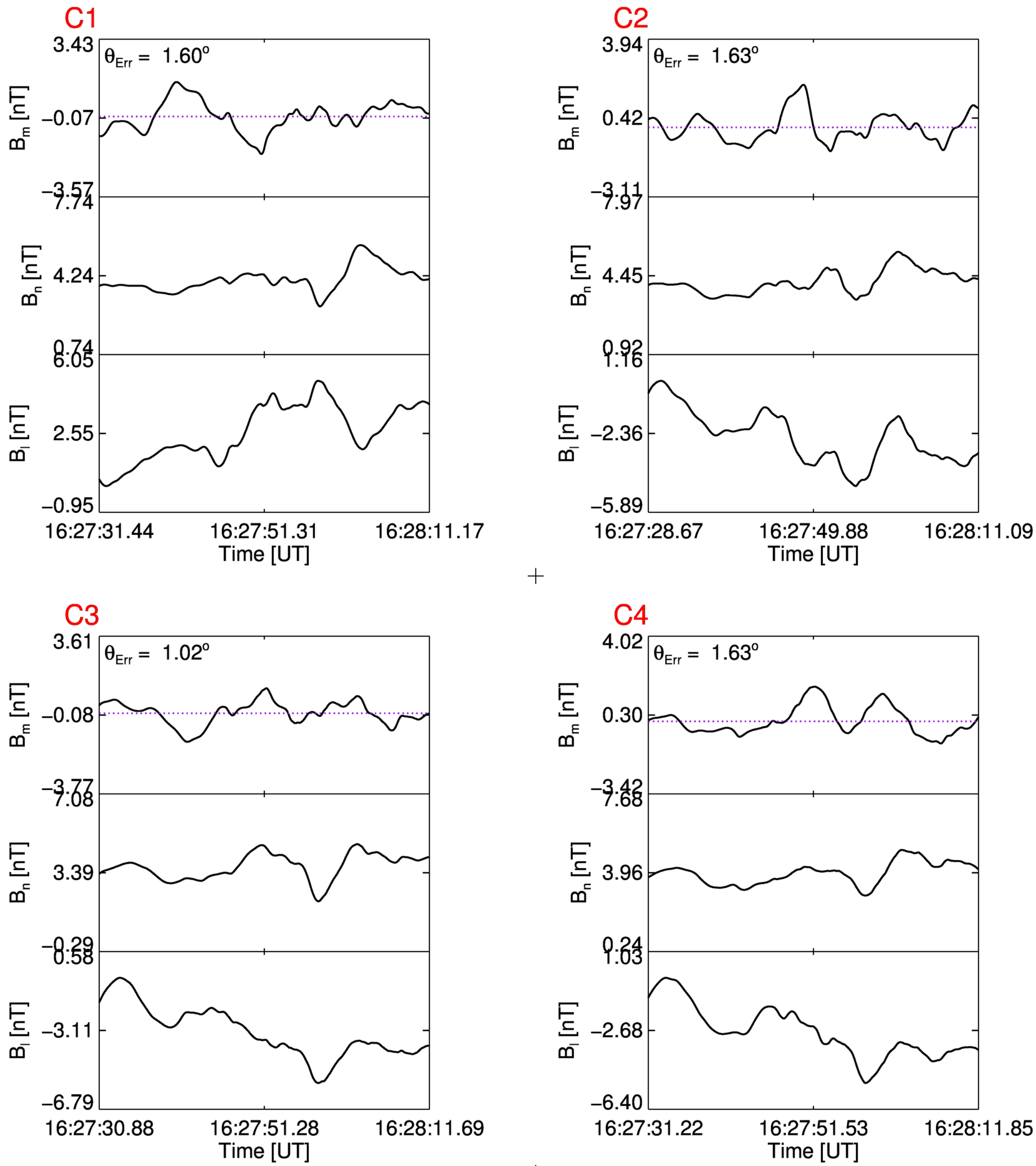

C1
θ_{Err} = 1.64°
3.46
-0.05
-3.56
B_m [nT]
-0.66
-4.17
-7.68
B_n [nT]
0.90
-2.61
-6.12
B_l [nT]
16:27:29.92
16:27:50.28
16:28:10.64
Time [UT]
C2
θ_{Err} = 1.81°
3.99
0.46
-3.07
B_m [nT]
8.00
4.47
0.93
B_n [nT]
1.19
-2.34
-5.88
B_l [nT]
16:27:29.03
16:27:49.39
16:28:09.75
Time [UT]
C3
θ_{Err} = 0.98°
3.64
-0.08
-3.80
B_m [nT]
7.31
3.59
-0.13
B_n [nT]
0.74
-2.98
-6.70
B_l [nT]
16:27:31.46
16:27:48.96
16:28:06.47
Time [UT]
C4
θ_{Err} = 1.61°
3.53
-0.22
-3.98
B_m [nT]
-0.37
-4.13
-7.88
B_n [nT]
1.21
-2.55
-6.30
B_l [nT]
16:27:32.20
16:27:49.97
16:28:07.75
Time [UT]

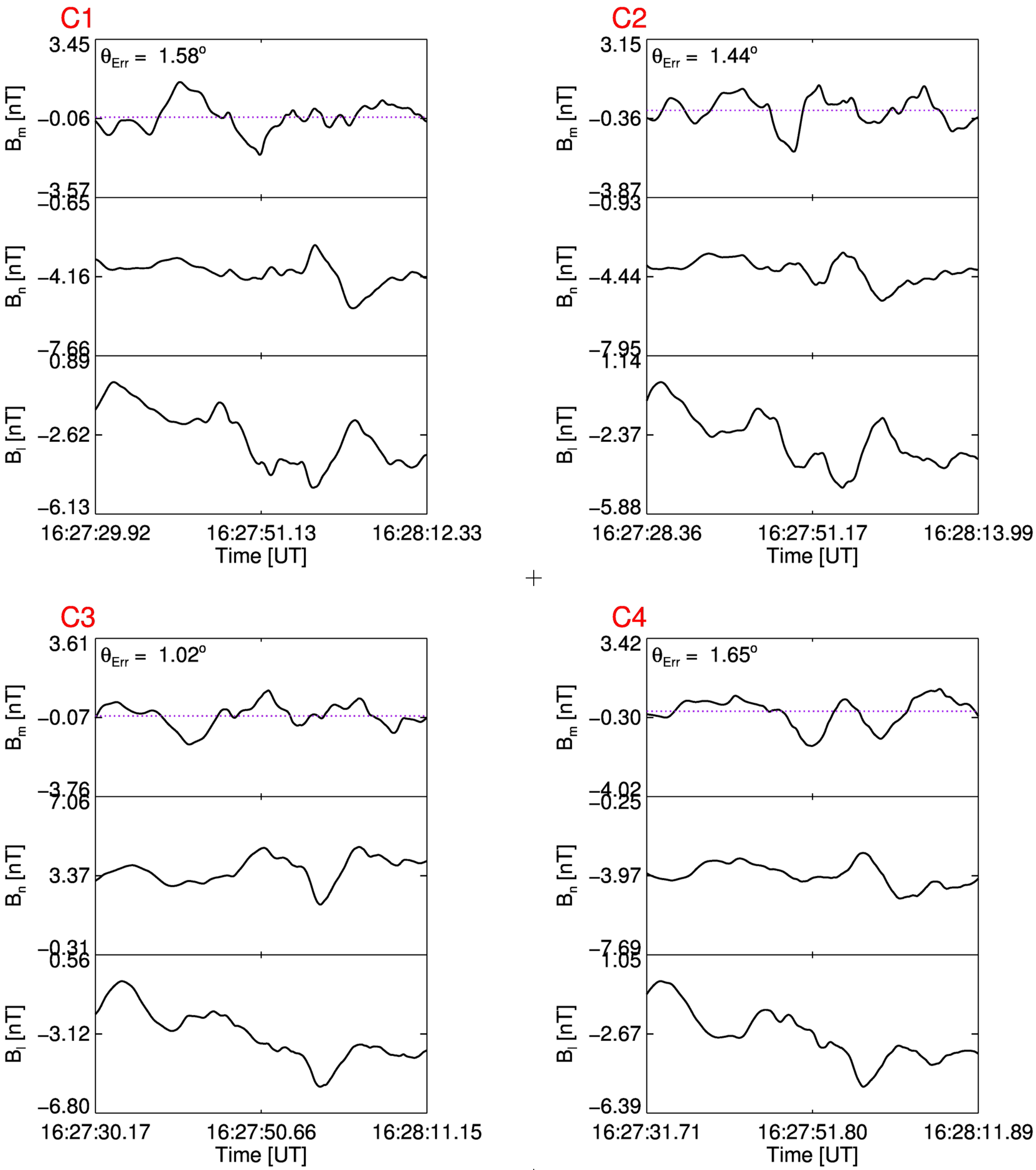

C1
θErr = 1.66°
3.56
0.05
−3.45
Bm [nT]
7.70
4.20
0.69
Bn [nT]
0.92
−2.58
−6.09
Bl [nT]
16:27:30.55
16:27:50.19
16:28:09.84
Time [UT]
C2
θErr = 1.82°
3.04
−0.50
−4.03
Bm [nT]
−0.92
−4.46
−7.99
Bn [nT]
1.18
−2.35
−5.89
Bl [nT]
16:27:28.50
16:27:48.95
16:28:09.39
Time [UT]
C3
θErr = 1.05°
3.83
0.11
−3.60
Bm [nT]
0.20
−3.51
−7.22
Bn [nT]
0.68
−3.03
−6.75
Bl [nT]
16:27:30.92
16:27:49.77
16:28:08.61
Time [UT]
C4
θErr = 1.65°
3.52
−0.23
−3.99
Bm [nT]
−0.37
−4.13
−7.88
Bn [nT]
1.20
−2.55
−6.31
Bl [nT]
16:27:33.14
16:27:50.33
16:28:07.52
Time [UT]



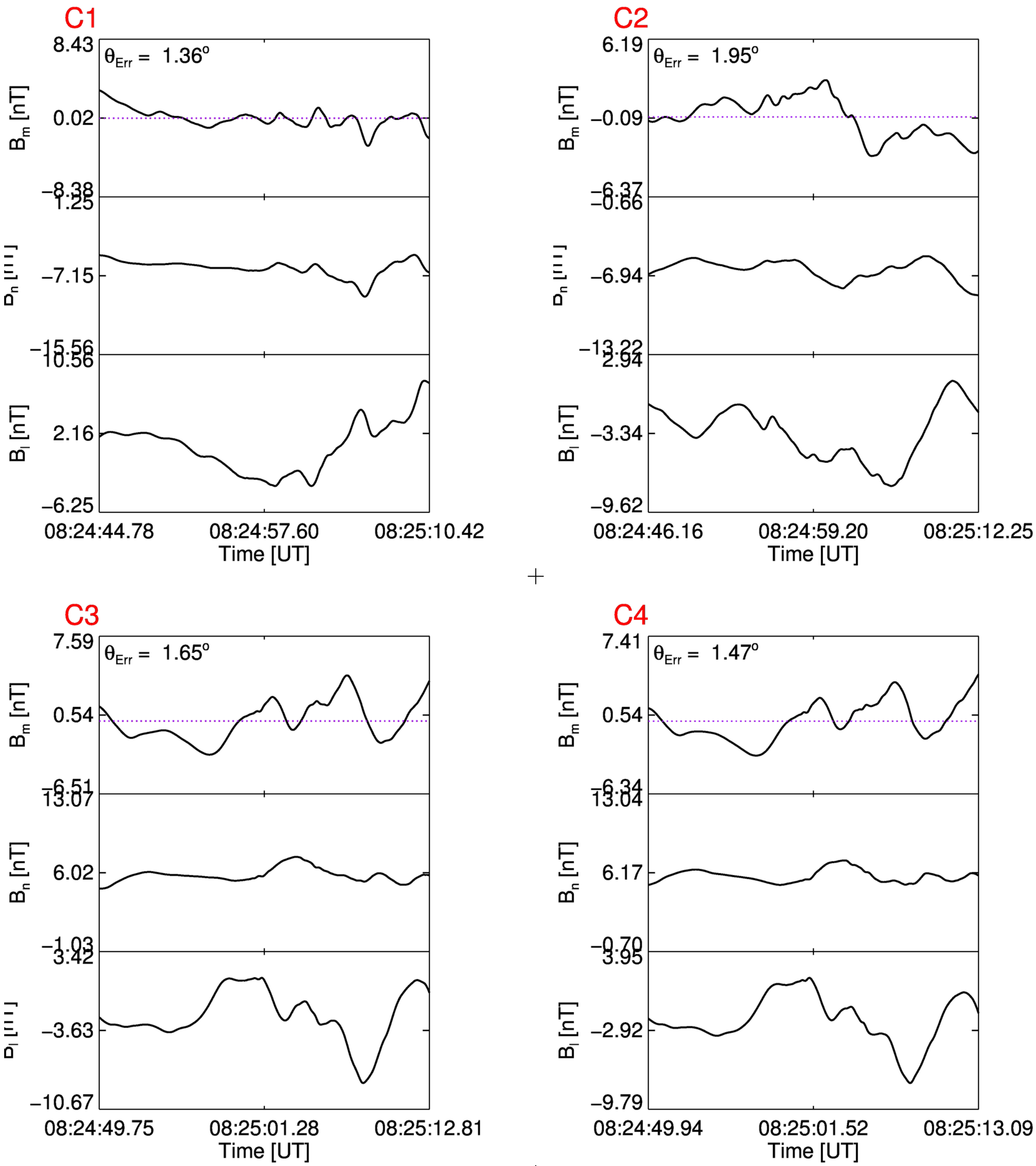
C1
θErr = 1.59°
3.60
0.09
−3.43
Bm [nT]
7.72
4.21
0.70
Bn [nT]
0.94
−2.57
−6.08
Bl [nT]
16:27:30.86
16:27:51.08
16:28:11.31
Time [UT]
C2
θErr = 1.56°
3.91
0.39
−3.12
Bm [nT]
7.96
4.45
0.94
Bn [nT]
1.16
−2.35
−5.87
Bl [nT]
16:27:29.34
16:27:50.73
16:28:12.12
Time [UT]
C3
θErr = 1.03°
3.60
−0.09
−3.77
Bm [nT]
7.08
3.39
−0.29
Bn [nT]
0.58
−3.11
−6.79
Bl [nT]
16:27:30.43
16:27:50.70
16:28:10.98
Time [UT]
C4
θErr = 1.65°
4.01
0.29
−3.43
Bm [nT]
7.69
3.97
0.25
Bn [nT]
1.05
−2.67
−6.39
Bl [nT]
16:27:31.62
16:27:51.62
16:28:11.63
Time [UT]

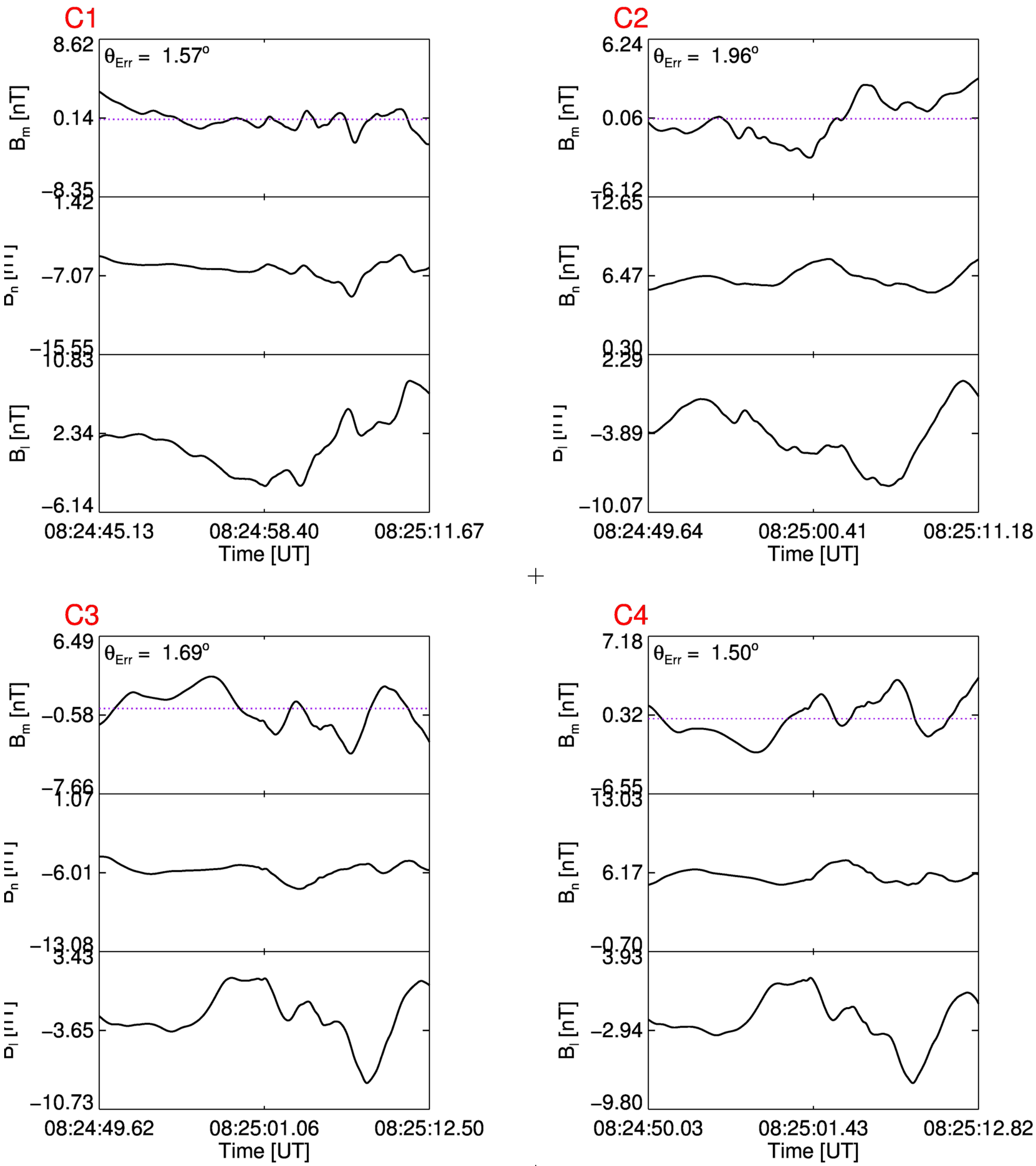

C1
θErr = 1.66°
3.40
−0.08
−3.57
7.73
4.25
0.76
6.03
2.54
−0.94
Bm [nT]
Bn [nT]
Bl [nT]
16:27:31.71
16:27:50.91
16:28:10.10
Time [UT]
C2
θErr = 1.80°
3.08
−0.44
−3.96
−0.95
−4.47
−8.00
1.19
−2.33
−5.85
16:27:29.97
16:27:50.10
16:28:10.24
C3
θErr = 1.01°
3.67
0.01
−3.66
0.21
−3.46
−7.13
0.60
−3.06
−6.73
16:27:33.02
16:27:51.55
16:28:10.08
C4
θErr = 1.62°
4.02
0.28
−3.47
7.82
4.08
0.33
1.16
−2.59
−6.33
16:27:31.49
16:27:49.97
16:28:08.46

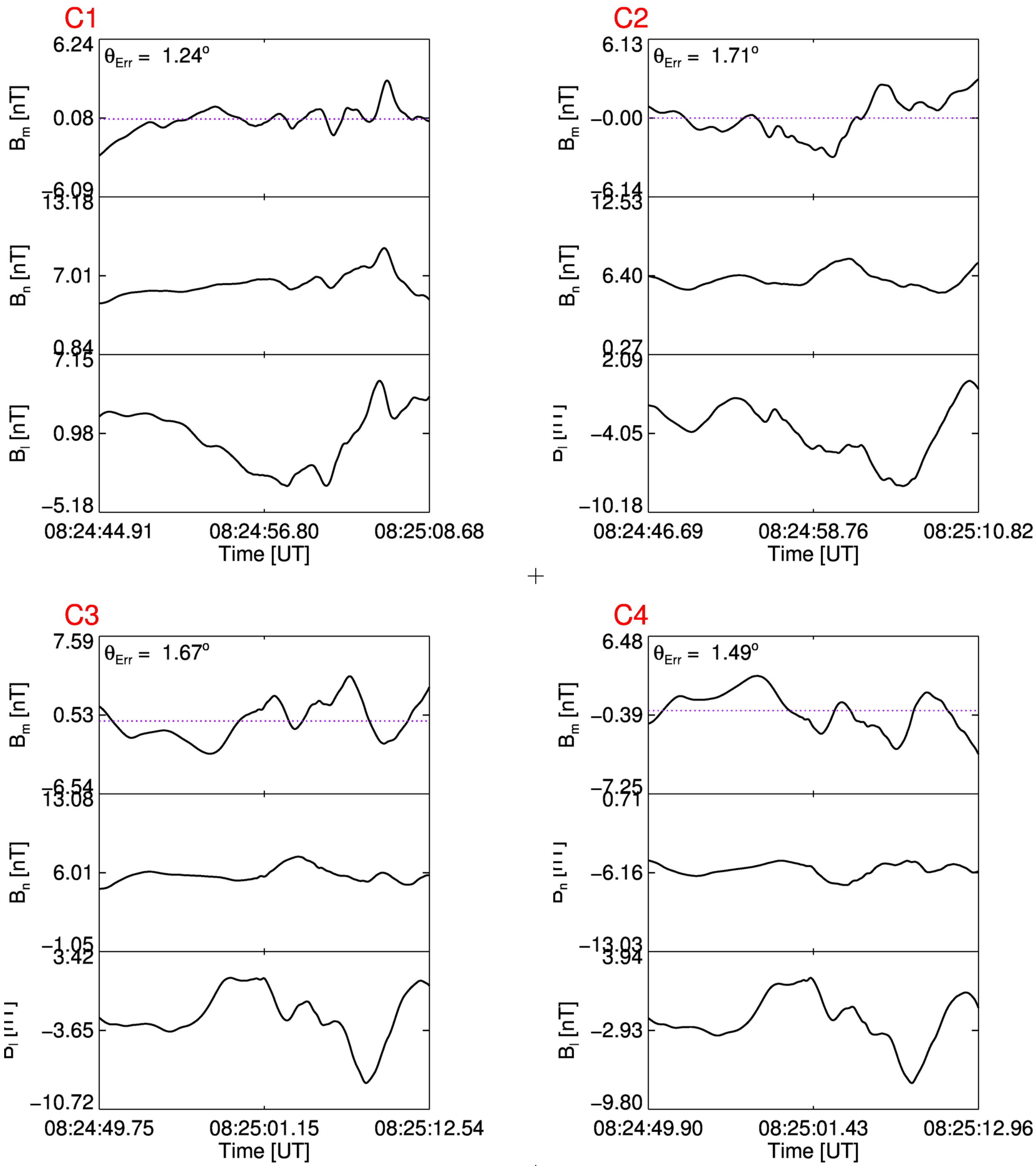

C1
θ_{Err} = 1.60°
B_m [nT]
B_n [nT]
B_l [nT]
3.43
−0.07
−3.57
7.74
4.24
0.74
6.05
2.55
−0.95
16:27:31.44
16:27:51.31
16:28:11.17
Time [UT]
C2
θ_{Err} = 1.63°
3.94
0.42
−3.11
7.97
4.45
0.92
1.16
−2.36
−5.89
16:27:28.67
16:27:49.88
16:28:11.09
Time [UT]
C3
θ_{Err} = 1.02°
3.61
−0.08
−3.77
7.08
3.39
−0.29
0.58
−3.11
−6.79
16:27:30.88
16:27:51.28
16:28:11.69
Time [UT]
C4
θ_{Err} = 1.63°
4.02
0.30
−3.42
7.68
3.96
0.24
1.03
−2.68
−6.40
16:27:31.22
16:27:51.53
16:28:11.85
Time [UT]

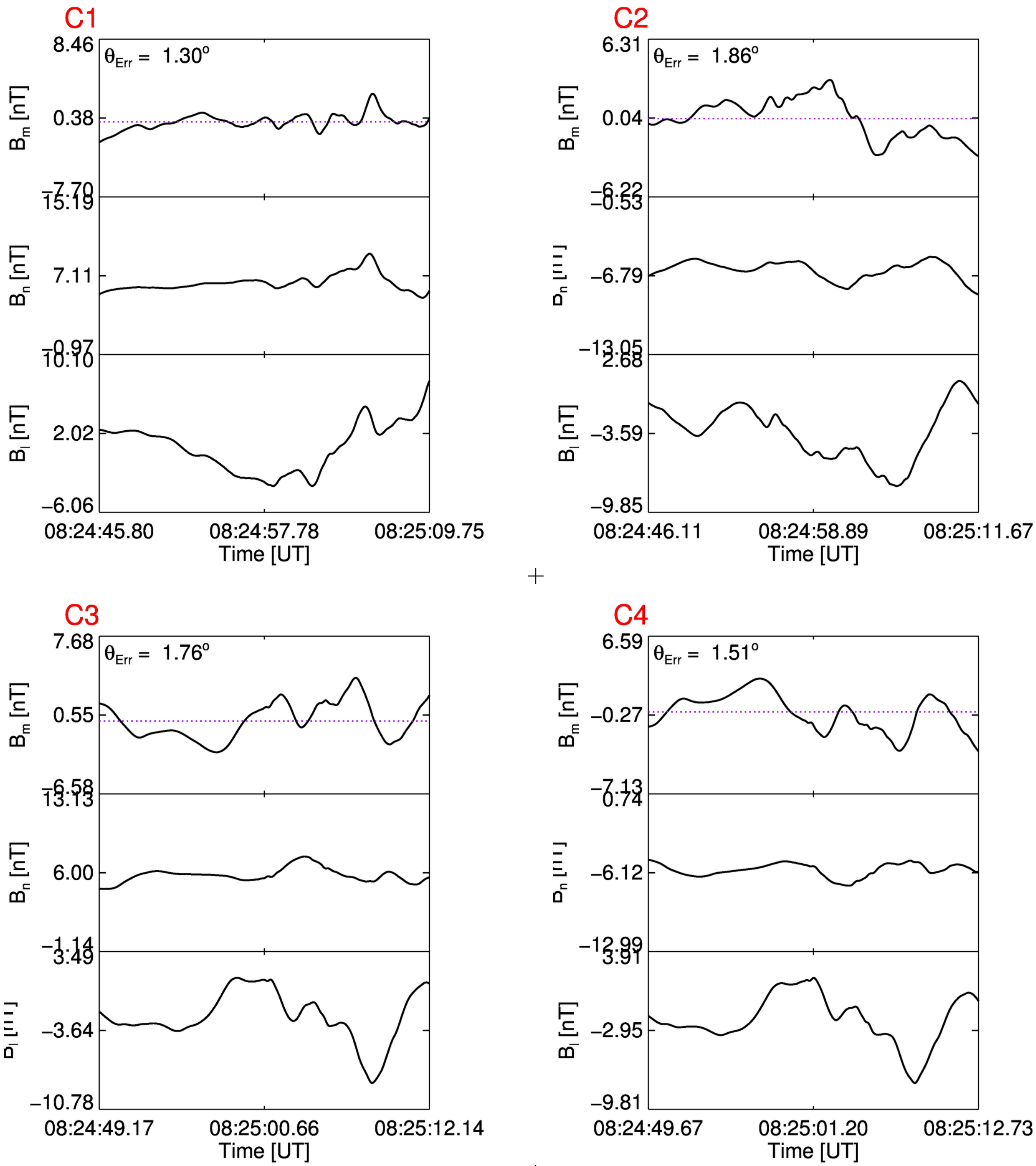

C1
θ_{Err} = 1.58°
3.45
−0.06
−3.57
B_m [nT]
−0.65
−4.16
−7.66
B_n [nT]
0.89
−2.62
−6.13
B_l [nT]
16:27:29.92
16:27:51.13
16:28:12.33
Time [UT]
C2
θ_{Err} = 1.44°
3.15
−0.36
−3.87
B_m [nT]
−0.93
−4.44
−7.95
B_n [nT]
1.14
−2.37
−5.88
B_l [nT]
16:27:28.36
16:27:51.17
16:28:13.99
Time [UT]
C3
θ_{Err} = 1.02°
3.61
−0.07
−3.76
B_m [nT]
7.06
3.37
−0.31
B_n [nT]
0.56
−3.12
−6.80
B_l [nT]
16:27:30.17
16:27:50.66
16:28:11.15
Time [UT]
C4
θ_{Err} = 1.65°
3.42
−0.30
−4.02
B_m [nT]
−0.25
−3.97
−7.69
B_n [nT]
1.05
−2.67
−6.39
B_l [nT]
16:27:31.71
16:27:51.80
16:28:11.89
Time [UT]

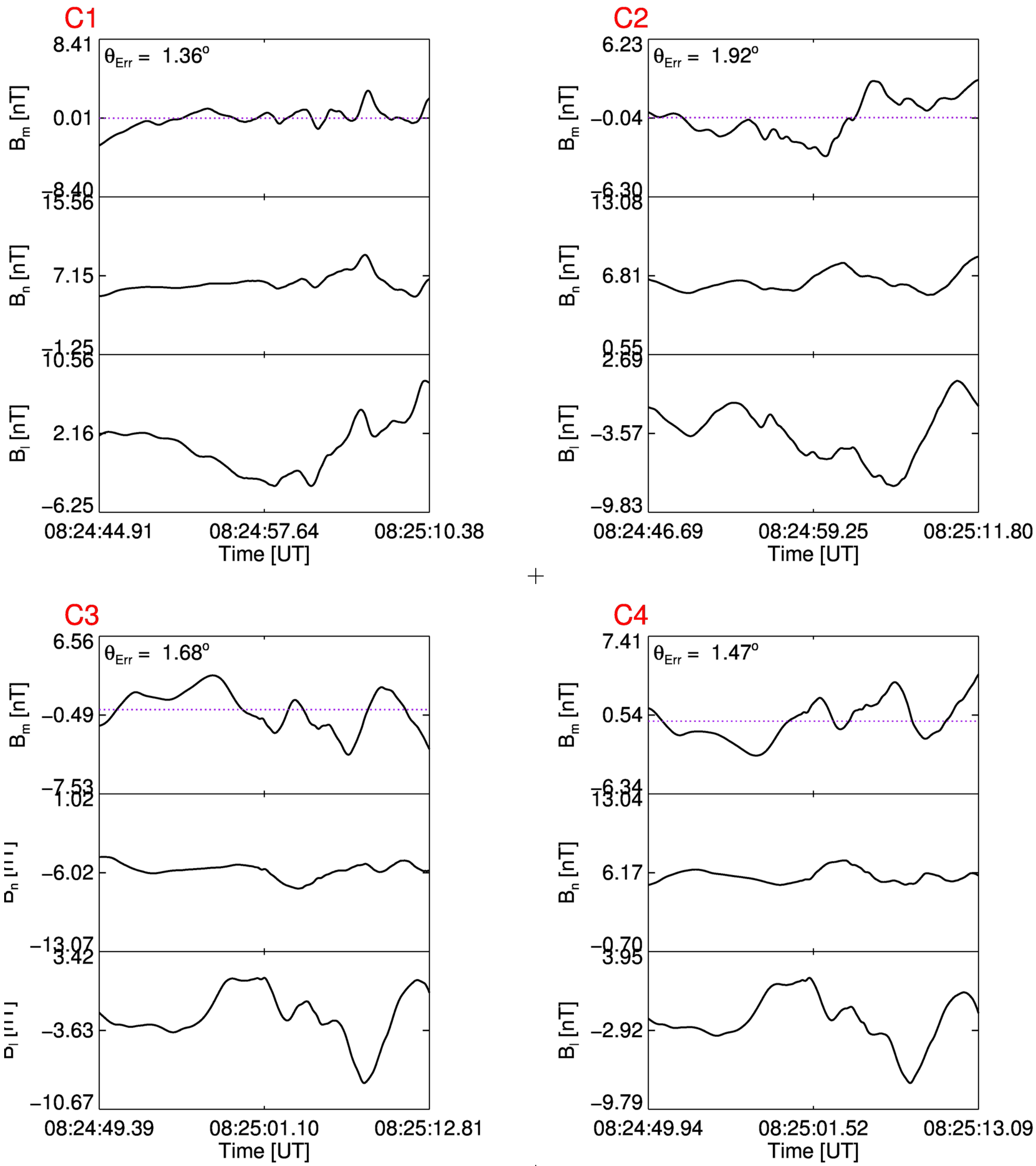
5.2.2. **5 April 2010**

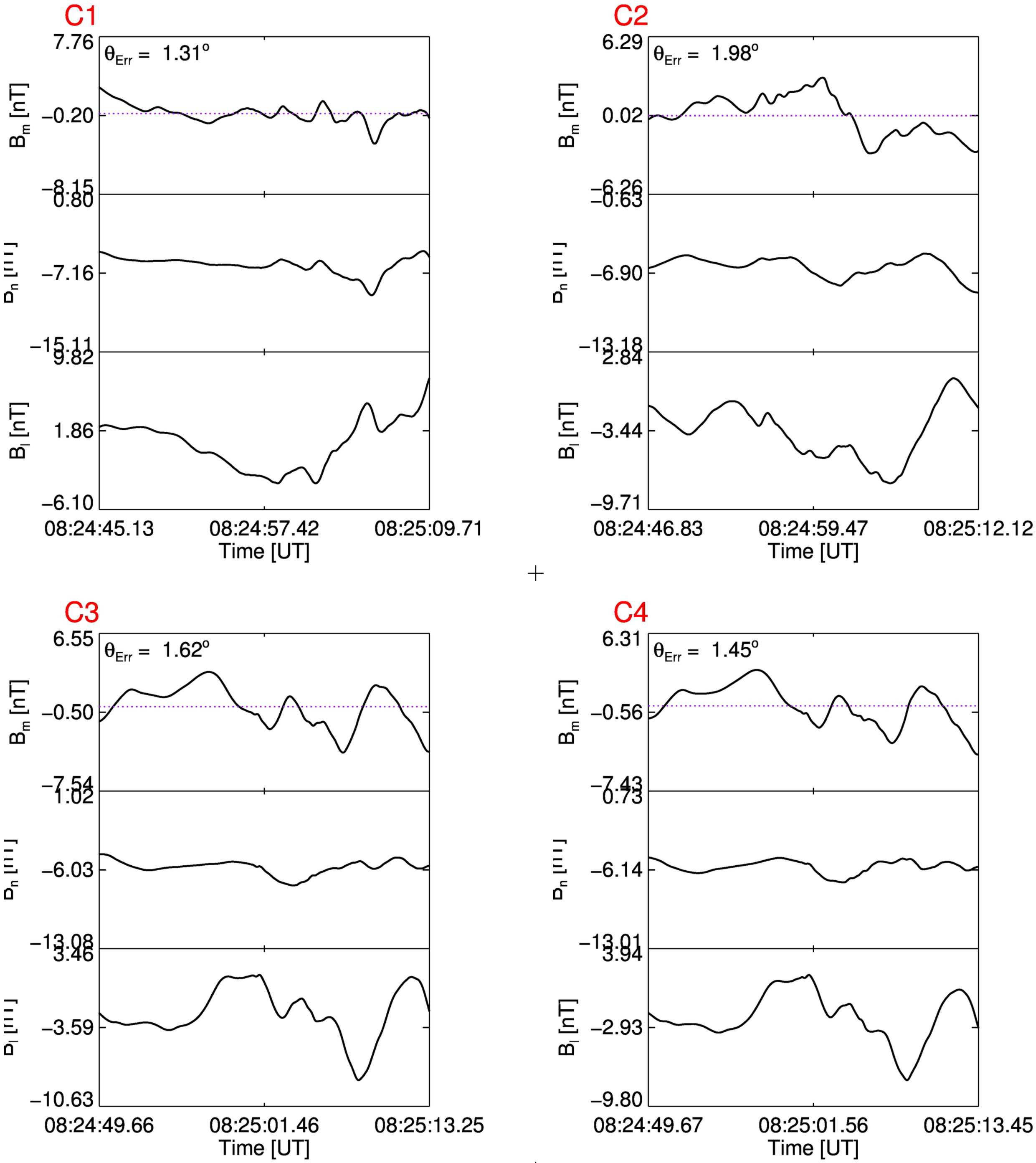


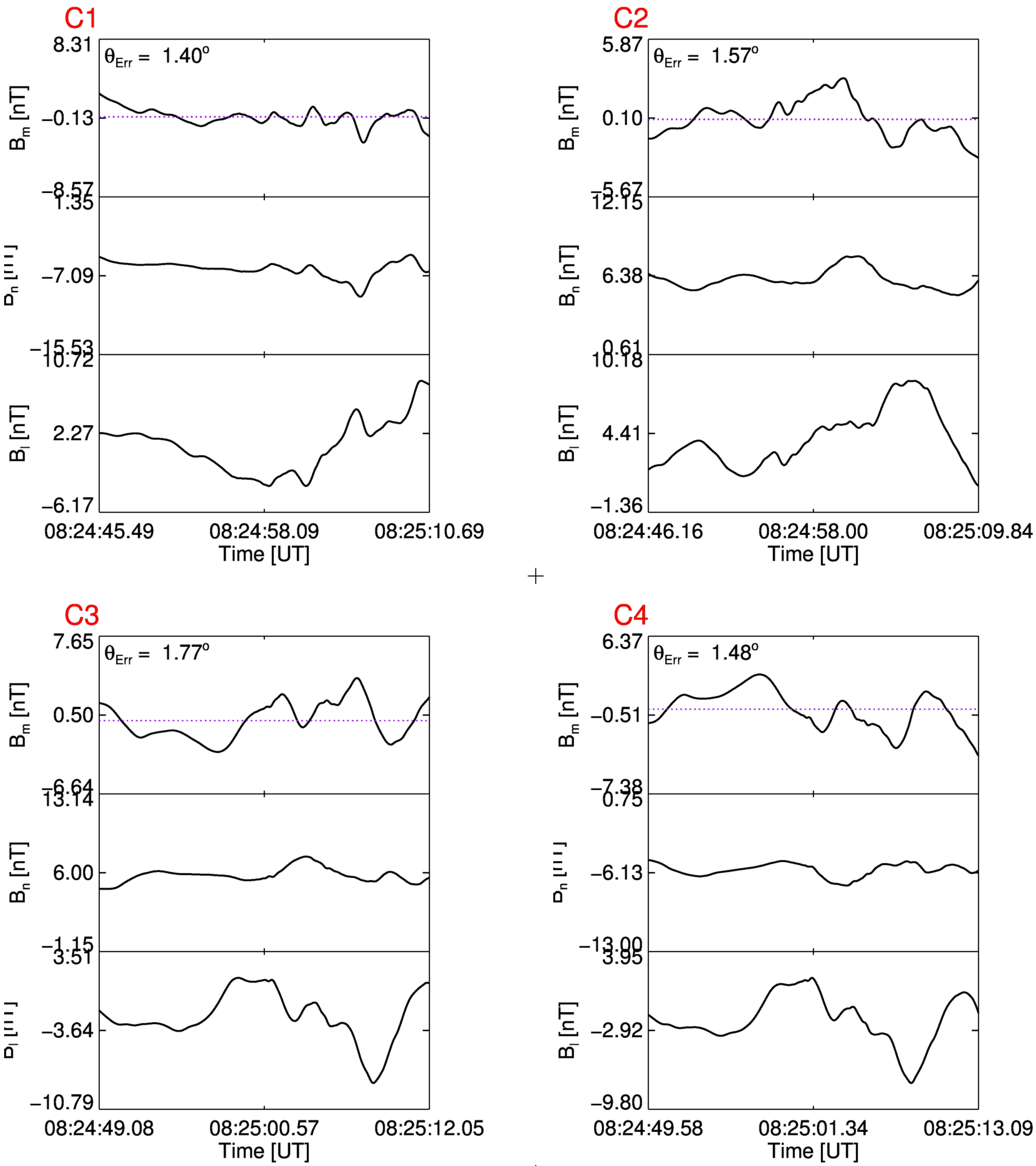

C1
θErr = 1.57°
8.62
0.14
−8.35
Bm [nT]
1.42
−7.07
−15.55
10.83
2.34
−6.14
Bl [nT]
08:24:45.13
08:24:58.40
08:25:11.67
Time [UT]
C2
θErr = 1.96°
6.24
0.06
−6.12
Bm [nT]
12.65
6.47
0.30
Bn [nT]
2.29
−3.89
−10.07
08:24:49.64
08:25:00.41
08:25:11.18
Time [UT]
C3
θErr = 1.69°
6.49
−0.58
−7.66
Bm [nT]
1.07
−6.01
−13.08
3.43
−3.65
−10.73
08:24:49.62
08:25:01.06
08:25:12.50
Time [UT]
C4
θErr = 1.50°
7.18
0.32
−6.55
Bm [nT]
13.03
6.17
−0.70
Bn [nT]
3.93
−2.94
−9.80
Bl [nT]
08:24:50.03
08:25:01.43
08:25:12.82
Time [UT]

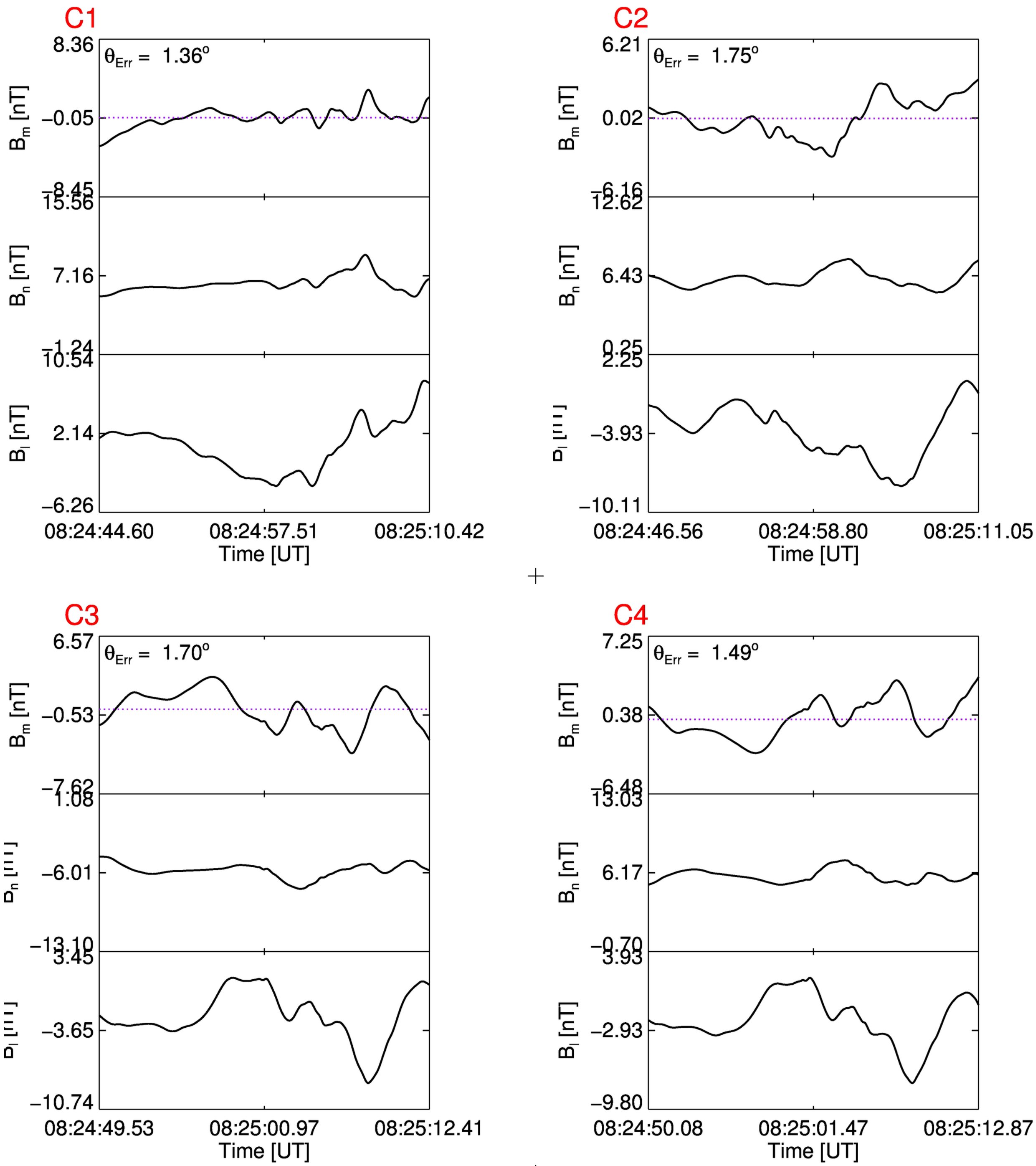

C1
θ_{Err} = 1.24°
6.24
0.08
−6.09
B_m [nT]
13.18
7.01
0.84
B_n [nT]
7.15
0.98
−5.18
B_l [nT]
08:24:44.91
08:24:56.80
08:25:08.68
Time [UT]
C2
θ_{Err} = 1.71°
6.13
−0.00
−6.14
B_m [nT]
12.53
6.40
0.27
B_n [nT]
2.09
−4.05
−10.18
08:24:46.69
08:24:58.76
08:25:10.82
Time [UT]
C3
θ_{Err} = 1.67°
7.59
0.53
−6.54
B_m [nT]
13.08
6.01
−1.05
B_n [nT]
3.42
−3.65
−10.72
08:24:49.75
08:25:01.15
08:25:12.54
Time [UT]
C4
θ_{Err} = 1.49°
6.48
−0.39
−7.25
B_m [nT]
0.71
−6.16
−13.03
3.94
−2.93
−9.80
B_l [nT]
08:24:49.90
08:25:01.43
08:25:12.96
Time [UT]

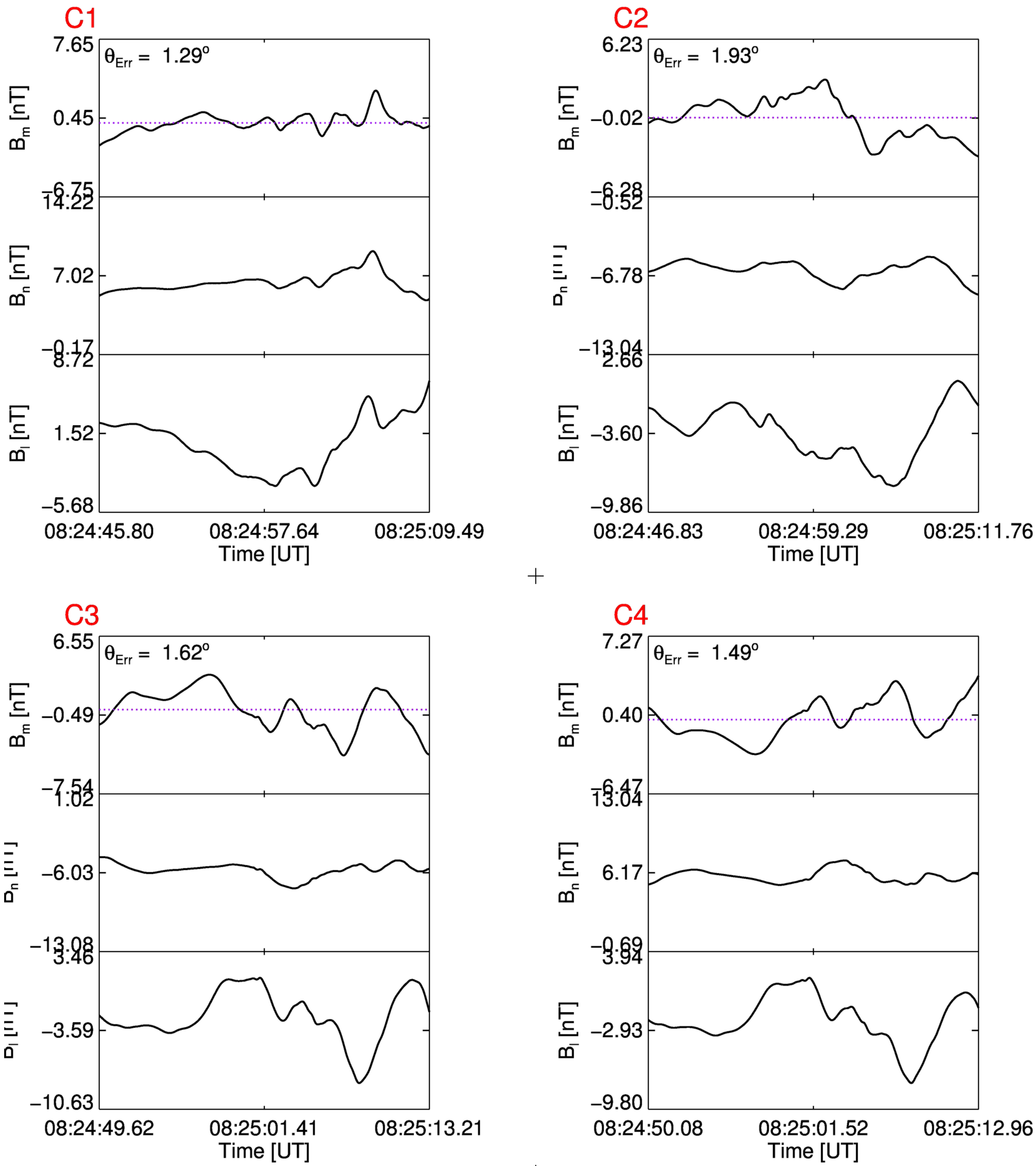

C1
θErr = 1.30°
8.46
0.38
−7.70
15.19
7.11
−0.97
10.10
2.02
−6.06
B_m [nT]
B_n [nT]
B_l [nT]
08:24:45.80
08:24:57.78
08:25:09.75
Time [UT]
C2
θErr = 1.86°
6.31
0.04
−6.22
−0.53
−6.79
−13.05
2.68
−3.59
−9.85
B_m [nT]
B_l [nT]
08:24:46.11
08:24:58.89
08:25:11.67
Time [UT]
C3
θErr = 1.76°
7.68
0.55
−6.58
13.13
6.00
−1.14
3.49
−3.64
−10.78
B_m [nT]
B_n [nT]
08:24:49.17
08:25:00.66
08:25:12.14
Time [UT]
C4
θErr = 1.51°
6.59
−0.27
−7.13
0.74
−6.12
−12.99
3.91
−2.95
−9.81
B_m [nT]
B_l [nT]
08:24:49.67
08:25:01.20
08:25:12.73
Time [UT]

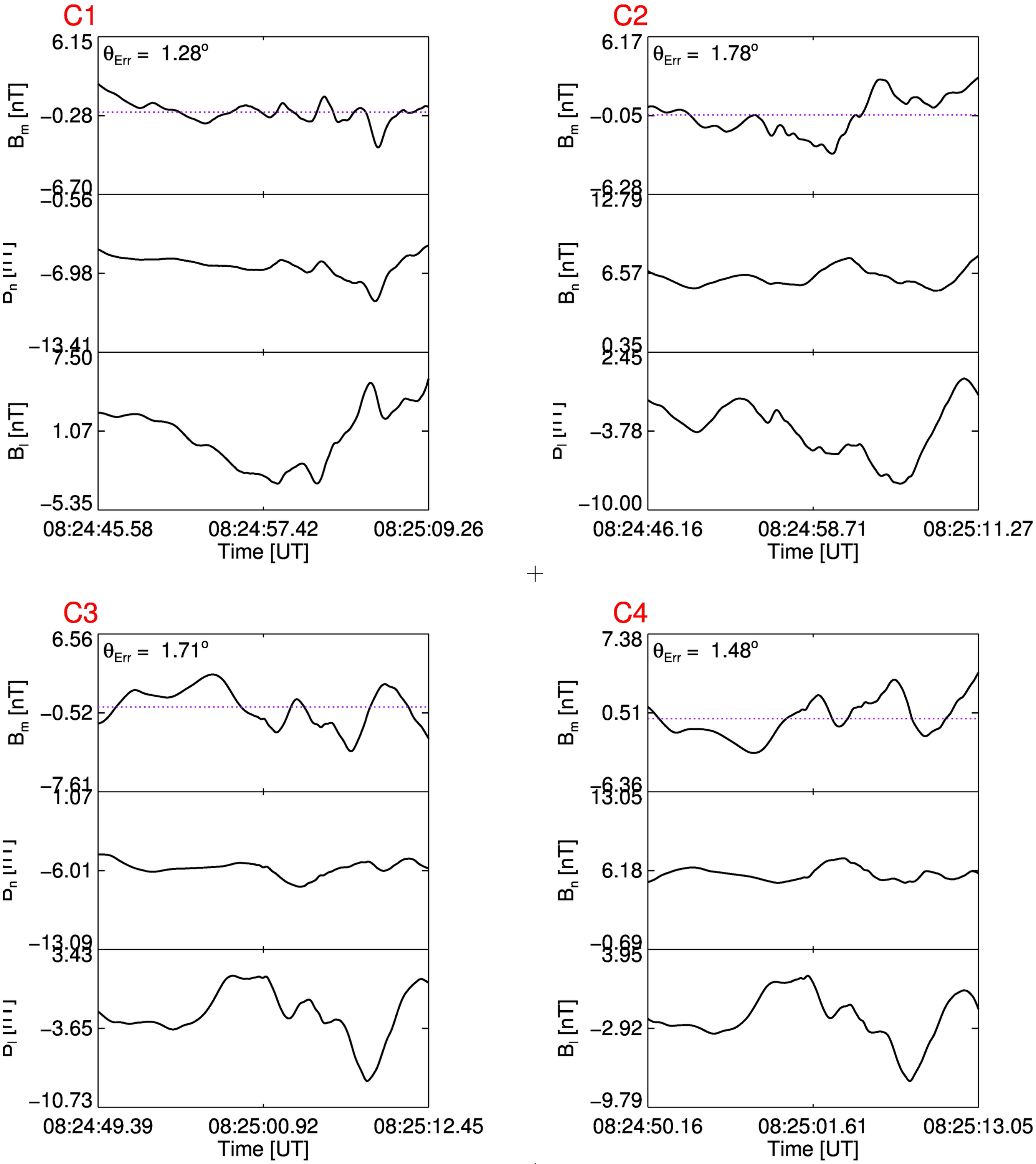

C1
θErr = 1.36°
8.41
0.01
−8.40
15.56
7.15
−1.25
10.56
2.16
−6.25
Bm [nT]
Bn [nT]
Bl [nT]
08:24:44.91
08:24:57.64
08:25:10.38
Time [UT]
C2
θErr = 1.92°
6.23
−0.04
−6.30
13.08
6.81
0.55
2.69
−3.57
−9.83
Bm [nT]
Bn [nT]
Bl [nT]
08:24:46.69
08:24:59.25
08:25:11.80
Time [UT]
C3
θErr = 1.68°
6.56
−0.49
−7.53
1.02
−6.02
−13.07
3.42
−3.63
−10.67
Bm [nT]
08:24:49.39
08:25:01.10
08:25:12.81
Time [UT]
C4
θErr = 1.47°
7.41
0.54
−6.34
13.04
6.17
−0.70
3.95
−2.92
−9.79
Bm [nT]
Bn [nT]
Bl [nT]
08:24:49.94
08:25:01.52
08:25:13.09
Time [UT]


C1
θErr = 1.31°
7.76
-0.20
-8.15
0.80
-7.16
-15.11
9.82
1.86
-6.10
B_m [nT]
B_l [nT]
08:24:45.13
08:24:57.42
08:25:09.71
Time [UT]
C2
θErr = 1.98°
6.29
0.02
-6.26
-0.63
-6.90
-13.18
2.84
-3.44
-9.71
B_m [nT]
B_l [nT]
08:24:46.83
08:24:59.47
08:25:12.12
Time [UT]
C3
θErr = 1.62°
6.55
-0.50
-7.54
1.02
-6.03
-13.08
3.46
-3.59
-10.63
B_m [nT]
08:24:49.66
08:25:01.46
08:25:13.25
Time [UT]
C4
θErr = 1.45°
6.31
-0.56
-7.43
0.73
-6.14
-13.01
3.94
-2.93
-9.80
B_m [nT]
B_l [nT]
08:24:49.67
08:25:01.56
08:25:13.45
Time [UT]

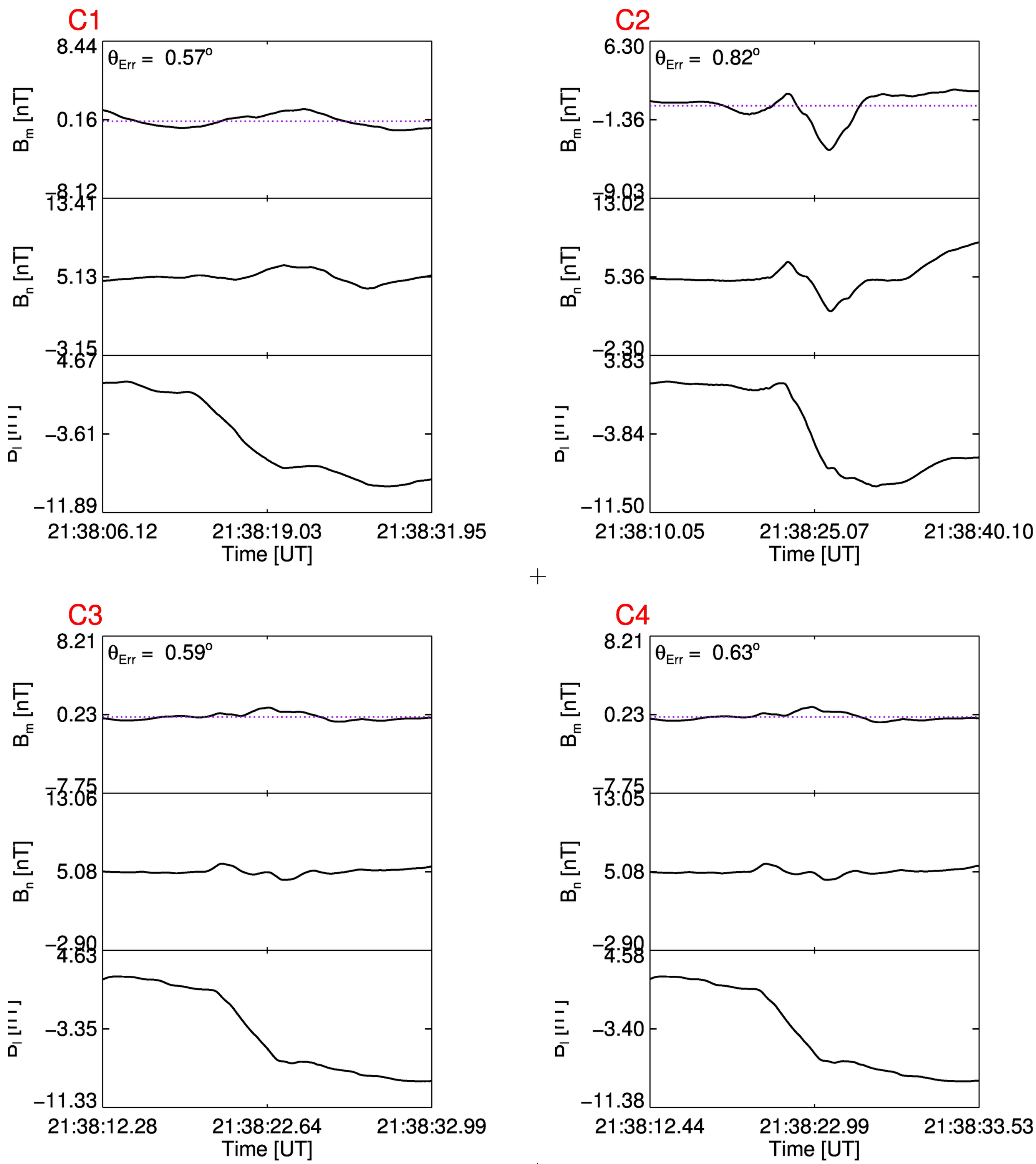

C1
θErr = 1.40°
8.31
−0.13
−8.57
Bm [nT]
1.35
−7.09
−15.53
10.72
2.27
−6.17
Bl [nT]
08:24:45.49
08:24:58.09
08:25:10.69
Time [UT]
C2
θErr = 1.57°
5.87
0.10
−5.67
Bm [nT]
12.15
6.38
0.61
Bn [nT]
10.18
4.41
−1.36
Bl [nT]
08:24:46.16
08:24:58.00
08:25:09.84
Time [UT]
C3
θErr = 1.77°
7.65
0.50
−6.64
Bm [nT]
13.14
6.00
−1.15
Bn [nT]
3.51
−3.64
−10.79
08:24:49.08
08:25:00.57
08:25:12.05
Time [UT]
C4
θErr = 1.48°
6.37
−0.51
−7.38
Bm [nT]
0.75
−6.13
−13.00
3.95
−2.92
−9.80
Bl [nT]
08:24:49.58
08:25:01.34
08:25:13.09
Time [UT]

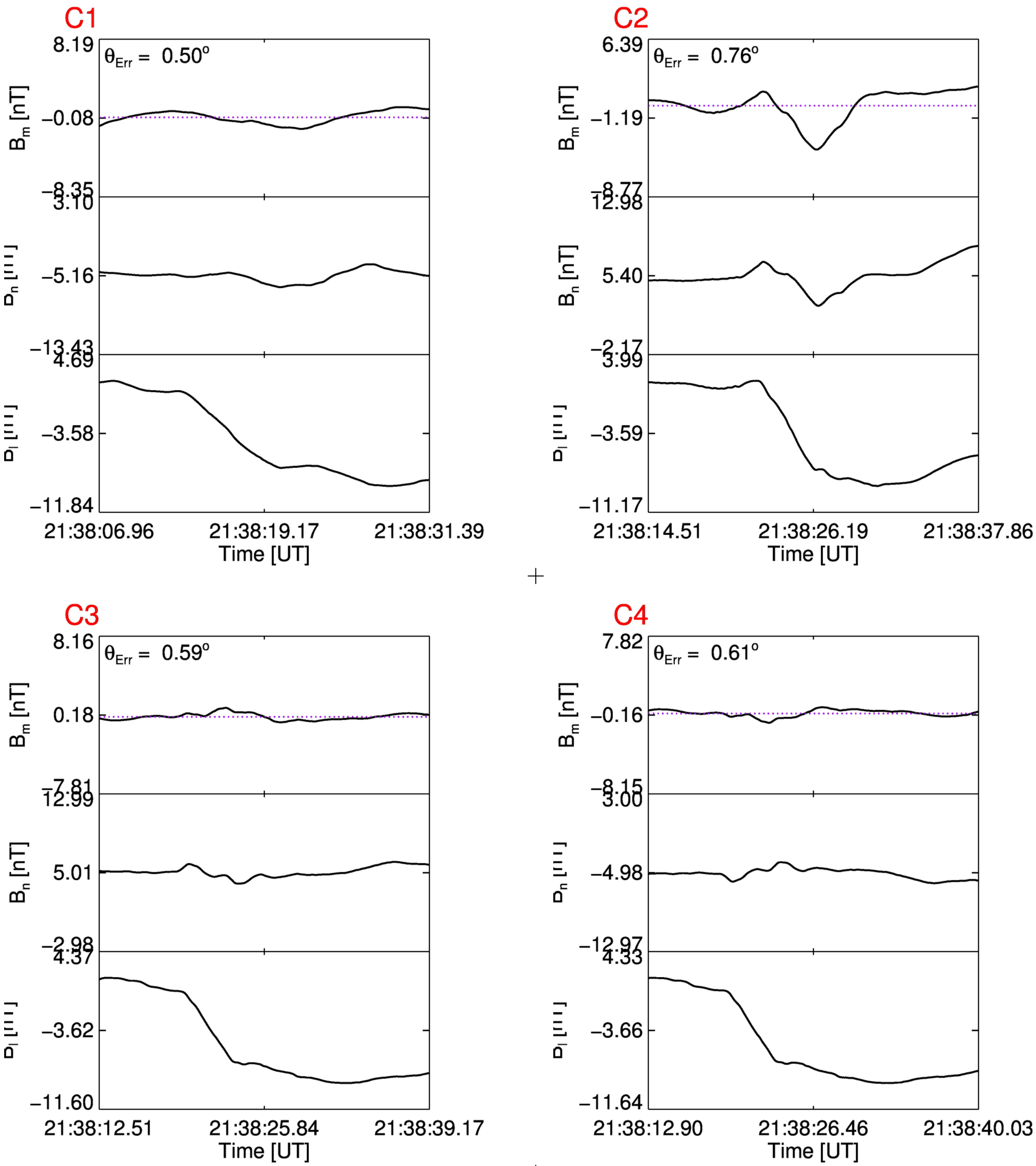

C1
θ_{Err} = 1.36°
B_m [nT]
B_n [nT]
B_l [nT]
8.36
−0.05
−8.45
15.56
7.16
−1.24
10.54
2.14
−6.26
08:24:44.60
08:24:57.51
08:25:10.42
Time [UT]
C2
θ_{Err} = 1.75°
B_m [nT]
B_n [nT]
6.21
0.02
−6.16
12.62
6.43
0.25
2.25
−3.93
−10.11
08:24:46.56
08:24:58.80
08:25:11.05
Time [UT]
C3
θ_{Err} = 1.70°
B_m [nT]
6.57
−0.53
−7.62
1.08
−6.01
−13.10
3.45
−3.65
−10.74
08:24:49.53
08:25:00.97
08:25:12.41
Time [UT]
C4
θ_{Err} = 1.49°
B_m [nT]
B_n [nT]
B_l [nT]
7.25
0.38
−6.48
13.03
6.17
−0.70
3.93
−2.93
−9.80
08:24:50.08
08:25:01.47
08:25:12.87
Time [UT]

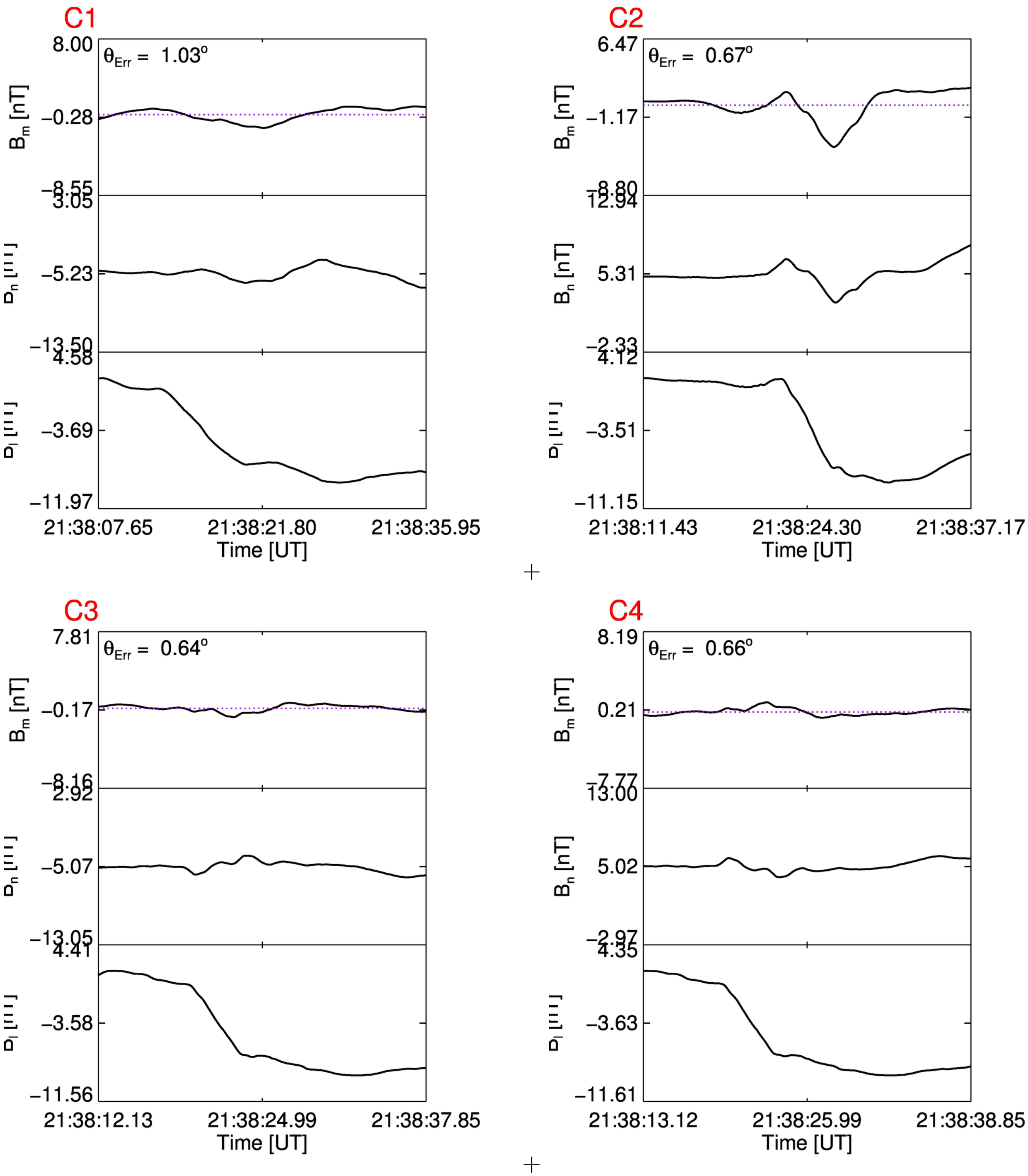

C1
θ_{Err} = 1.29°
7.65
0.45
−6.75
14.22
7.02
−0.17
8.72
1.52
−5.68
B_m [nT]
B_n [nT]
B_l [nT]
08:24:45.80
08:24:57.64
08:25:09.49
Time [UT]
C2
θ_{Err} = 1.93°
6.23
−0.02
−6.28
−0.52
−6.78
−13.04
2.66
−3.60
−9.86
B_m [nT]
B_l [nT]
08:24:46.83
08:24:59.29
08:25:11.76
Time [UT]
C3
θ_{Err} = 1.62°
6.55
−0.49
−7.54
1.02
−6.03
−13.08
3.46
−3.59
−10.63
B_m [nT]
08:24:49.62
08:25:01.41
08:25:13.21
Time [UT]
C4
θ_{Err} = 1.49°
7.27
0.40
−6.47
13.04
6.17
−0.69
3.94
−2.93
−9.80
B_m [nT]
B_n [nT]
B_l [nT]
08:24:50.08
08:25:01.52
08:25:12.96
Time [UT]

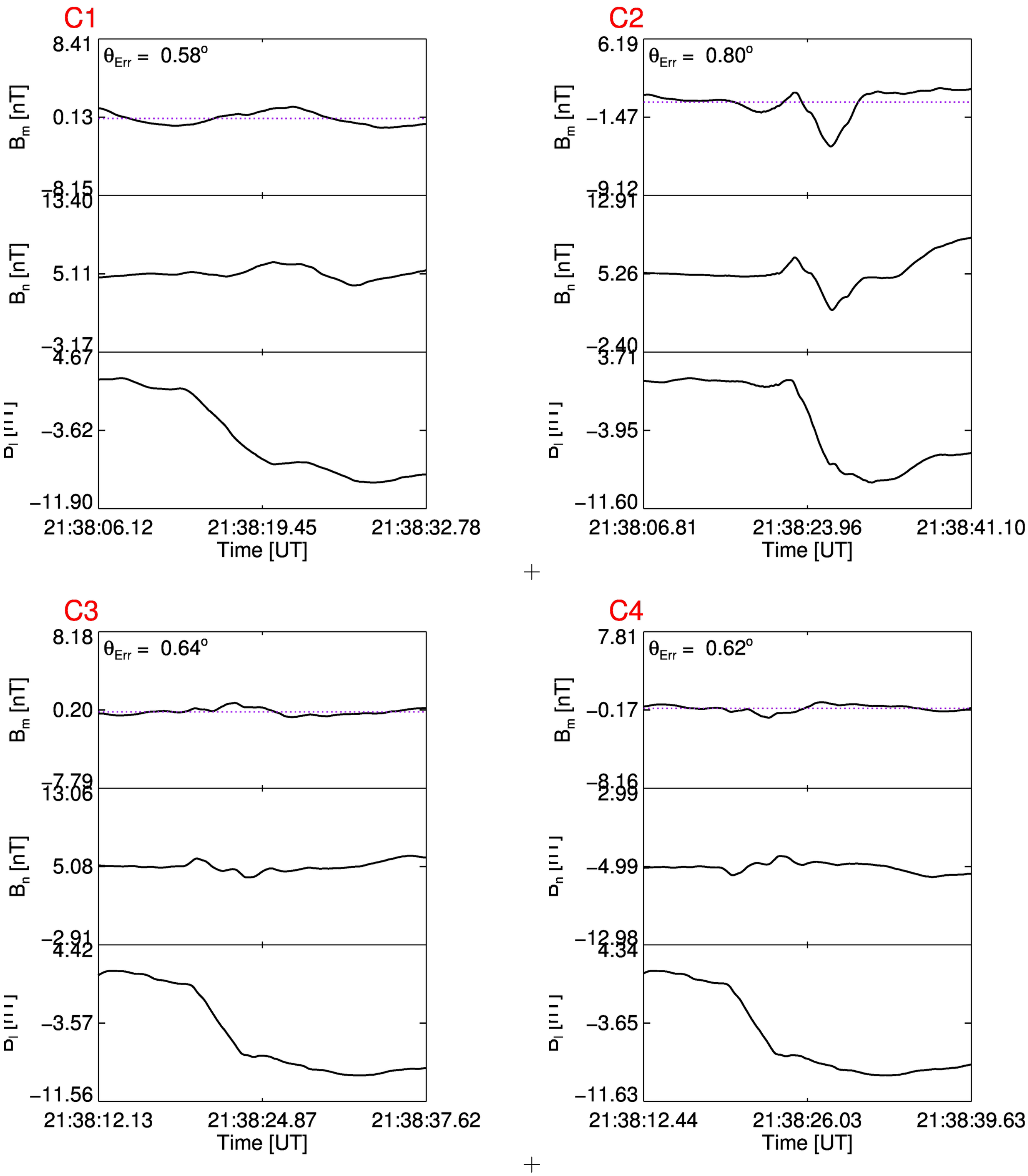

C1
θ_Err = 1.28°
6.15
−0.28
−6.70
B_m [nT]
−0.56
−6.98
−13.41
B_n [nT]
7.50
1.07
−5.35
B_l [nT]
08:24:45.58
08:24:57.42
08:25:09.26
Time [UT]
C2
θ_Err = 1.78°
6.17
−0.05
−6.28
B_m [nT]
12.79
6.57
0.35
B_n [nT]
2.45
−3.78
−10.00
B_l [nT]
08:24:46.16
08:24:58.71
08:25:11.27
Time [UT]
C3
θ_Err = 1.71°
6.56
−0.52
−7.61
B_m [nT]
1.07
−6.01
−13.09
B_n [nT]
3.43
−3.65
−10.73
B_l [nT]
08:24:49.39
08:25:00.92
08:25:12.45
Time [UT]
C4
θ_Err = 1.48°
7.38
0.51
−6.36
B_m [nT]
13.05
6.18
−0.69
B_n [nT]
3.95
−2.92
−9.79
B_l [nT]
08:24:50.16
08:25:01.61
08:25:13.05
Time [UT]

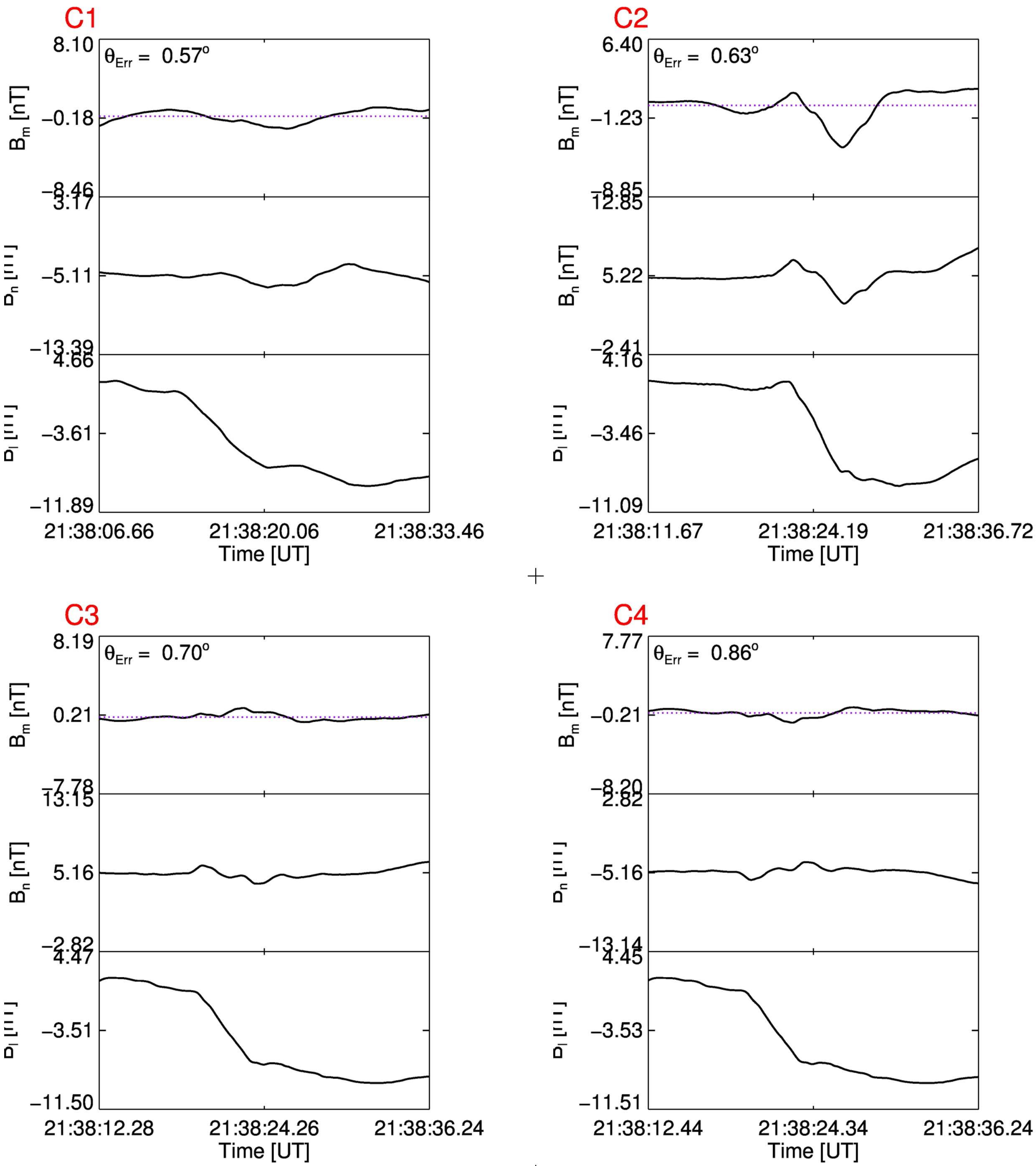
5.3. **26 February 2012**

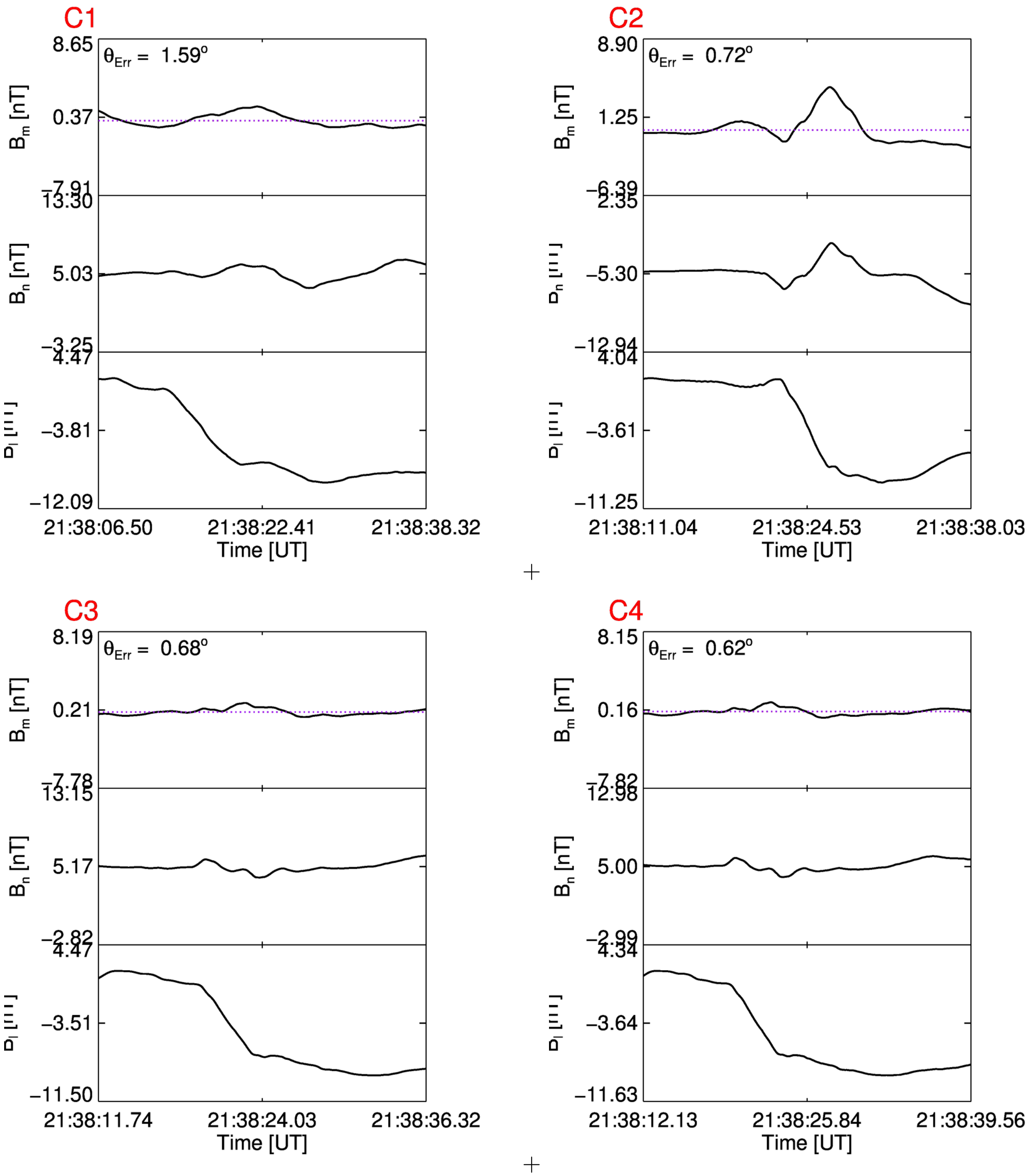


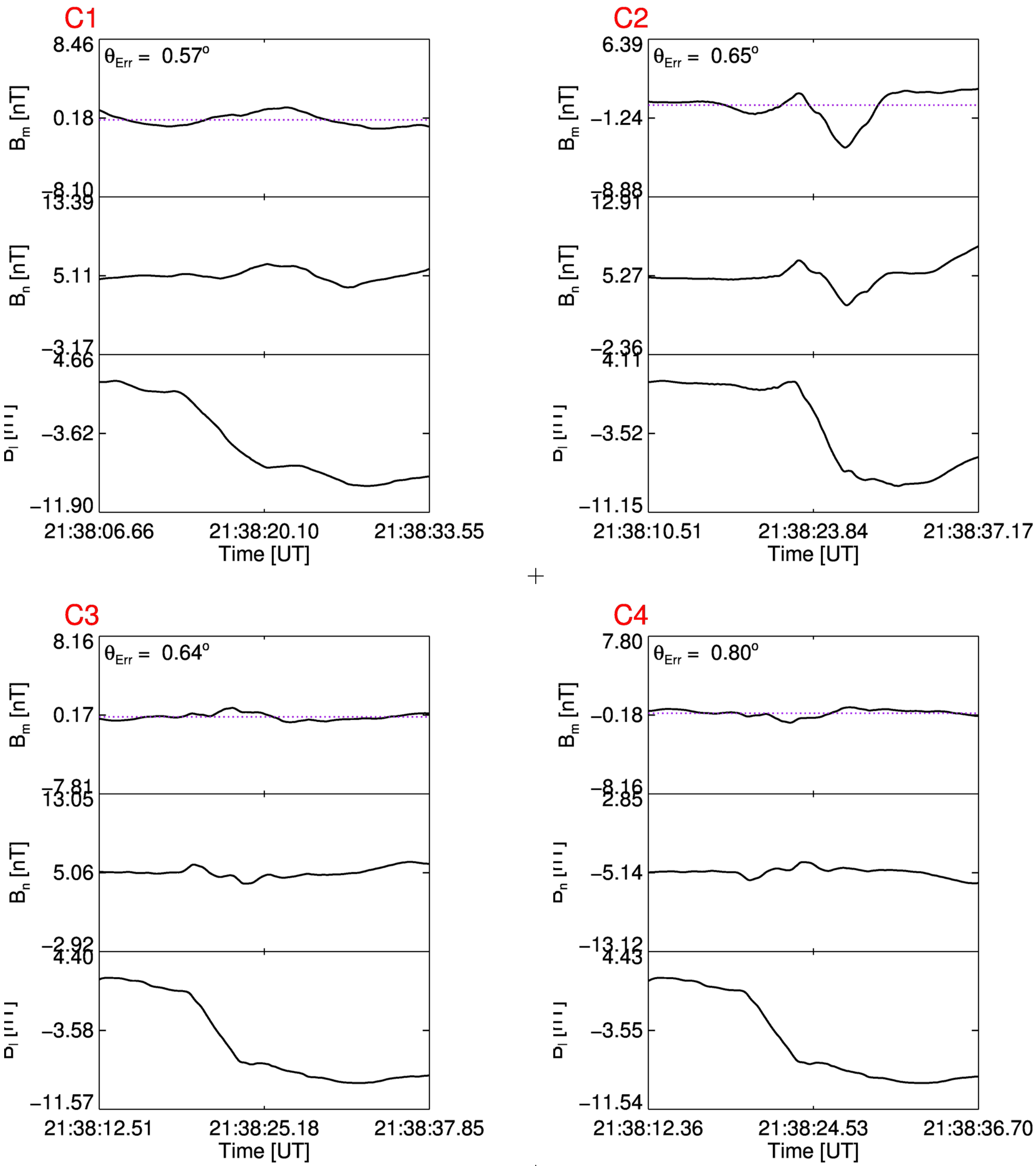

C1
θErr = 0.50°
C2
θErr = 0.76°
C3
θErr = 0.59°
C4
θErr = 0.61°
Bm [nT]
Bn [nT]
Time [UT]
21:38:06.96
21:38:19.17
21:38:31.39
21:38:14.51
21:38:26.19
21:38:37.86
21:38:12.51
21:38:25.84
21:38:39.17
21:38:12.90
21:38:26.46
21:38:40.03


C1
θErr = 1.03°
8.00
-0.28
-8.55
3.05
-5.23
-13.50
4.58
-3.69
-11.97
Bm [nT]
21:38:07.65
21:38:21.80
21:38:35.95
Time [UT]
C2
θErr = 0.67°
6.47
-1.17
-8.80
12.94
5.31
-2.33
4.12
-3.51
-11.15
Bm [nT]
Bn [nT]
21:38:11.43
21:38:24.30
21:38:37.17
Time [UT]
C3
θErr = 0.64°
7.81
-0.17
-8.16
2.92
-5.07
-13.05
4.41
-3.58
-11.56
Bm [nT]
21:38:12.13
21:38:24.99
21:38:37.85
Time [UT]
C4
θErr = 0.66°
8.19
0.21
-7.77
13.00
5.02
-2.97
4.35
-3.63
-11.61
Bm [nT]
Bn [nT]
21:38:13.12
21:38:25.99
21:38:38.85
Time [UT]

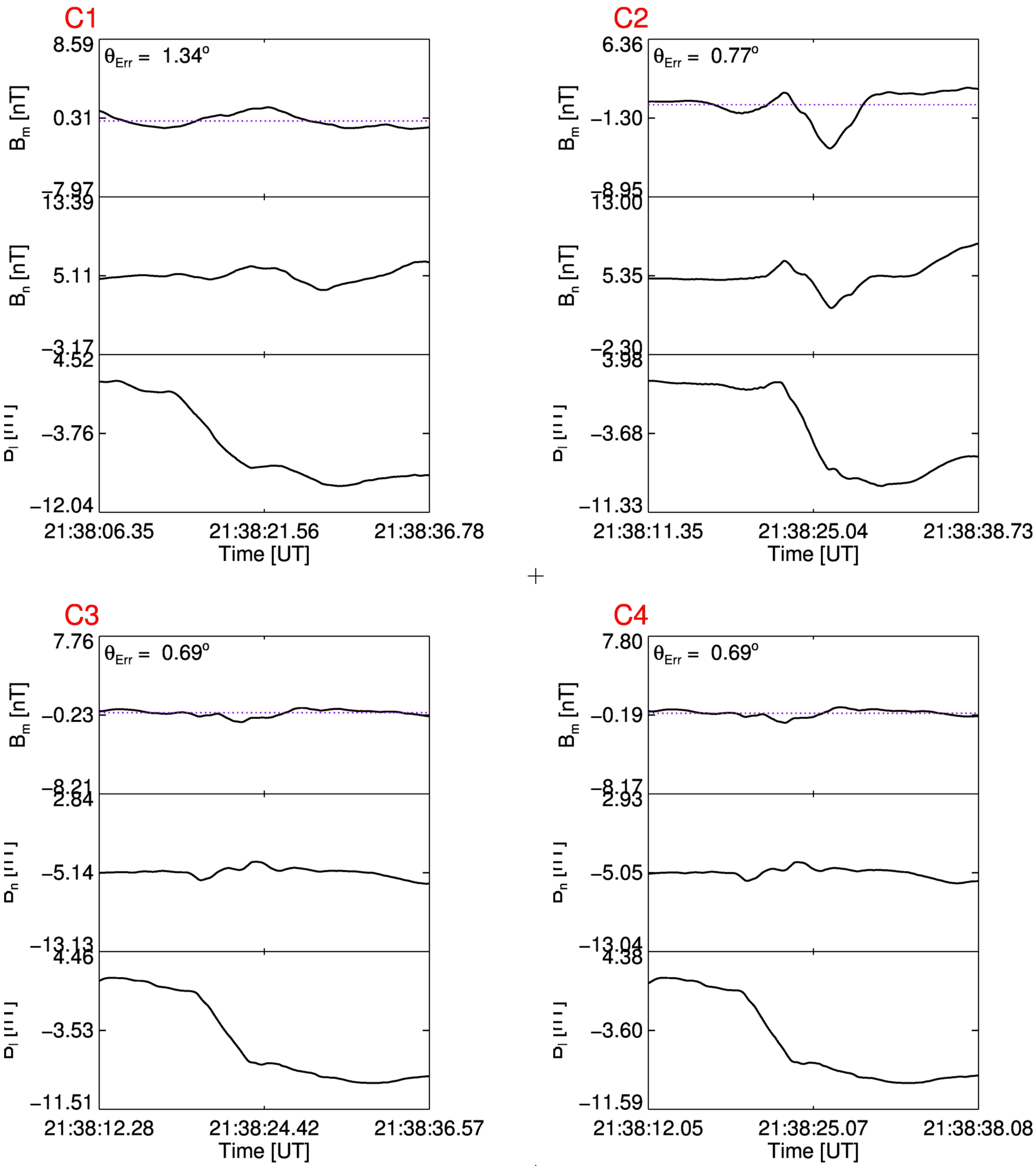

C1
θ_{Err} = 0.58°
B_m [nT]
8.41
0.13
−8.15
B_n [nT]
13.40
5.11
−3.17
4.67
−3.62
−11.90
21:38:06.12
21:38:19.45
21:38:32.78
Time [UT]
C2
θ_{Err} = 0.80°
B_m [nT]
6.19
−1.47
−9.12
B_n [nT]
12.91
5.26
−2.40
3.71
−3.95
−11.60
21:38:06.81
21:38:23.96
21:38:41.10
Time [UT]
C3
θ_{Err} = 0.64°
B_m [nT]
8.18
0.20
−7.79
B_n [nT]
13.06
5.08
−2.91
4.42
−3.57
−11.56
21:38:12.13
21:38:24.87
21:38:37.62
Time [UT]
C4
θ_{Err} = 0.62°
B_m [nT]
7.81
−0.17
−8.16
2.99
−4.99
−12.98
4.34
−3.65
−11.63
21:38:12.44
21:38:26.03
21:38:39.63
Time [UT]

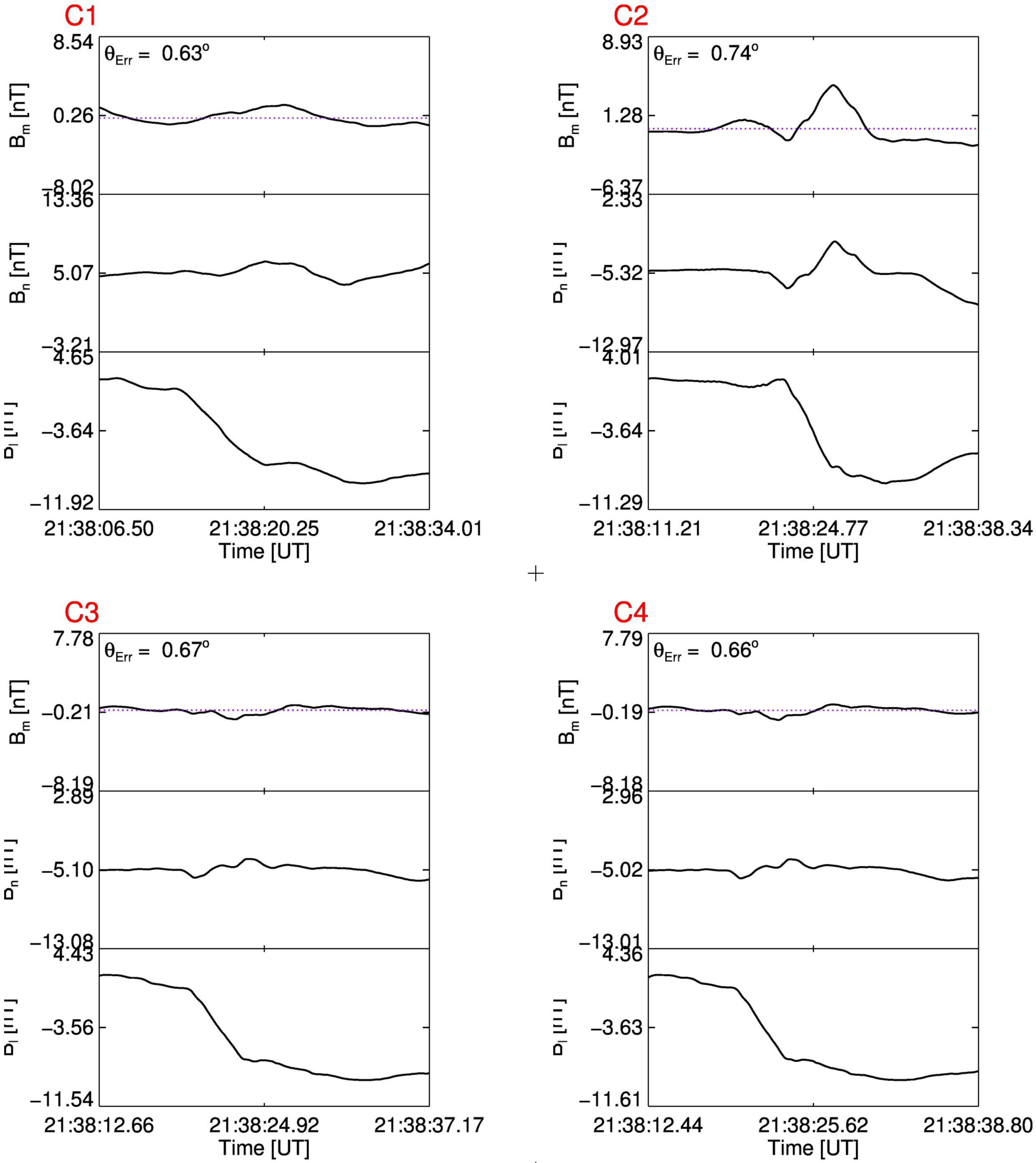

C1
θErr = 0.57°
8.10
–0.18
–8.46
Bm [nT]
3.17
–5.11
–13.39
4.66
–3.61
–11.89
21:38:06.66
21:38:20.06
21:38:33.46
Time [UT]
C2
θErr = 0.63°
6.40
–1.23
–8.85
Bm [nT]
12.85
5.22
–2.41
Bn [nT]
4.16
–3.46
–11.09
21:38:11.67
21:38:24.19
21:38:36.72
Time [UT]
C3
θErr = 0.70°
8.19
0.21
–7.78
Bm [nT]
13.15
5.16
–2.82
Bn [nT]
4.47
–3.51
–11.50
21:38:12.28
21:38:24.26
21:38:36.24
Time [UT]
C4
θErr = 0.86°
7.77
–0.21
–8.20
Bm [nT]
2.82
–5.16
–13.14
4.45
–3.53
–11.51
21:38:12.44
21:38:24.34
21:38:36.24
Time [UT]

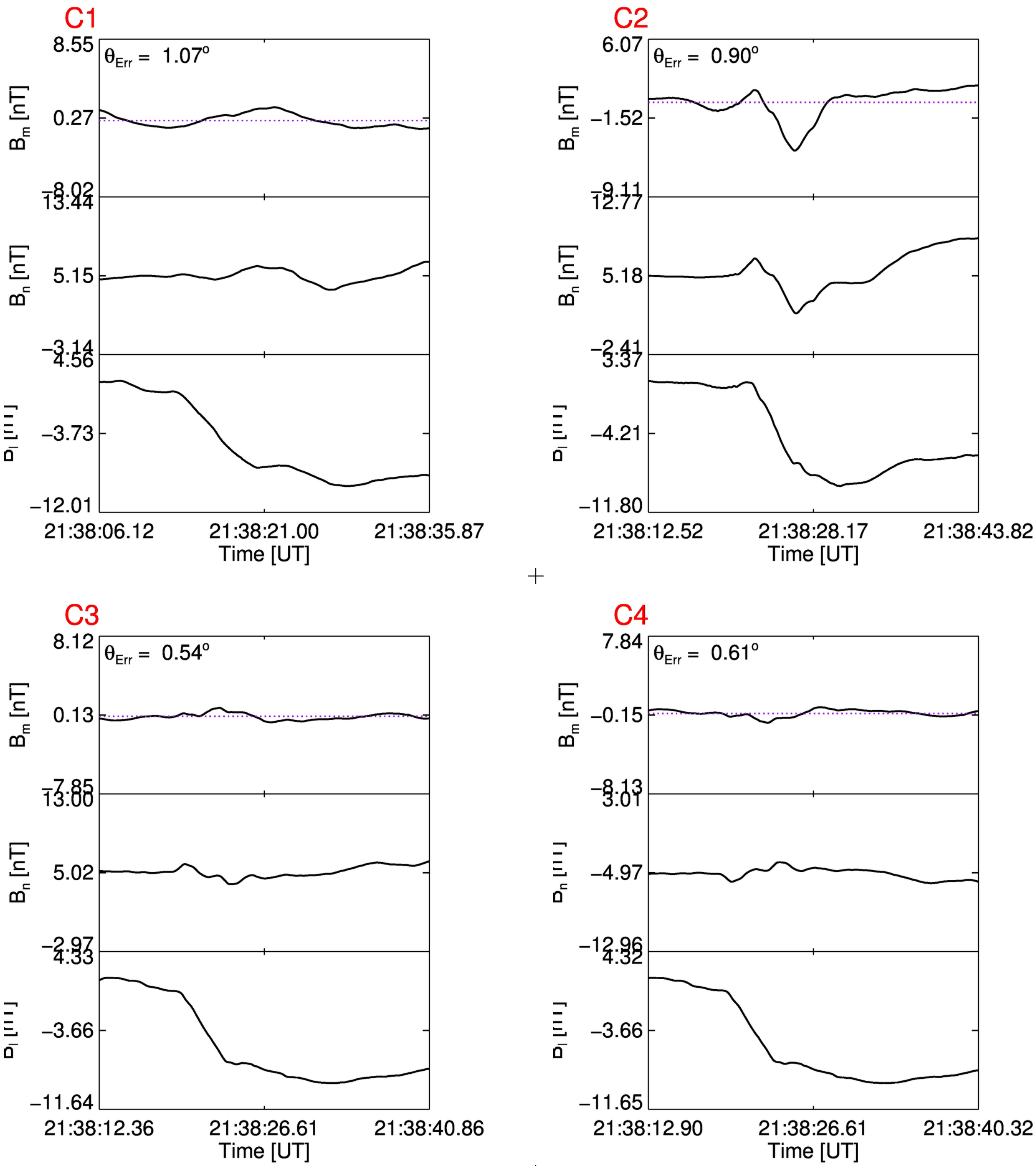

C1
θErr = 1.59°
8.65
0.37
−7.91
Bm [nT]
13.30
5.03
−3.25
Bn [nT]
4.47
−3.81
−12.09
21:38:06.50
21:38:22.41
21:38:38.32
Time [UT]
C2
θErr = 0.72°
8.90
1.25
−6.39
Bm [nT]
2.35
−5.30
−12.94
4.04
−3.61
−11.25
21:38:11.04
21:38:24.53
21:38:38.03
Time [UT]
C3
θErr = 0.68°
8.19
0.21
−7.78
Bm [nT]
13.15
5.17
−2.82
Bn [nT]
4.47
−3.51
−11.50
21:38:11.74
21:38:24.03
21:38:36.32
Time [UT]
C4
θErr = 0.62°
8.15
0.16
−7.82
Bm [nT]
12.98
5.00
−2.99
Bn [nT]
4.34
−3.64
−11.63
21:38:12.13
21:38:25.84
21:38:39.56
Time [UT]



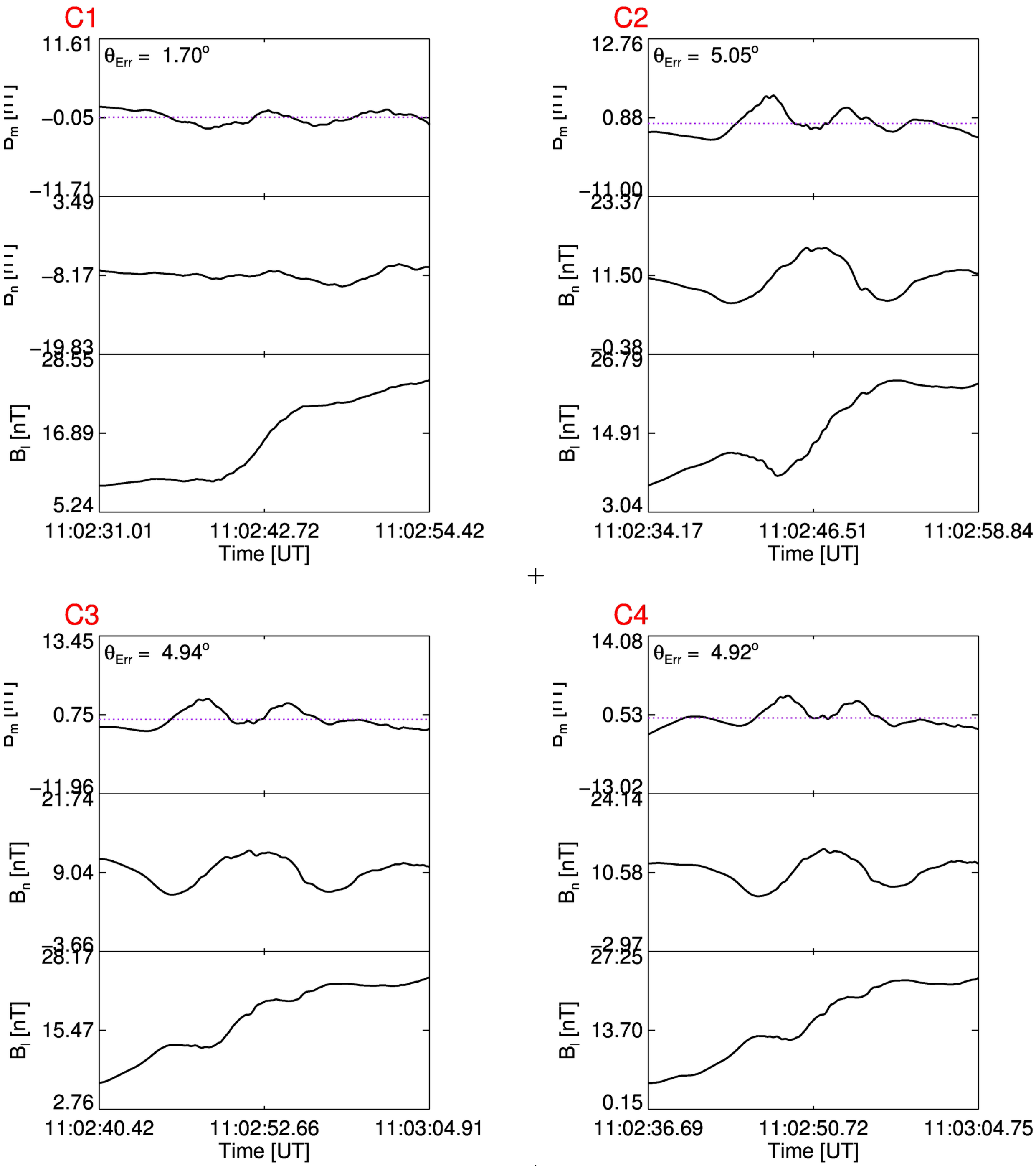
C1
θErr = 0.57°
8.46
0.18
−8.10
Bm [nT]
13.39
5.11
−3.17
Bn [nT]
4.66
−3.62
−11.90
21:38:06.66
21:38:20.10
21:38:33.55
Time [UT]
C2
θErr = 0.65°
6.39
−1.24
−8.88
Bm [nT]
12.91
5.27
−2.36
Bn [nT]
4.11
−3.52
−11.15
21:38:10.51
21:38:23.84
21:38:37.17
Time [UT]
C3
θErr = 0.64°
8.16
0.17
−7.81
Bm [nT]
13.05
5.06
−2.92
Bn [nT]
4.40
−3.58
−11.57
21:38:12.51
21:38:25.18
21:38:37.85
Time [UT]
C4
θErr = 0.80°
7.80
−0.18
−8.16
Bm [nT]
2.85
−5.14
−13.12
4.43
−3.55
−11.54
21:38:12.36
21:38:24.53
21:38:36.70
Time [UT]

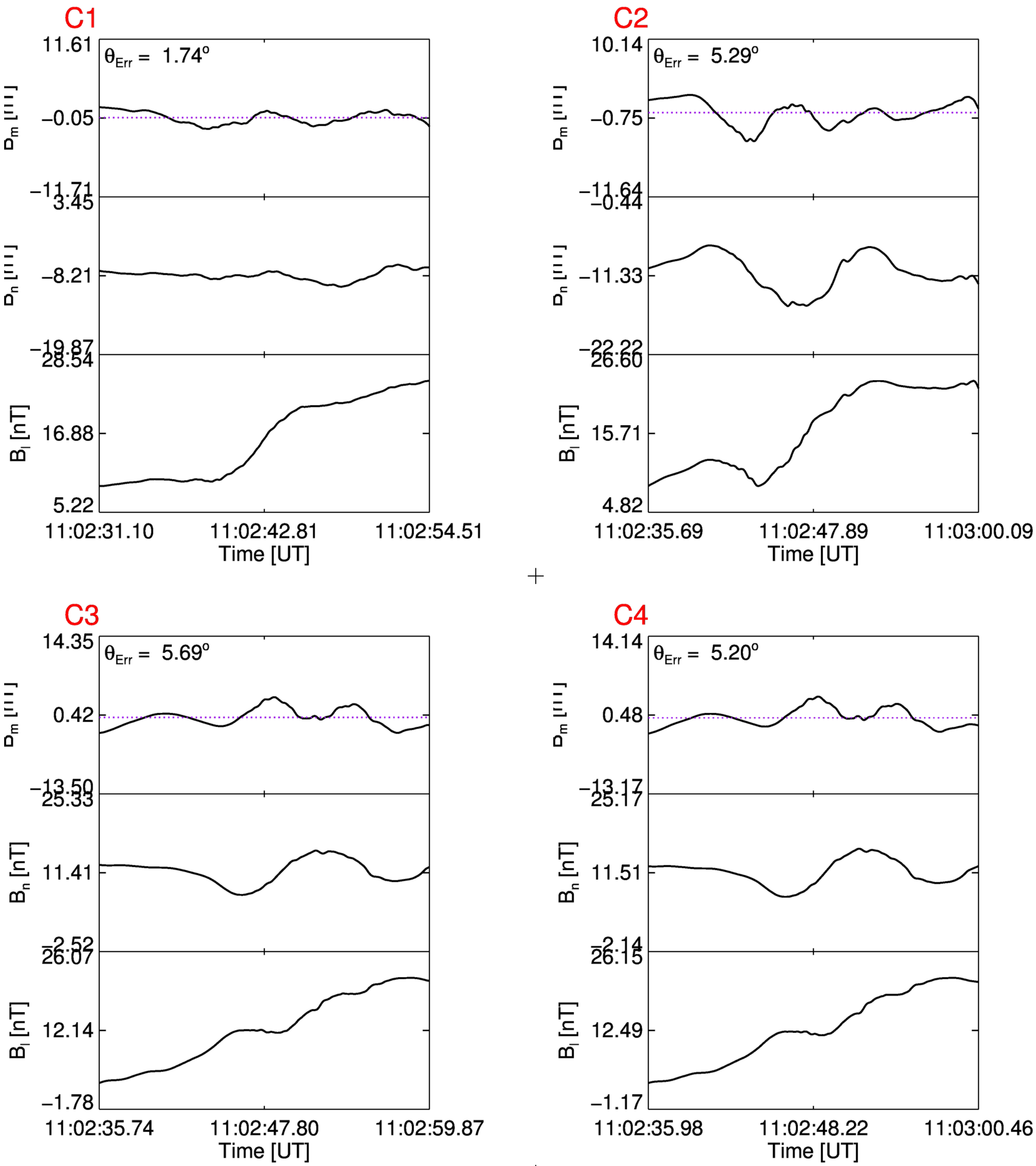

C1
θ_{Err} = 1.34°
8.59
0.31
−7.97
B_m [nT]
13.39
5.11
−3.17
B_n [nT]
4.52
−3.76
−12.04
21:38:06.35
21:38:21.56
21:38:36.78
Time [UT]
C2
θ_{Err} = 0.77°
6.36
−1.30
−8.95
B_m [nT]
13.00
5.35
−2.30
B_n [nT]
3.98
−3.68
−11.33
21:38:11.35
21:38:25.04
21:38:38.73
Time [UT]
C3
θ_{Err} = 0.69°
7.76
−0.23
−8.21
B_m [nT]
2.84
−5.14
−13.13
4.46
−3.53
−11.51
21:38:12.28
21:38:24.42
21:38:36.57
Time [UT]
C4
θ_{Err} = 0.69°
7.80
−0.19
−8.17
B_m [nT]
2.93
−5.05
−13.04
4.38
−3.60
−11.59
21:38:12.05
21:38:25.07
21:38:38.08
Time [UT]

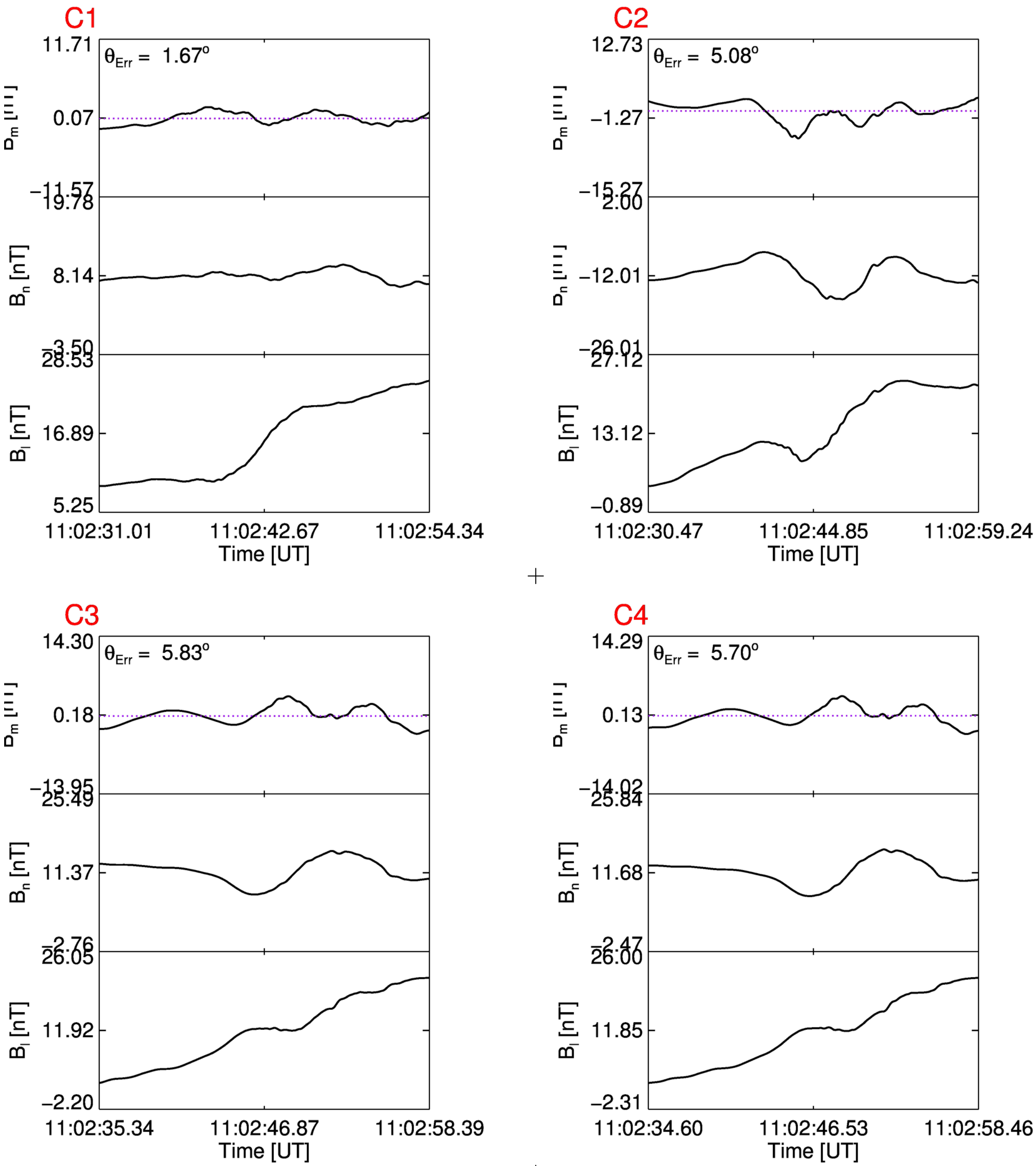

C1
θErr = 0.63°
8.54
0.26
−8.02
Bm [nT]
13.36
5.07
−3.21
Bn [nT]
4.65
−3.64
−11.92
21:38:06.50
21:38:20.25
21:38:34.01
Time [UT]
C2
θErr = 0.74°
8.93
1.28
−6.37
Bm [nT]
2.33
−5.32
−12.97
4.01
−3.64
−11.29
21:38:11.21
21:38:24.77
21:38:38.34
Time [UT]
C3
θErr = 0.67°
7.78
−0.21
−8.19
Bm [nT]
2.89
−5.10
−13.08
4.43
−3.56
−11.54
21:38:12.66
21:38:24.92
21:38:37.17
Time [UT]
C4
θErr = 0.66°
7.79
−0.19
−8.18
Bm [nT]
2.96
−5.02
−13.01
4.36
−3.63
−11.61
21:38:12.44
21:38:25.62
21:38:38.80
Time [UT]

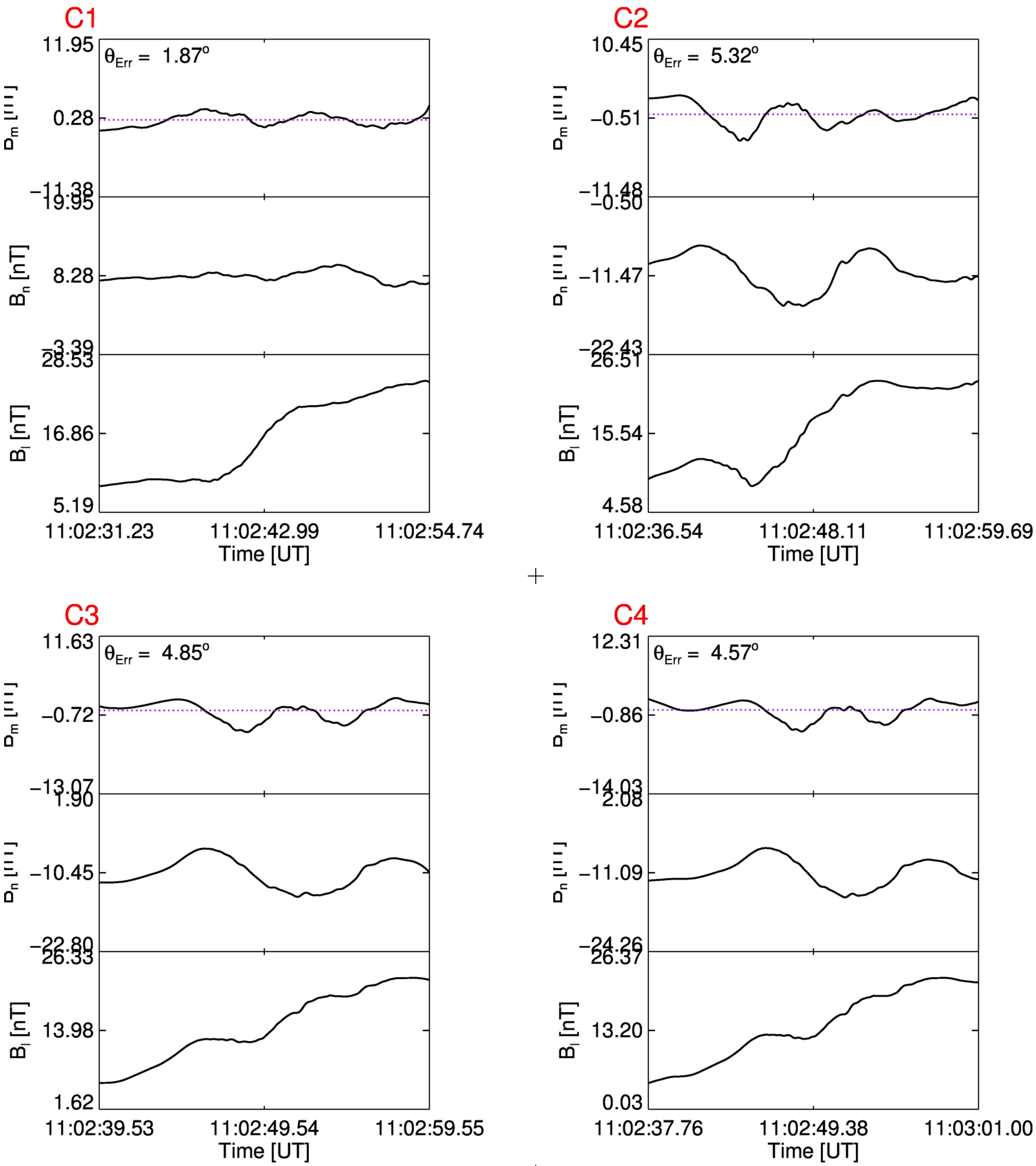

C1
θErr = 1.07°
8.55
0.27
−8.02
13.44
5.15
−3.14
4.56
−3.73
−12.01
Bm [nT]
Bn [nT]
21:38:06.12
21:38:21.00
21:38:35.87
Time [UT]
C2
θErr = 0.90°
6.07
−1.52
−9.11
12.77
5.18
−2.41
3.37
−4.21
−11.80
Bm [nT]
Bn [nT]
21:38:12.52
21:38:28.17
21:38:43.82
Time [UT]
C3
θErr = 0.54°
8.12
0.13
−7.85
13.00
5.02
−2.97
4.33
−3.66
−11.64
Bm [nT]
Bn [nT]
21:38:12.36
21:38:26.61
21:38:40.86
Time [UT]
C4
θErr = 0.61°
7.84
−0.15
−8.13
3.01
−4.97
−12.96
4.32
−3.66
−11.65
Bm [nT]
21:38:12.90
21:38:26.61
21:38:40.32
Time [UT]

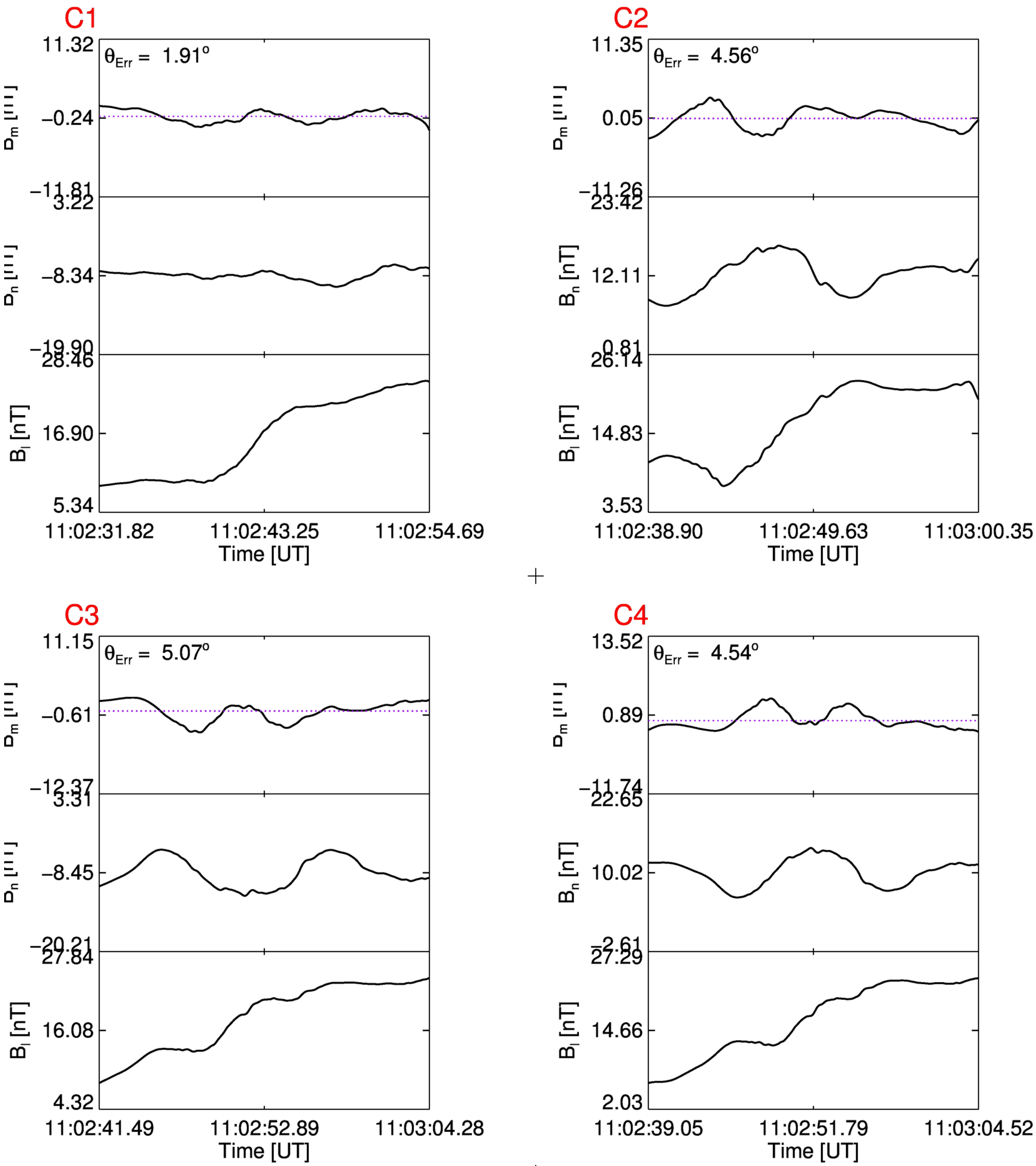
5.3.1. **8 March 2012**

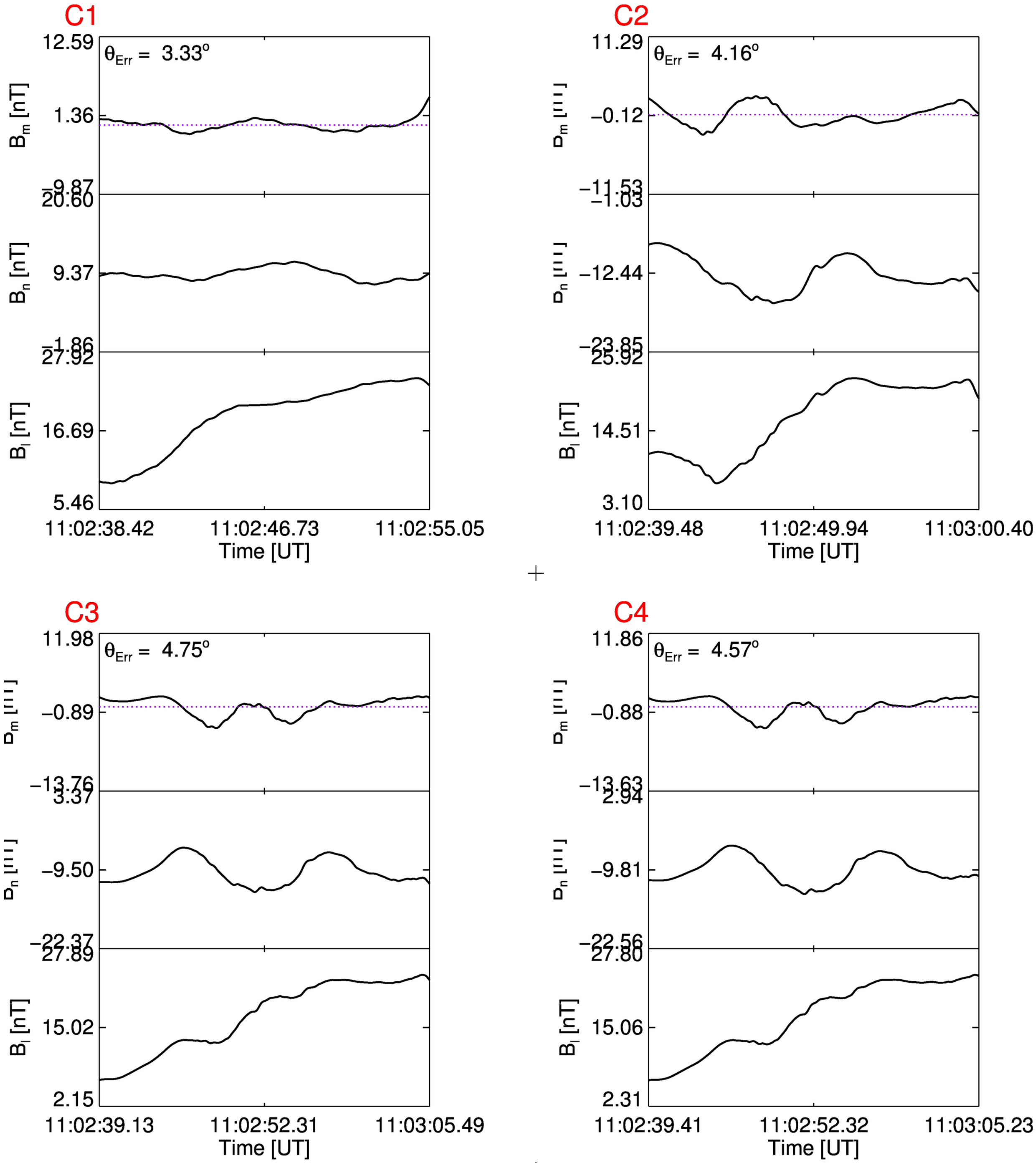


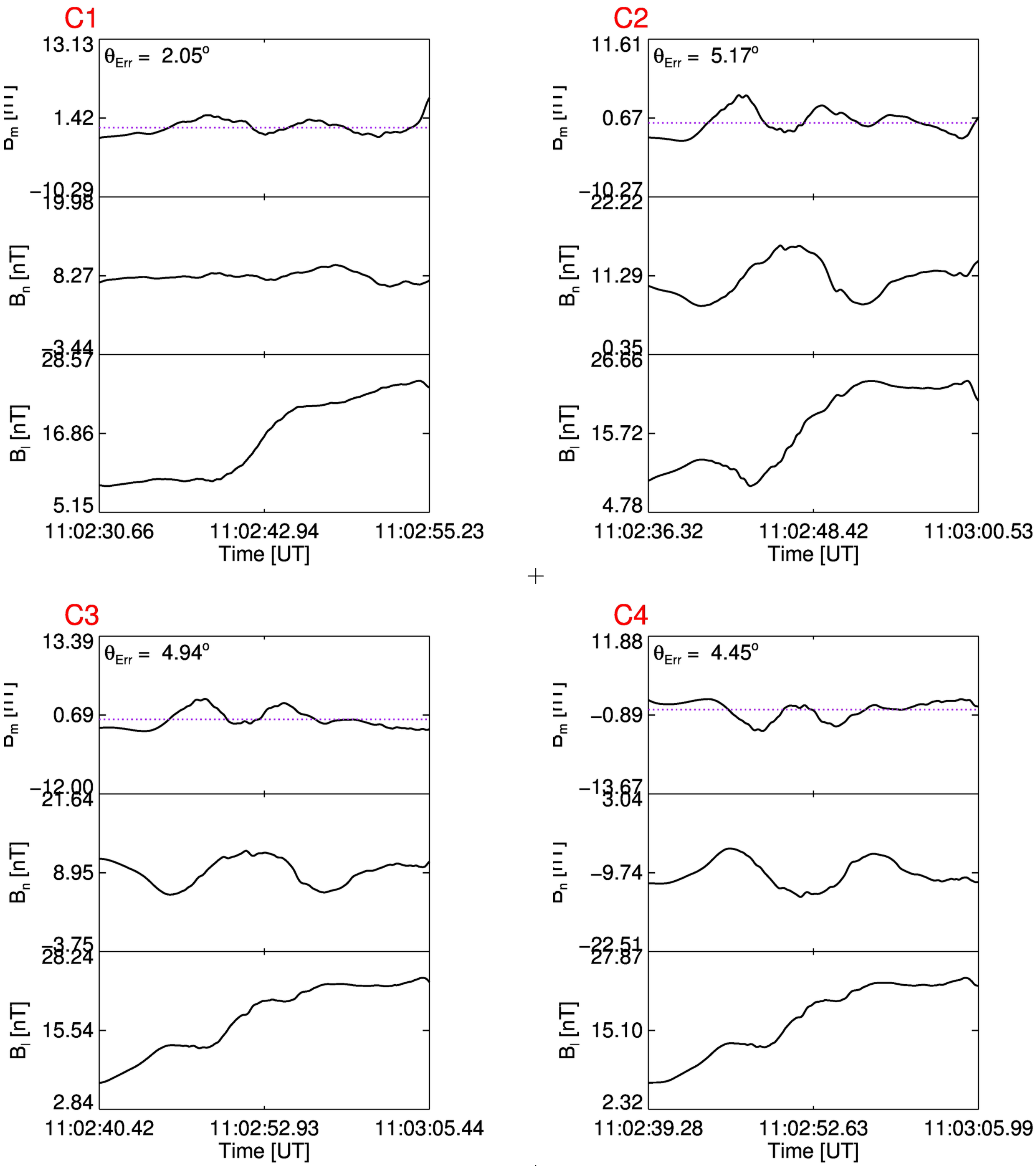

C1
θErr = 1.74°
11.61
−0.05
−11.71
3.45
−8.21
−19.87
28.54
16.88
5.22
Bl [nT]
11:02:31.10
11:02:42.81
11:02:54.51
Time [UT]
C2
θErr = 5.29°
10.14
−0.75
−11.64
−0.44
−11.33
−22.22
26.60
15.71
4.82
Bl [nT]
11:02:35.69
11:02:47.89
11:03:00.09
Time [UT]
C3
θErr = 5.69°
14.35
0.42
−13.50
25.33
11.41
−2.52
26.07
12.14
−1.78
Bn [nT]
Bl [nT]
11:02:35.74
11:02:47.80
11:02:59.87
Time [UT]
C4
θErr = 5.20°
14.14
0.48
−13.17
25.17
11.51
−2.14
26.15
12.49
−1.17
Bn [nT]
Bl [nT]
11:02:35.98
11:02:48.22
11:03:00.46
Time [UT]


C1
θErr = 1.67°
11.71
0.07
−11.57
19.78
8.14
−3.50
28.53
16.89
5.25
Bn [nT]
Bl [nT]
11:02:31.01
11:02:42.67
11:02:54.34
Time [UT]
C2
θErr = 5.08°
12.73
−1.27
−15.27
2.00
-12.01
−26.01
27.12
13.12
−0.89
Bl [nT]
11:02:30.47
11:02:44.85
11:02:59.24
Time [UT]
C3
θErr = 5.83°
14.30
0.18
−13.95
25.49
11.37
−2.76
26.05
11.92
−2.20
Bn [nT]
Bl [nT]
11:02:35.34
11:02:46.87
11:02:58.39
Time [UT]
C4
θErr = 5.70°
14.29
0.13
−14.02
25.84
11.68
−2.47
26.00
11.85
−2.31
Bn [nT]
Bl [nT]
11:02:34.60
11:02:46.53
11:02:58.46
Time [UT]

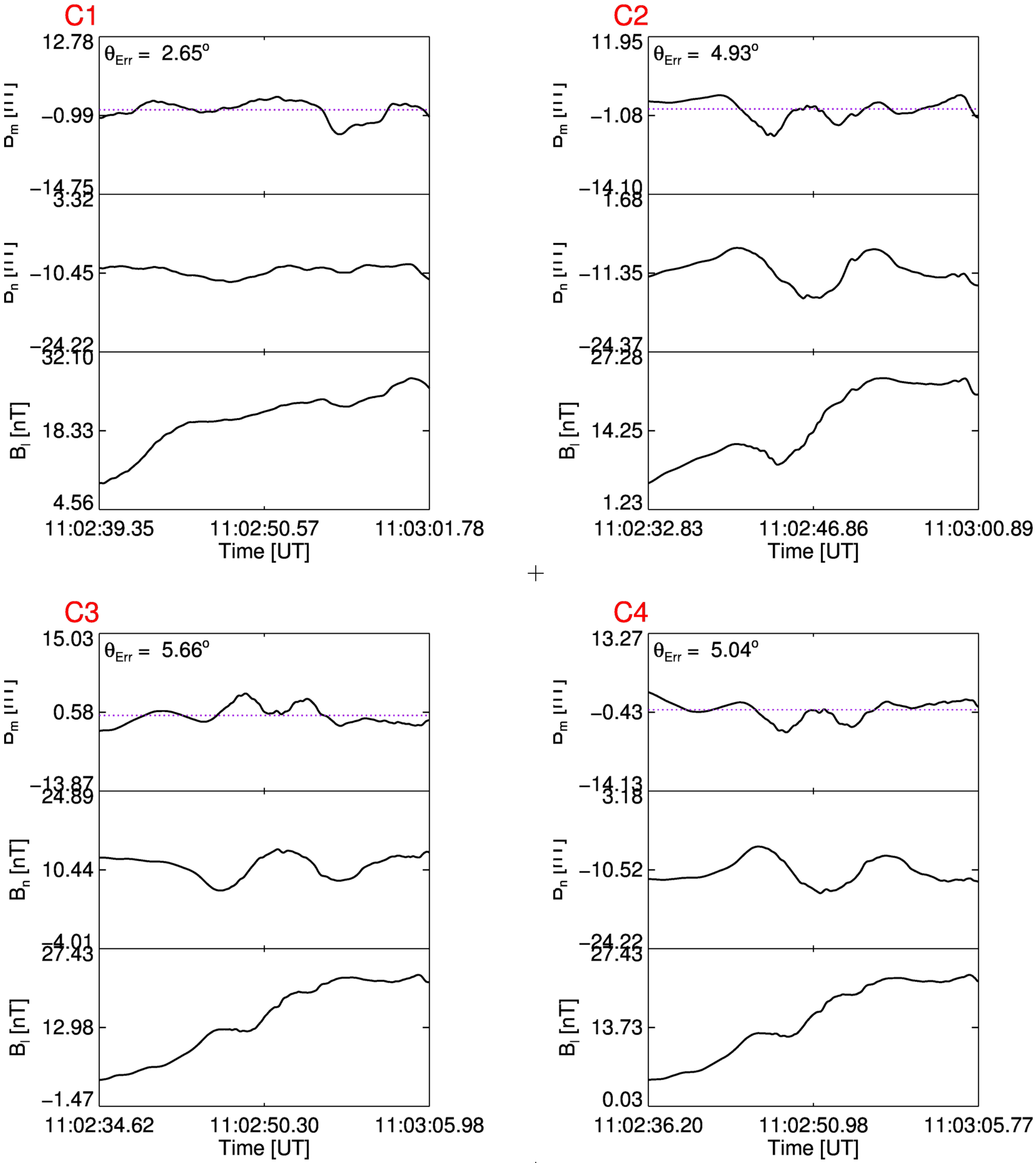

C1
θErr = 1.87°
11.95
0.28
−11.38
19.95
8.28
−3.39
28.53
16.86
5.19
Bm
Bn [nT]
Bl [nT]
11:02:31.23
11:02:42.99
11:02:54.74
Time [UT]
C2
θErr = 5.32°
10.45
−0.51
−11.48
−0.50
−11.47
−22.43
26.51
15.54
4.58
Bm
Bn
Bl [nT]
11:02:36.54
11:02:48.11
11:02:59.69
Time [UT]
C3
θErr = 4.85°
11.63
−0.72
−13.07
1.90
−10.45
−22.80
26.33
13.98
1.62
Bm
Bn
Bl [nT]
11:02:39.53
11:02:49.54
11:02:59.55
Time [UT]
C4
θErr = 4.57°
12.31
−0.86
−14.03
2.08
−11.09
−24.26
26.37
13.20
0.03
Bm
Bn
Bl [nT]
11:02:37.76
11:02:49.38
11:03:01.00
Time [UT]

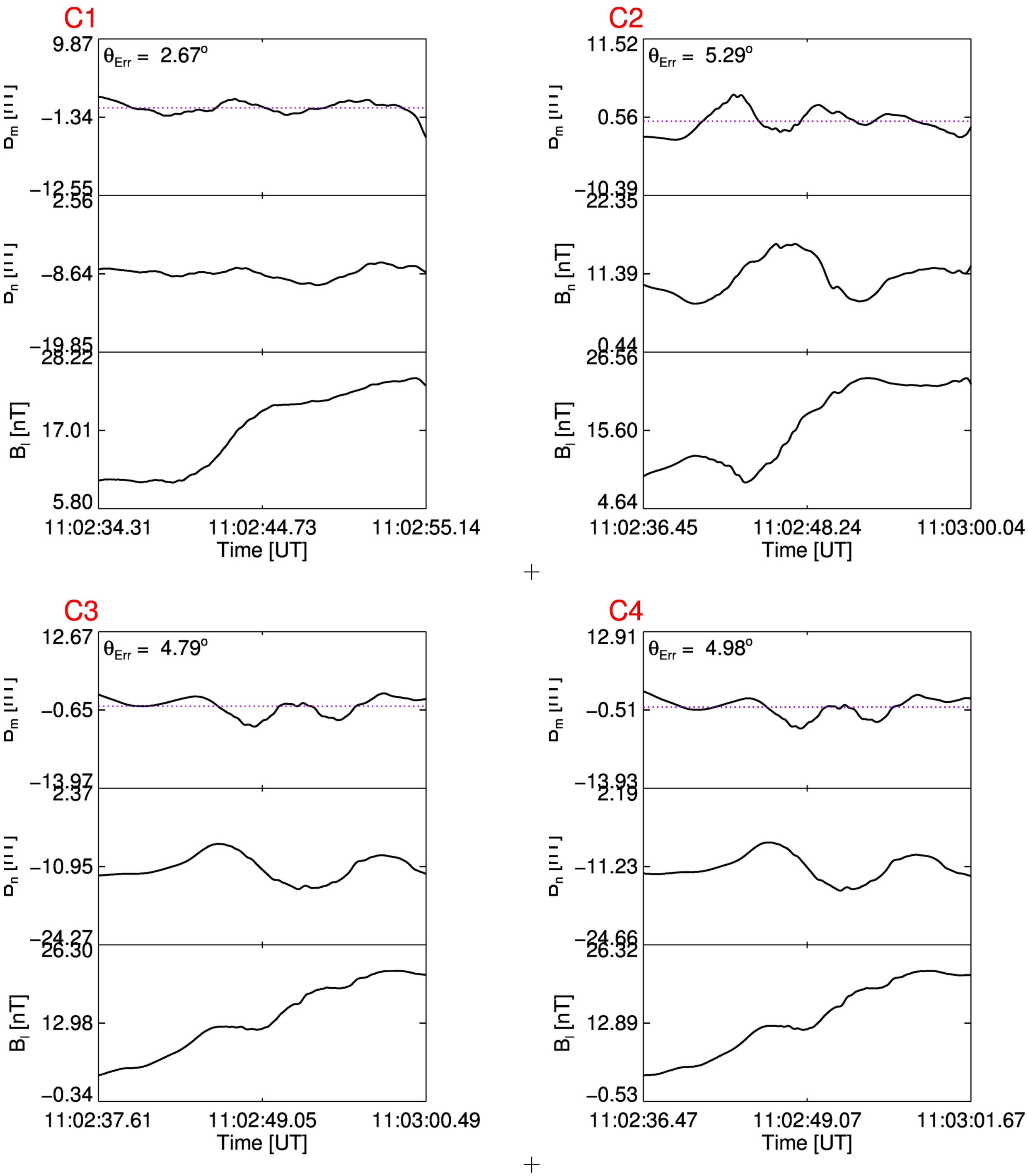

C1
θ_{Err} = 1.91°
11.32
−0.24
−11.81
B_m [nT]
3.22
−8.34
−19.90
B_n [nT]
28.46
16.90
5.34
B_l [nT]
11:02:31.82
11:02:43.25
11:02:54.69
Time [UT]
C2
θ_{Err} = 4.56°
11.35
0.05
−11.26
B_m [nT]
23.42
12.11
0.81
B_n [nT]
26.14
14.83
3.53
B_l [nT]
11:02:38.90
11:02:49.63
11:03:00.35
Time [UT]
C3
θ_{Err} = 5.07°
11.15
−0.61
−12.37
B_m [nT]
3.31
−8.45
−20.21
B_n [nT]
27.84
16.08
4.32
B_l [nT]
11:02:41.49
11:02:52.89
11:03:04.28
Time [UT]
C4
θ_{Err} = 4.54°
13.52
0.89
−11.74
B_m [nT]
22.65
10.02
−2.61
B_n [nT]
27.29
14.66
2.03
B_l [nT]
11:02:39.05
11:02:51.79
11:03:04.52
Time [UT]


C1
θErr = 3.33°
12.59
1.36
−9.87
20.60
9.37
−1.86
27.92
16.69
5.46
Bm [nT]
Bn [nT]
Bl [nT]
11:02:38.42
11:02:46.73
11:02:55.05
Time [UT]
C2
θErr = 4.16°
11.29
−0.12
−11.53
−1.03
−12.44
−23.85
25.92
14.51
3.10
Bl [nT]
11:02:39.48
11:02:49.94
11:03:00.40
Time [UT]
C3
θErr = 4.75°
11.98
−0.89
−13.76
3.37
−9.50
−22.37
27.89
15.02
2.15
Bl [nT]
11:02:39.13
11:02:52.31
11:03:05.49
Time [UT]
C4
θErr = 4.57°
11.86
−0.88
−13.63
2.94
−9.81
−22.56
27.80
15.06
2.31
Bl [nT]
11:02:39.41
11:02:52.32
11:03:05.23
Time [UT]

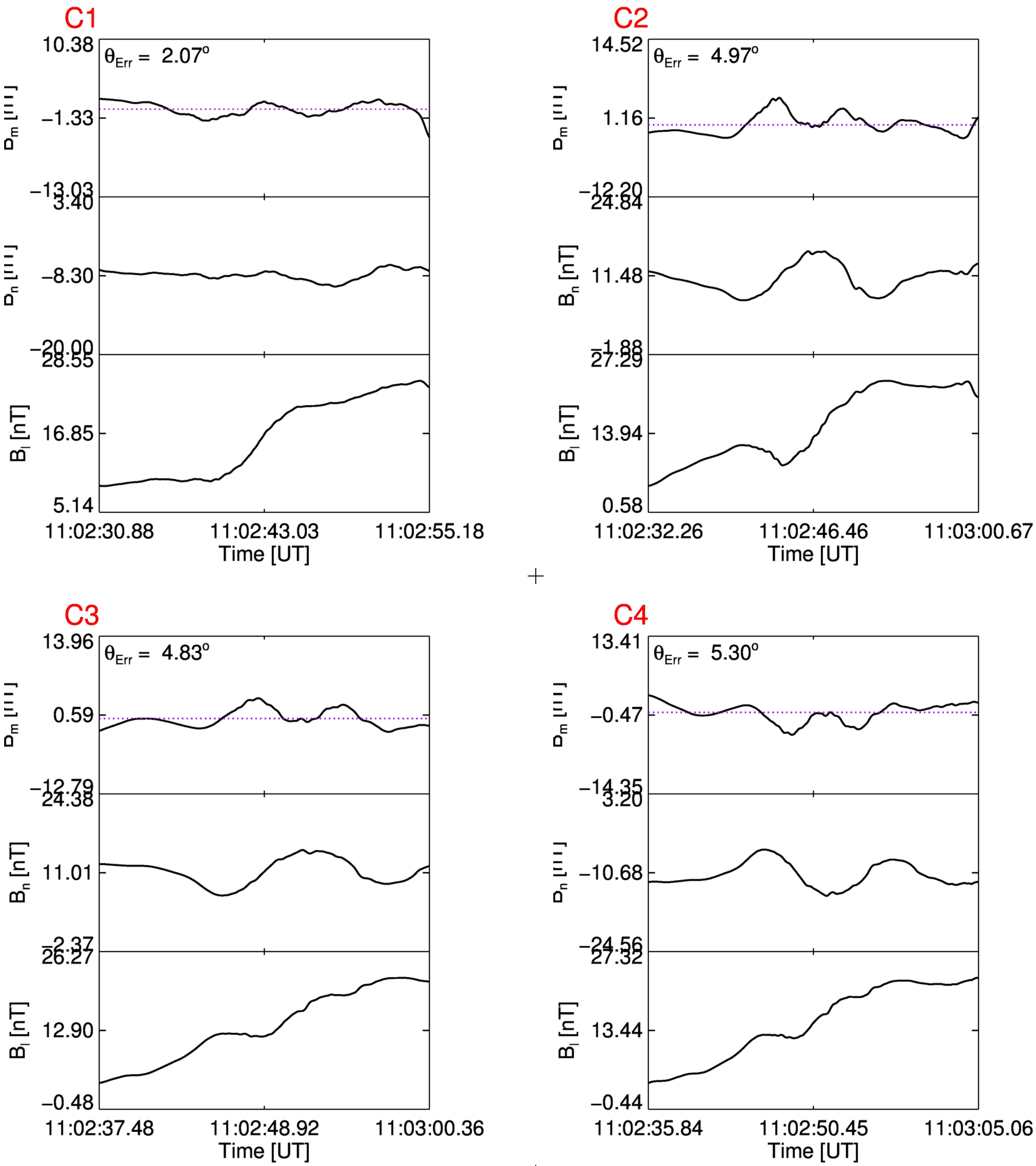


C1
θErr = 2.05°
13.13
1.42
−10.29
19.98
8.27
−3.44
28.57
16.86
5.15
B_n [nT]
B_l [nT]
11:02:30.66
11:02:42.94
11:02:55.23
Time [UT]
C2
θErr = 5.17°
11.61
0.67
−10.27
22.22
11.29
0.35
26.66
15.72
4.78
B_n [nT]
B_l [nT]
11:02:36.32
11:02:48.42
11:03:00.53
Time [UT]
C3
θErr = 4.94°
13.39
0.69
−12.00
21.64
8.95
−3.75
28.24
15.54
2.84
B_n [nT]
B_l [nT]
11:02:40.42
11:02:52.93
11:03:05.44
Time [UT]
C4
θErr = 4.45°
11.88
−0.89
−13.67
3.04
−9.74
−22.51
27.87
15.10
2.32
B_l [nT]
11:02:39.28
11:02:52.63
11:03:05.99
Time [UT]


C1
θErr = 2.65°
B_l [nT]
11:02:39.35
11:02:50.57
11:03:01.78
Time [UT]
C2
θErr = 4.93°
11:02:32.83
11:02:46.86
11:03:00.89
Time [UT]
C3
θErr = 5.66°
B_n [nT]
11:02:34.62
11:02:50.30
11:03:05.98
Time [UT]
C4
θErr = 5.04°
11:02:36.20
11:02:50.98
11:03:05.77
Time [UT]



C1
θ_{Err} = 2.67°
9.87
−1.34
−12.55
2.56
−8.64
−19.85
28.22
17.01
5.80
B_l [nT]
11:02:34.31
11:02:44.73
11:02:55.14
Time [UT]
C2
θ_{Err} = 5.29°
11.52
0.56
−10.39
22.35
11.39
0.44
26.56
15.60
4.64
B_n [nT]
B_l [nT]
11:02:36.45
11:02:48.24
11:03:00.04
Time [UT]
C3
θ_{Err} = 4.79°
12.67
−0.65
−13.97
2.37
−10.95
−24.27
26.30
12.98
−0.34
B_l [nT]
11:02:37.61
11:02:49.05
11:03:00.49
Time [UT]
C4
θ_{Err} = 4.98°
12.91
−0.51
−13.93
2.19
−11.23
−24.66
26.32
12.89
−0.53
B_l [nT]
11:02:36.47
11:02:49.07
11:03:01.67
Time [UT]


C1
θErr = 2.07°
10.38
-1.33
-13.03
3.40
-8.30
-20.00
28.55
B_l [nT]
16.85
5.14
11:02:30.88
11:02:43.03
11:02:55.18
Time [UT]
C2
θErr = 4.97°
14.52
1.16
-12.20
24.84
B_n [nT]
11.48
-1.88
27.29
B_l [nT]
13.94
0.58
11:02:32.26
11:02:46.46
11:03:00.67
Time [UT]
C3
θErr = 4.83°
13.96
0.59
-12.79
24.38
B_n [nT]
11.01
-2.37
26.27
B_l [nT]
12.90
-0.48
11:02:37.48
11:02:48.92
11:03:00.36
Time [UT]
C4
θErr = 5.30°
13.41
-0.47
-14.35
3.20
-10.68
-24.56
27.32
B_l [nT]
13.44
-0.44
11:02:35.84
11:02:50.45
11:03:05.06
Time [UT]

REFERENCES

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