Detailed evolution and rotation of the active regions NOAA 11101, 11106 from the SDO/HMI data

Elena Benevolenskaya
Pulkovo Astronomical Observatory
Saint Petersburg State University

Differential Rotation and Magnetism across the HR Diagram', Nordita, Stockholm, Sweden, 12April 2013

For our purpose we have analyzed the 720sec cadence of line-of-sight component of the strength of the magnetic field (**LOS**) and images **in continuum (INT)** using magnetic data of the Solar Dynamics Observatory obtained by the Helioseismic and Magnetic Imager (HMI). The HMI observes the full solar disk at 6173 A (Fe I line) with a resolution of 1 arcsec and as a result we have a matrix with values of **LOS** and **INT** for 4096x4096 pixels.

Comparison of line-of-sight magnetograms from the *Helioseismic and Magnetic Imager (**HMI**) onboard the Solar Dynamics Observatory (**SDO**) and the Michelson Doppler Imager (**MDI**) onboard the Solar and Heliospheric Observatory (**SOHO**). The line-of-sight* magnetic signal inferred from the calibrated **MDI** data is greater than that derived from the **HMI** data by a factor of 1.40.

Y. Liu · J.T. Hoeksema · P.H. Scherrer · J. Schou · S. Couvidat · R.I. Bush · T.L. Duvall Jr · K. Hayashi · X. Sun · X. Zhao, 2012

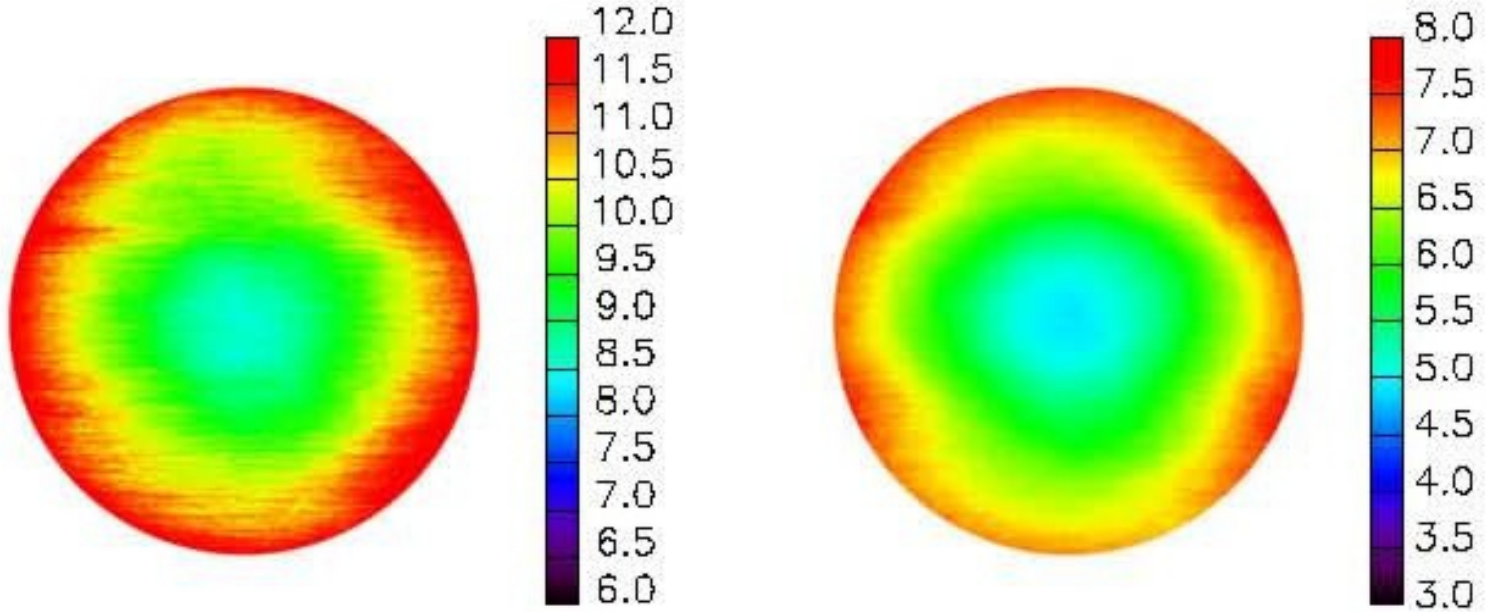

Figure 2 Distribution of noise in the line-of-sight magnetic field over Sun's disk derived from 11 520 HMI 45-second magnetograms at a cadence of 720 seconds taken in June – August 2010 (left), and from 10 800 HMI 720-second magnetograms at a cadence of 720 seconds taken in June – August 2010 (right). The median of the noise is 10.3 Mx cm^{-2} for the 45-second magnetograms, and 6.4 Mx cm^{-2} for the 720-second magnetograms. Note that the color bars are different in order to show comparable detail in the two images.

Y. Liu · J.T. Hoeksema · P.H. Scherrer · J. Schou · S. Couvidat · R.I. Bush · T.L. Duvall Jr · K. Hayashi · X. Sun · X. Zhao, 2012

A simulation with HMI filter transmission profiles and velocity algorithm indicates that, for a disk-center field greater than 3200 G, the uncompensated HMI measurements become saturated every 12 hours when the satellite reaches its maximum radial velocity.

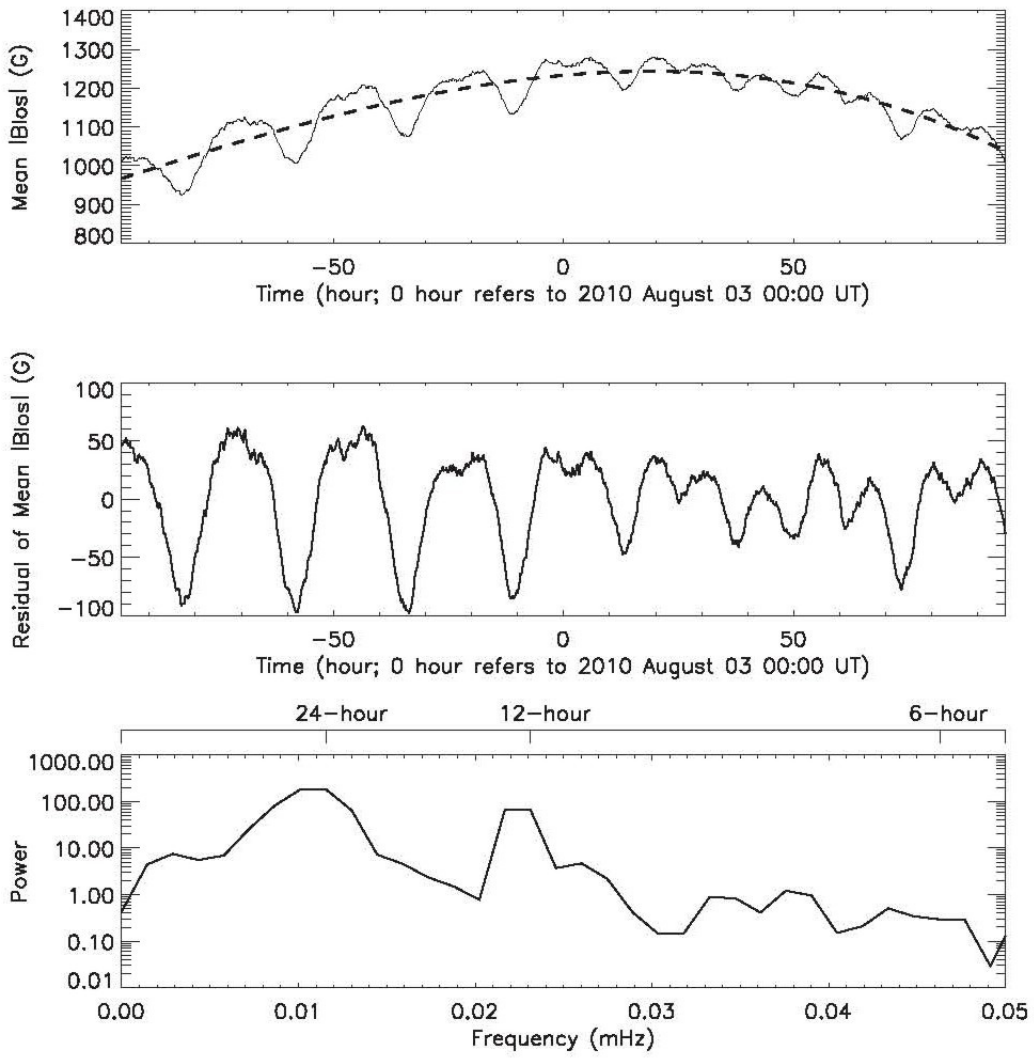

Figure 5 Top panel: The temporal profile of the mean unsigned field of AR11092 (solid line), over– plotted by a third-degree polynomial that fits the data (dashed line). Pixels with unsigned field greater than 600 Mxcm−2 are chosen to compute the mean field in order to examine periodicity in strong field. 600 Mxcm−2 is arbitrarily selected here. **Middle panel:** residual of the mean unsigned field, *i.e. the difference* between the mean unsigned field and the fitted polynomial shown by the dashed line in the top panel. **Bottom panel**: Power spectrum of the residual of the unsigned field (in the middle panel). The observation runs eight days, from 30 July to 6 August. 24-hour and 12-hour periodicities are clearly seen. The variation due to the periodicities is about 2.7 % of the signal on average.

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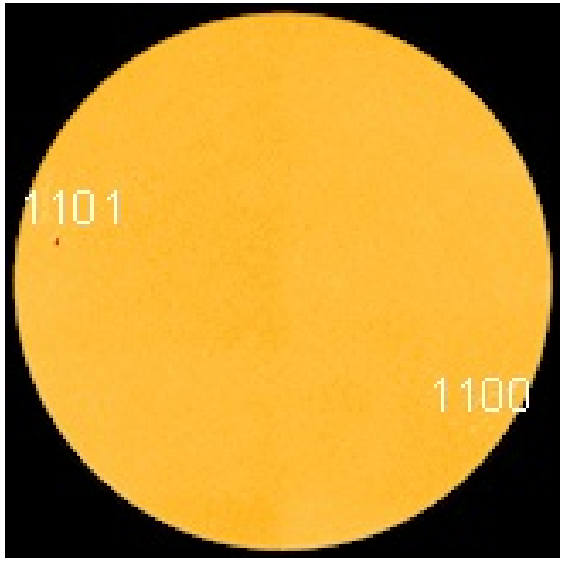


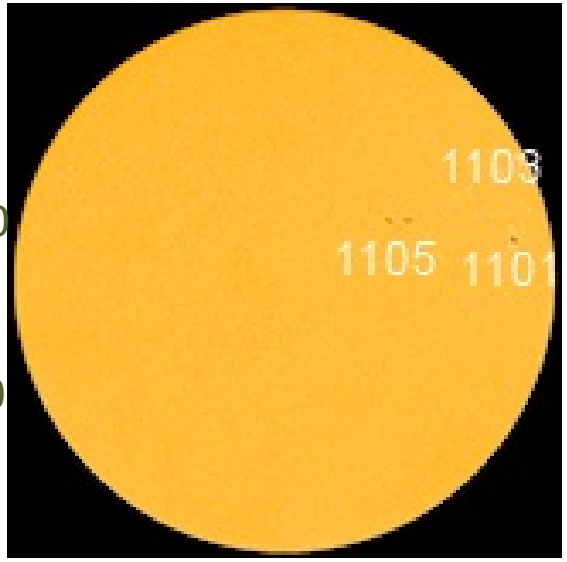
2010 Aug 26

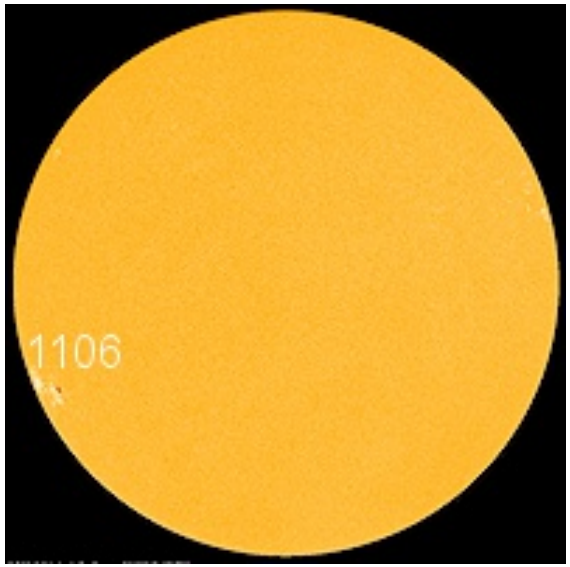
Nmbr Location Lo Area

11101 N12E61 082 0090

2010 Sep 04

1101 N12W57 081 0130





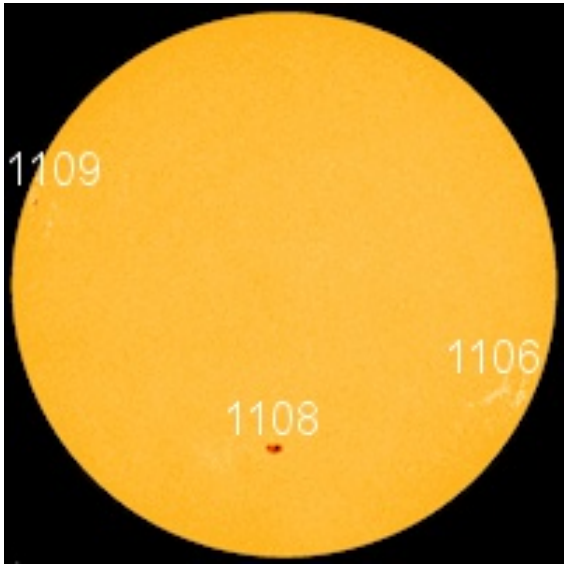
2010 Sep 12

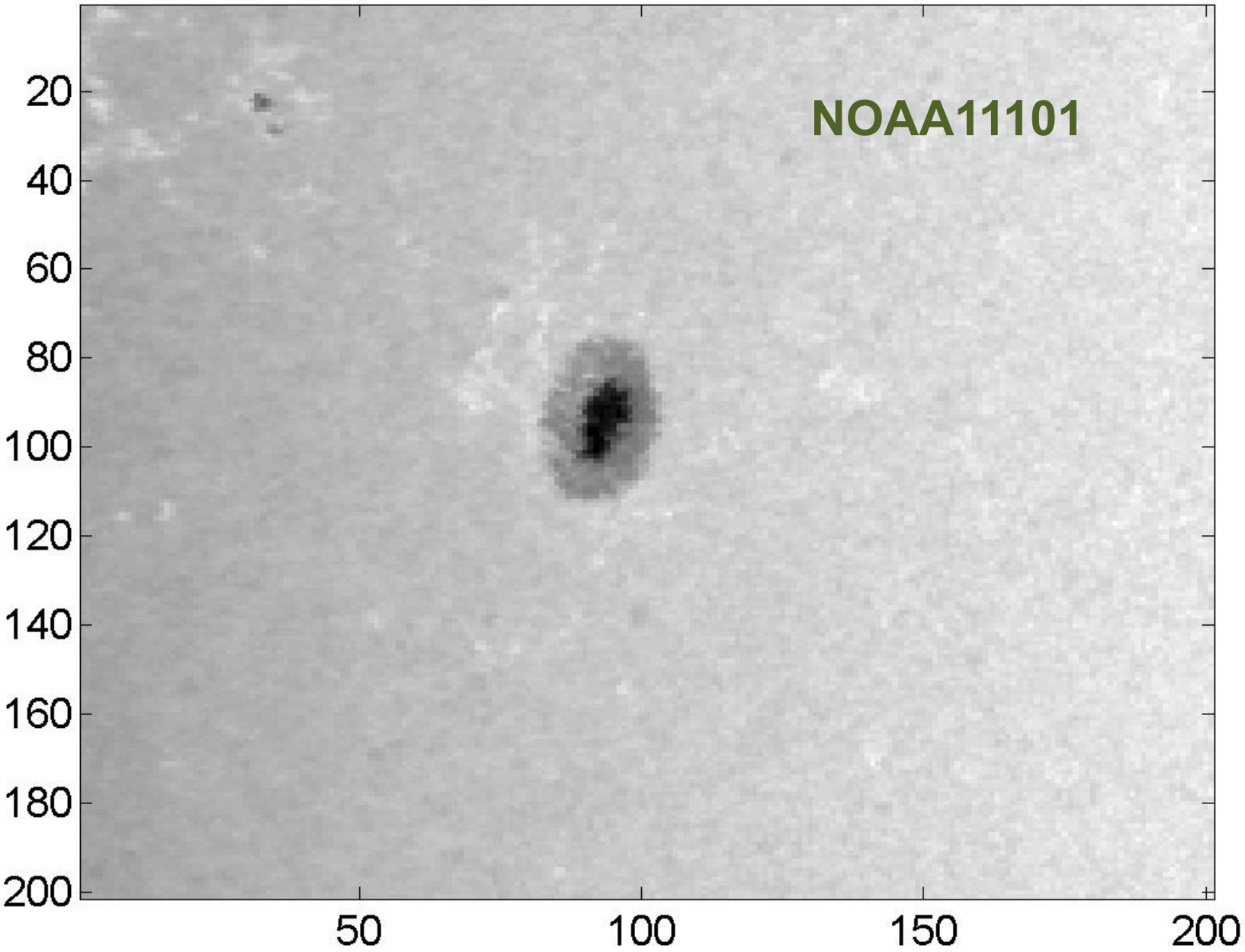
Nmbr Location Lo Area

11106 S18E64 215 0050

2010 Sep 20

1106 S20W34 207 0090

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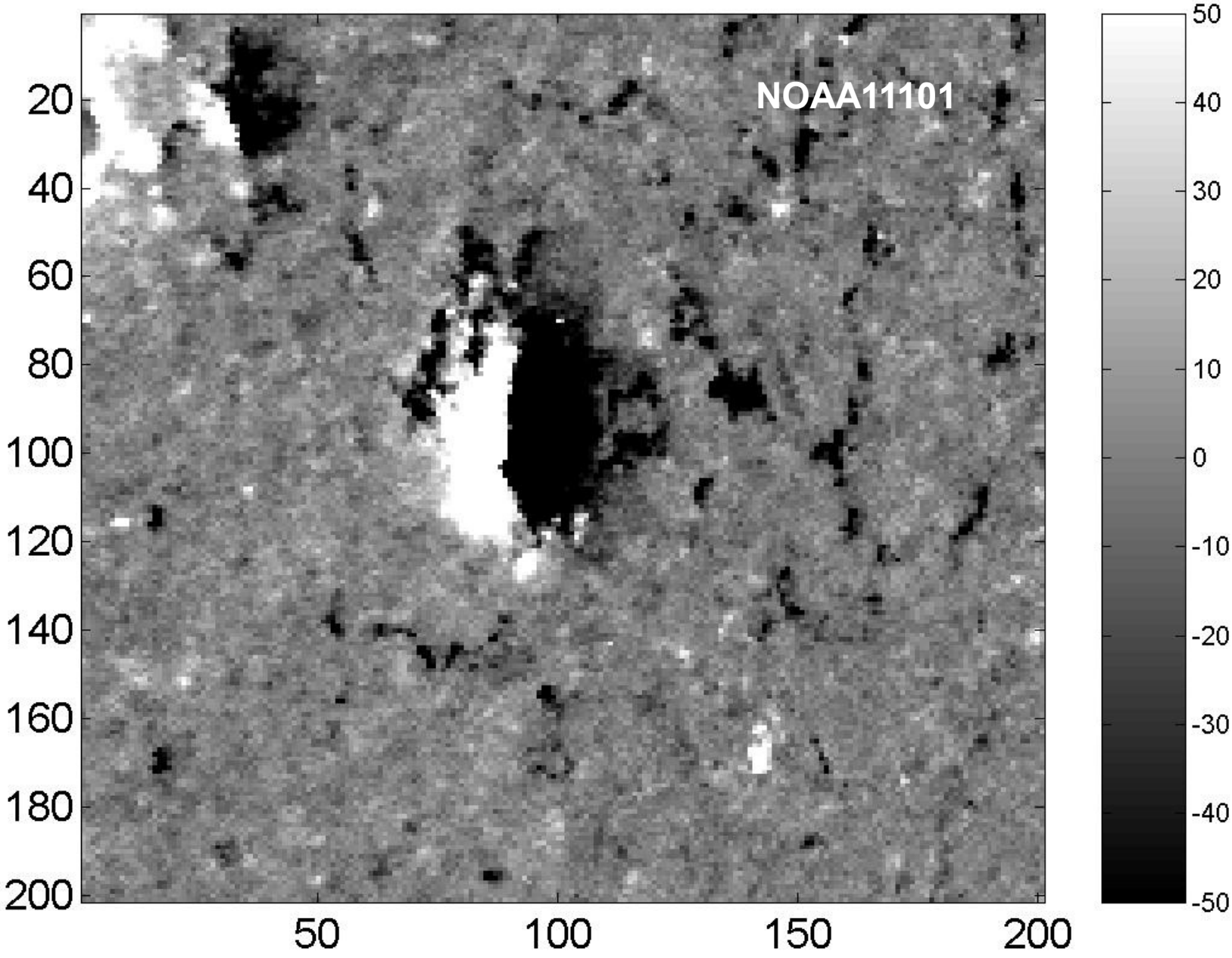
40
60
80
100
120
140
160
180
200
50
100
150
200


NOAA11101
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40
60
80
100
120
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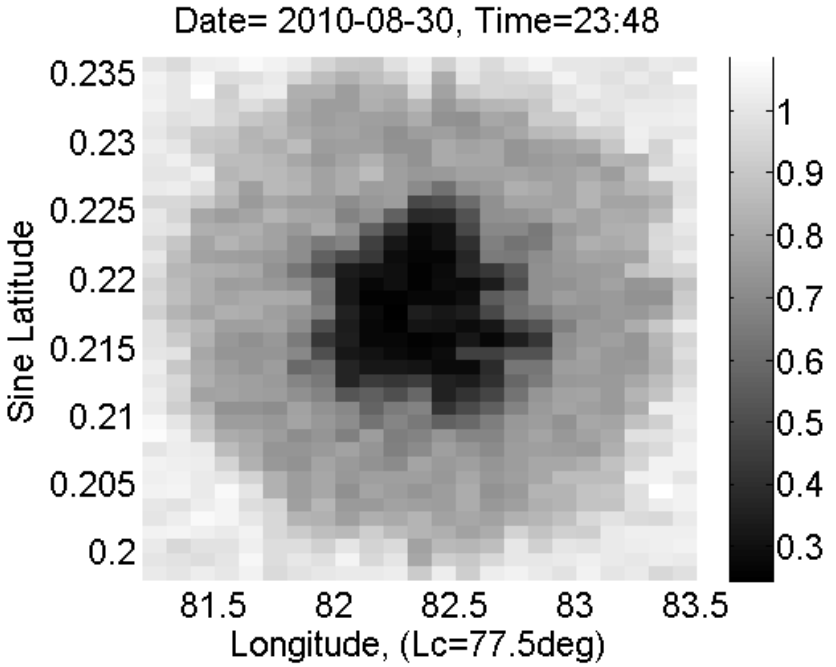
200
50
100
150
200
50
40
30
20
10
0
-10
-20
-30
-40
-50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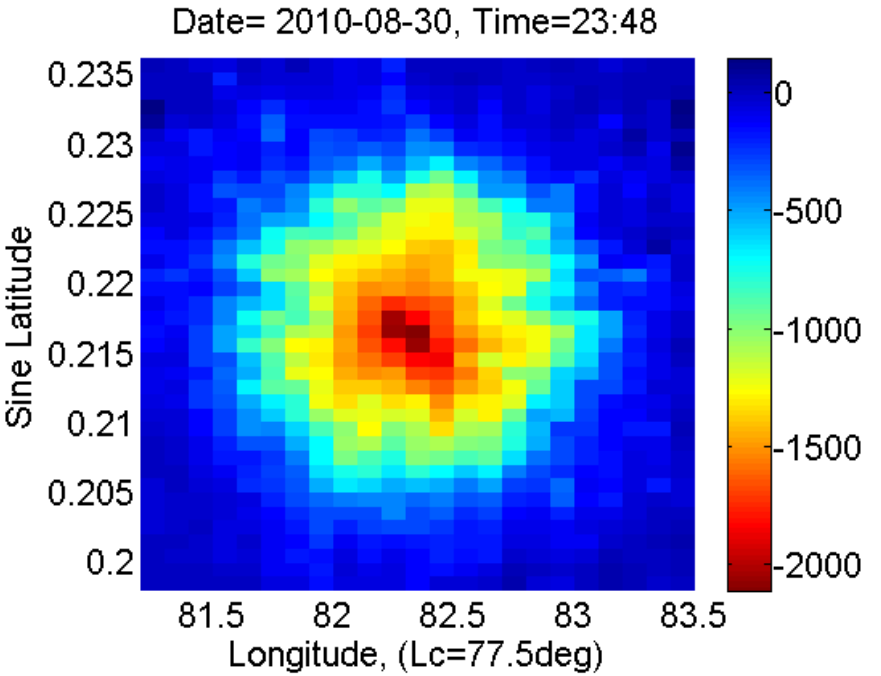
0.23
0.225
0.22
0.215
0.21
0.205
0.2
81.5
82
82.5
83
83.5
Longitude, (Lc=77.5deg)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3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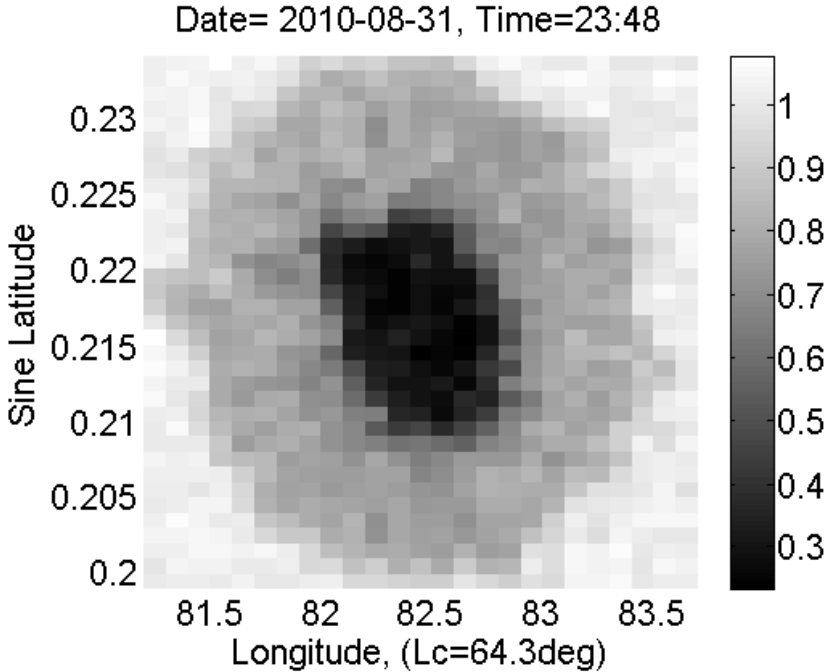
0.225
0.22
0.215
0.21
0.205
0.2
81.5
82
82.5
83
83.5
Longitude, (Lc=77.5deg)
0
-500
-1000
-1500
-2000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0.225
0.22
0.215
0.21
0.205
0.2
81.5
82
82.5
83
83.5
Longitude, (Lc=64.3deg)
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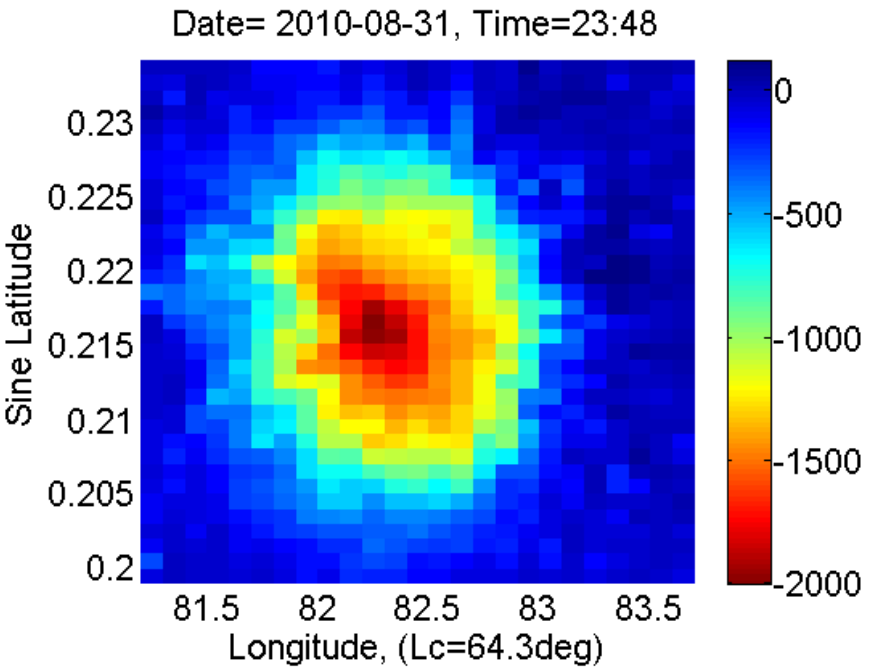
0.9
0.8
0.7
0.6
0.5
0.4
0.3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Sine Latitude
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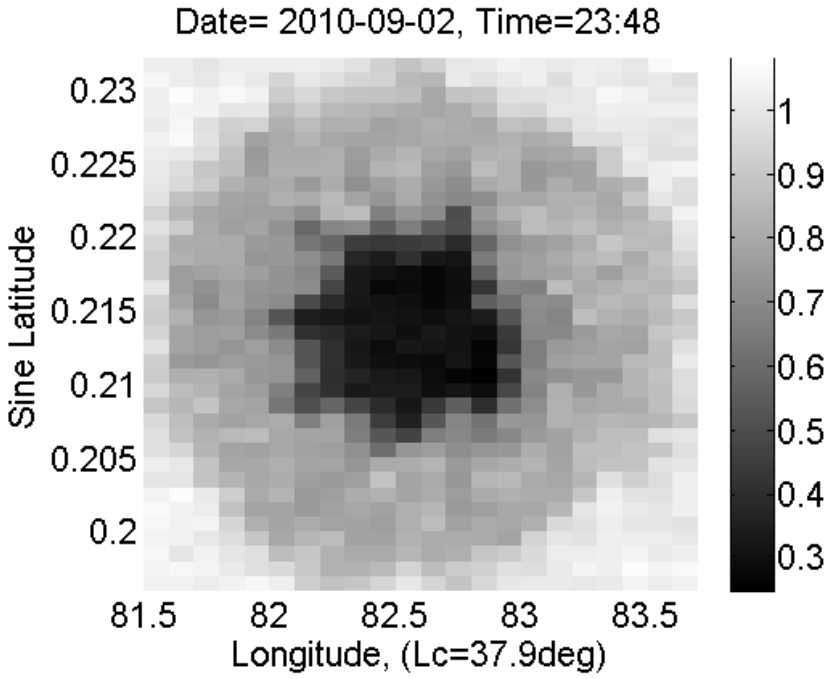
0.22
0.215
0.21
0.205
0.2
81.5
82
82.5
83
83.5
Longitude, (Lc=64.3deg)
0
-500
-1000
-1500
-2000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0.225
0.22
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0.21
0.205
0.2
81.5
82
82.5
83
83.5
Longitude, (Lc=37.9deg)
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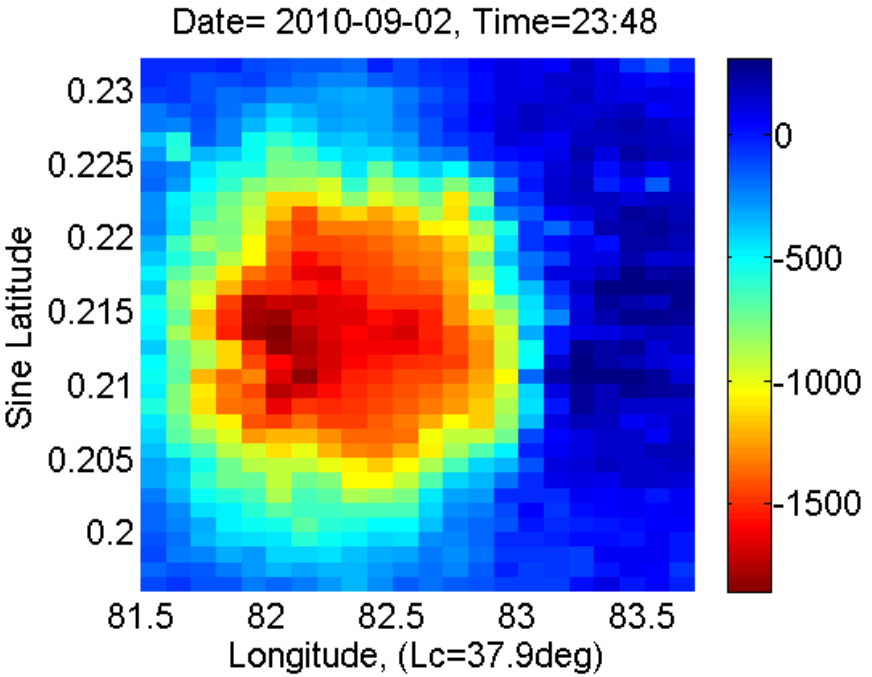
0.9
0.8
0.7
0.6
0.5
0.4
0.3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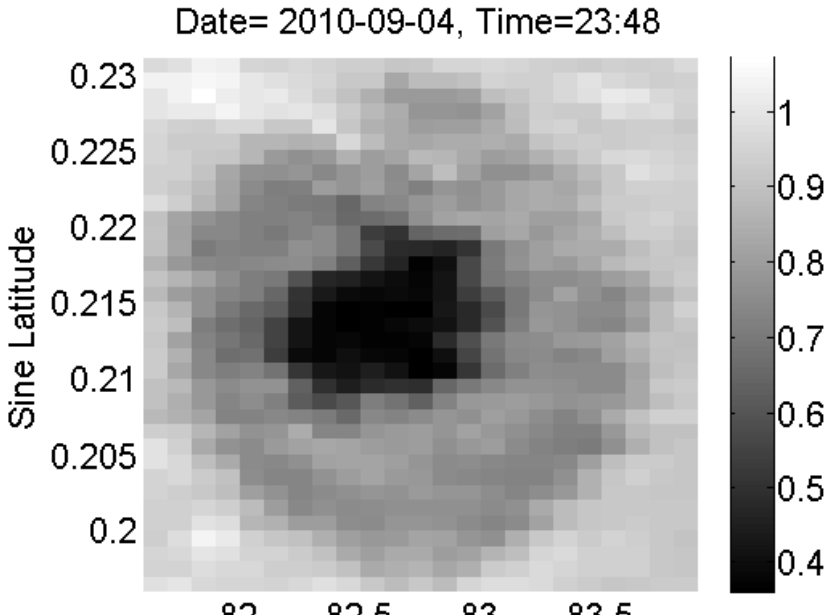
0.22
0.215
0.21
0.205
0.2
81.5
82
82.5
83
83.5
Longitude, (Lc=37.9deg)
0
-500
-1000
-1500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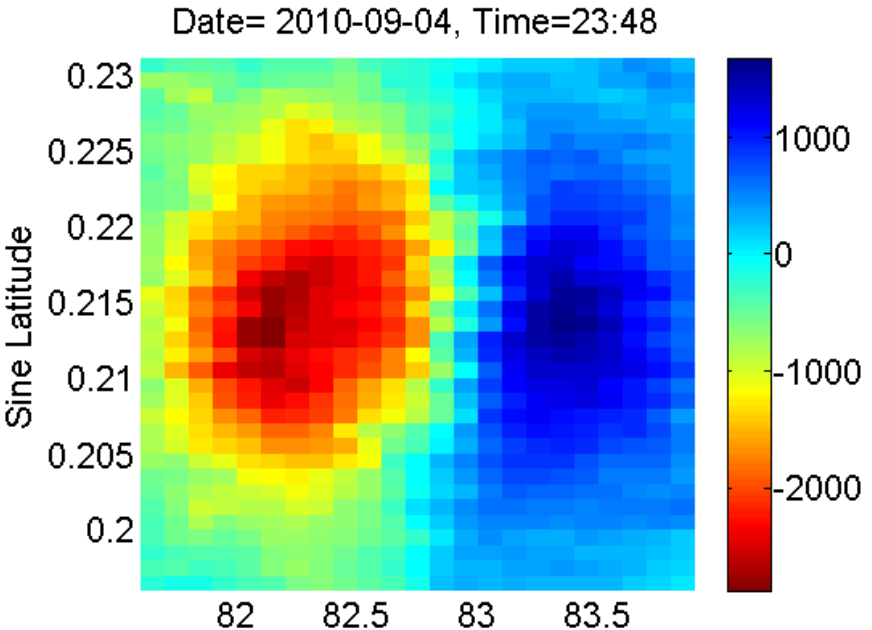
0.22
0.215
0.21
0.205
0.2
1
0.9
0.8
0.7
0.6
0.5
0.4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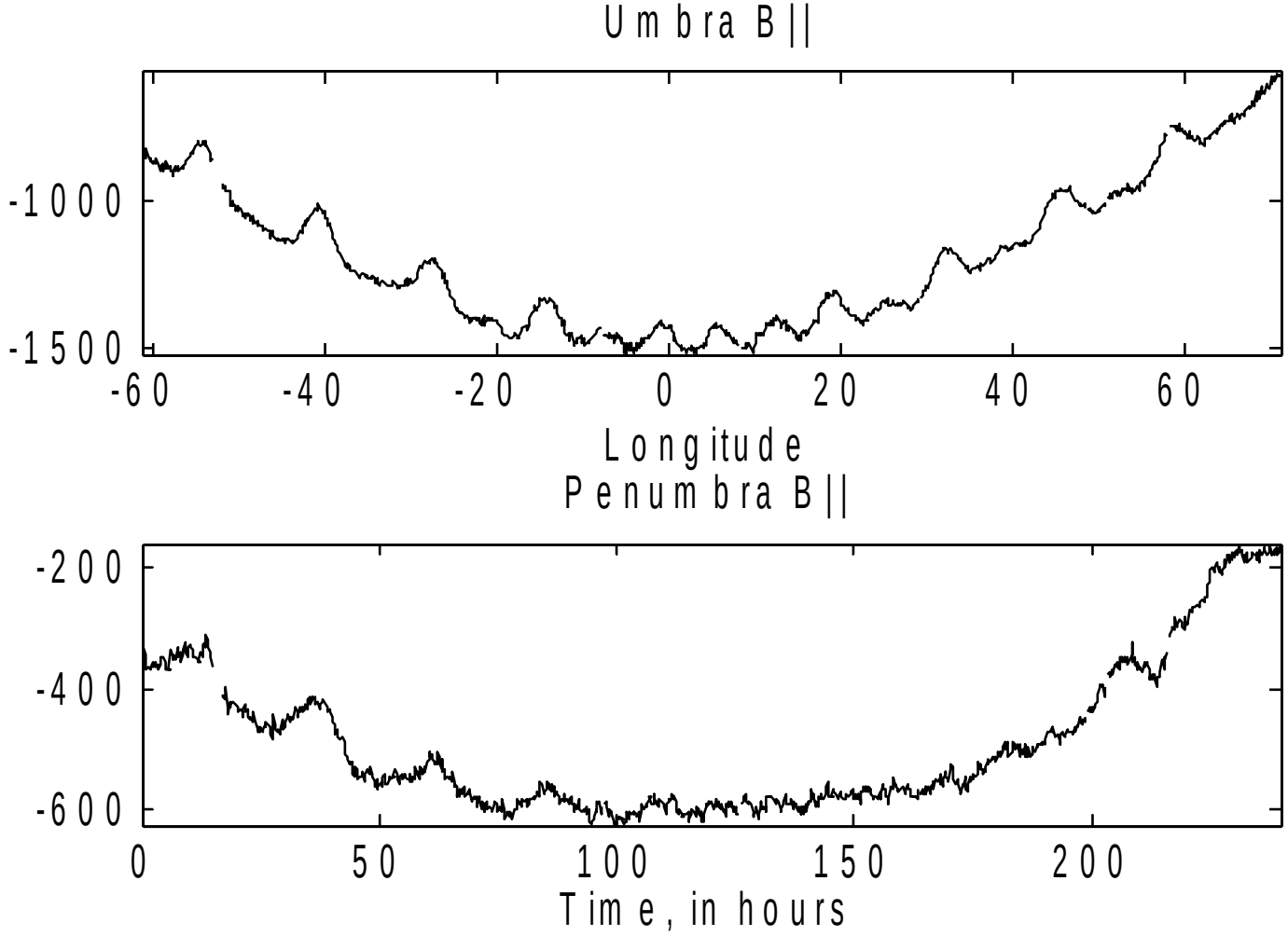
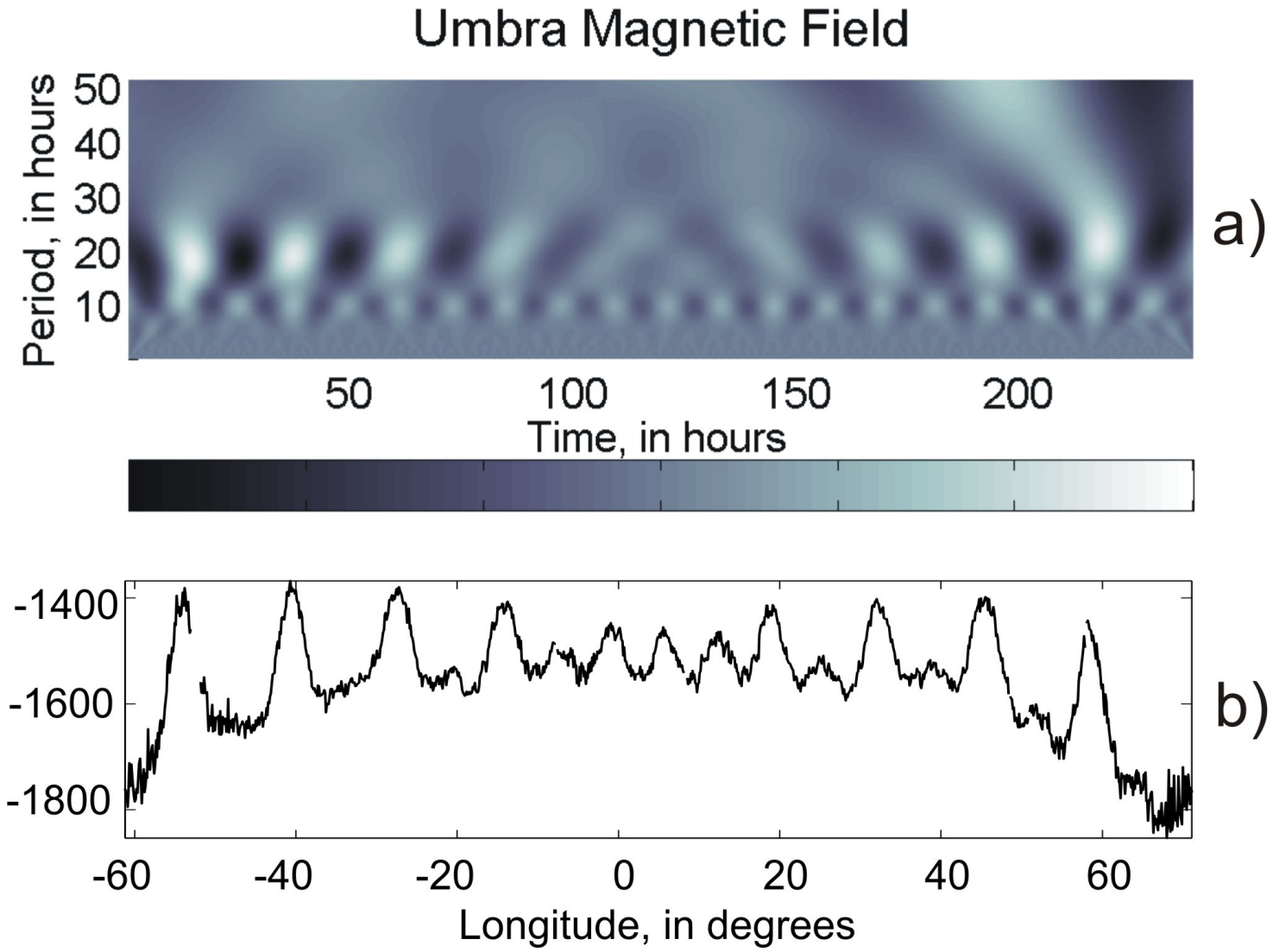
0.225
0.22
0.215
0.21
0.205
0.2
82
82.5
83
83.5
1000
0
-1000
-2000


Umbra B||
-1000
-1500
-60
-40
-20
0
20
40
60
Longitude
Penumbra B||
-200
-400
-600
0
50
100
150
200
Time, in hours

The wavelet transform is usually used to analyze time series that contain non-stationary power at many different frequencies.

Here, the Morlet wavelet with $\omega o = 6$ is applied because of this Morlet wavelet scale is almost equal to Fourier period.


Umbra Magnetic Field
Period, in hours
50
40
30
20
10
50
100
150
200
Time, in hours
a)
-1400
-1600
-1800
-60
-40
-20
0
20
40
60
Longitude, in degrees
b)

Total magnetic flux:

$$F_{total} = {R_\odot}^2 \int_{\varphi 1}^{\varphi 2} \int_{\theta 1}^{\theta 2} |B_r| d\theta d\varphi,$$

Где θ- co-latitude. $B_r \approx B_{||} / \sin\theta$.

Signed magnetic flux:

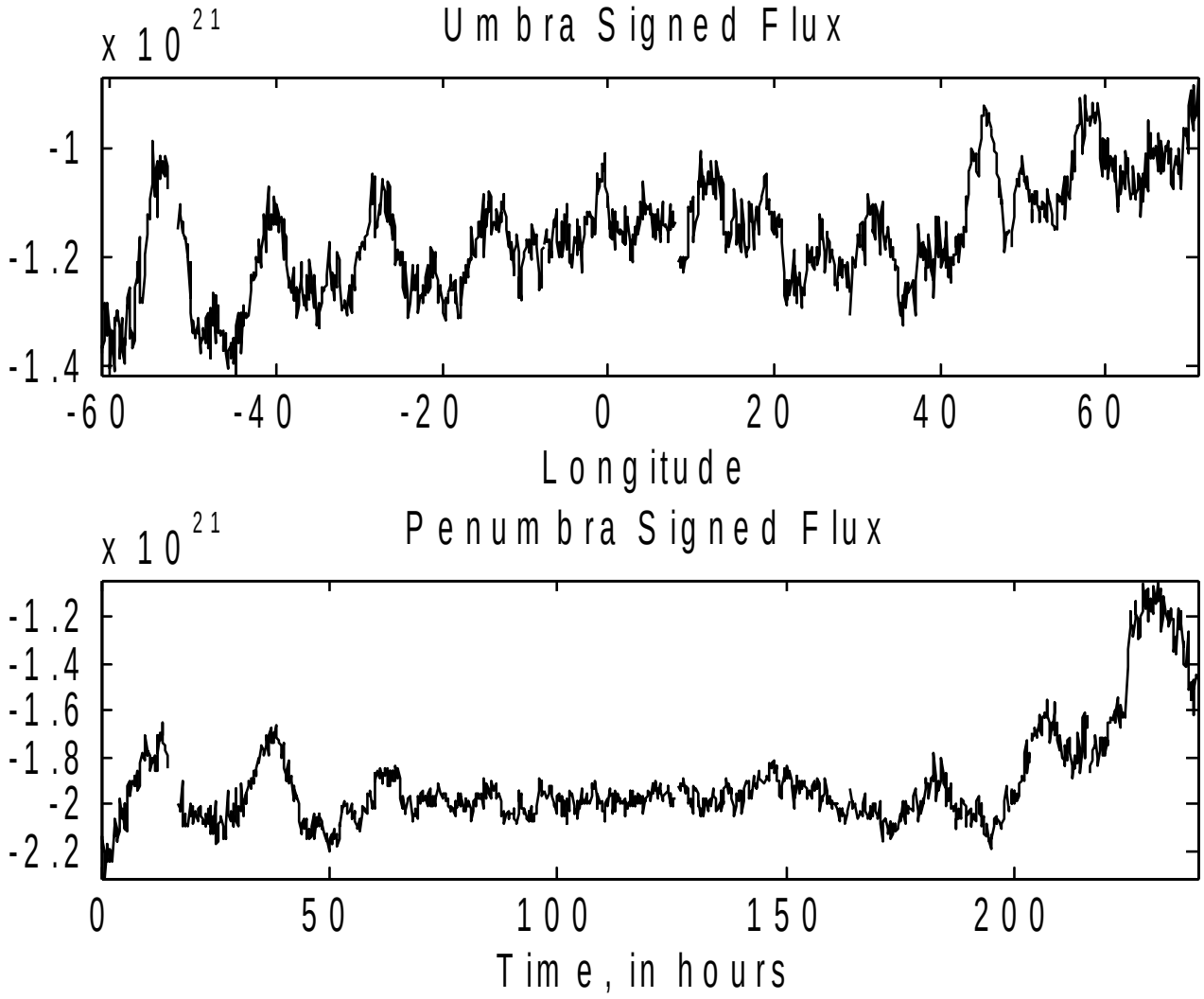
$$F = {R_\odot}^2 \int_{\varphi 1}^{\varphi 2} \int_{\theta 1}^{\theta 2} B_r \sin\theta \, d\theta d\varphi$$

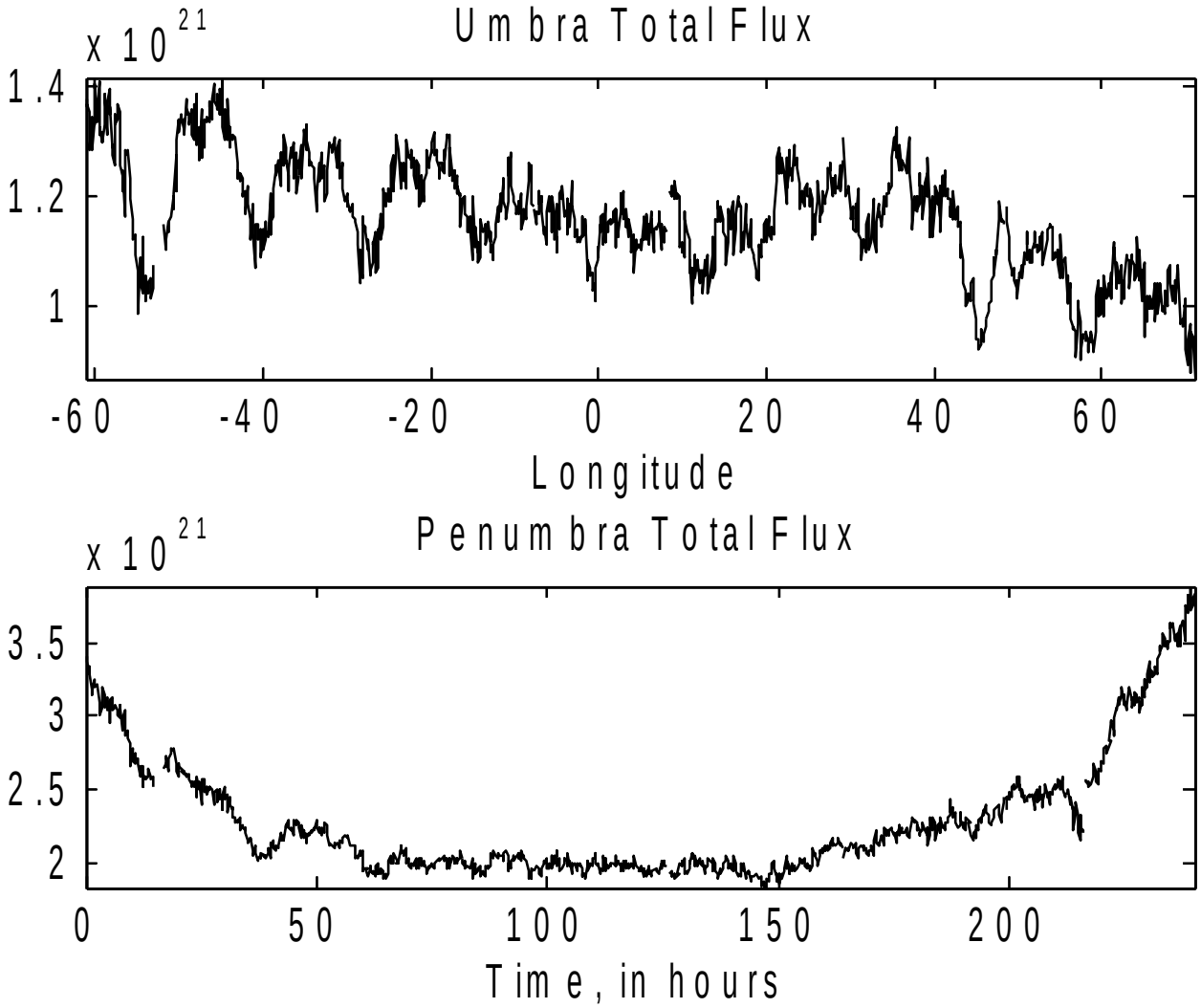
Positive Magnetic flux:

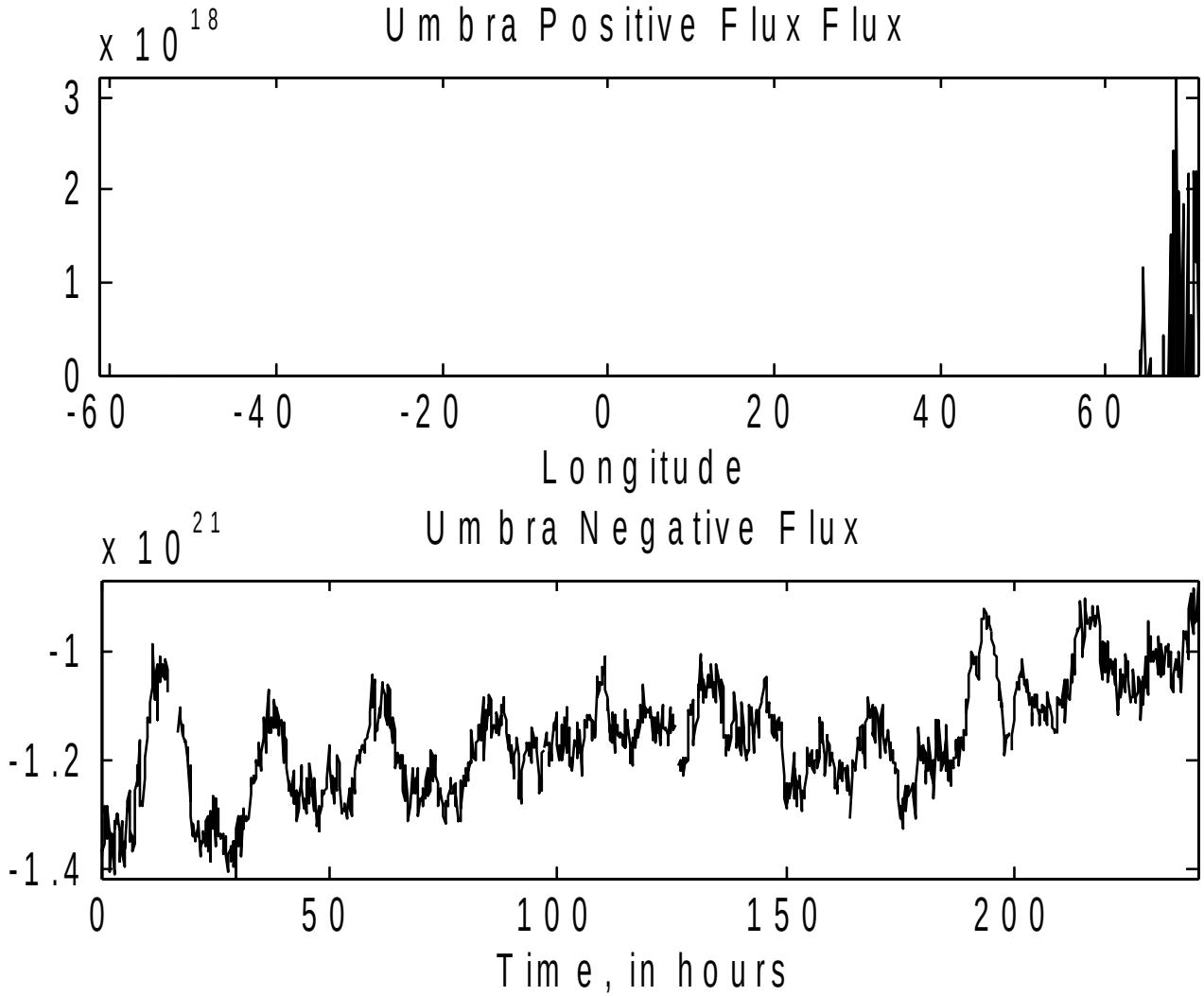
$$F = {R_\odot}^2 \int_{\varphi 1}^{\varphi 2} \int_{\theta 1}^{\theta 2} B_r \sin\theta \, d\theta d\varphi, \qquad B_r > 0$$

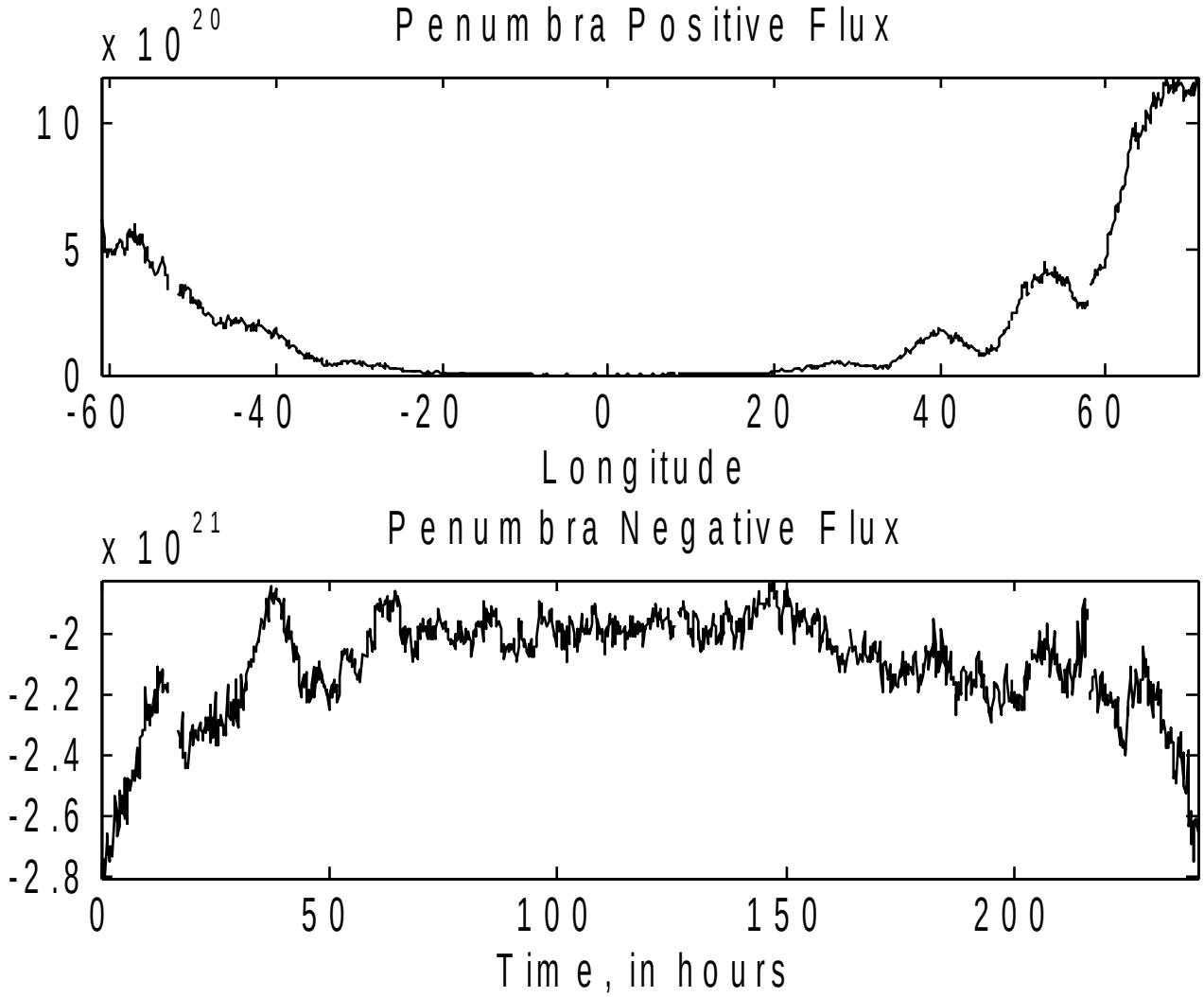
Negative Magnetic Flux:

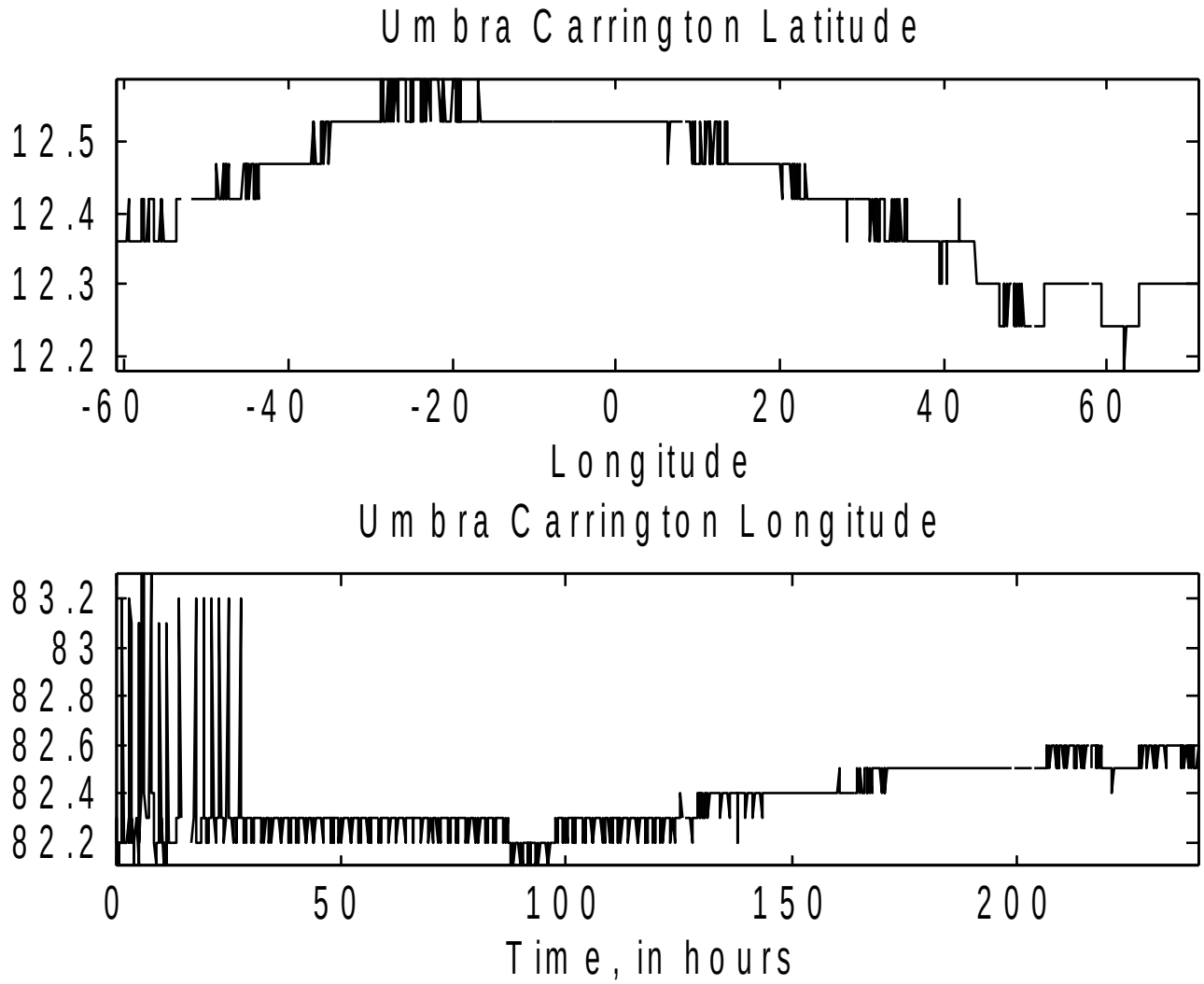
$$F = {R_\odot}^2 \int_{\varphi 1}^{\varphi 2} \int_{\theta 1}^{\theta 2} B_r \sin\theta \, d\theta d\varphi, \qquad B_r < 0$$

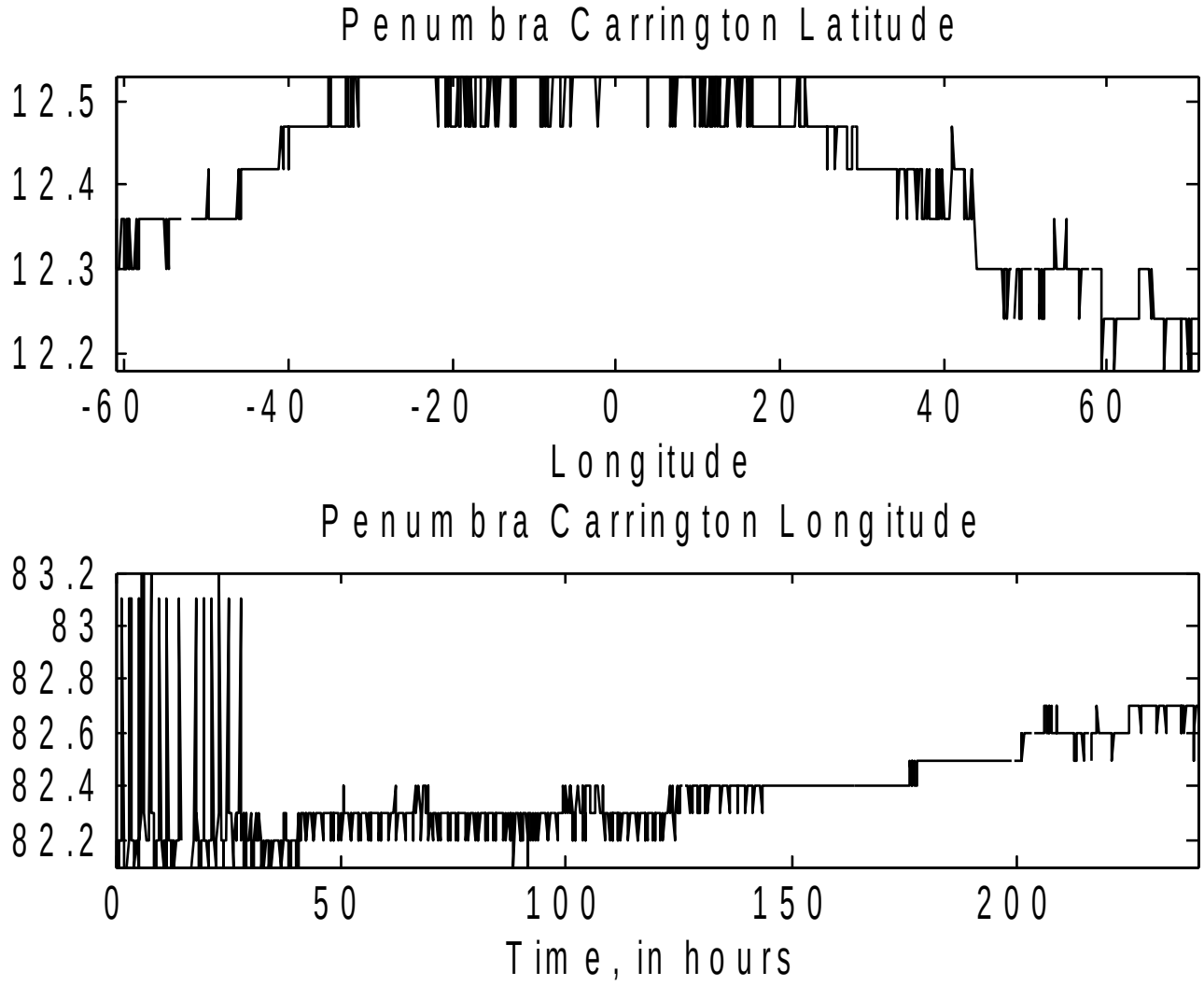

Umbra Signed Flux
x 10^21
-1
-1.2
-1.4
-60
-40
-20
0
20
40
60
Longitude
Penumbra Signed Flux
x 10^21
-1.2
-1.4
-1.6
-1.8
-2
-2.2
0
50
100
150
200
Time, in hours

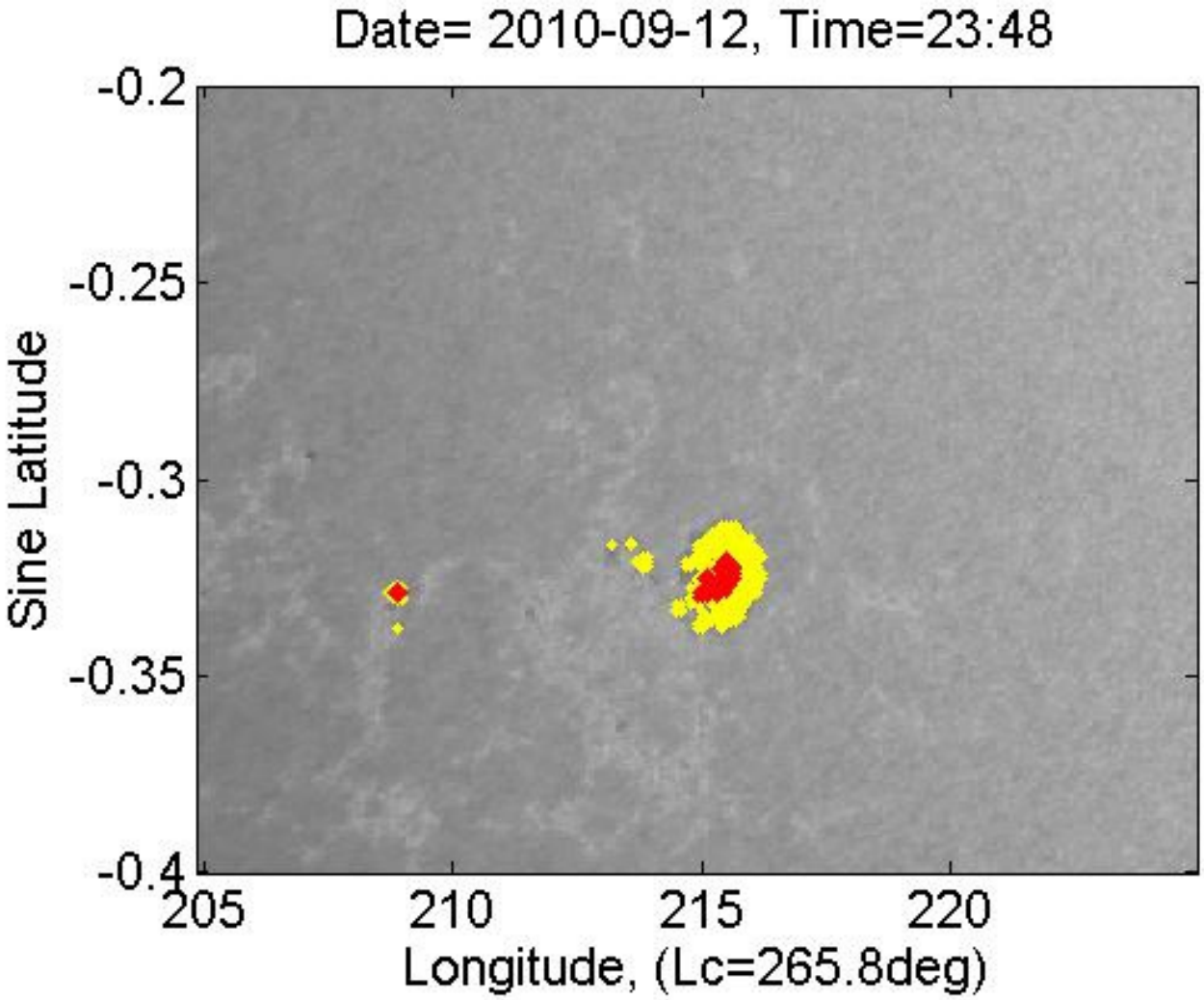

Umbra Total Flux
x 10^21
1.4
1.2
1
-60
-40
-20
0
20
40
60
Longitude
Penumbra Total Flux
x 10^21
3.5
3
2.5
2
0
50
100
150
200
Time, in hours


Umbra Positive Flux Flux
x 10^18
3
2
1
0
-60
-40
-20
0
20
40
60
Longitude
Umbra Negative Flux
x 10^21
-1
-1.2
-1.4
0
50
100
150
200
Time, in hours


Penumbra Positive Flux
x 10^20
10
5
0
-60
-40
-20
0
20
40
60
Longitude
Penumbra Negative Flux
x 10^21
-2
-2.2
-2.4
-2.6
-2.8
0
50
100
150
200
Time, in hours


Umbra Carrington Latitude
12.5
12.4
12.3
12.2
-60
-40
-20
0
20
40
60
Longitude
Umbra Carrington Longitude
83.2
83
82.8
82.6
82.4
82.2
0
50
100
150
200
Time, in hours


Penumbra Carrington Latitude
12.5
12.4
12.3
12.2
-60
-40
-20
0
20
40
60
Longitude
Penumbra Carrington Longitude
83.2
83
82.8
82.6
82.4
82.2
0
50
100
150
200
Time, in hours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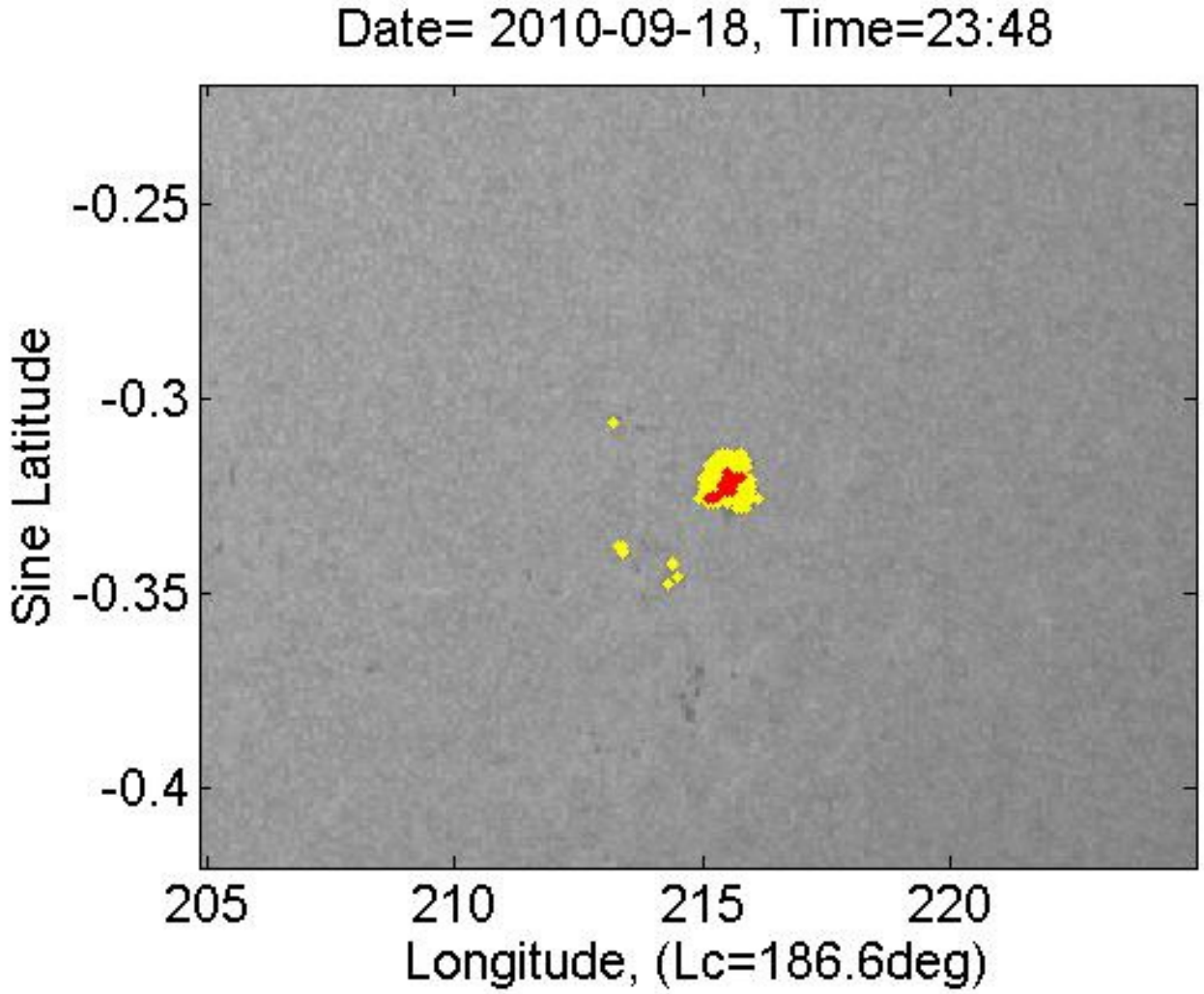
-0.2
-0.25
-0.3
-0.35
-0.4
Sine Latitude
205
210
215
220
Longitude, (Lc=265.8deg)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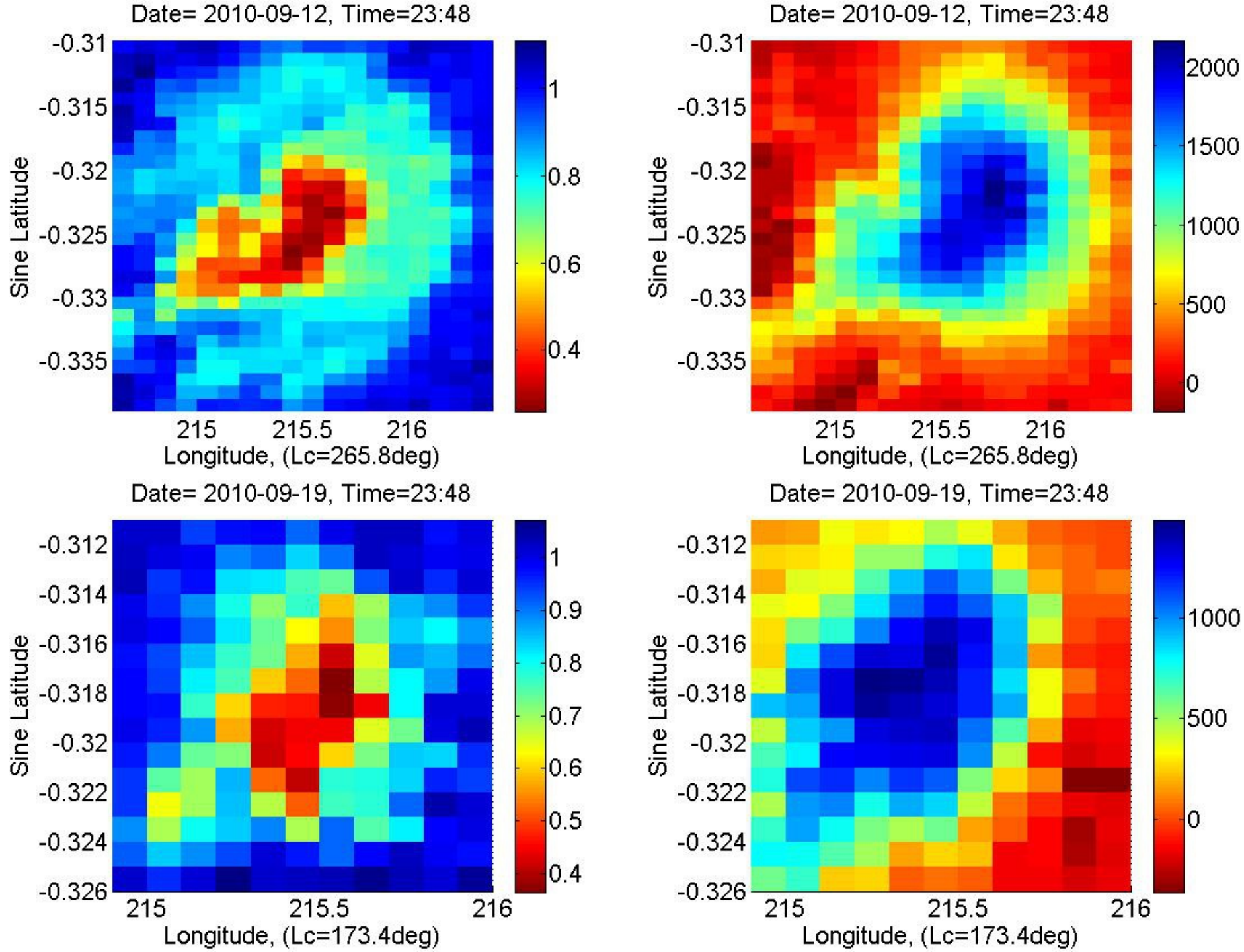
Sine Latitude
205
210
215
220
Longitude, (Lc=186.6deg)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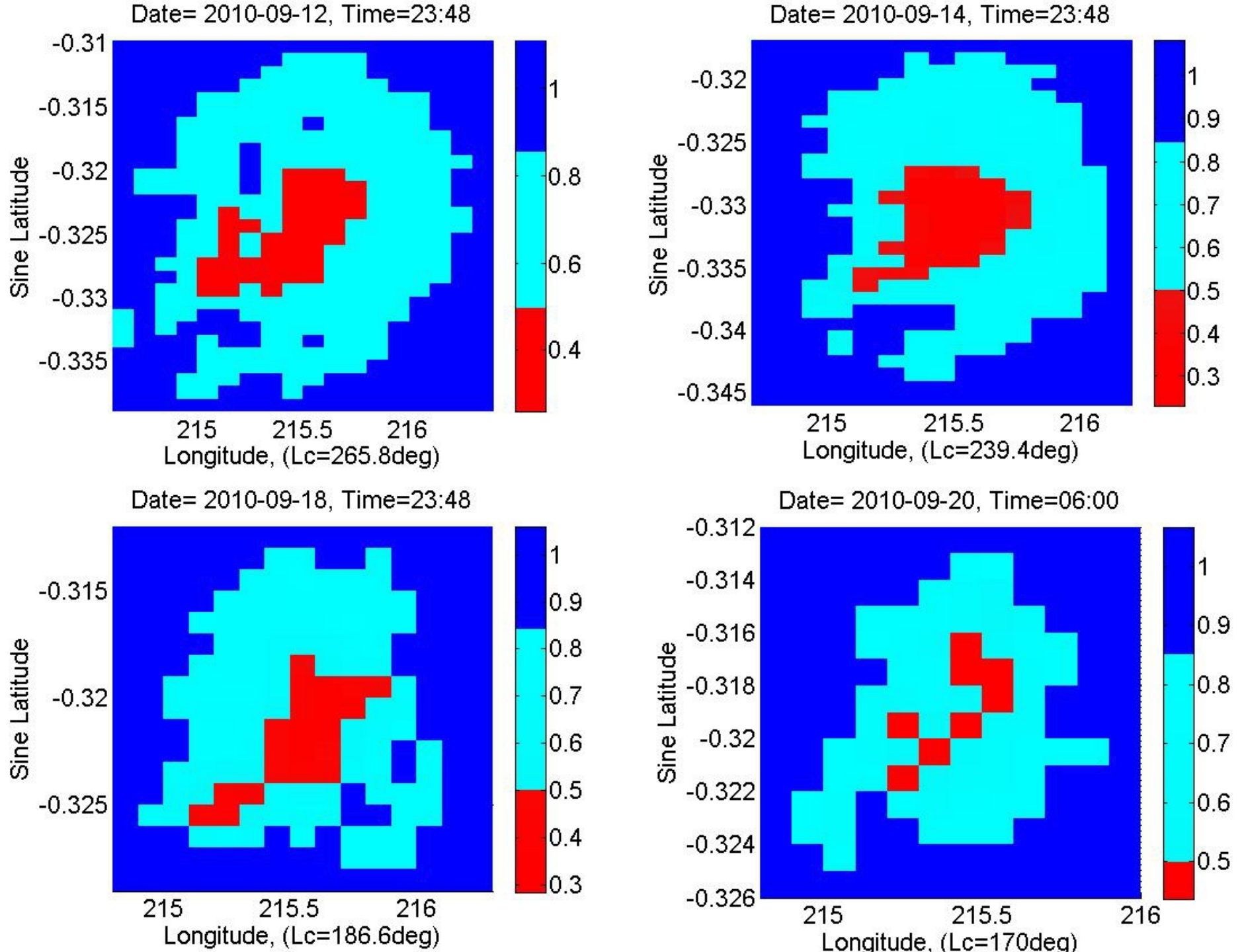
-0.31
-0.315
-0.32
-0.325
-0.33
-0.335
215
215.5
216
Longitude, (Lc=265.8deg)
1
0.8
0.6
0.4
Date= 2010-09-12, Time=23:48
Sine Latitude
-0.31
-0.315
-0.32
-0.325
-0.33
-0.335
215
215.5
216
Longitude, (Lc=265.8deg)
2000
1500
1000
500
0
Date= 2010-09-19, Time=23:48
Sine Latitude
-0.312
-0.314
-0.316
-0.318
-0.32
-0.322
-0.324
-0.326
215
215.5
216
Longitude, (Lc=173.4deg)
1
0.9
0.8
0.7
0.6
0.5
0.4
Date= 2010-09-19, Time=23:48
Sine Latitude
-0.312
-0.314
-0.316
-0.318
-0.32
-0.322
-0.324
-0.326
215
215.5
216
Longitude, (Lc=173.4deg)
1000
500
0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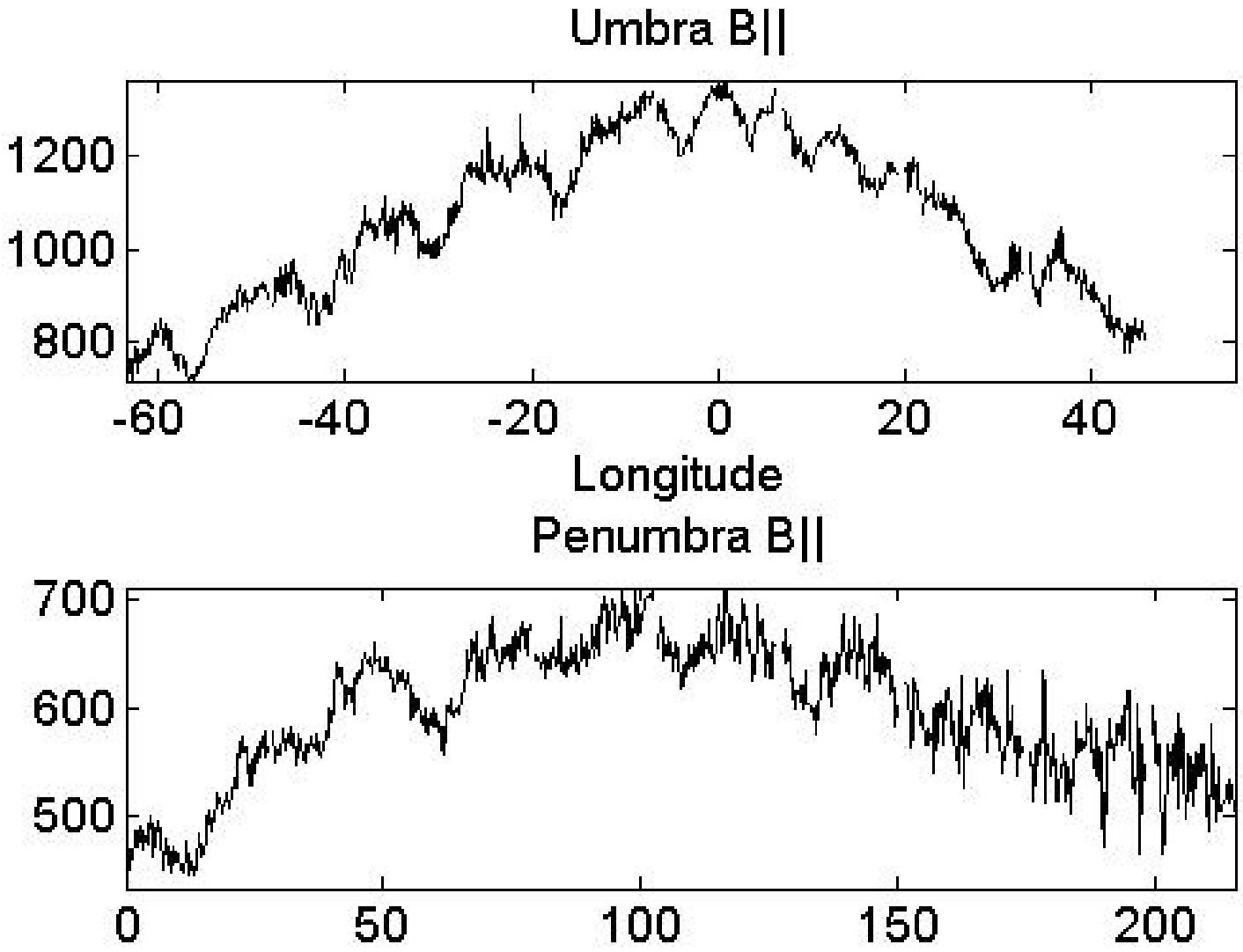
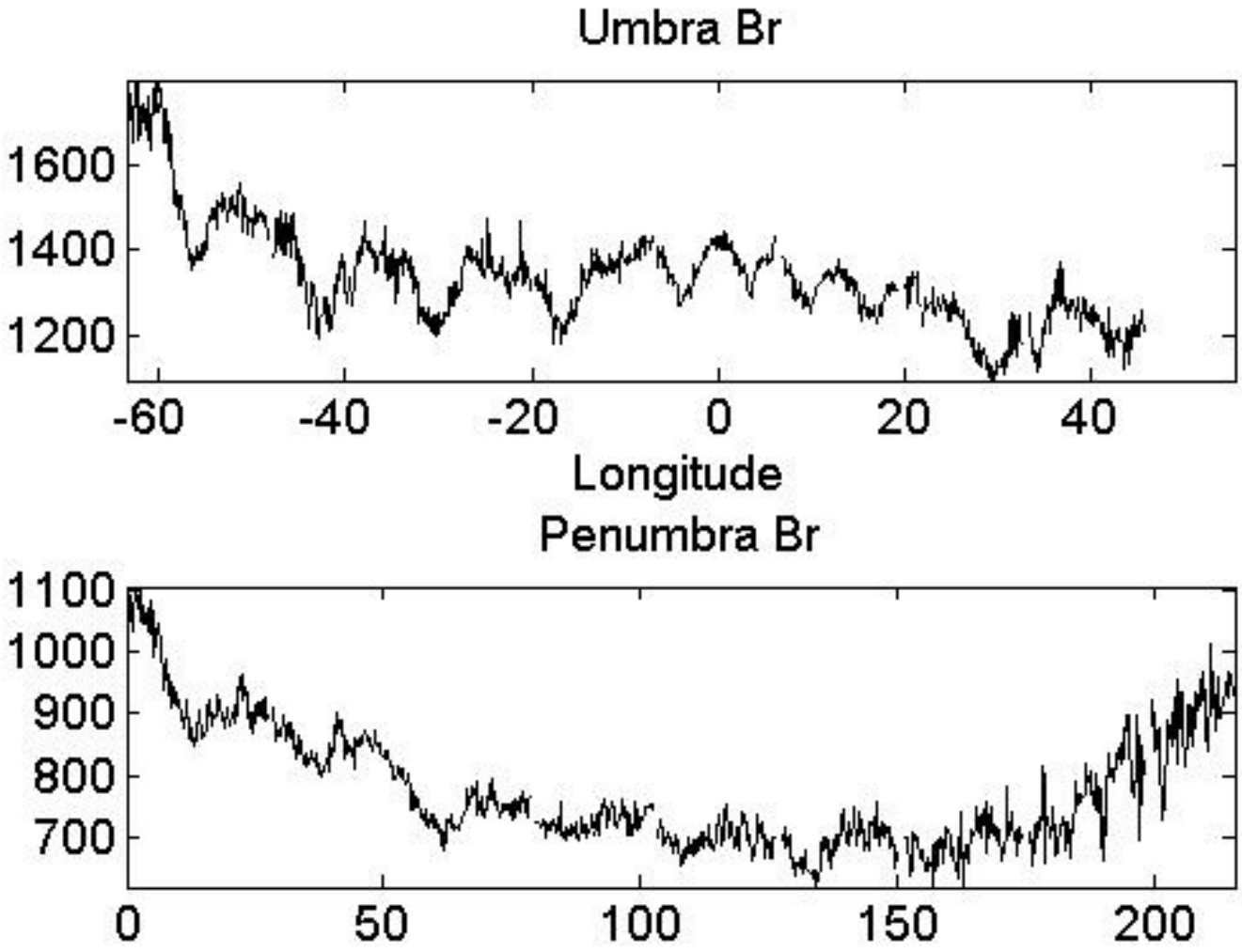
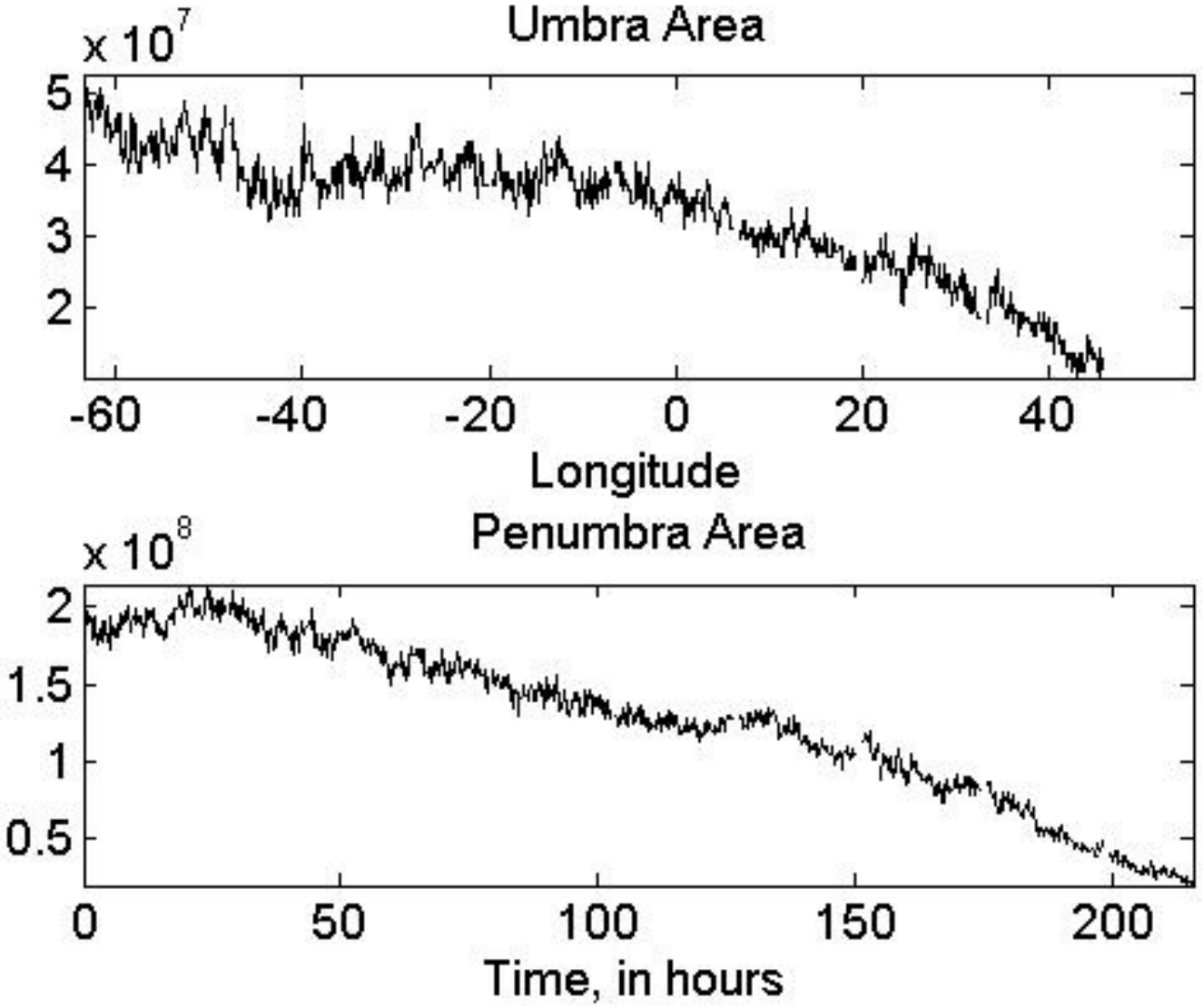
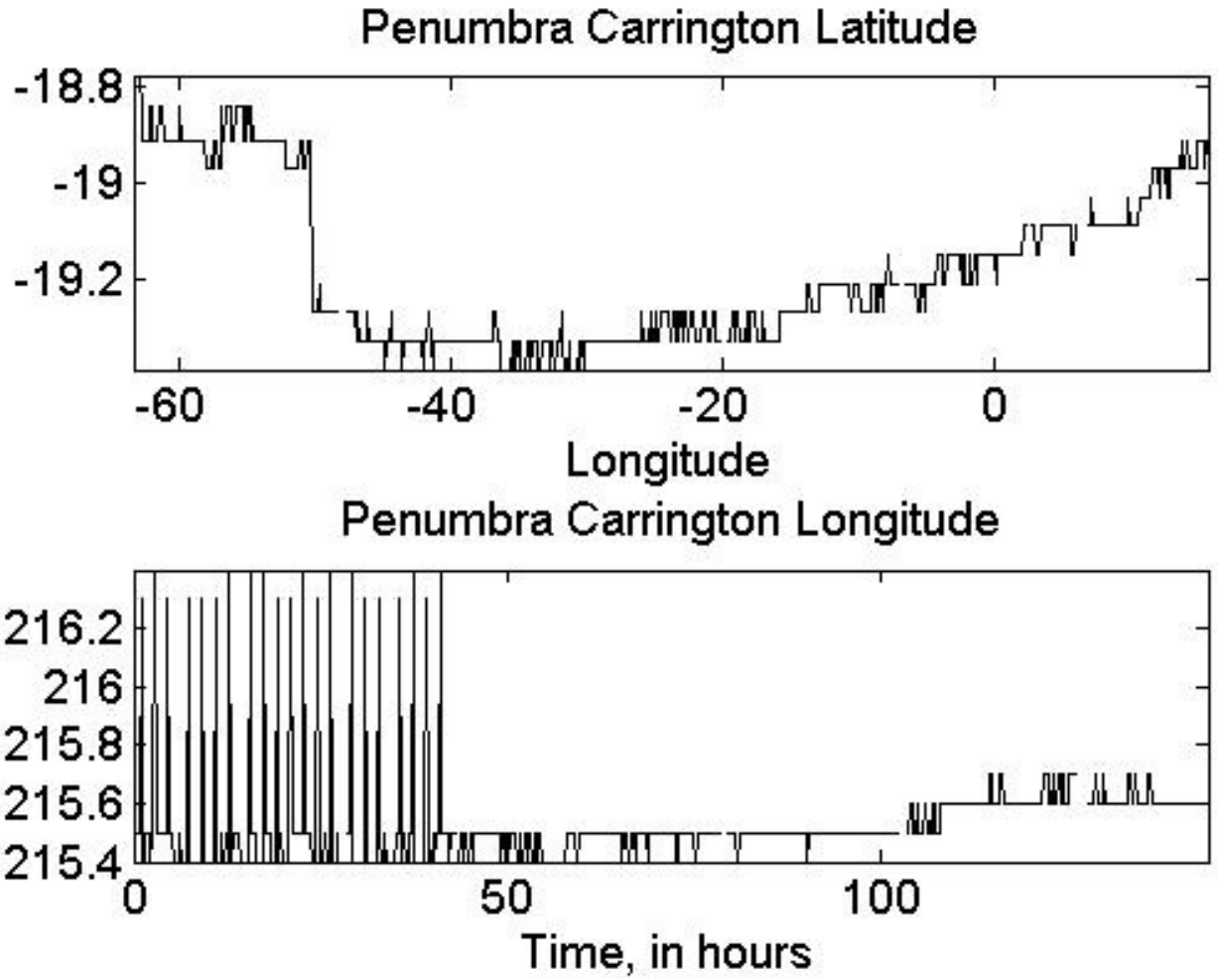
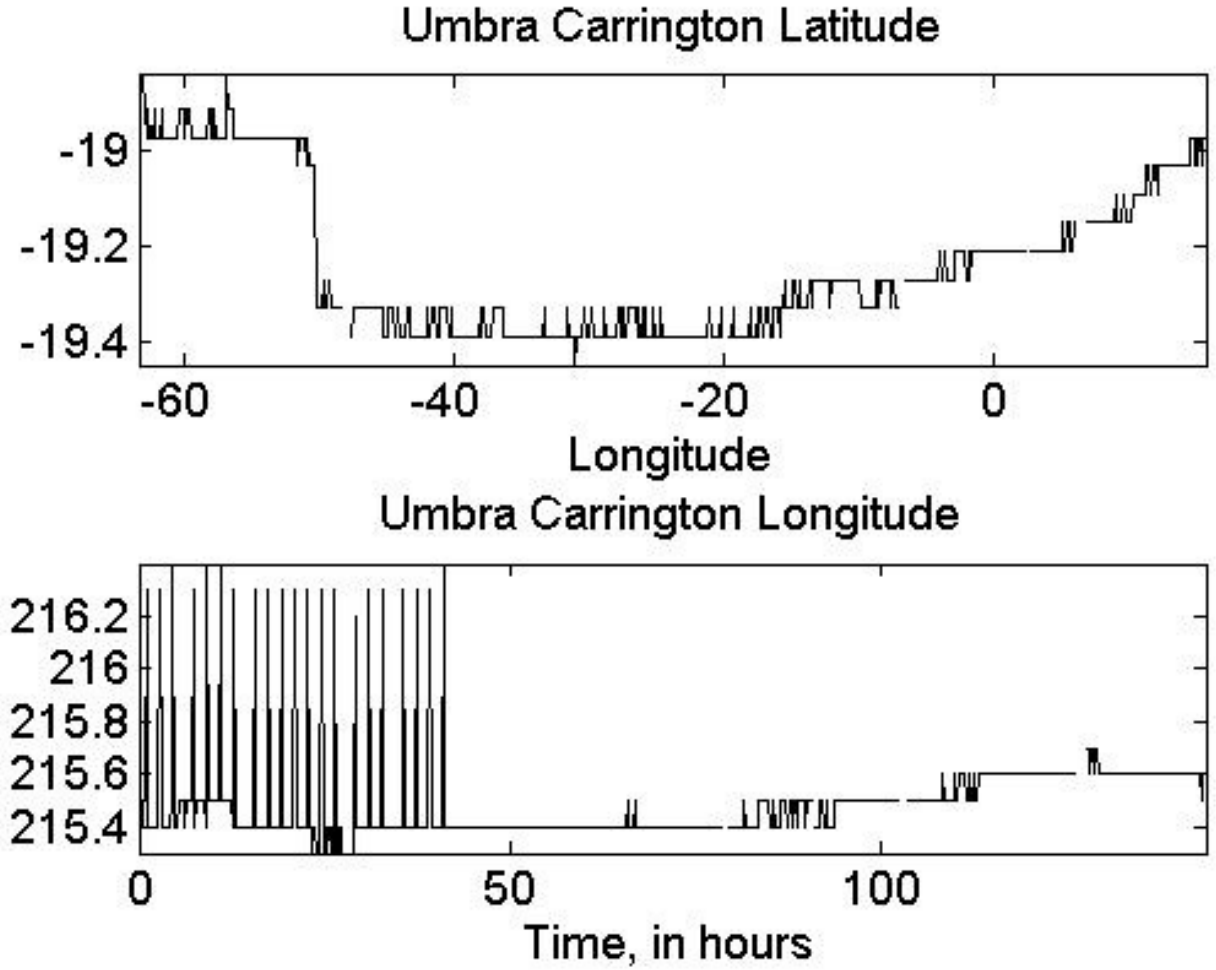
Sine Latitude
-0.31
-0.315
-0.32
-0.325
-0.33
-0.335
215
215.5
216
Longitude, (Lc=265.8deg)
1
0.8
0.6
0.4
Date= 2010-09-14, Time=23:48
Sine Latitude
-0.32
-0.325
-0.33
-0.335
-0.34
-0.345
215
215.5
216
Longitude, (Lc=239.4deg)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
Date= 2010-09-18, Time=23:48
Sine Latitude
-0.315
-0.32
-0.325
215
215.5
216
Longitude, (Lc=186.6deg)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
Date= 2010-09-20, Time=06:00
Sine Latitude
-0.312
-0.314
-0.316
-0.318
-0.32
-0.322
-0.324
-0.326
215
215.5
216
Longitude, (Lc=170deg)
1
0.9
0.8
0.7
0.6
0.5


Umbra B||
1200
1000
800
-60
-40
-20
0
20
40
Longitude
Penumbra B||
700
600
500
0
50
100
150
200


Umbra Br
1600
1400
1200
-60
-40
-20
0
20
40
Longitude
Penumbra Br
1100
1000
900
800
700
0
50
100
150
200


Umbra Area
x 10^7
5
4
3
2
-60
-40
-20
0
20
40
Longitude
Penumbra Area
x 10^8
2
1.5
1
0.5
0
50
100
150
200
Time, in hours


Penumbra Carrington Latitude
-18.8
-19
-19.2
-60
-40
-20
0
Longitude
Penumbra Carrington Longitude
216.2
216
215.8
215.6
215.4
0
50
100
Time, in hours


Umbra Carrington Latitude
-19
-19.2
-19.4
-60
-40
-20
0
Longitude
Umbra Carrington Longitude
216.2
216
215.8
215.6
215.4
0
50
100
Time, in hours

Questions

- The oscillations in the east of the solar disk visible in variations of the longitude of the center of mass (umbra and penumbra).

  Is it an instrumental effect?

- Is it some kind of sunspot oscillations?
- Or the result of the interaction between the rotation and a sunspot flux tube?
- ???