Ground observation of electromagnetic emissions related to clusters of earthquakes

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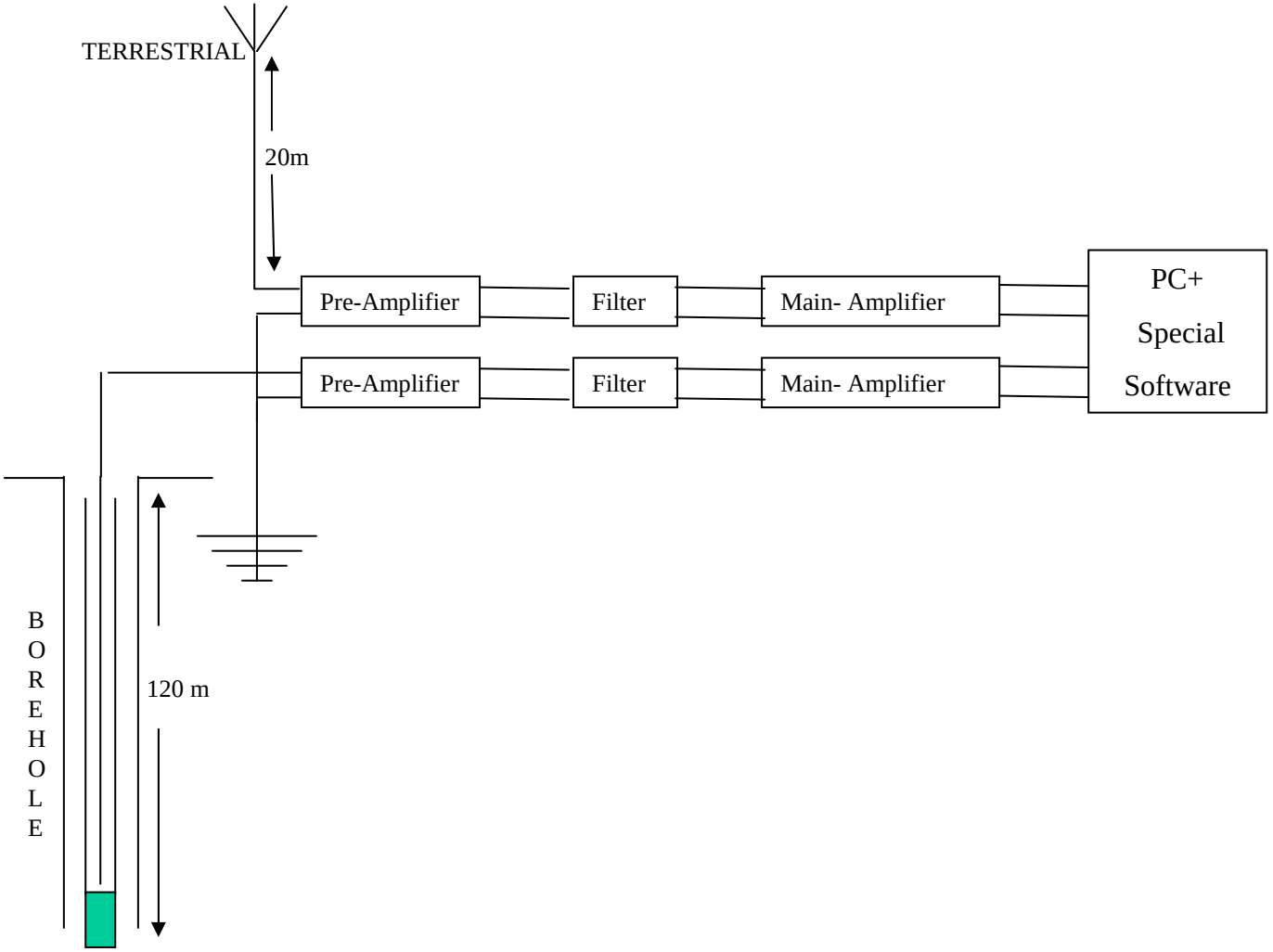
ULF-VLF data obtained from three ground based experiments working at Agra station (geograph. Lat. 27.2^0N, Long. 78^0E) in India namely measurement of ultra low frequency (ULF) magnetic field emissions using a 3-component search coil magnetometer, vertical component of very low frequency (VLF) electric field emissions with a borehole antenna, and phase and amplitude of fixed frequency VLF transmitter signals using AbsPAL receiver are analysed in search of possible precursors of two major seismic activities that occurred in Sumatra (Indonesia) during post-tsunami period between January and April, 2005. These two major seismic events occurred as clusters of earthquakes during 27-29 January and 28-30 March, 2005. The results show that barring borehole all the experiments showed precursors due to these clusters of earthquakes. Such precursors were not seen in the case of isolated large magnitude earthquakes. Further, the precursory duration was influenced by the magnetic storm which occurred about a week before the clusters. The mechanism of ULF propagation to long distances between Sumatra and Agra, and perturbations in the ionosphere before the clusters are discussed.

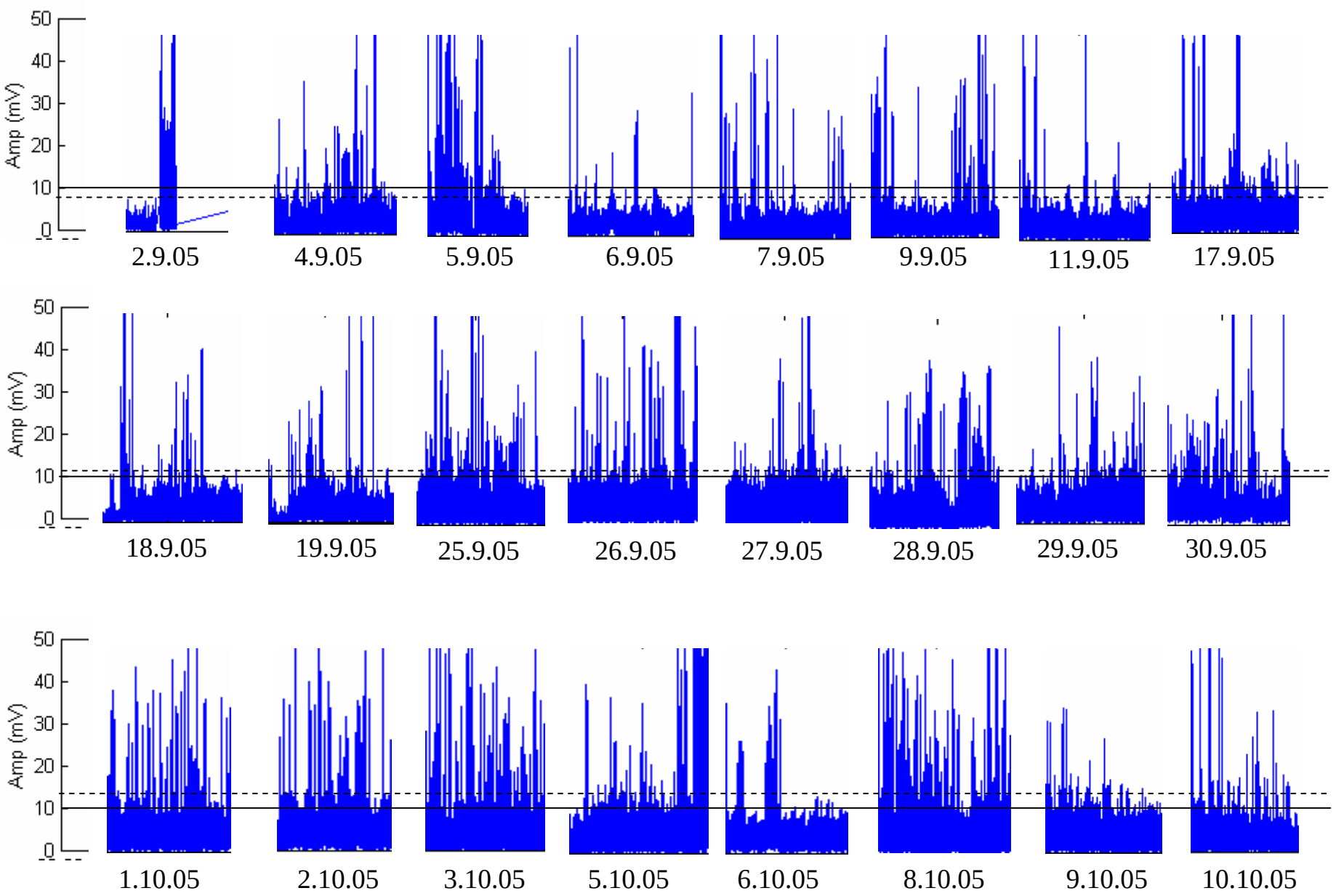
Experimental set up

- **Ground observations**
  - Measurement of sub-surface VLF electric field emissions associated with earthquakes using borehole antenna.
  - Monitoring of ULF magnetic field emissions associated with earthquakes using 3-axis search coil magnetometer.
  - Monitoring of fixed frequency VLF transmitter signals using AbsPAL receiver.

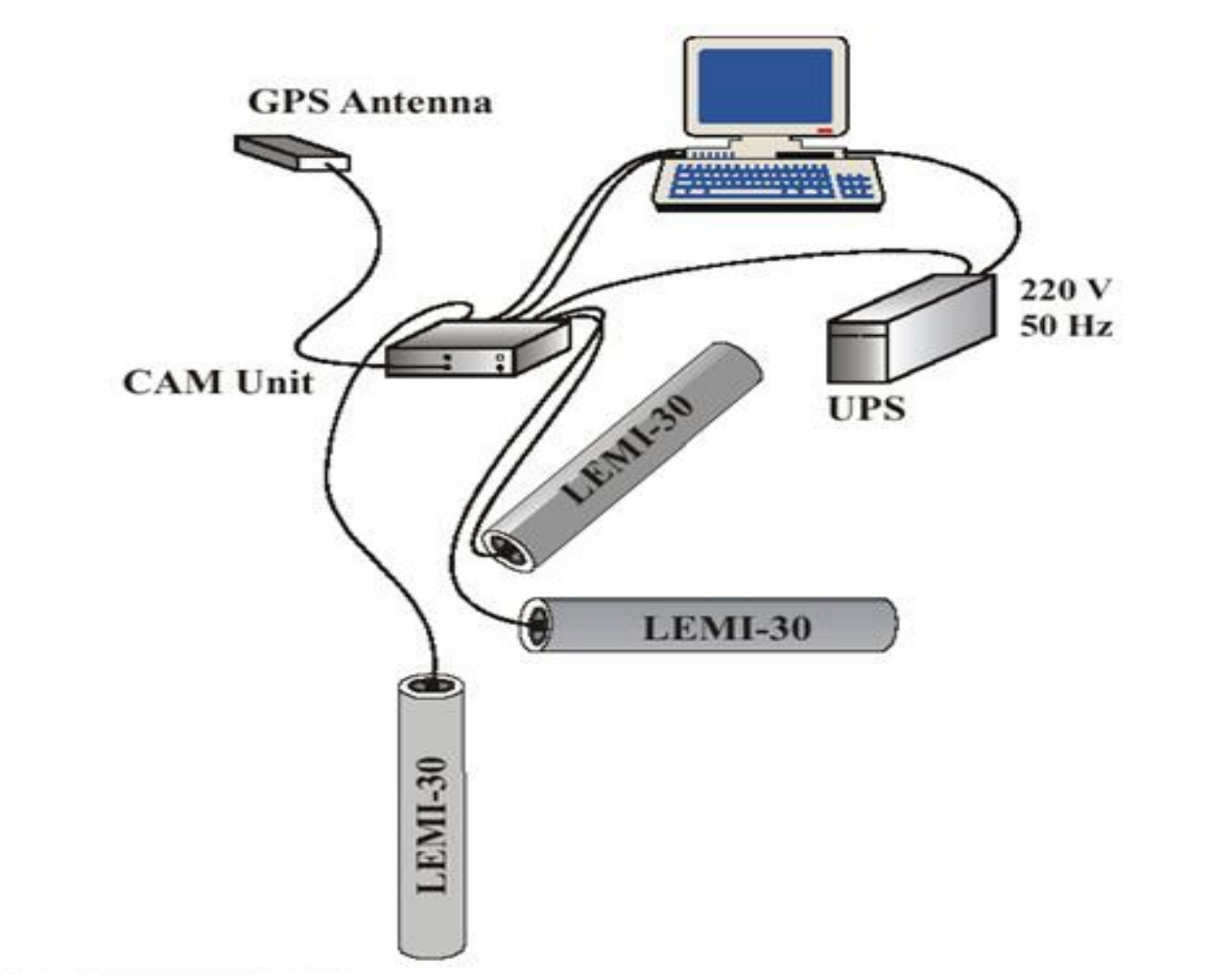
Measurement of sub-surface VLF electric field



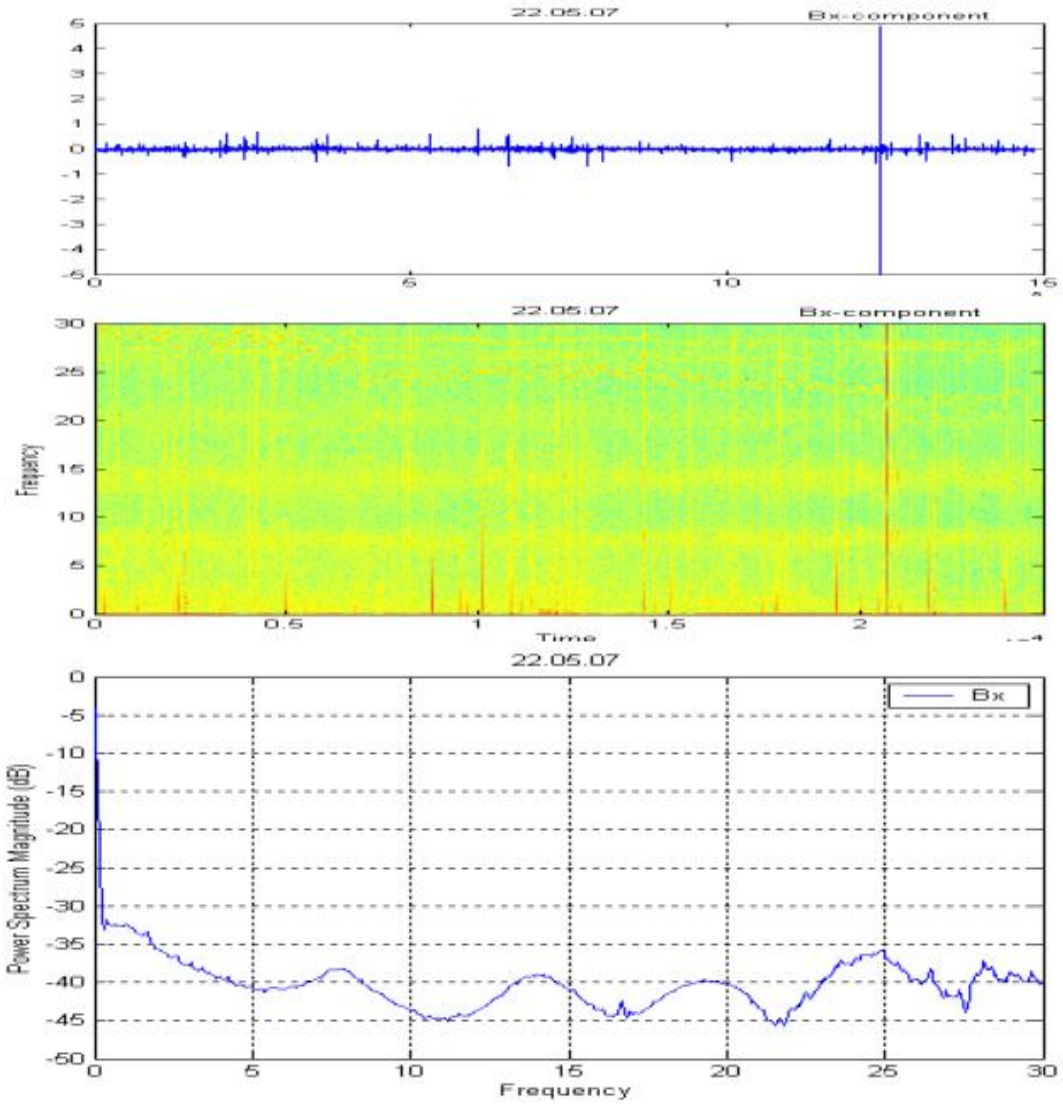
Example of raw data of Borehole activity



Experimental set-up for monitoring ULF magnetic field emissions

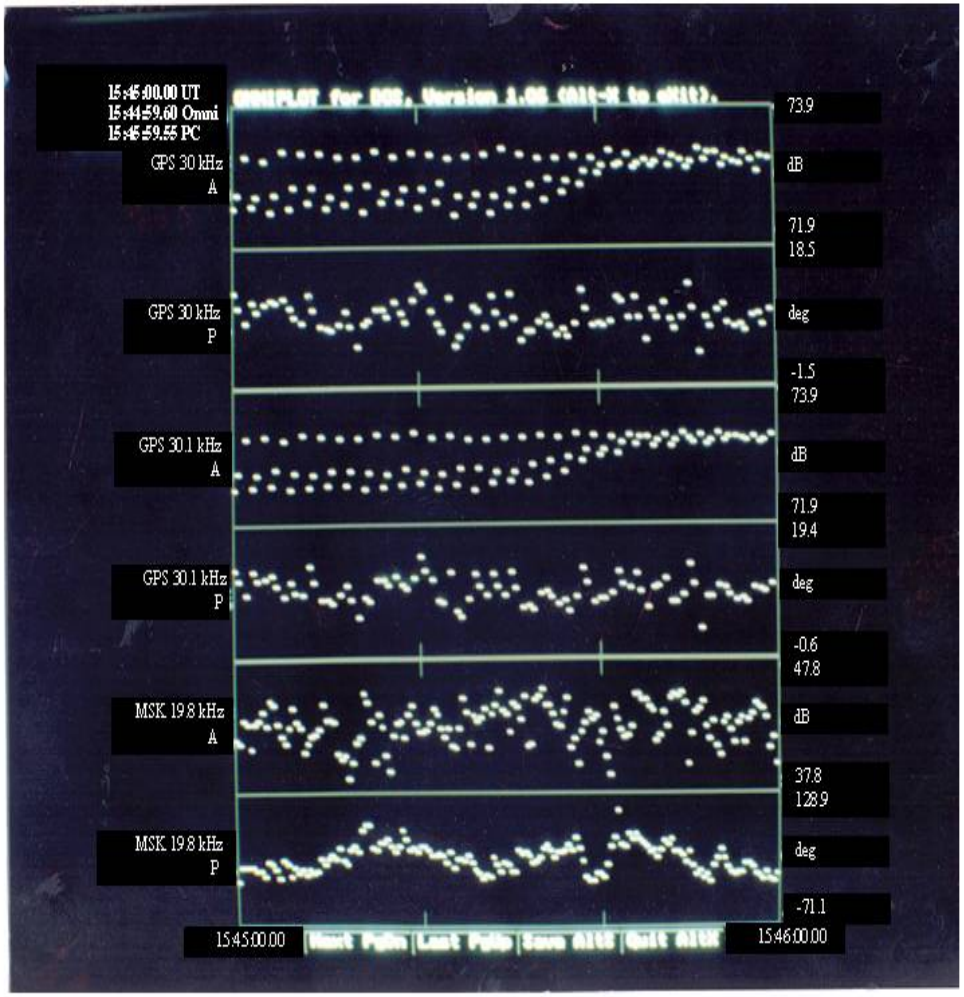


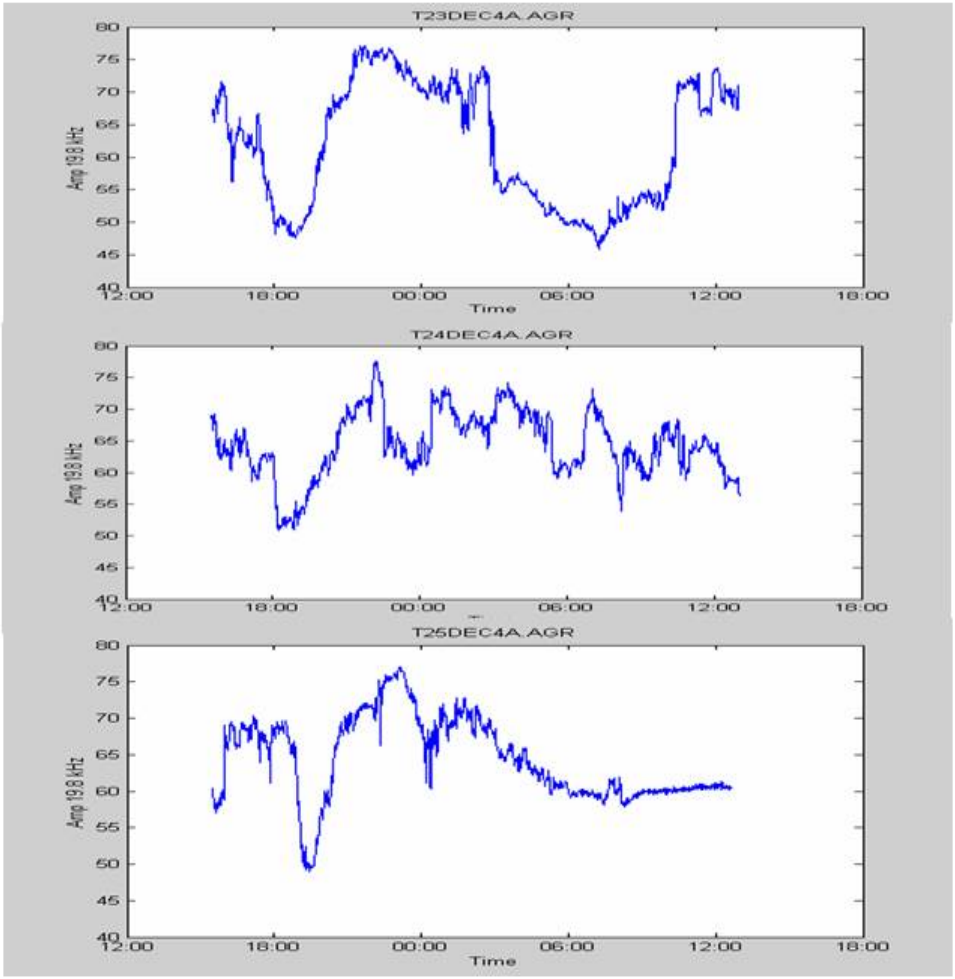
Raw data of ULF activity



Antenna system for recording sub-ionospheric VLF fixed frequency transmitter signals

Raw data of VLF




T23DEC4A.AGR
Amp 19.8 kHz
80
75
70
65
60
55
50
45
40
12:00
18:00
00:00
06:00
12:00
18:00
Time
T24DEC4A.AGR
Amp 19.8 kHz
80
75
70
65
60
55
50
45
40
12:00
18:00
00:00
06:00
12:00
18:00
T25DEC4A.AGR
Amp 19.8 kHz
80
75
70
65
60
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12:00
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18:00
Time

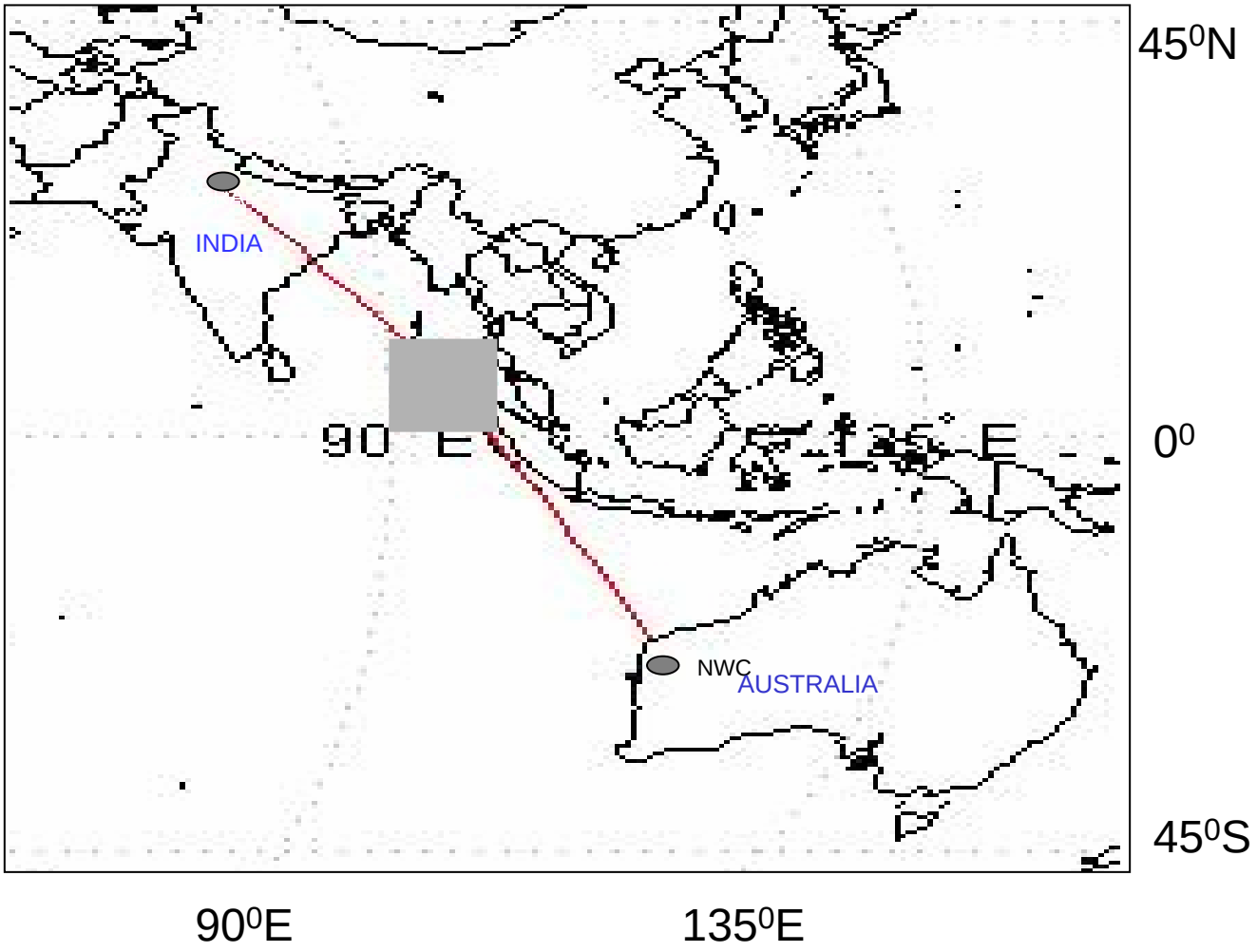
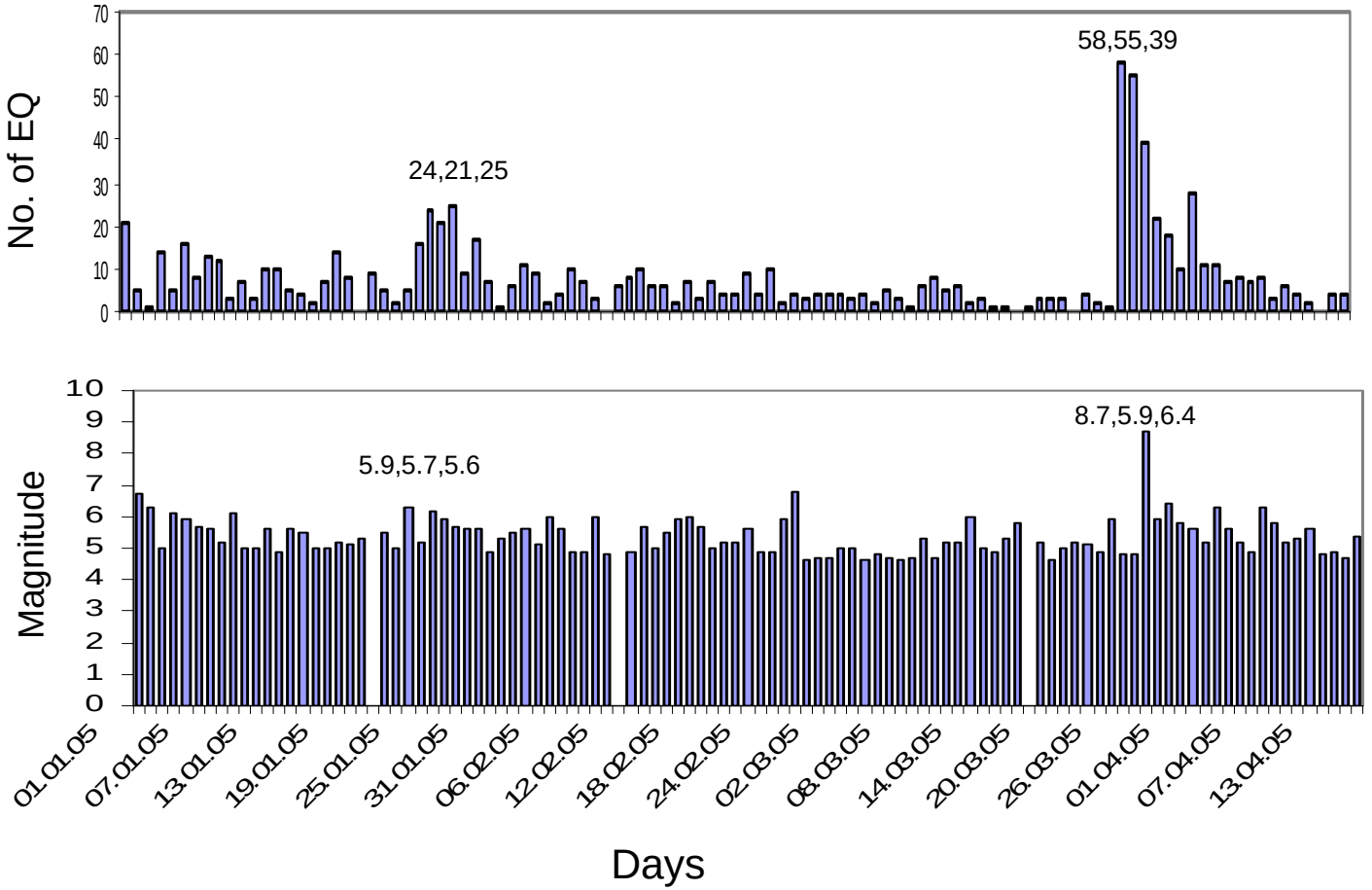
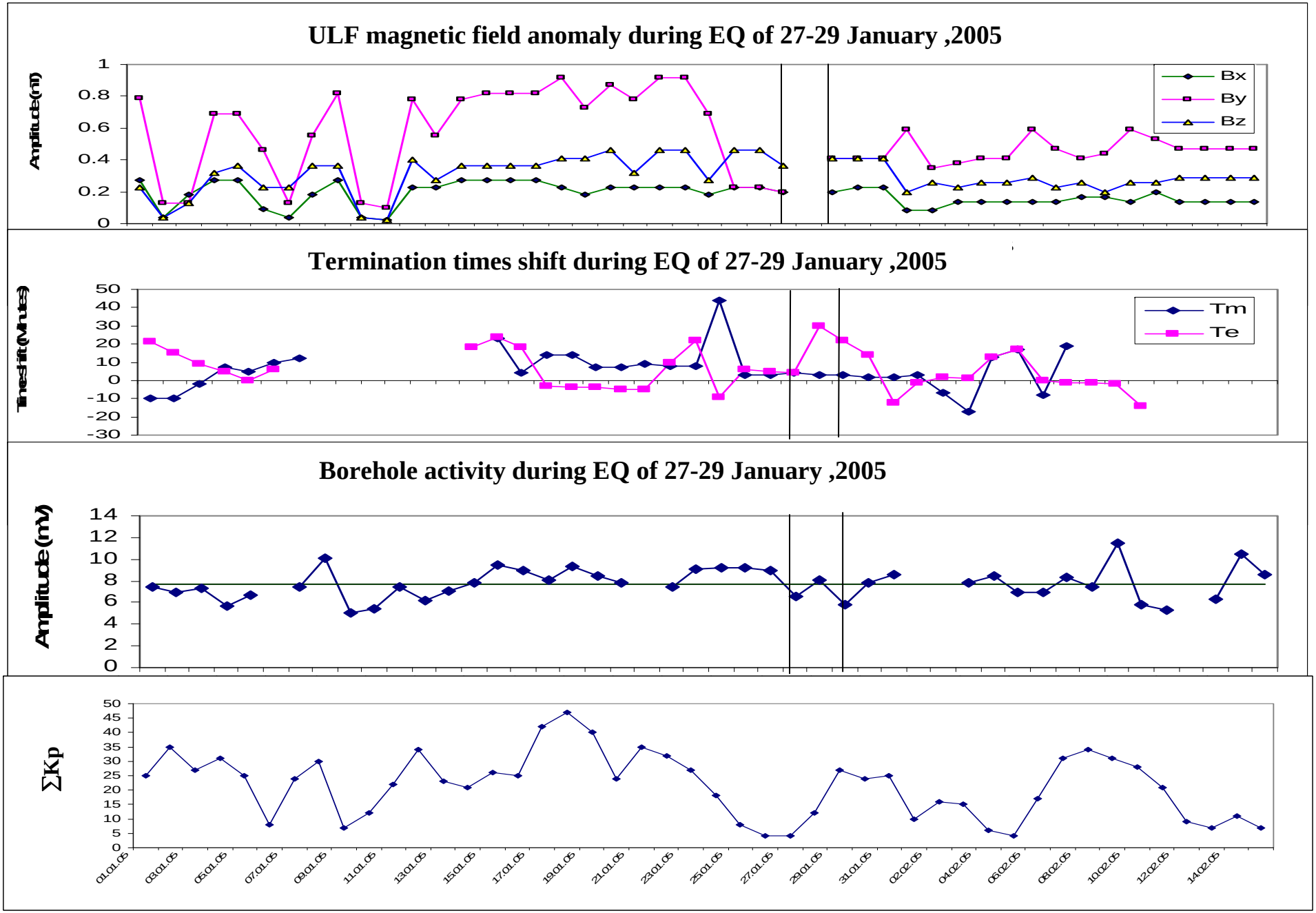


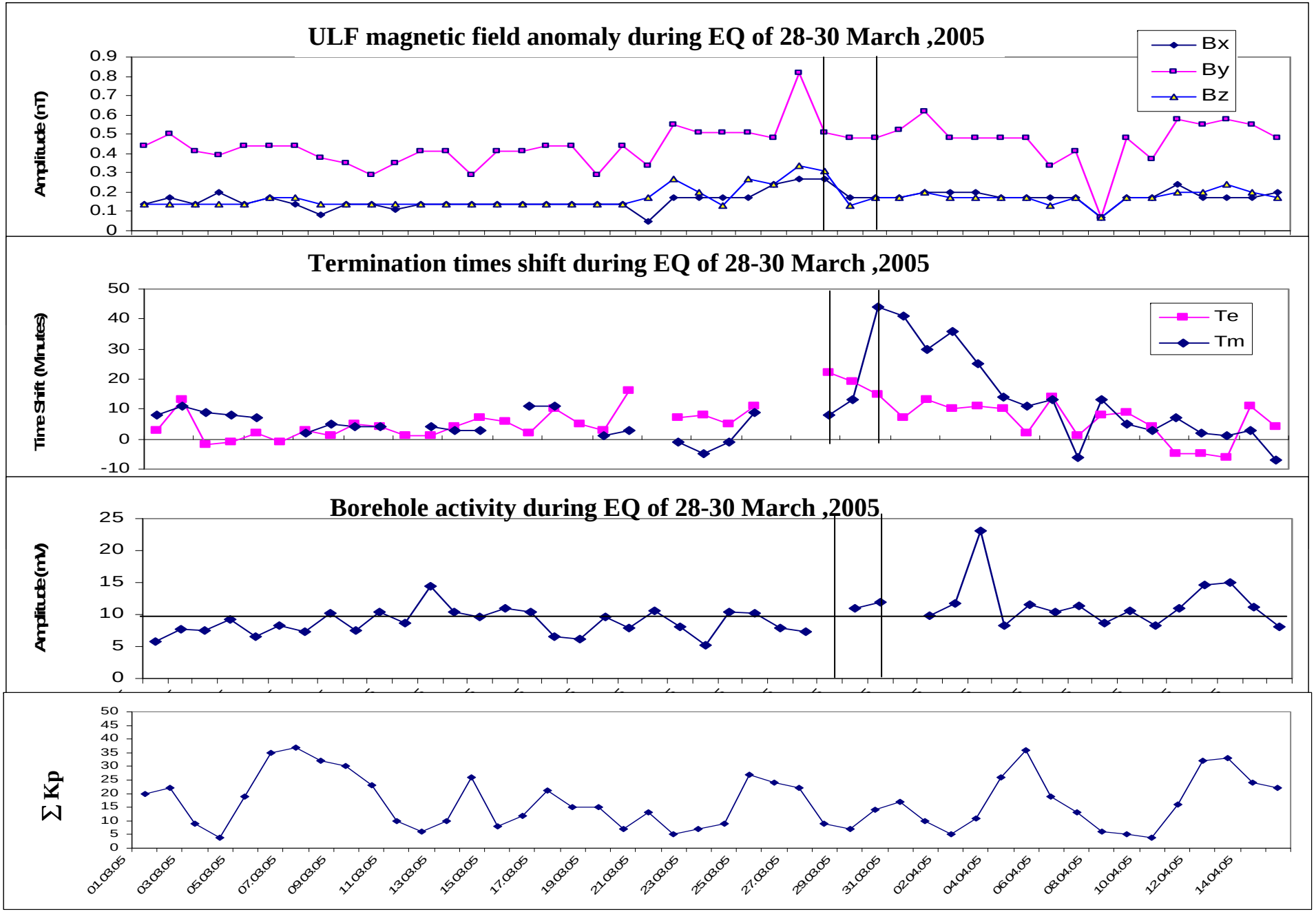
Fig.3

Details of earthquakes in the clusters

No. of cluster	Date of earthquakes	No. of earthquakes	Depth of earthquakes, Km	Largest magnitude of earthquakes	Location	
					Lat. Deg.(^{0}N)	Long. Deg. (^{0}E)
1	27 Jan., 2005 28 Jan., 2005 29 Jan., 2005	24 21 25	30 43 30	5.9 5.7 5.6	7.88 7.91 7.91	94.09 94.03 94.39
2	28 March, 2005 29 March, 2005 30 March, 2005	58 55 39	30 30 22	8.7 5.9 6.4	2.09 2.65 2.99	97.11 96.58 95.41


No. of EQ
70
60
50
40
30
20
10
0
58,55,39
24,21,25
Magnitude
10
9
8
7
6
5
4
3
2
1
0
8.7,5.9,6.4
5.9,5.7,5.6
01.01.05
07.01.05
13.01.05
19.01.05
25.01.05
31.01.05
06.02.05
12.02.05
18.02.05
24.02.05
02.03.05
08.03.05
14.03.05
20.03.05
26.03.05
01.04.05
07.04.05
13.04.05
Days


ULF magnetic field anomaly during EQ of 27-29 January ,2005
Amplitude(nT)
1
0.8
0.6
0.4
0.2
0
Bx
By
Bz
Termination times shift during EQ of 27-29 January ,2005
50
40
30
20
10
0
-10
-20
-30
Tm
Te
Borehole activity during EQ of 27-29 January ,2005
Amplitude(mV)
14
12
10
8
6
4
2
0
∑Kp
50
45
40
35
30
25
20
15
10
5
0
01.01.05
03.01.05
05.01.05
07.01.05
09.01.05
11.01.05
13.01.05
15.01.05
17.01.05
19.01.05
21.01.05
23.01.05
25.01.05
27.01.05
29.01.05
31.01.05
02.02.05
04.02.05
06.02.05
08.02.05
10.02.05
12.02.05
14.02.05


ULF magnetic field anomaly during EQ of 28-30 March ,2005
Amplitude (nT)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Bx
By
Bz
Termination times shift during EQ of 28-30 March ,2005
Time Shift (Minutes)
50
40
30
20
10
0
-10
Te
Tm
Borehole activity during EQ of 28-30 March ,2005
Amplitude (mV)
25
20
15
10
5
0
Σ Kp
50
45
40
35
30
25
20
15
10
5
0
01.03.05
03.03.05
05.03.05
07.03.05
09.03.05
11.03.05
13.03.05
15.03.05
17.03.05
19.03.05
21.03.05
23.03.05
25.03.05
27.03.05
29.03.05
31.03.05
02.04.05
04.04.05
06.04.05
08.04.05
10.04.05
12.04.05
14.04.05

Results and discussions

The results show that By component of the magnetic field emissions and termination times show precursory enhancements in the data by at least 4 and 1 days before the two clusters of earthquakes respectively. The propagation of ULF signals to large distances are interpreted in terms of low attenuation which justify propagation between Sumatra and Agra through middle layer crust and emergence in the atmosphere through windows of low conductivity

The most recent mechanism has been suggested by Pulinets (2004). According to him the strong vertical electric field produced between the ionosphere and near ground plasma in the form of long living ion clusters which are the result of ion-molecular reactions (after ionisation by radon) plays very important role in ionopspheric disturbances due to earthquakes. Such electric fields may penetrate the E and F region of the ionosphere and generate AGW and irregularities which in turn can produce ELF/VLF emission.

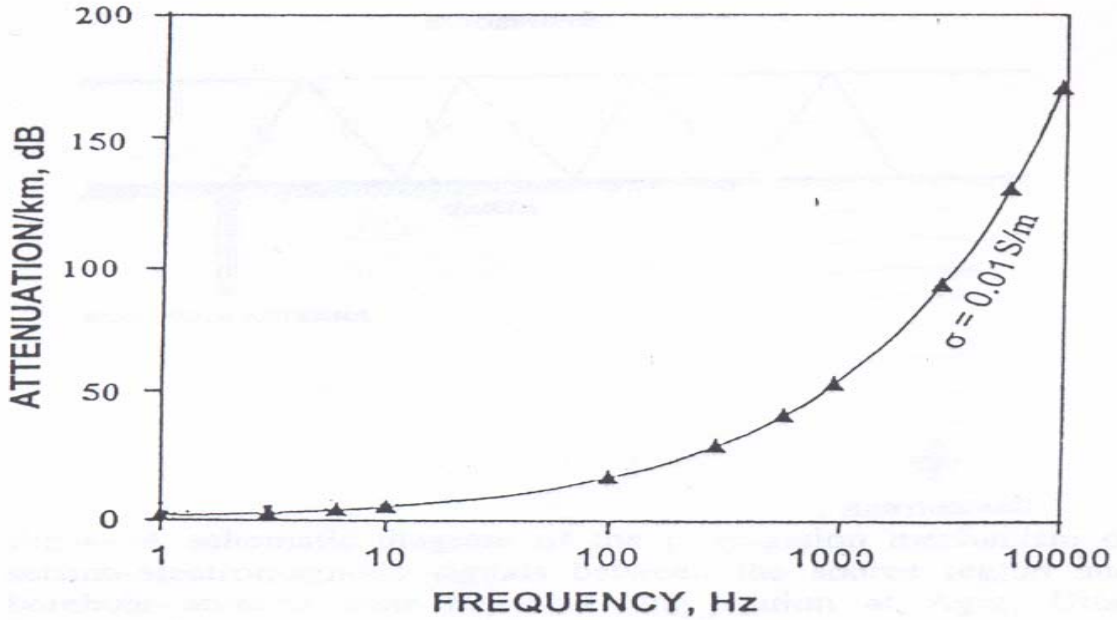


Fig.3(a)—Attenuation calculated for ULF-VLF emissions in upper layer crust model

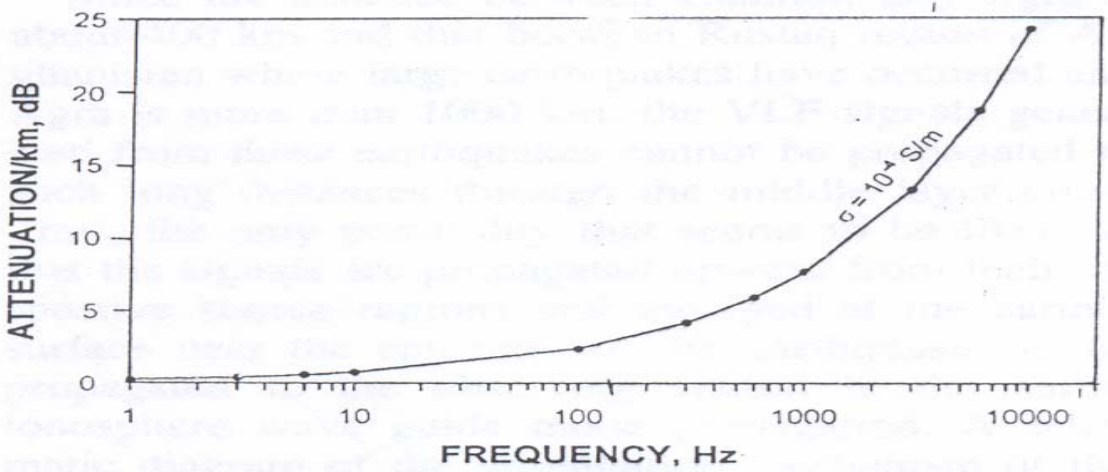


Fig.3(b)—Attenuation calculated for ULF-VLF emissions in middle layer crust model

The borehole data in the third panel do not show any significant response to these clusters. This is quite understandable also because Agra station is more than 2300 km away from the epicenter of the earthquake and as found by us the borehole antenna is sensitive to nearby (≤ 400 km) earthquakes only (Singh et al., 2003, **Varotsos et al., 2000)**. The VLF band of emissions is unlikely to travel to large distances between the epicenter of the earthquakes and Agra station due to heavy attenuation in the earth curst (Singh et al., 2004b).

Thank you