



ULF electric field anomalies by DEMETER satellite and comparison with ground-based observation around Wenchuan M8.0 earthquake

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Introduction

- ❖ 2005 □ Working Group on Earthquake satellite was founded in the framework of China-France Bilateral Space Committee
- ❖ Share Demeter data during 2004-2010
- ❖ Data application in case study



Application Development of satellite data in China

- ❖ Software and techniques
- ❖ Case study and statistical results
- ❖ Theoretical simulation of propagation of VLF electromagnetic waves



Demetersoft

Demetersoft version 1.1.1 R2009a

System Utility Process Help

Database Manager Product Display Background Calculation Seismic Event Analysis

User / Schema: ☒ Save

Table Name	Table Space N...	Total Record	Record Quality	Create Date	Last Modified D...	Status
------------	------------------	--------------	----------------	-------------	--------------------	--------

Background Area

Orbit Time: 2008-5-2 19:42:22 Kp Index: 00 8+

2008-5-24 19:42:22 AE Index: 0 999

☐ Interval(Every month,every quarter...)

0 M 0 D 0 M 0 D

Geographic Area: Latitude: -90 90 Longitude: -180 180

Product Type: 1132 VLF SP Eij Spectrum

Frequency Range: 400-500Hz

Grid Resolution: Longitude: 4 degree Latitude: 2 degree

Up or Down: All (equal to day or night)

Compute Mode: Mean

Map Color Range: 0 0

☐ Export after display

Load settings Save settings Display BG Export to Database Export to File

Grid TimeSerial

Longitude: 0 YMin: 0 Latitude: 0 YMax: 0

Display TimeSerial Export to File

Different Background Area Comparison

CREATETIME	DATERANGE	INTE...	MIN...	MAX...	MIN...

Import from Database Delete selected To BG #1 To BG #2

Background #1: File... Background #2: File...

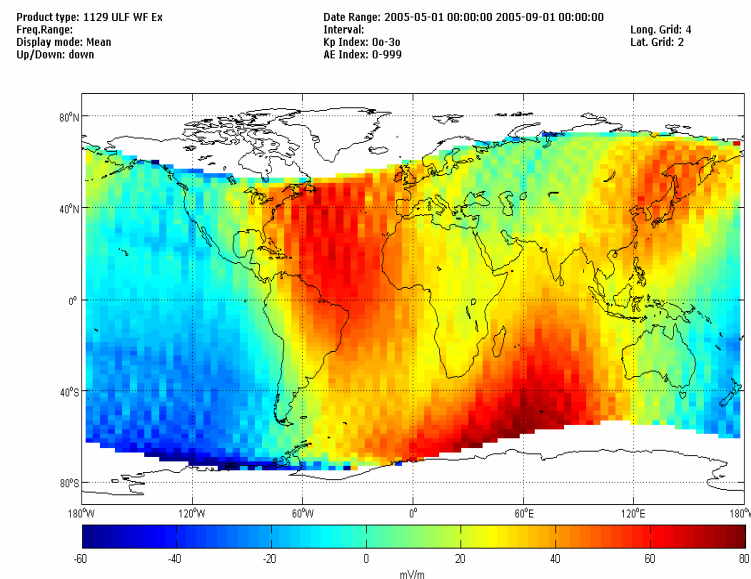
BG#1 information: BG#2 information:

Display BG#1 Display BG#2

Method: (mean(BG1)-mean(BG2))/std(BG2)

BG#1 BG#2 Match Display DBG

Demeter Background Area



Visit: [Demeter Home Page](#)

Ready

OrclStatus

MatlabStatus

Background —diurnal variation

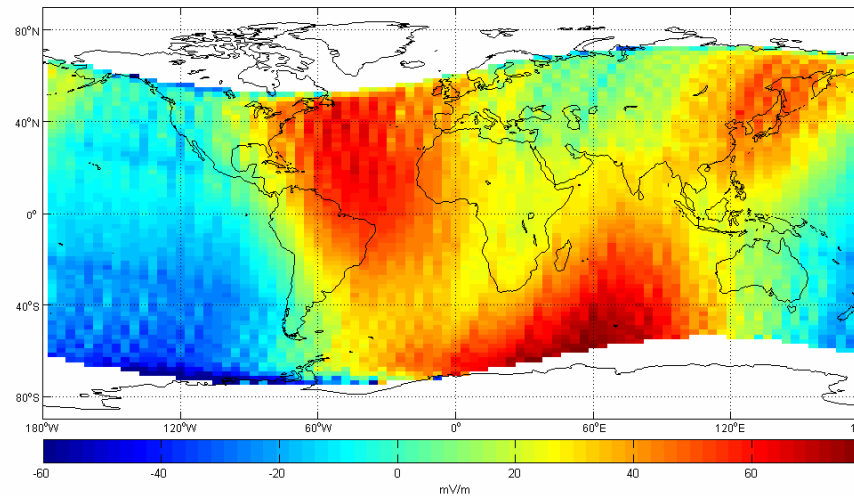


Demeter Background Area

Product type: 1129 ULF WF Ex
Freq.Range:
Display mode: Mean
Up/Down: down

Date Range: 2005-05-01 00:00:00 2005-09-01 00:00:00
Interval:
Kp Index: 00-30
AE Index: 0-999

Long. Grid: 4
Lat. Grid: 2



Local daytime

2005 Summer
Electric field Ex

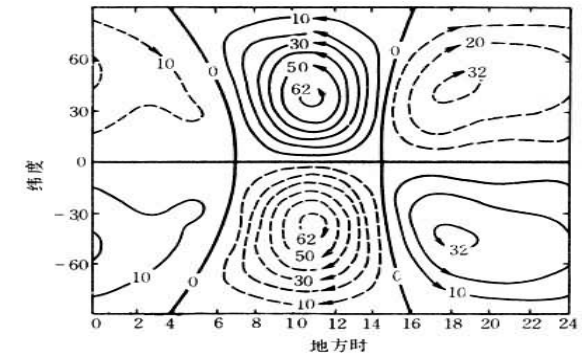


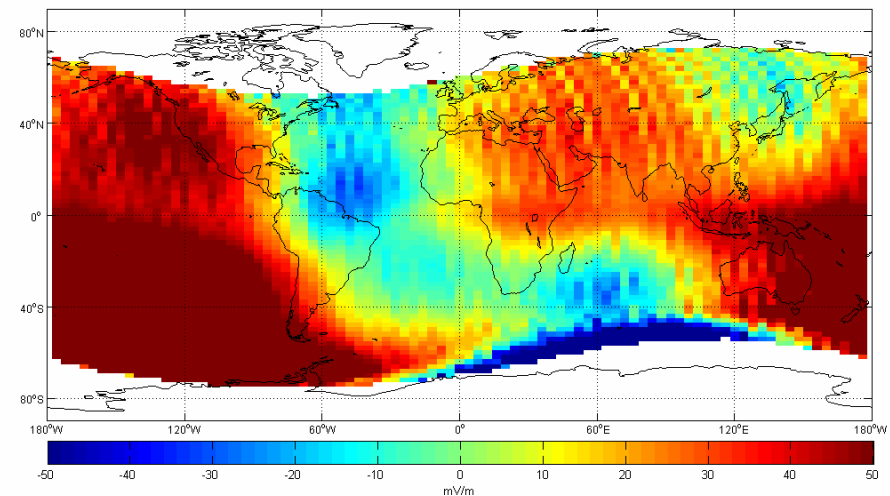
图2 春秋分时期太阳静日变化 Sq 的外部等效电流体系(电流单位为 kA)

Local nighttime
Demeter Background Area

Product type: 1129 ULF WF Ex
Freq.Range:
Display mode: Mean
Up/Down: up

Date Range: 2005-05-01 00:00:00 2005-09-01 00:00:00
Interval:
Kp Index: 00-30
AE Index: 0-999

Long. Grid: 4
Lat. Grid: 2





Background —seasonal variation



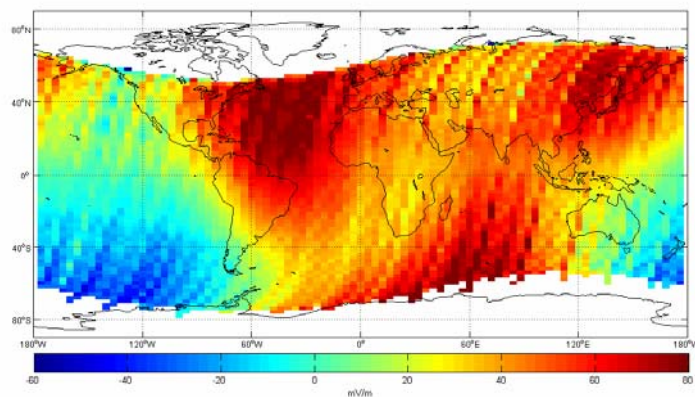
Spring

Product type: 1129 ULF WF Ex
Freq Range:
Display mode: Mean
Up/Down: down

Demeter Background Area

Date Range: 2005-03-01 00:00:00 2005-05-01 00:00:00
Interval:
Kp Index: 00-30
AE Index: 0-999

Long. Grid: 4
Lat. Grid: 2



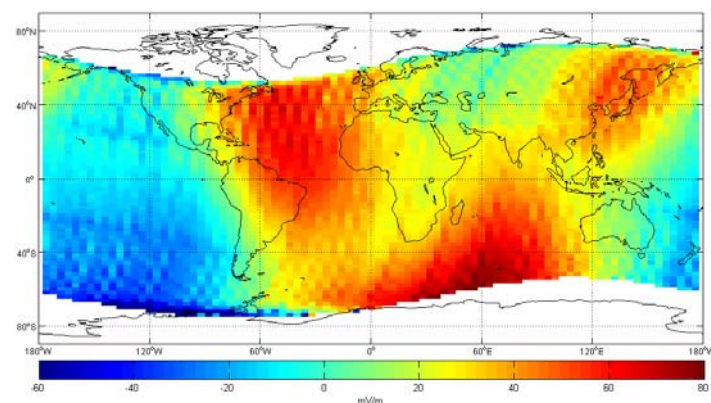
Summer

Product type: 1129 ULF WF Ex
Freq Range:
Display mode: Mean
Up/Down: down

Demeter Background Area

Date Range: 2005-05-01 00:00:00 2005-09-01 00:00:00
Interval:
Kp Index: 00-30
AE Index: 0-999

Long. Grid: 4
Lat. Grid: 2



2005 daytime Ex

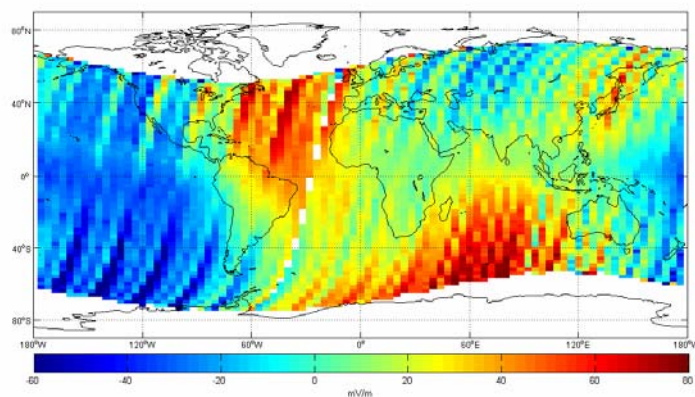
Autumn

Product type: 1129 ULF WF Ex
Freq Range:
Display mode: Mean
Up/Down: down

Demeter Background Area

Date Range: 2005-09-01 00:00:00 2005-11-01 00:00:00
Interval:
Kp Index: 00-30
AE Index: 0-999

Long. Grid: 4
Lat. Grid: 2



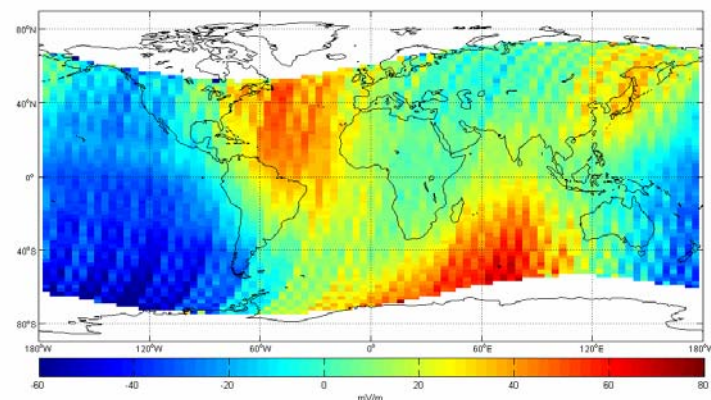
Winter

Product type: 1129 ULF WF Ex
Freq Range:
Display mode: Mean
Up/Down: down

Demeter Background Area

Date Range: 2005-11-01 00:00:00 2006-03-01 00:00:00
Interval:
Kp Index: 00-30
AE Index: 0-999

Long. Grid: 4
Lat. Grid: 2



Background —annual variation



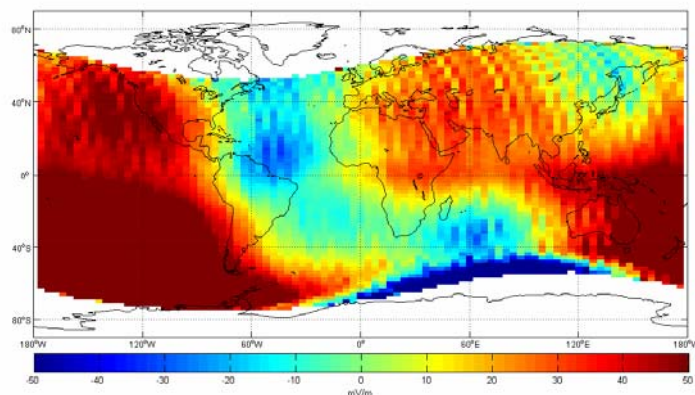
2005

Product type: 1129 ULF WF Ex
Freq Range:
Display mode: Mean
Up/Down: up

Demeter Background Area

Date Range: 2005-05-01 00:00:00 2005-09-01 00:00:00
Interval:
Kp Index: 00-30
AE Index: 0-999

Long. Grid: 4
Lat. Grid: 2



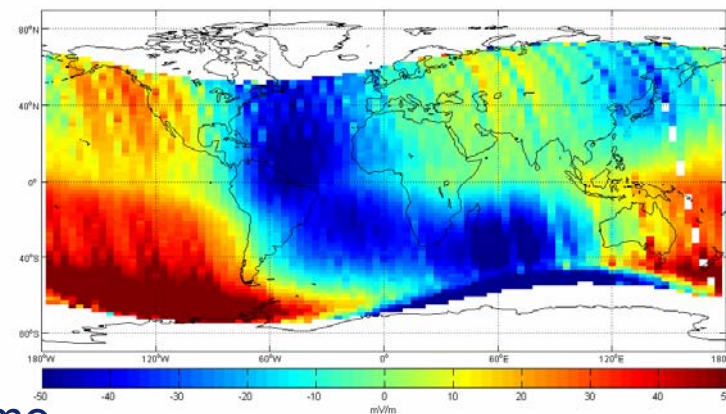
2006

Product type: 1129 ULF WF Ex
Freq Range:
Display mode: Mean
Up/Down: up

Demeter Background Area

Date Range: 2006-05-01 00:00:00 2006-09-01 00:00:00
Interval:
Kp Index: 00-30
AE Index: 0-999

Long. Grid: 4
Lat. Grid: 2



Local nighttime

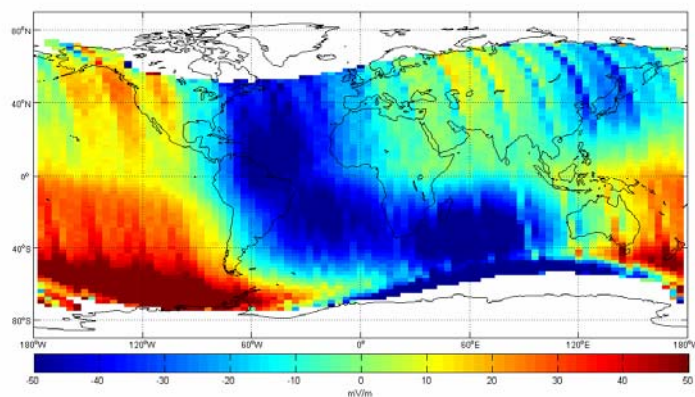
2007

Product type: 1129 ULF WF Ex
Freq Range:
Display mode: Mean
Up/Down: up

Demeter Background Area

Date Range: 2007-05-01 00:00:00 2007-09-01 00:00:00
Interval:
Kp Index: 00-30
AE Index: 0-999

Long. Grid: 4
Lat. Grid: 2



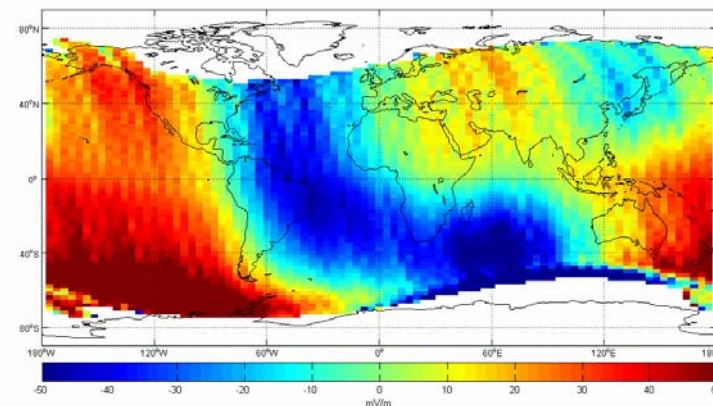
Summer Ex **2008**

Product type: 1129 ULF WF Ex
Freq Range:
Display mode: Mean
Up/Down: up

Demeter Background Area

Date Range: 2008-05-01 00:00:00 2008-09-01 00:00:00
Interval:
Kp Index: 00-30
AE Index: 0-999

Long. Grid: 4
Lat. Grid: 2



Demetersoft

Seismic Event

UT Range:

2008- 5- 2

23:11:09

2008- 5-24

23:11:09

Geo. Range:

Latitude: -90 - 90

Longitude: -180 - 180

Eq Num: 1 - 10000

Magnitude: 0 - 8

Depth: 0 - 500 km

Location: All

Eq Type: All

Search Earthquake

Load Settings

Save Settings

Eq Num	UT	GeoLat	GeoLon	Magnitude	Depth
6544	2008-5-3 3:53:36	-2.890000	101.360001	5.700000	50.299999
6545	2008-5-3 19:01:46	-6.650000	155.080002	5.400000	35.000000
6546	2008-5-3 0:26:56	36.189999	141.699997	5.100000	10.000000
6547	2008-5-5 2:50:35	-22.730000	173.429993	5.300000	35.000000
6548	2008-5-5 21:57:56	28.430000	54.080002	5.300000	49.700001
6549	2008-5-6 10:06:32	-20.309999	168.839996	5.100000	10.000000
6550	2008-5-6 12:42:14	-20.309999	168.839996	5.300000	10.000000
6551	2008-5-6 23:27:38	-7.860000	123.169998	5.400000	211.100006
6552	2008-5-7 5:35:38	12.750000	123.769997	5.000000	31.600000
6553	2008-5-7 16:02:03	36.189999	141.539993	6.200000	19.600000

Delete Selected

Delete All

Selected Eq Num: 89

Background Select

CREATETIME	DATERANGE	INTE...	MIN...	MAX...	MIN
2010-03-25 ...	2008-05-02...		-90	90	-180
2010-03-25 ...	2008-05-02...		-90	90	-180
2010-03-28 ...	2008-05-02...		-90	90	-180
2010-03-28 ...	2008-05-02...		-90	90	-180
2010-03-29 ...	2008-05-02...		-90	90	-180
2010-03-29 ...	2008-05-02...		-90	90	-180
2010-03-29 ...	2008-05-02...		-90	90	-180
2010-03-29 ...	2008-05-02...		-90	90	-180

Import from Database

To BG

Background: BG#Oracle#

File...

Orbit filter & Product Select

Kp Index: 00 - 8+

Up Down: All

AE Index: 0 - 999

Product Type: 1132 VLF SP Ej

Freq. Range: 200 - 300 Hz

Figure Option

Max Distance: 2000 km

Distance Res.: 100 km

Time Range: 24 hour

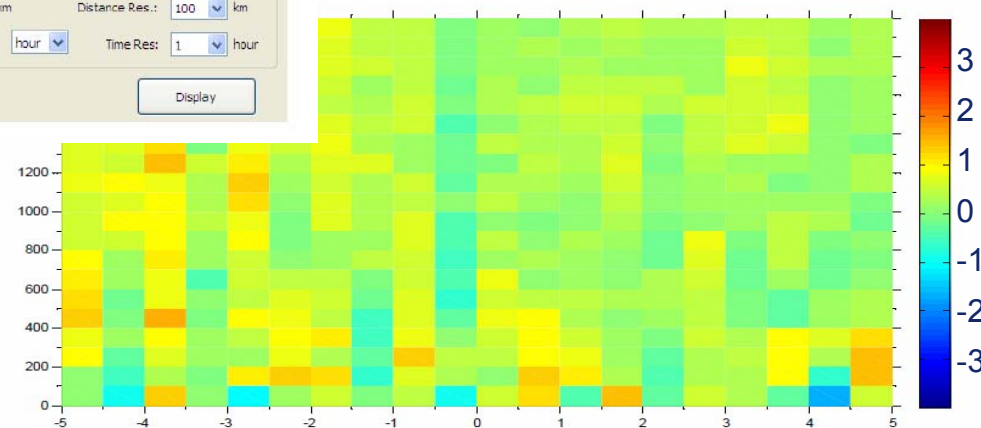
Time Res: 1 hour

Display

EMETER SEISMIC EVENT CHART

Kp Index: 00-8+
AE Index: 0-999

Seismic Number: 90
Magnitude: 0-8
Depth(km): 0-500



地震前后五天的图像

Demeter_data analysis

卫星电磁数据处理分析系统 V1.0

系统(S) 功能(U) 分析(A) 关于(A)

数据获取 信号分析

用户名: dmt

密码: *****

数据库: orcl

连接方式: Normal

服务器: 10.16.24.56

连接测试

获取ELF/IAP数据

获取ULF数据

分析(A) 菜单:

- 相关性分析(Z)
- 自功率谱分析(X)
- 互功率谱分析(C)
- 相关度分析(V)
- 分维分析(B)
- 空间梯度(N)
- 离散小波(M)
- 连续小波(L)
- SVD异常检测(S)
- DMTEPro(I)

查询条件:

起始: 2011- 8-29 10:02:34

升/降轨: 全部

查询

经度 结束... 起始... 结束... 测点数 升降

数据存放路径显示: E:\demeter_20110222\Debug\

完成



- ❖ Sumatra M8.5 earthquake on Mar. 28, 2005 (VLF E, Ne)
- ❖ Wenchuan earthquake on May 12, 2008 (Ne, Ni, Ti, VLF E and B)
- ❖ Chile M8.8 earthquake on Feb. 27, 2010 (high energy particles)
- ❖ Yushu M7.1 earthquake on April 13, 2010 (VLF B)

Some cases with electrostatic perturbations in Chile (16/24)



Table 1
Catalogue of Chile earthquakes with magnitude above 6.0 during the DEMETER mission (the 10th earthquake is excluded in the analysis due to missing orbits).

Num	Year	Month	Day	Time (UT)	Lat/°	Long/°	Depth/km	M	Precursor	After
1	2004	8	28	134125.60	-35.17	-70.53	5	6.5	Y	N
2	2005	6	2	105601.70	-24.22	-67	196	6.1	N	N
3	2005	11	17	192654.50	-22.36	-67.89	147	6.8	Y	Y
4	2006	4	15	235014.70	-29.77	-72	19	6	Y	N
5	2006	4	30	191715.00	-27.02	-71.02	12	6.7	Y	Y
	2006	4	30	0214058.4	-27.21	-71.06	12	6.5		
6	2006	7	16	0114241.4	-28.72	-72.54	10	6.2	N	N
7	2006	8	25	004446.16	-24.4	-67.03	184	6.6	N	N
8	2006	9	12	133055.70	-28.94	-68.9	114	6	Y	No orbit
9	2006	9	17	093413.58	-31.73	-67.14	137	6.2	Y	N
10	2006	10	12	180556.60	-31.26	-71.37	31	6.4	No orbit	No orbit
11	2007	11	14	154050.50	-22.25	-69.89	40	7.7	Y	N
	2007	11	15	190308.80	-22.87	-70.41	27	6.3		
	2007	11	15	190558.40	-22.92	-70.24	26	6.8		
12	2007	11	20	175551.50	-22.92	-70.48	15	6.1	Y	N
13	2007	12	13	052021.85	-23.16	-70.48	15	6	N	Y
	2007	12	13	072339.89	-23.2	-70.55	16	6.2		
14	2007	12	16	080917.93	-22.95	-70.18	45	6.7	Y	N
15	2008	2	4	170130.00	-20.17	-70.04	35	6.3	N	N
16	2008	2	16	144511.70	-21.35	-68.39	130	6.1	Y	Y
17	2008	3	24	203907.60	-20.04	-68.96	120	6.2	N	Y
18	2008	12	18	211928.40	-32.46	-71.73	18	6.2	Y	N
	2008	12	18	215028.00	-32.47	-72.05	25	6		
19	2010	2	27	063414.23	-35.93	-72.78	35	8.8	Y	Y
	2010	2	27	065117.64	-31.66	-69.14	39	6		
	2010	2	27	065234.14	-34.85	-72.68	35	6.2		
	2010	2	27	071228.44	-33.88	-71.94	35	6		
	2010	2	27	073717.96	-36.87	-72.67	35	6		
	2010	2	27	080123.55	-37.75	-75.1	37	6.9		
	2010	2	27	082529.62	-34.75	-72.43	35	6.1		
	2010	2	27	103031.00	-34.11	-72.88	35	6		
	2010	2	27	172430.80	-36.31	-73.16	19	6.1		
	2010	2	27	190006.70	-33.42	-71.8	29	6.3		
	2010	2	28	112536.00	-34.87	-71.57	46	6.2		
20	2010	3	3	174425.30	-36.45	-73.08	19	6.1	Y	N
21	2010	3	4	015950.68	-33.16	-72.1	35	6	N	N
	2010	3	4	0223926.6	-22.19	-68.25	114	6.4		
22	2010	3	5	091937.85	-36.53	-73.25	35	6.1	N	N
	2010	3	5	114707.10	-36.6	-73.23	18	6.6		
23	2010	3	11	143944.20	-34.26	-71.93	11	6.9	Y	N
	2010	3	11	145528.00	-34.28	-71.84	18	6.7		
	2010	3	11	150601.90	-34.41	-71.91	29	6		
24	2010	3	15	110828.70	-35.78	-73.34	10	6.1	Y	N
	2010	3	16	022157.93	-36.22	-73.25	18	6.7		
25	2010	3	26	145207.45	-27.96	-70.69	42	6.3	Y	Y



Statistical research on earthquakes in China 30

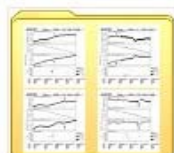
地震名称	时间 (世界时)	经度	纬度	震级 (Ms)	震源深度 (km)
台湾宜兰沿岸	2005-03-05 19:06:52.8	121.9	24.7	6.3	15
苏门答腊北部	2005-03-28 16:09:34.6	97.0	2.2	8.5	33
西藏仲巴	2005-04-07 20:04:43.5	83.7	30.5	6.5	33
烟台北部	2005-09-26 01:55:34.0	-76.4	-5.7	7.6	96
塔里木盆地东北缘	2006-04-20 23:25:03.0	167.2	61.0	8.0	33
汤加	2006-05-03 15:26:33.8	-174.2	-20.0	7.9	15
千岛群岛	2006-11-15 11:14:17.6	153.3	46.6	8.0	33
西藏日土、改则交界地区	2007-05-05 08:51:41.5	81.9	34.3	6.1	33
印尼苏门答腊南部海中	2007-09-12 11:10:23.9	101.5	-4.4	8.5	15
智利	2007-11-14 15:40:50.0	-69.7	-22.1	7.9	33
西藏改则县	2008-01-09 08:26:47.0	85.2	32.5	6.9	33
新疆于田县	2008-03-20 22:33:02.6	81.6	35.6	7.3	33
四川汶川县	2008-05-12 06:28:04.0	103.4	31.0	8.0	14
四川省广元市青川县	2008-08-05 09:49:18.7	105.5	32.8	6.1	10
西藏自治区日喀则地区仲巴县	2008-08-25 13:22:00.1	83.6	31.0	6.8	10
新疆维吾尔自治区克孜勒苏柯尔克孜自治州乌恰县	2008-10-05 15:52:49.5	73.9	39.5	6.8	33
青海省海西蒙古族藏族自治州	2008-11-10 01:22:05.6	95.9	37.6	6.3	10
印度尼西亚巴厘群岛北部	2009-01-03 19:43:53.8	132.8	-0.7	7.7	33
汤加地区	2009-03-19 18:17:37.4	-174.7	-23.0	10	7.9
新西兰南岛西海岸近海	2009-07-15 09:22:32.4	166.4	-45.7	7.8	33
青海省海西蒙古族藏族自治州	2009-08-28 01:52:06.0	95.8	37.6	6.4	7
萨摩亚群岛地区	2009-09-29 17:48:15.3	-172.2	-15.5	8.0	33
台湾花莲海域	2009-12-19 13:02:13.9	121.7	23.8	6.7	30
海地区	2010-01-12 21:53:08.2	-72.5	18.5	7.3	10
琉球群岛	2010-02-26 20:31:02.0	128.6	25.9	7.2	33
智利	2010-02-27 06:34:16.4	-72.7	-35.8	8.8	33
台湾高雄县、屏东县交界	2010-03-04 00:18:50.2	120.6	22.9	6.7	6
日本本州东岸近海	2010-03-14 08:08:05	141.56	37.78	6.6	39
苏门答腊北部	2010-04-06 22:15:01.0	97.1	2.4	7.8	33
青海省玉树藏族自治州玉树县	2010-04-13 23:49:37.9	96.6	33.2	7.1	14



ULF electric field



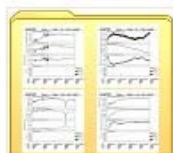
20041009



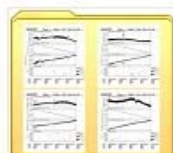
20041111



20041115



20041122



20041126



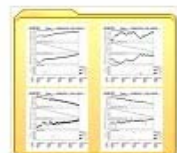
20041128



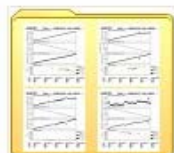
20041226



20050205



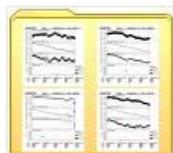
20050302



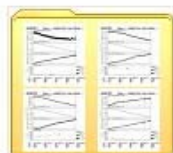
20050328



20050613



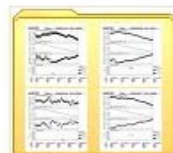
20050615



20050724



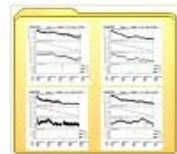
20050816



20050909



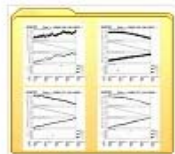
20050926



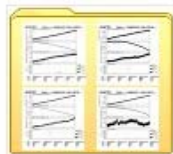
20051114



20060102



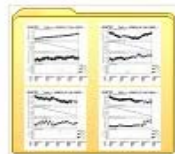
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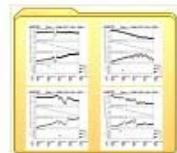
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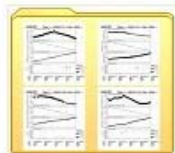
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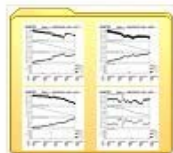
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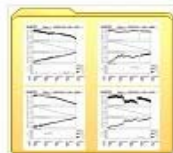
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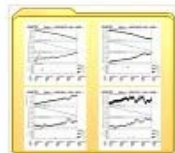
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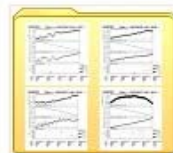
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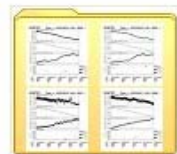
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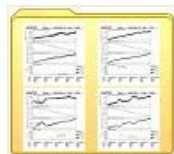
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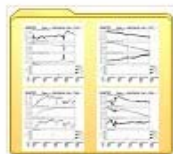
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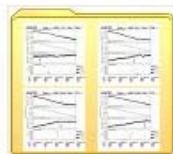
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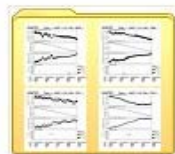
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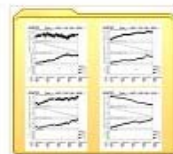
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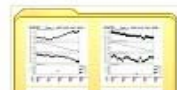
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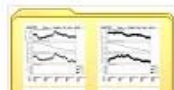
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20080109



20080116



20080123



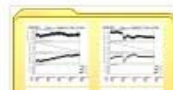
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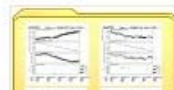
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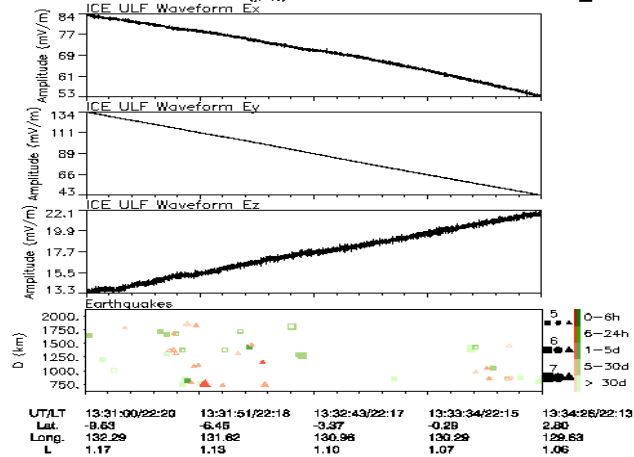
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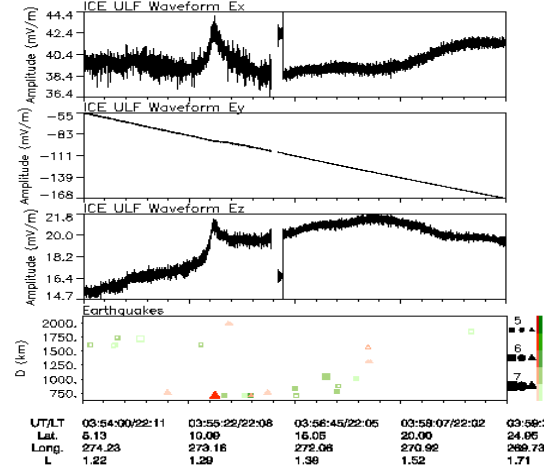
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Typical abnormal shapes

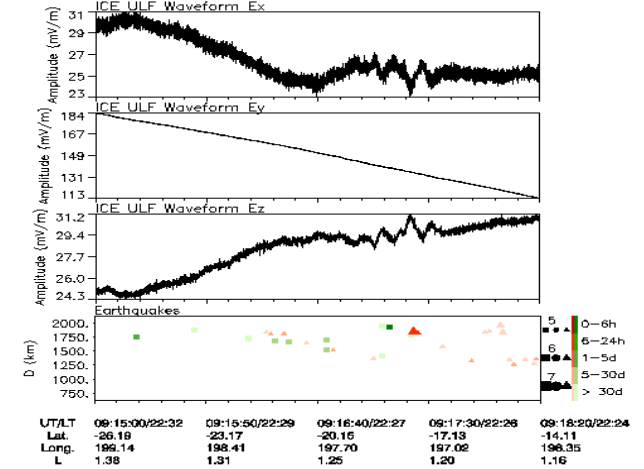
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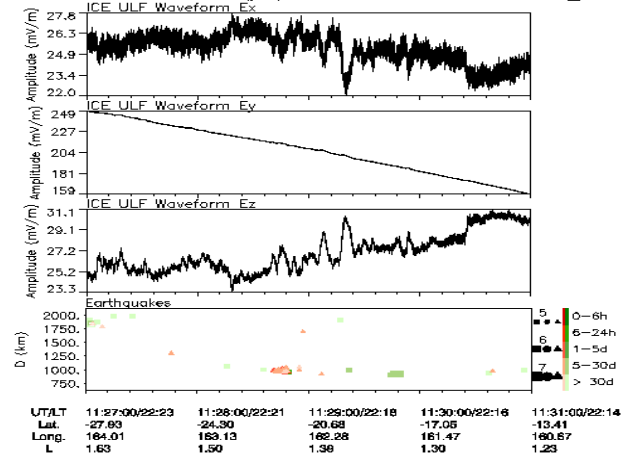
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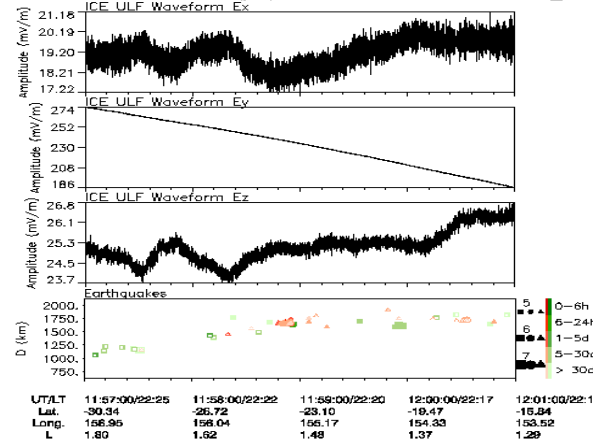
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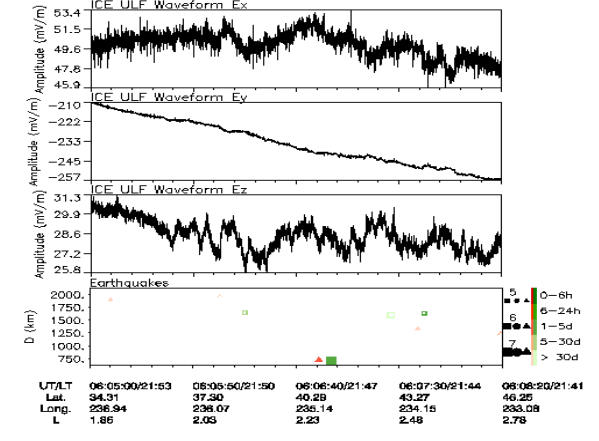
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DEMETER Date $_{(y/m/d)}$: 2005/06/16 Orbit: 05074_1



different-shape curves of ULF electric field waveform



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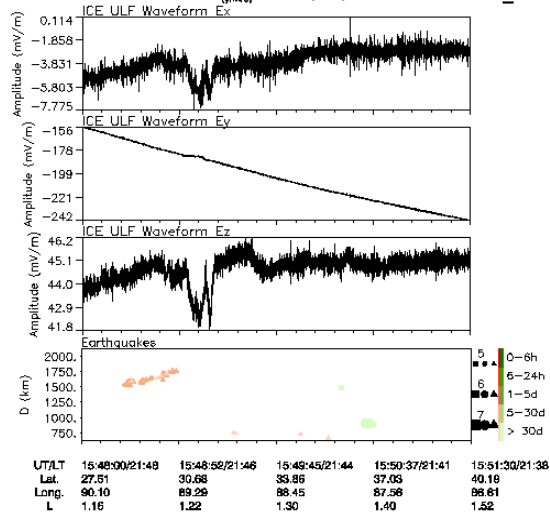
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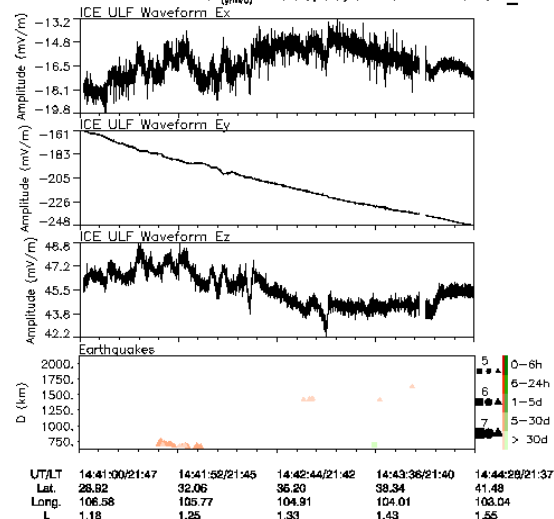
Anomalous signals around Wenchuan earthquake



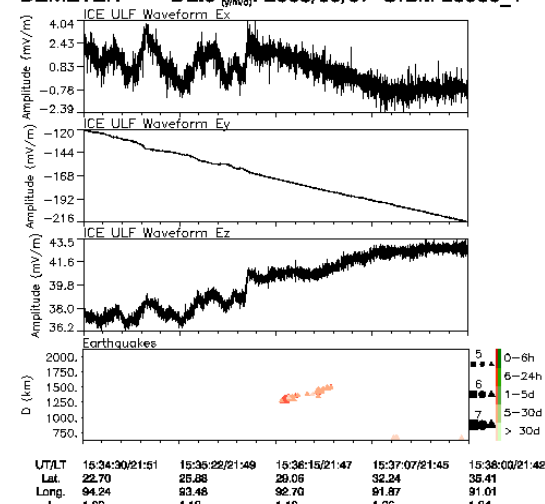
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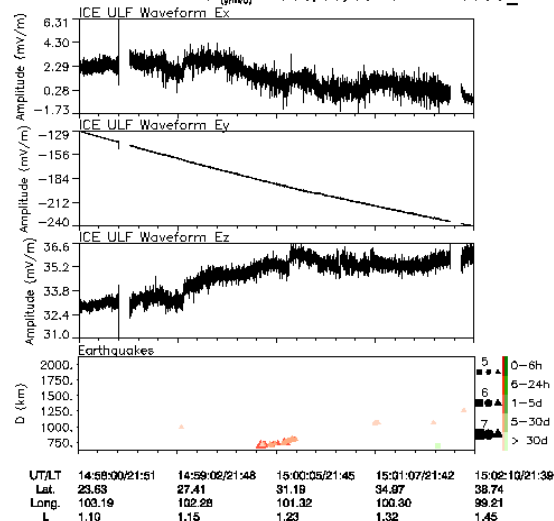
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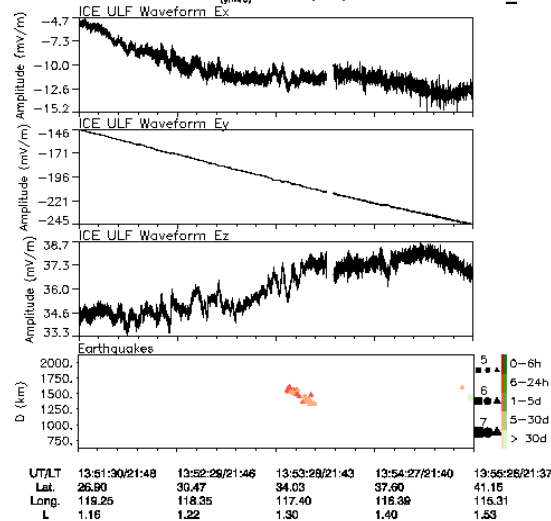
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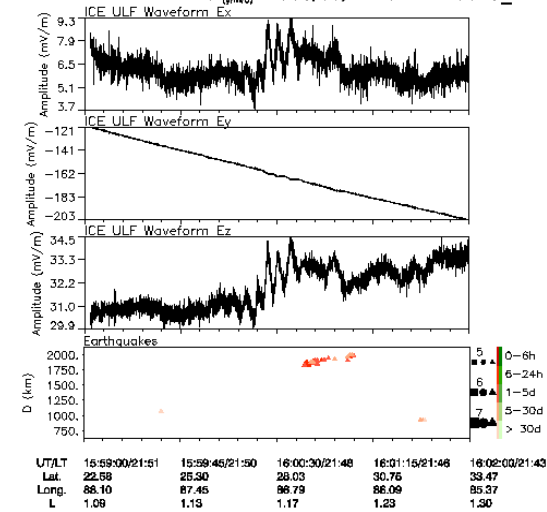
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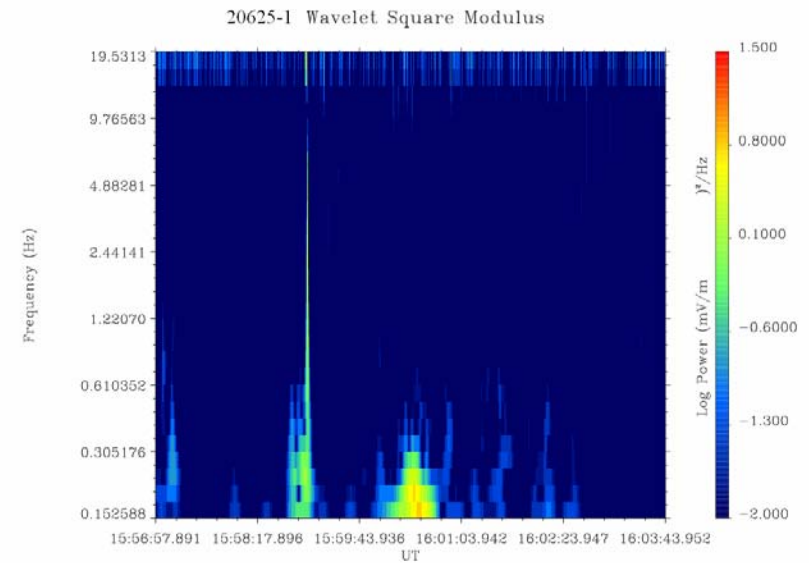
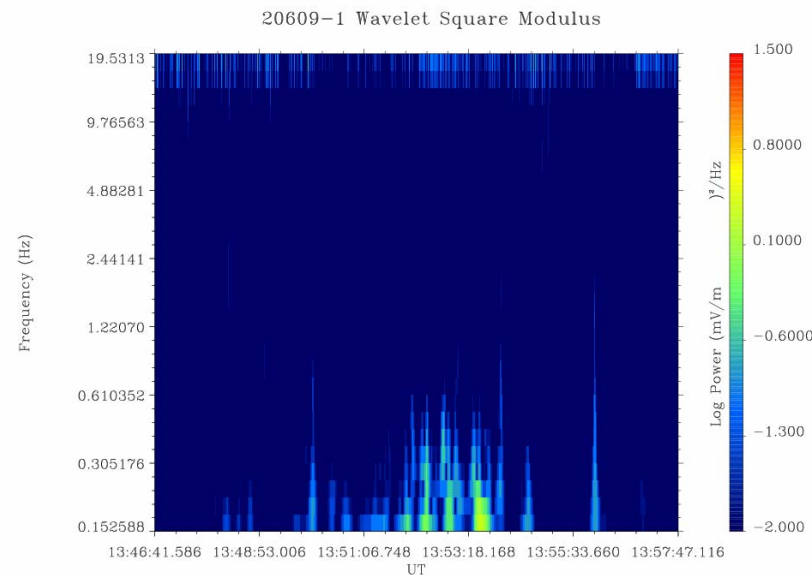
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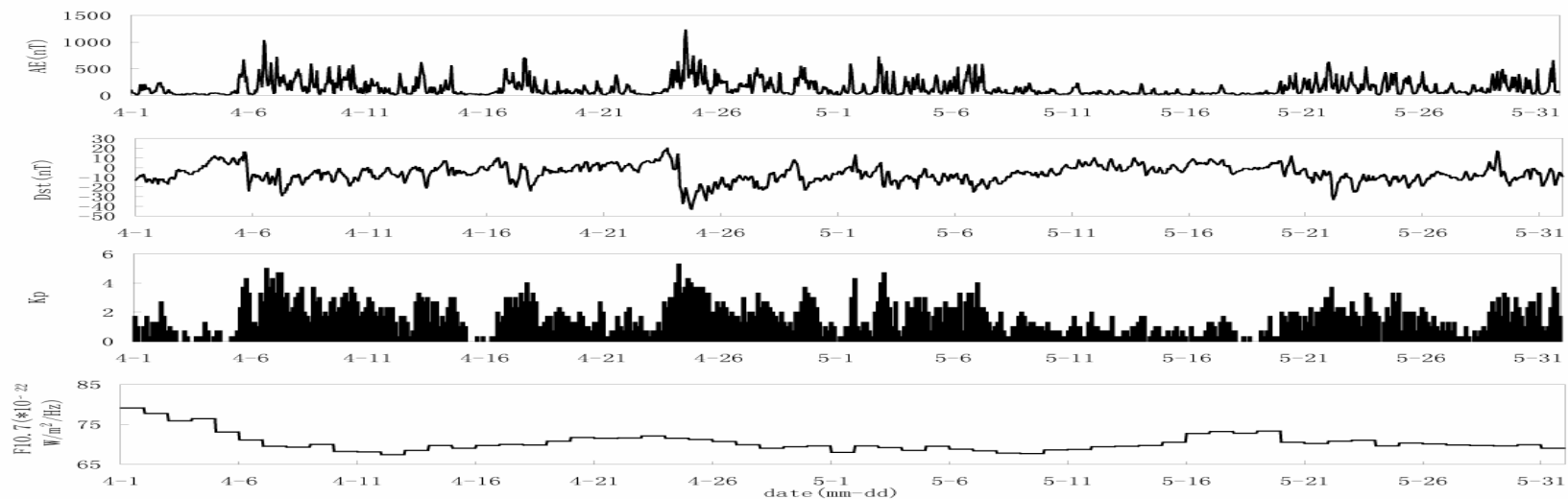
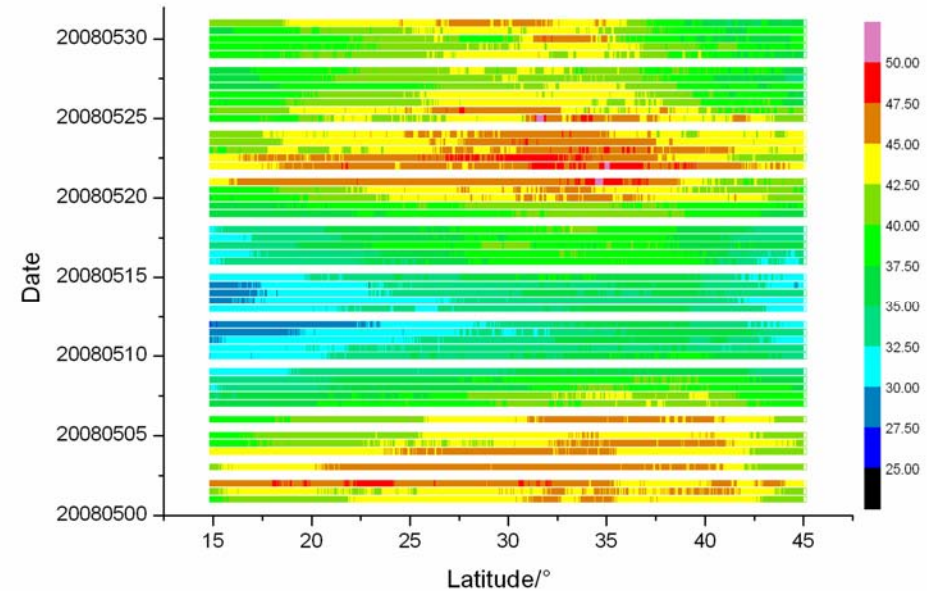
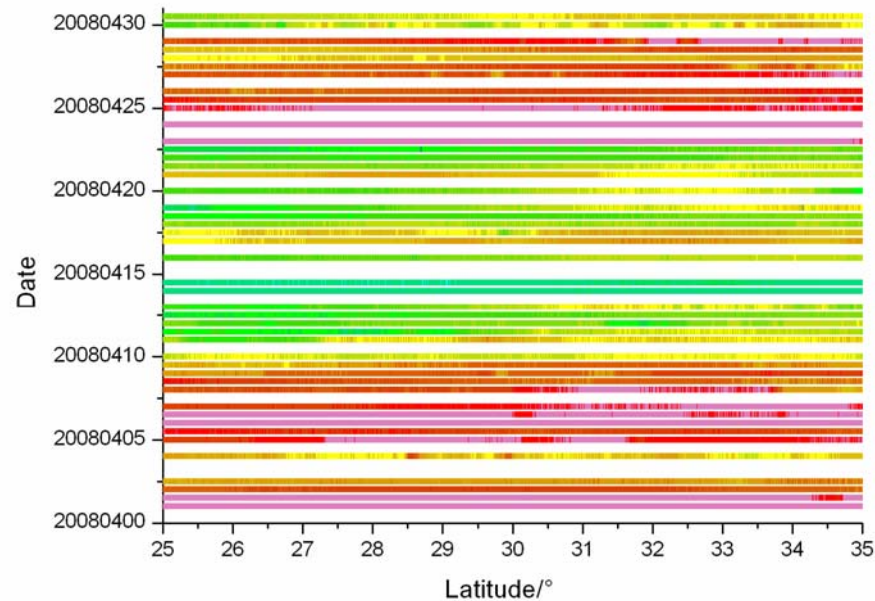


Anomalous signals around Wenchuan earthquake

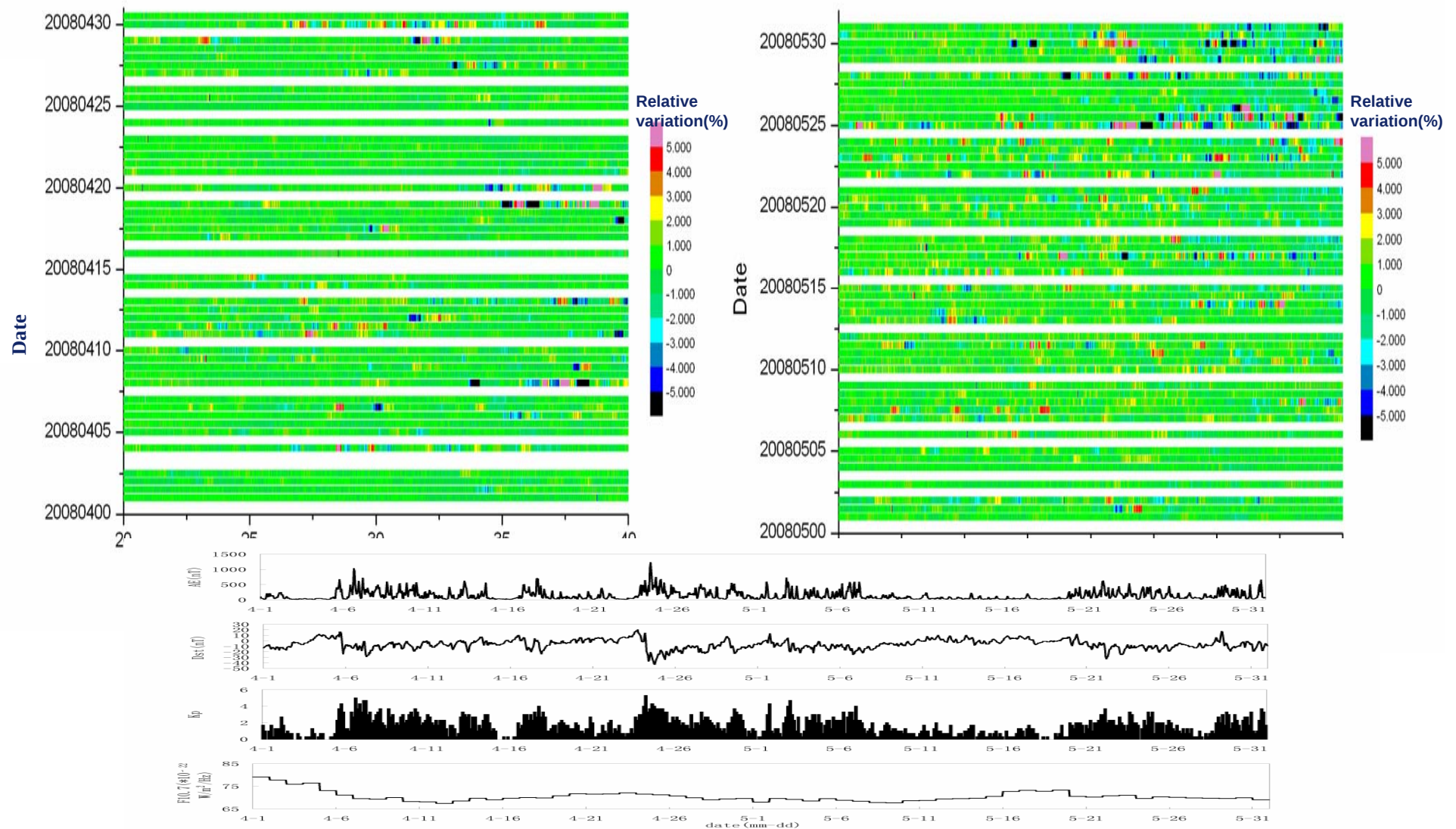


Wavelet analysis on data recorded on May 10 and 11

Anomalous signals around Wenchuan earthquake



Anomalous signals around Wenchuan earthquake





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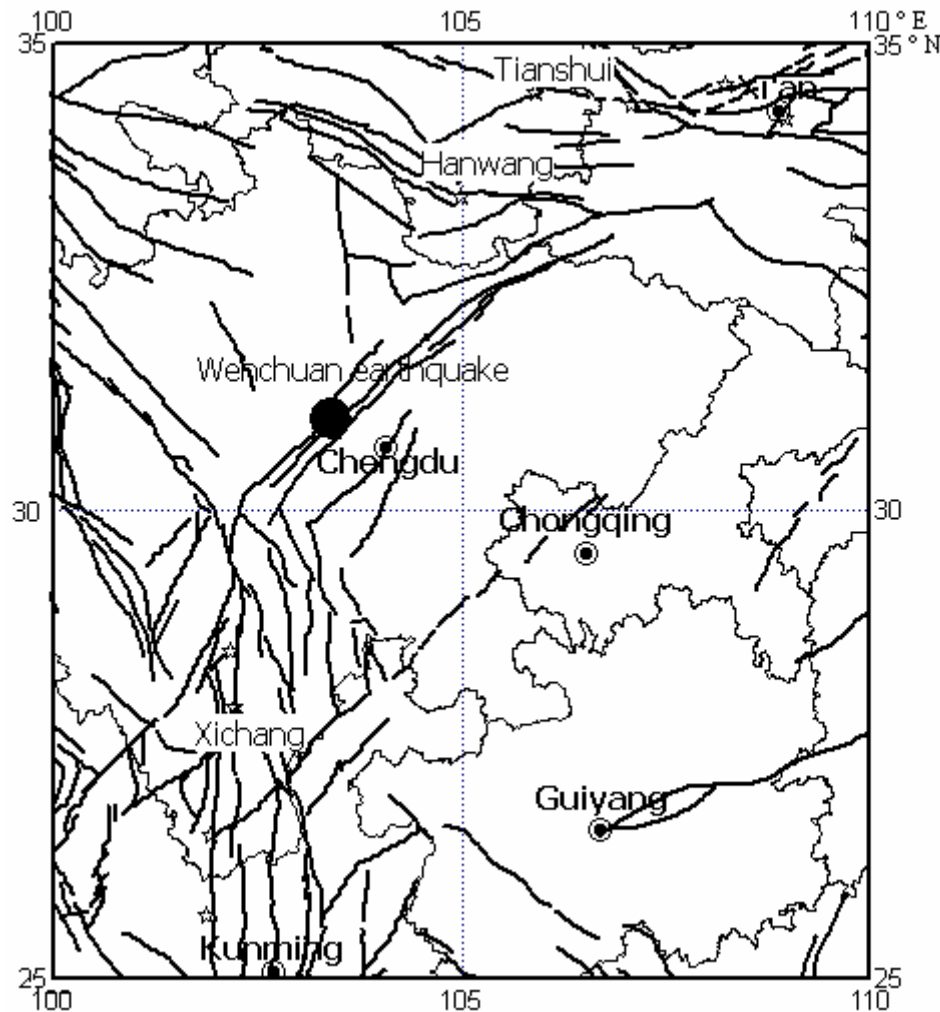
3

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4

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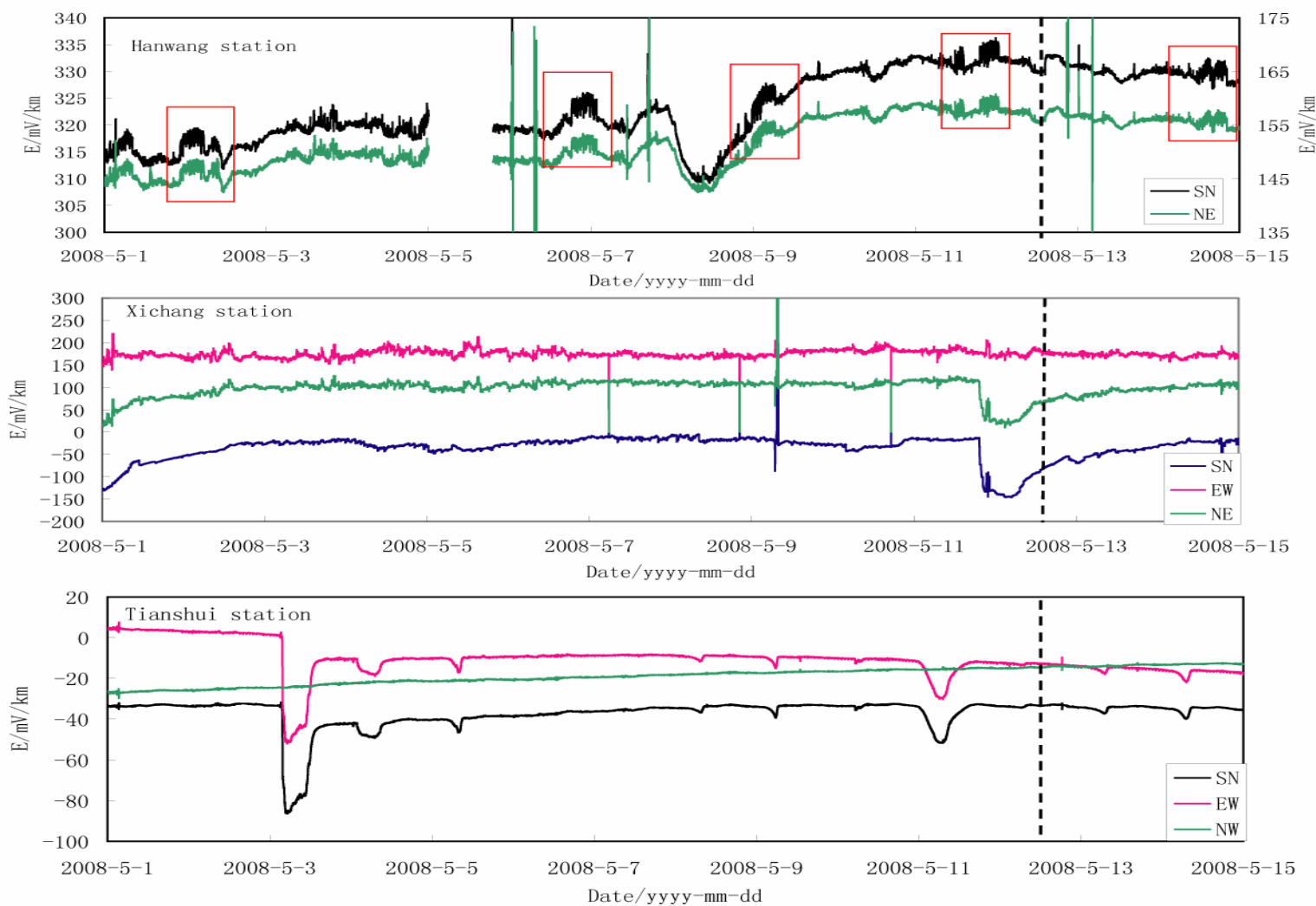
Data analysis on ground-based ULF electric field



The accuracy of voltage is about $\pm$ (0.1% reading +0.02% full scale), with resolution superior to $10\mu\text{V}$. The dynamic range is $\geq 100\text{dB}$. Frequency bands are 0-0.1Hz. Sampling rate is always taken as 60s at stations. Solid non-polarized electrodes are buried 3-4m underground to detect the geo-electric field at two or three directions, where two electrodes are separated in a distance of 300m or 150m.



Data analysis on ground-based ULF electric field



Data analysis on ground-based ULF electric field

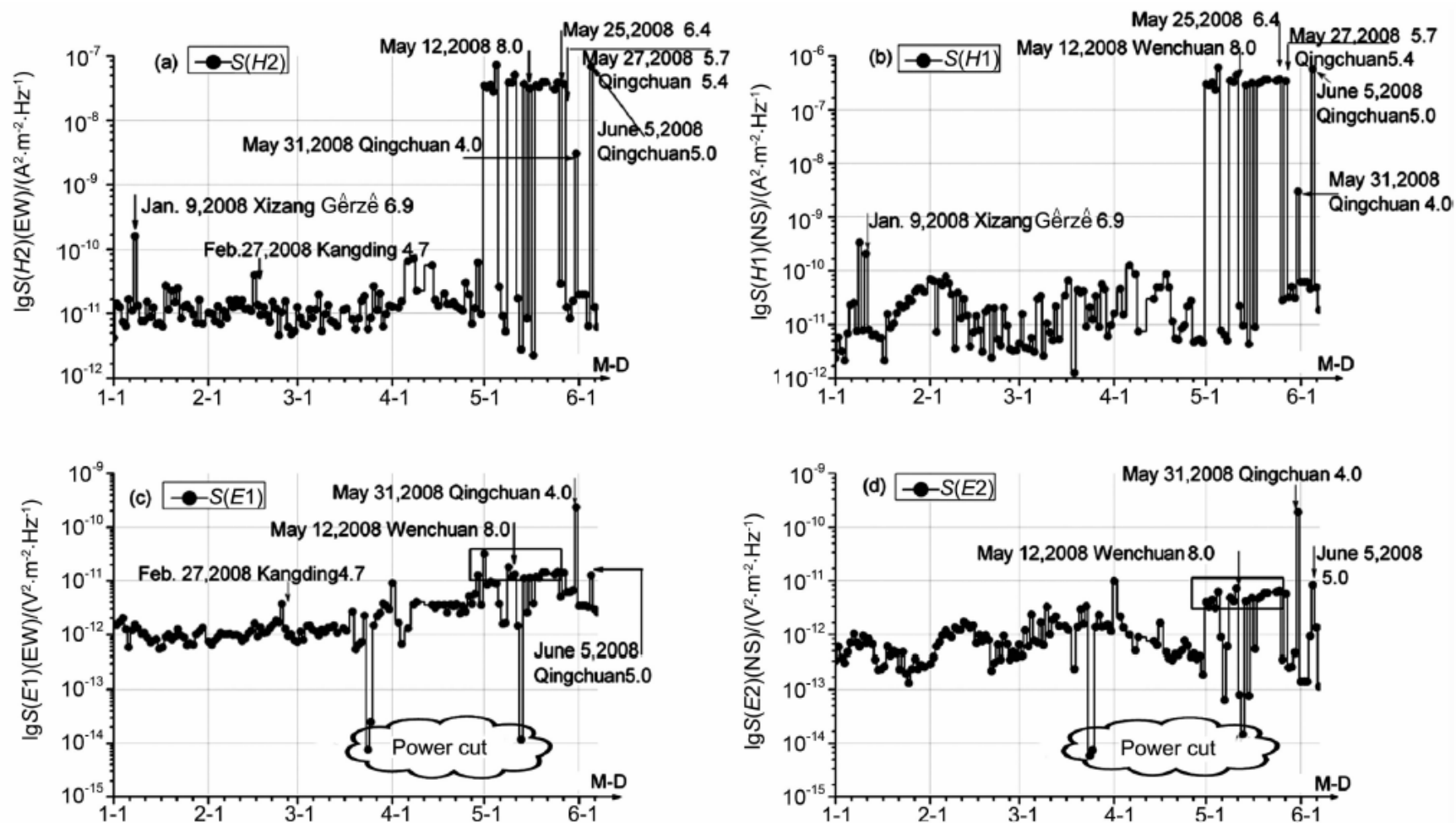
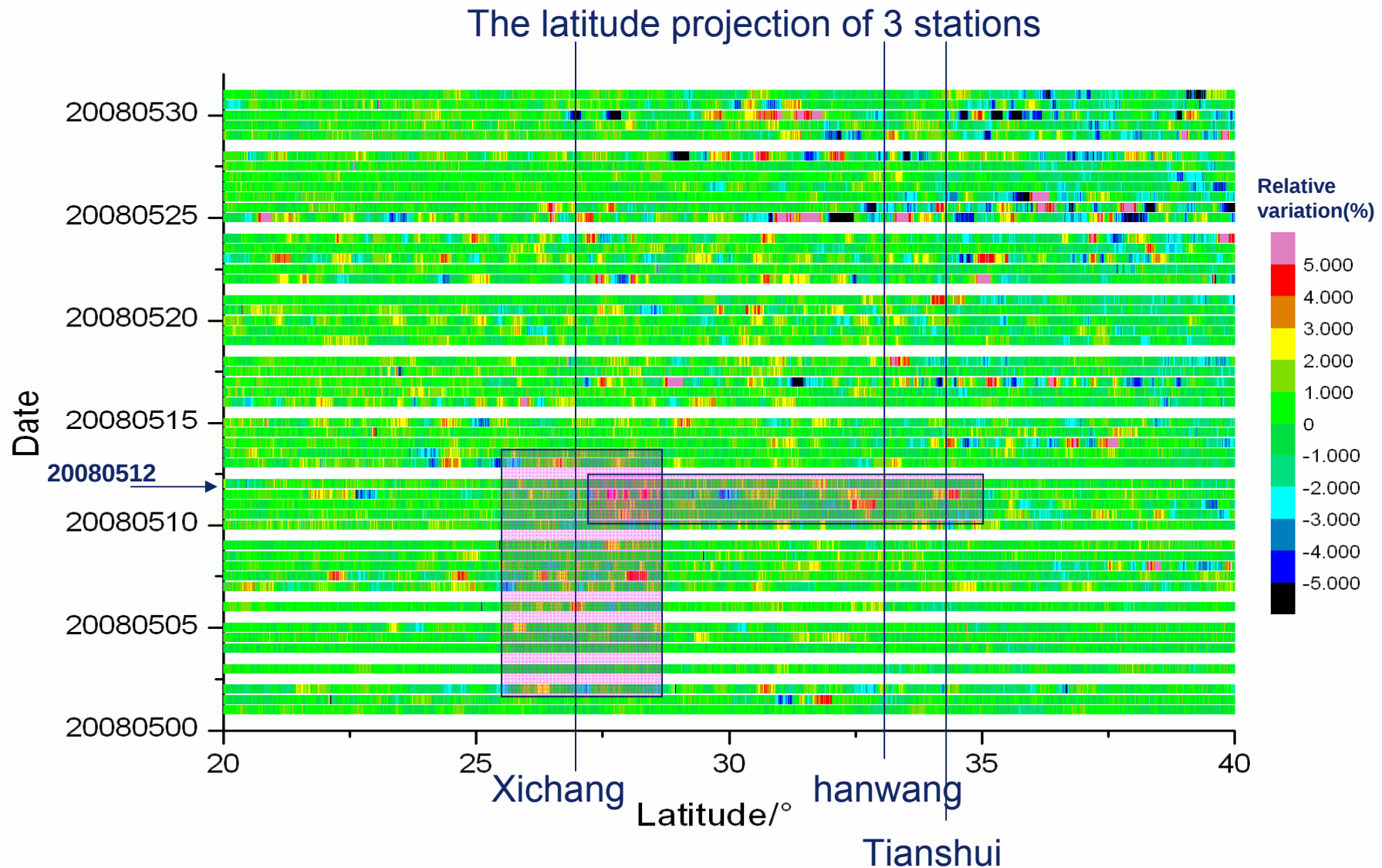


图 7 2008 年 1 月 1 日至 6 月 7 日陇南汉王 ELF 观测的电磁场(1 Hz, $S(H)$, $S(E)$)功率谱曲线

Fig. 7 The auto-spectrum of electromagnetic field of Longnan Hanwang ELF recording (1 Hz, $S(H)$, $S(E)$) from Jan. 1 to June 7, 2008

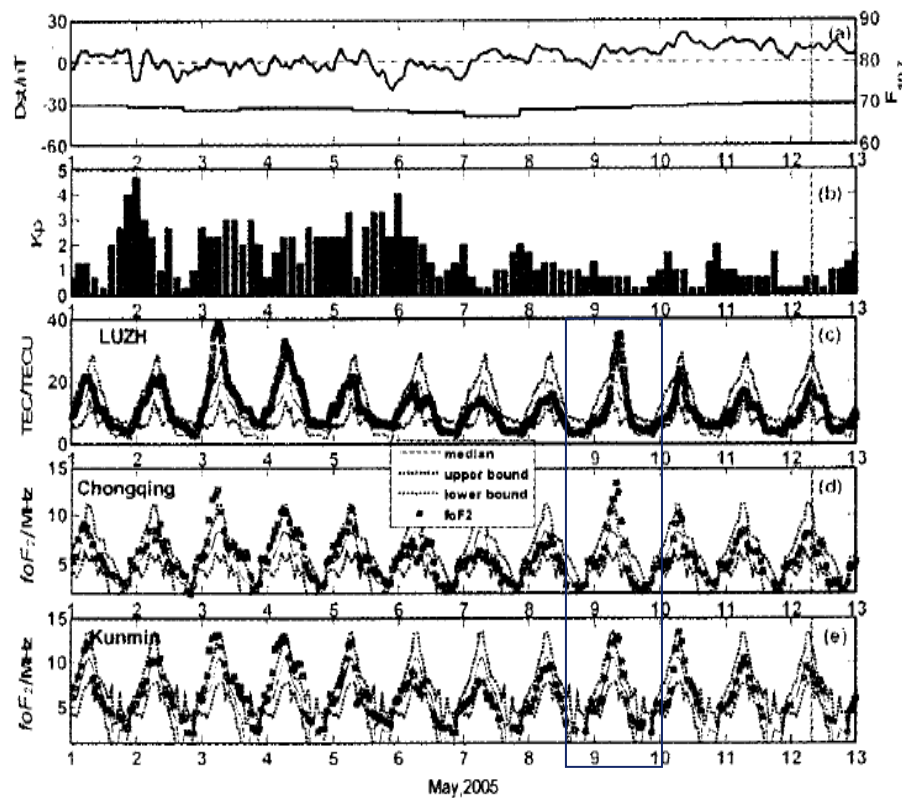
Anomalous signals around Wenchuan earthquake





Other ground-based observation

❖ foF2



Geomagnetic field

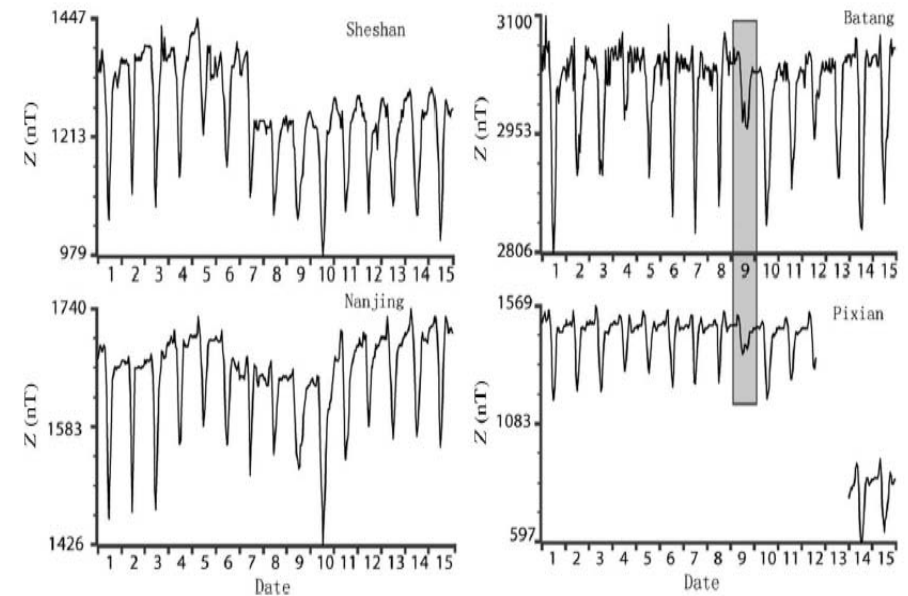
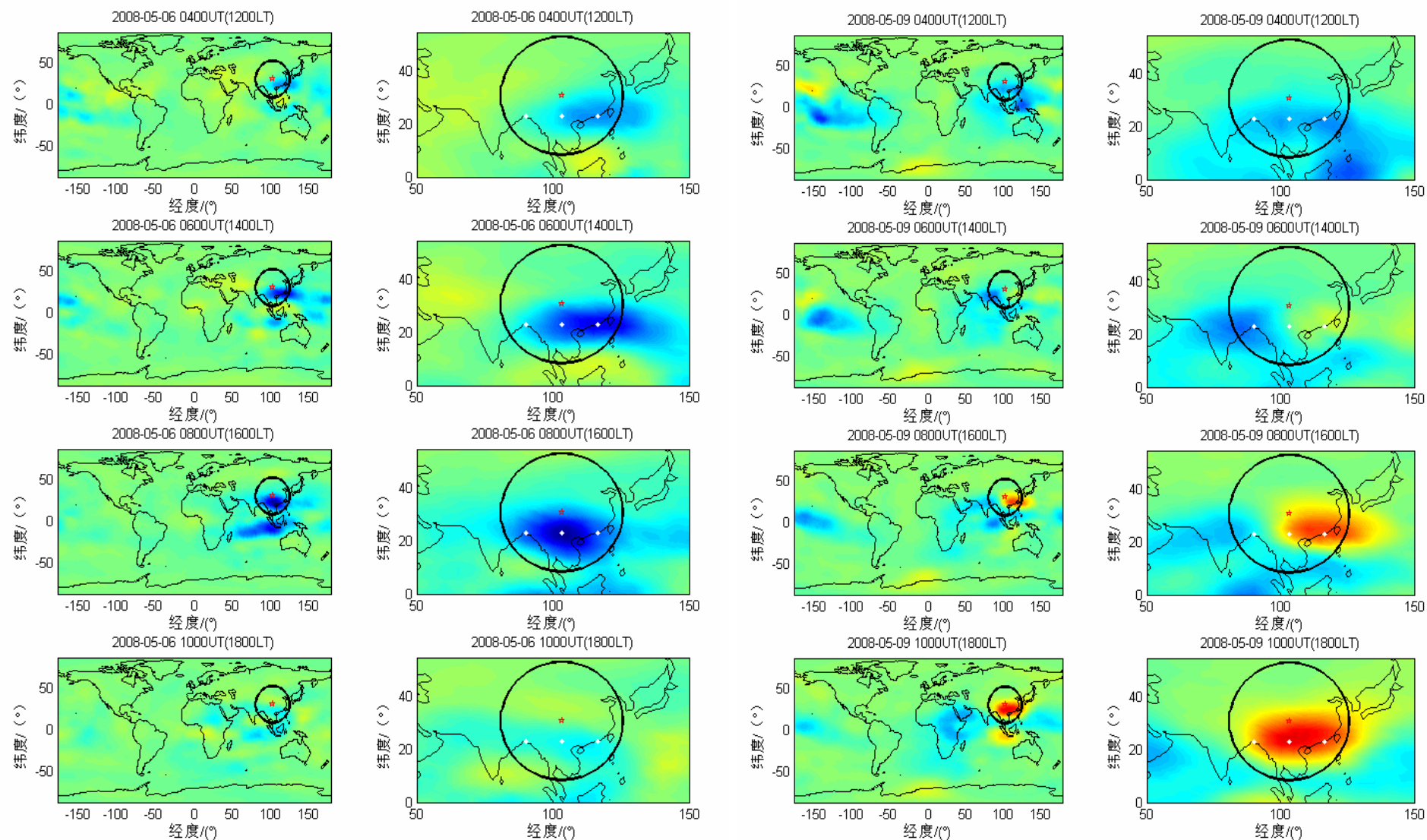


Figure 6. Vertical component of geomagnetic fields observed at four stations at the surface (red rectangle shows the anomalies on 9 May at Batang and Pixian stations near the epicentre).



GPS TEC





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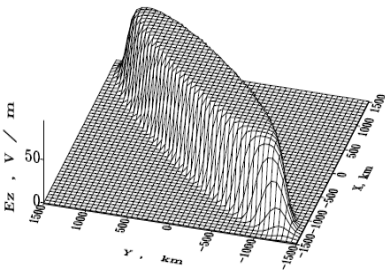
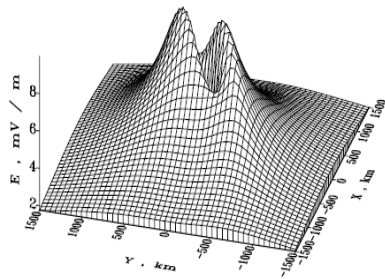


Fig. 3. Spatial distributions of DC electric field calculated for the angle $\beta=45^\circ$ of orientation of the fault axis relatively to magnetic meridian plane. Upper panel: Horizontal component of DC electric field in the ionosphere. Angle of magnetic field inclination is 20° . Lower panel: Vertical component of DC electric field on the ground.

1

DC electric field

**Direct
propagation of
ULF / ELF
electromagnetic
wave from
lithosphere to
ionosphere**

2

**Acoustic gravity
wave**

3

**Precipitation
of high
energy
particles**



Conclusions

1

The periodical variations in ULF electric field by satellite are: annual, seasonal, monthly, diurnal variation.

There are mainly six-kinds of abnormal shapes in ULF electric field.

2

Satellite ULF electric field shows perturbations over the epicentral area with amplitude of about 3-5mV/m a few days before Wenchuan earthquake, especially on May 11, which is consistent with that in ground observation, showing the internal connection between them in time and space domain.

3

The amplitude of ground electric field anomalies was about 3mV/km to 100mV/km, which may be correlated with individual underground electromagnetic conditions. But the direction of anomalies may be affected and controlled by regional stress state.

4

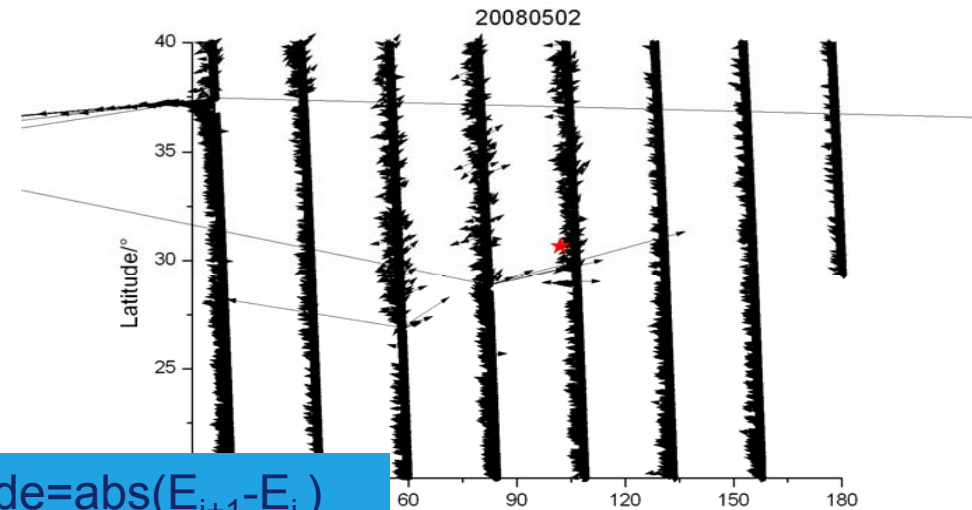
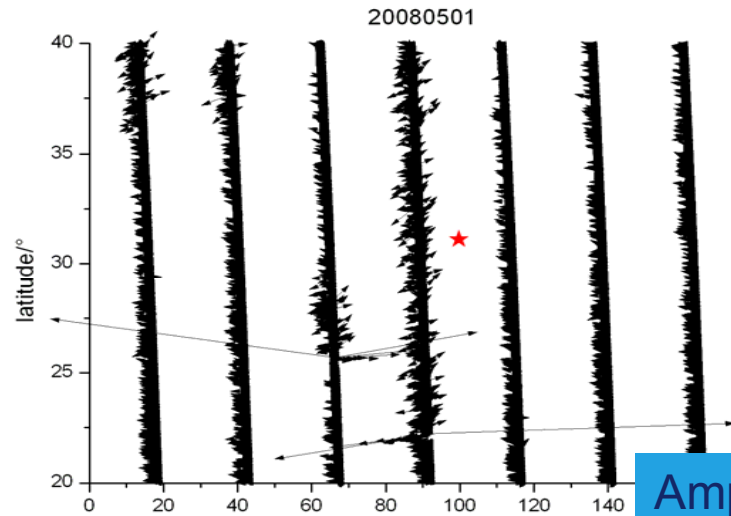
The intensity amplitude differs largely at ground and satellite observation. It is difficult to connect both of them by direct propagation of electromagnetic waves in lithosphere-atmosphere-ionosphere. But acoustic waves excited by ground tremors may be the transmitting media between lithosphere and ionosphere.



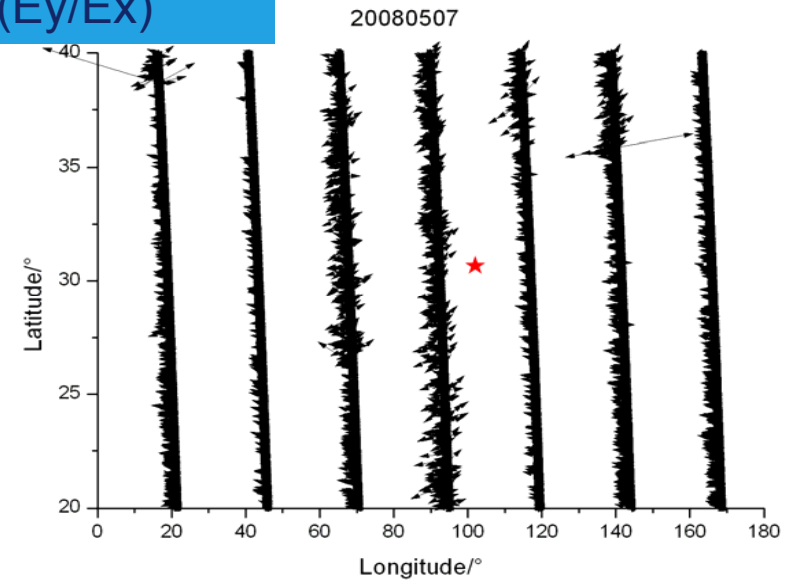
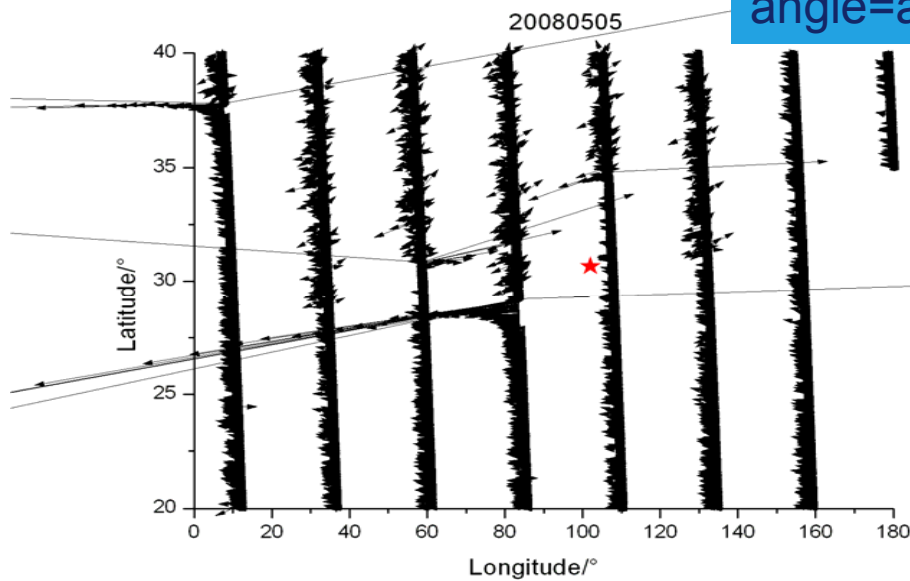
Thanks for your attention !



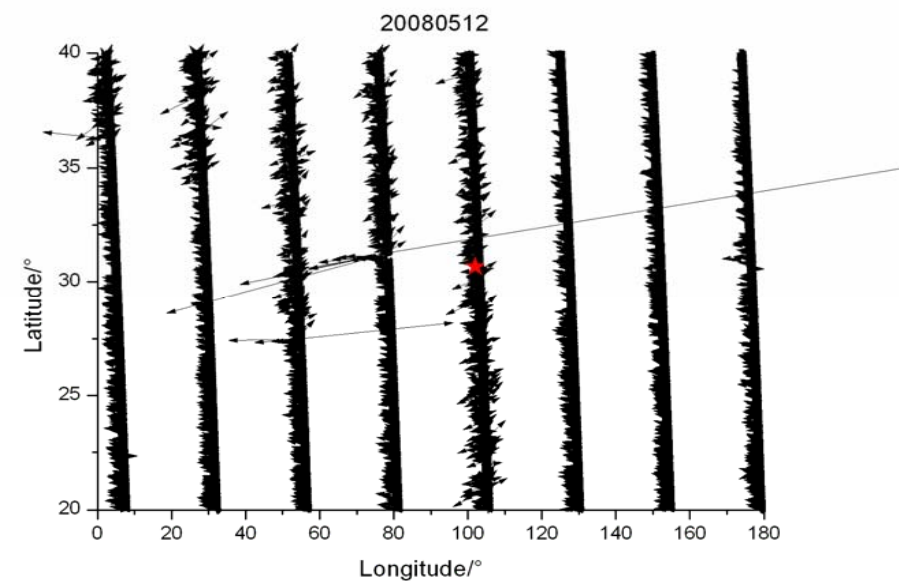
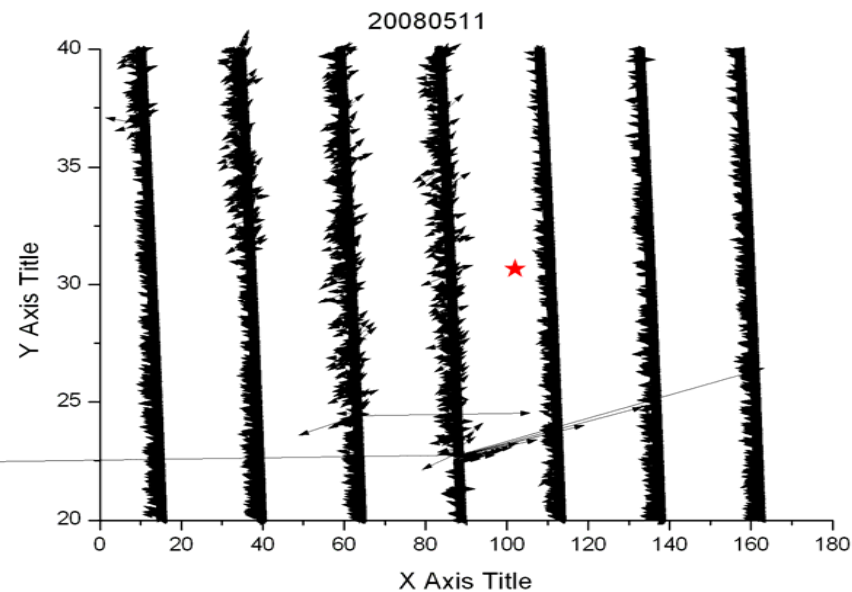
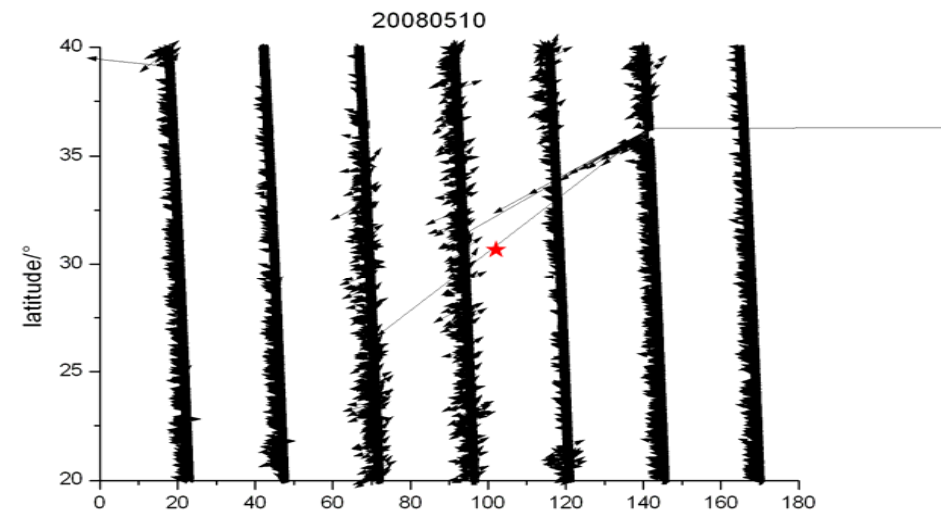
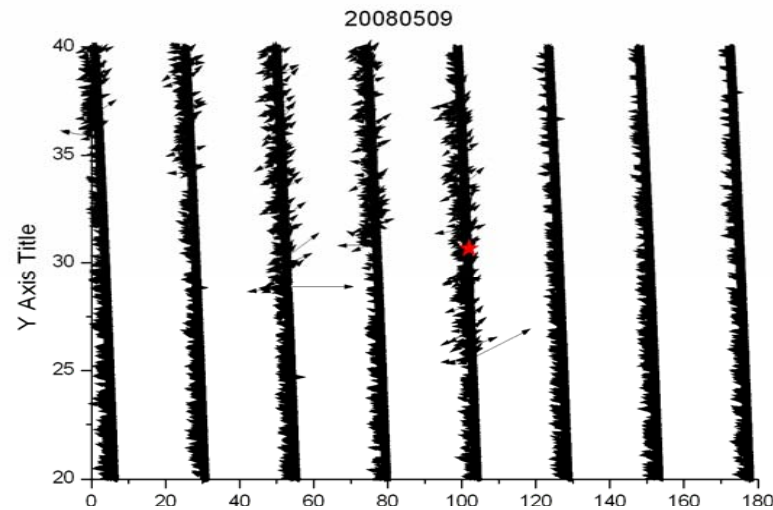
High-speed disturbances in geomagnetic coordinate system



Amplitude= $\text{abs}(E_{i+1}-E_i)$
angle= $\text{arctan}(E_y/E_x)$



High-speed disturbances in geomagnetic coordinate system





Introduction

❖ **Wenchuan M8.0 earthquake on May 12, 2008**

❖ **Previous research**

- GPS TEC
- Plasma parameters
- ELF/VLF electric field

❖ **ULF electric field observation on DEMETER satellite**

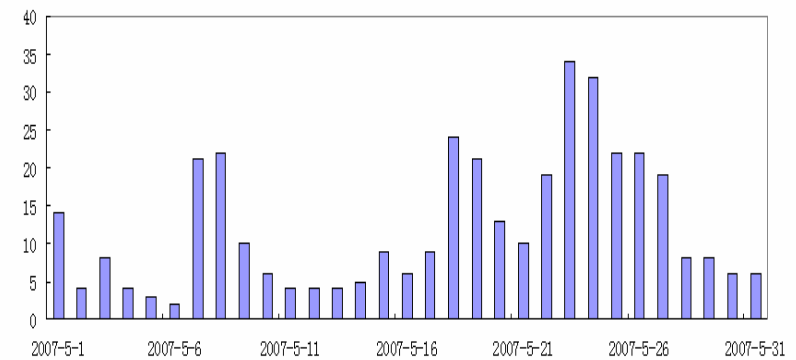
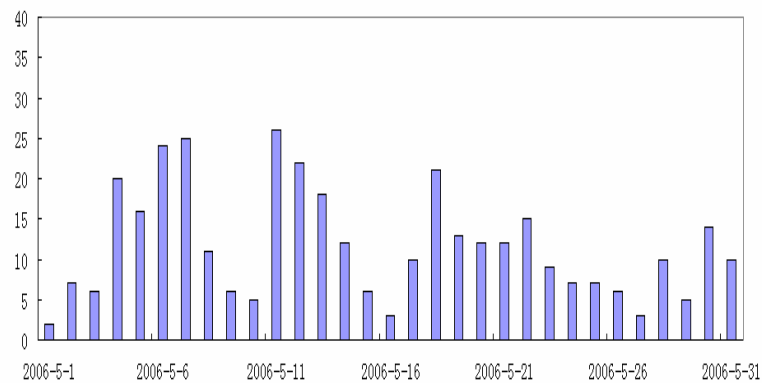
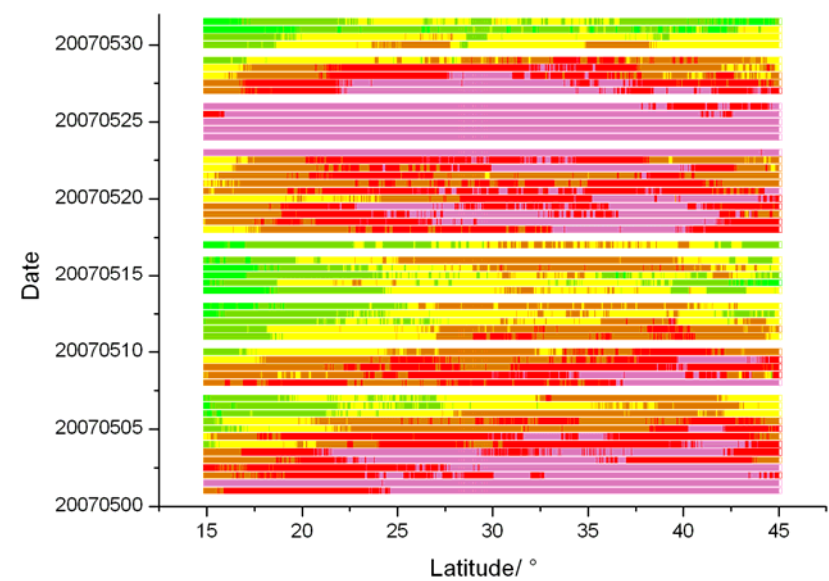
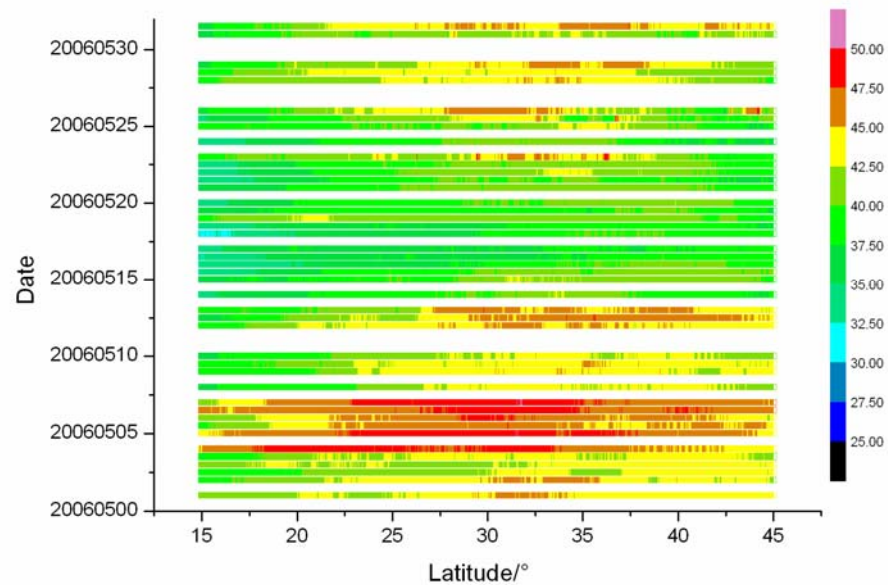


Data analysis on DEMETER ULF electric field

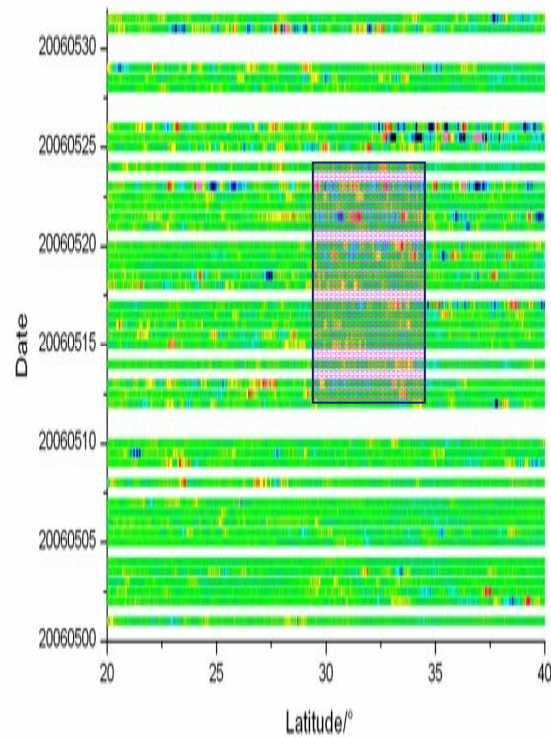


- ❖ **Background** information in ULF electric field by DEMETER satellite
 - Diurnal variation
 - Seasonal variation
 - Annual variation
- ❖ The **typical abnormal shapes** in ULF electric field
- ❖ **Data analysis** of ULF electric field around Wenchuan earthquake

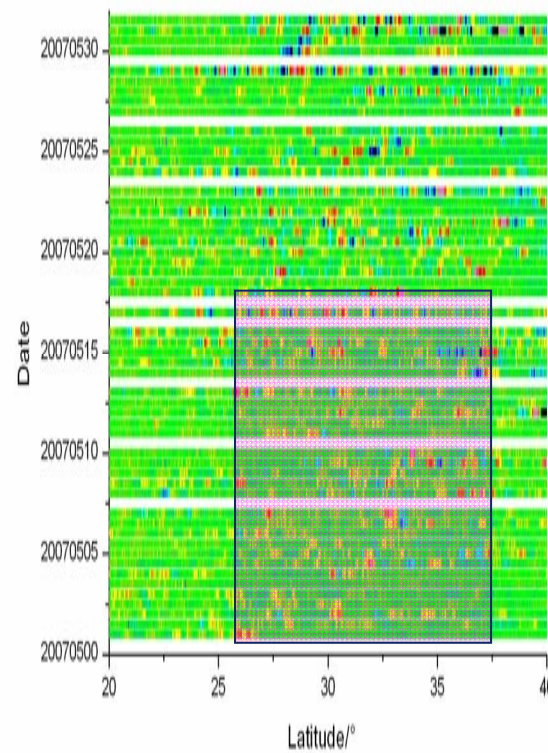
Anomalous signals around Wenchuan earthquake



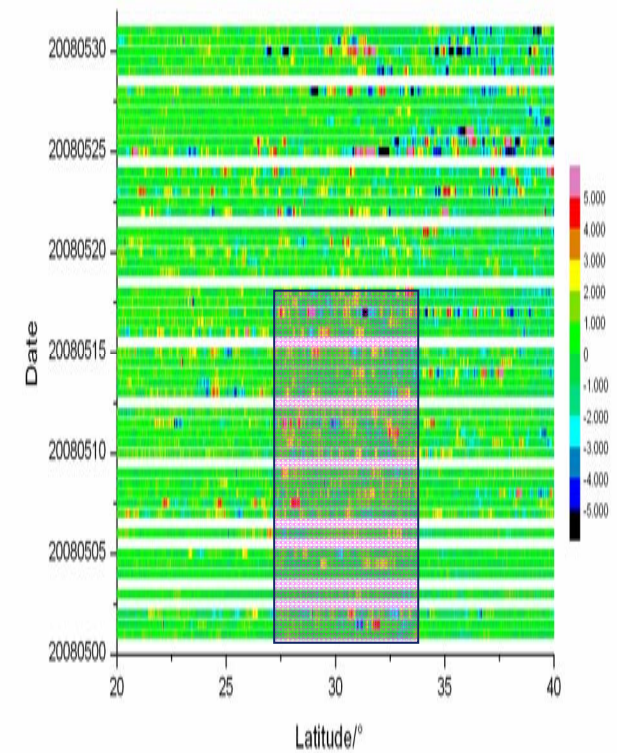
Anomalous signals around Wenchuan earthquake



2006



2007

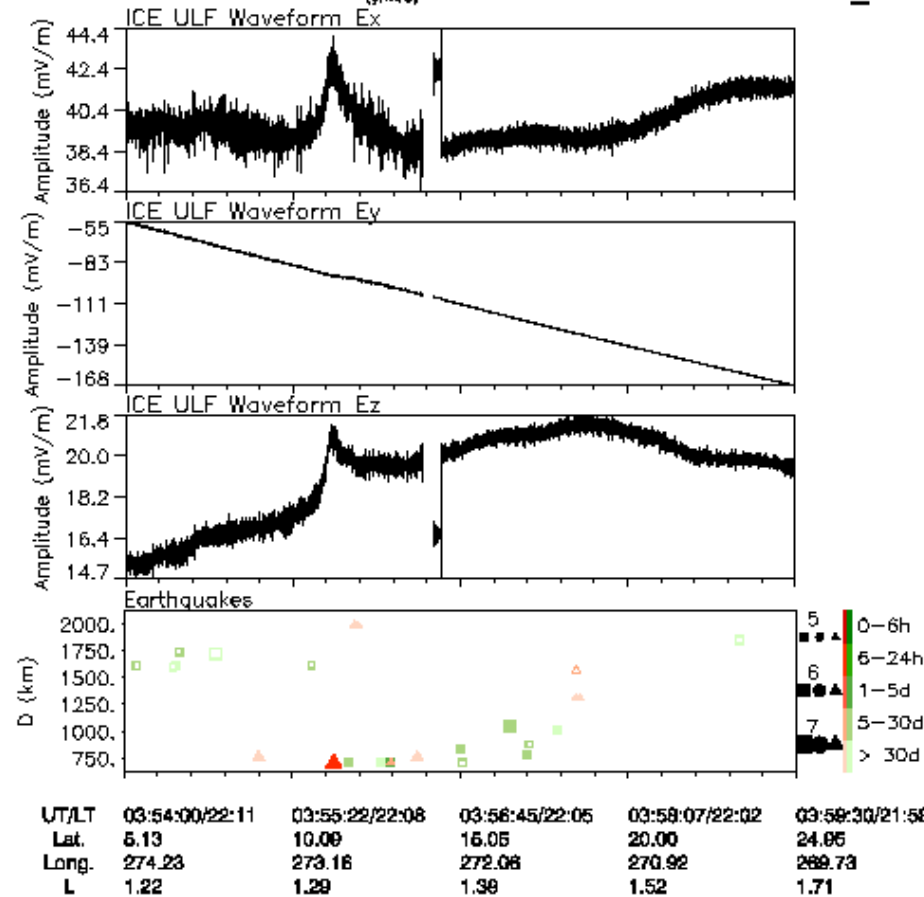


2008

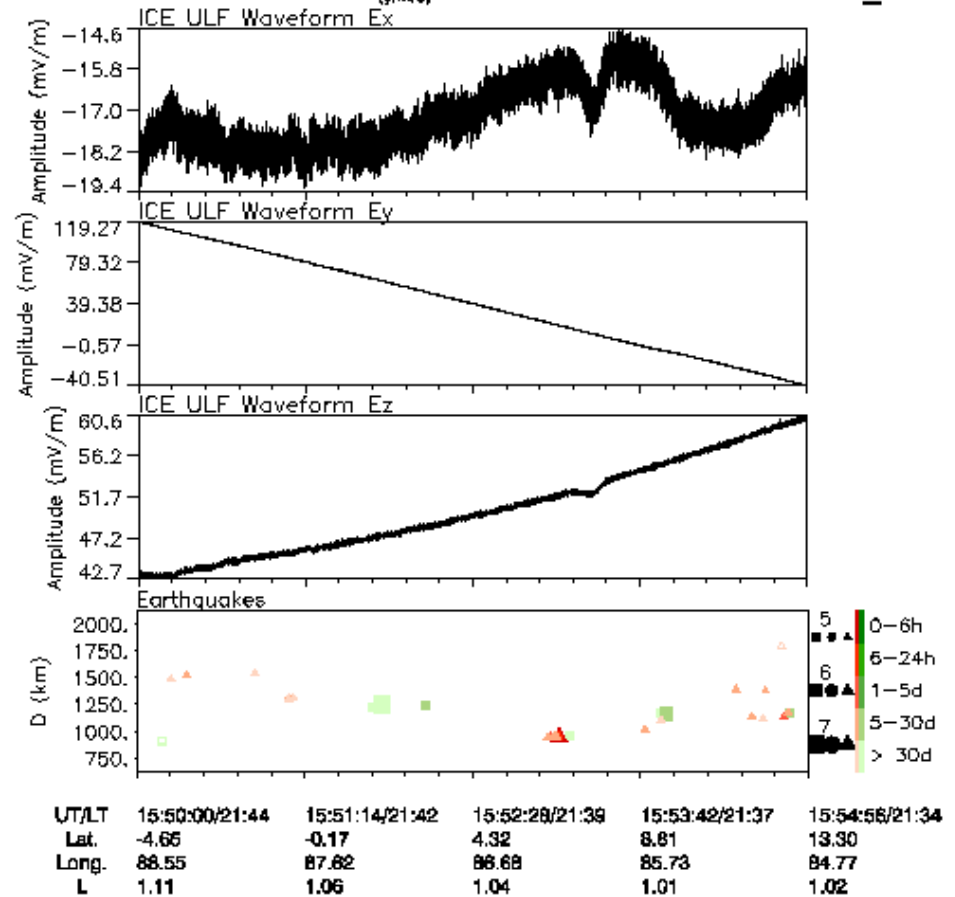
Typical abnormal shapes



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DEMETER Date (yy/mm/dd): 2010/06/12 Orbit: 31821_1

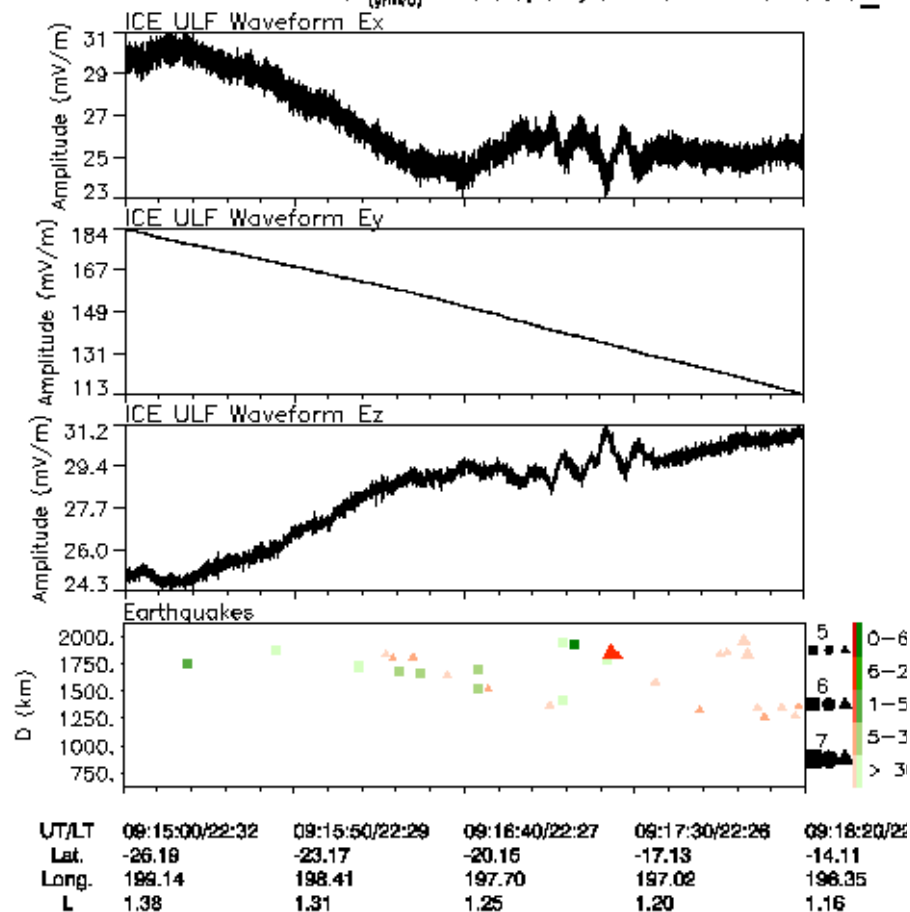


Abnormal-shape curves in ULF electric field single pulse

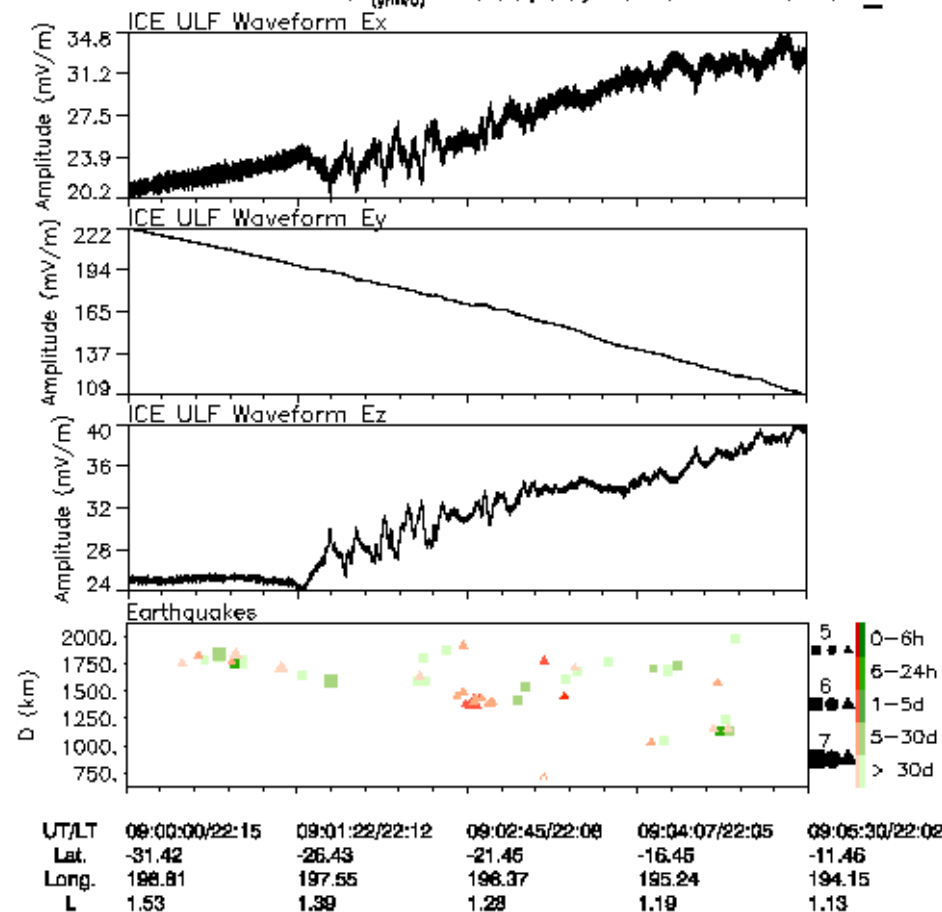
Typical abnormal shapes



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DEMETER Date (y/m/d): 2009/03/16 Orbit: 25161_1

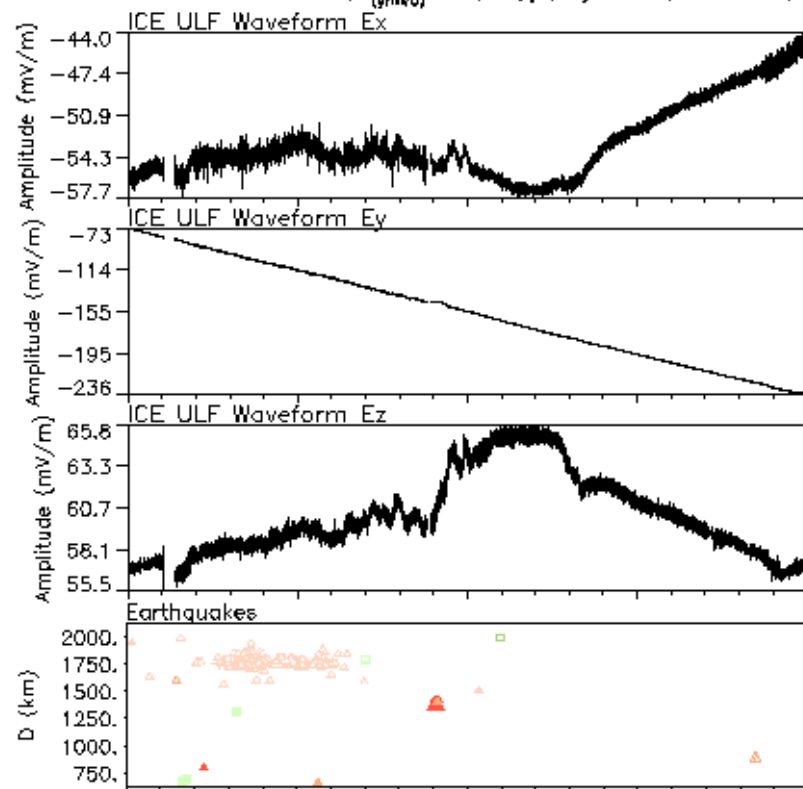


Abnormal-shape curves in ULF electric field regular waveform

Typical abnormal shapes

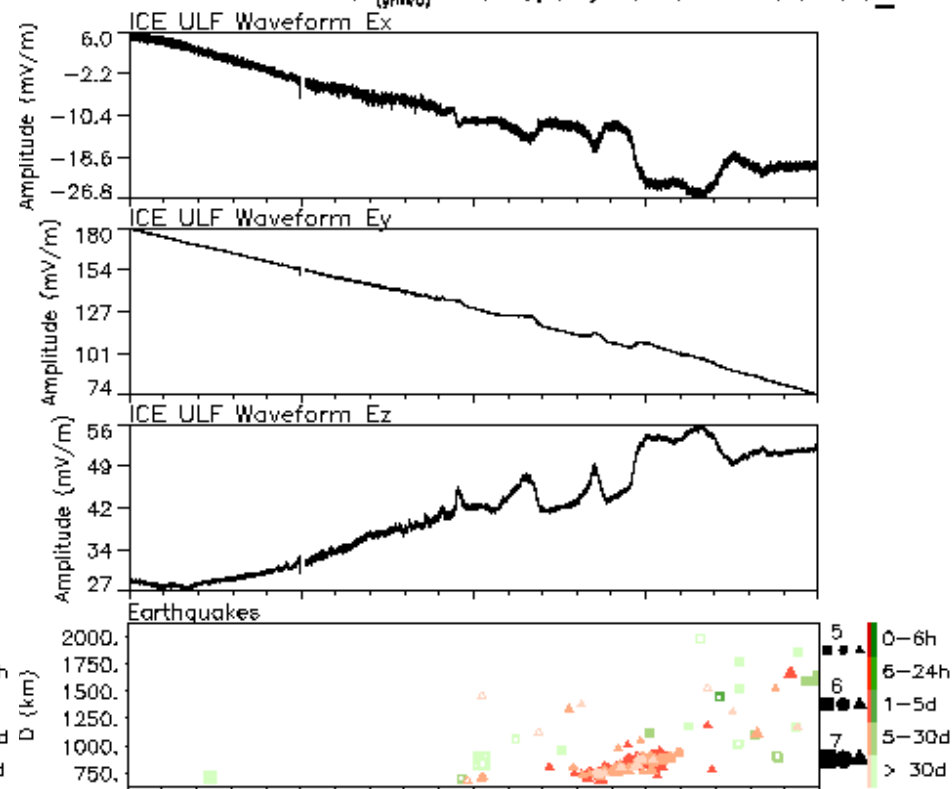


DEMETER Date (y/m/d): 2010/01/11 Orbit: 29579_1



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Lat.	7.85	15.07	22.28	29.49	36.68
Long.	300.99	299.44	297.81	296.06	294.11
L	1.36	1.50	1.72	2.07	2.65

DEMETER Date (y/m/d): 2010/02/26 Orbit: 30256_1



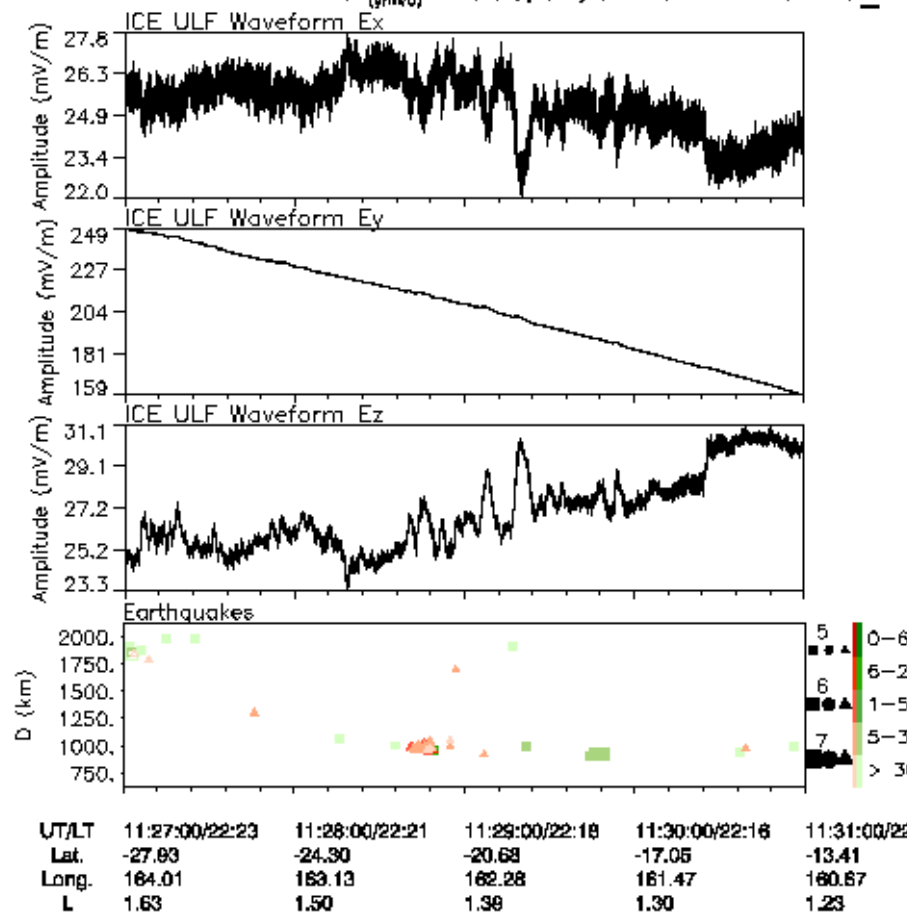
UT/LT	03:10:30/22:47	03:12:58/22:29	03:15:29/22:17	03:17:58/22:08	03:20:29/22:01
Lat.	-62.37	-63.55	-44.61	-36.61	-26.57
Long.	294.20	298.98	285.37	282.56	280.19
L	2.40	1.83	1.51	1.32	1.20

Abnormal-shape curves in ULF electric field **big step variation**

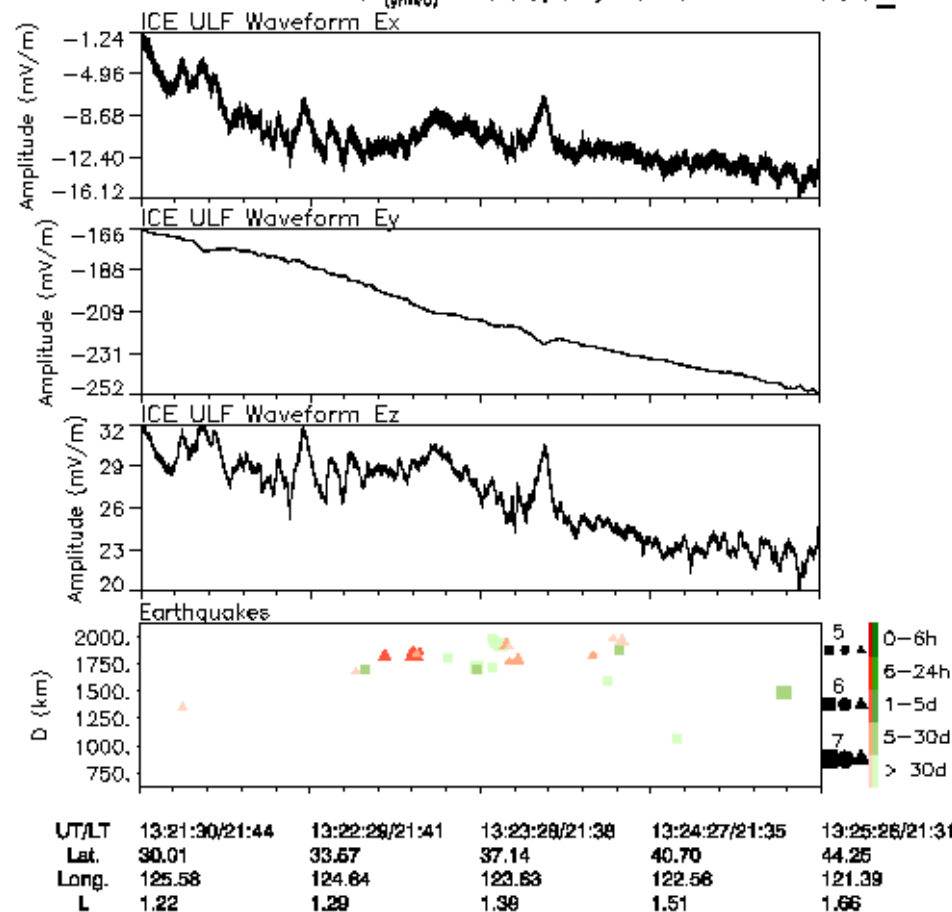
Typical abnormal shapes



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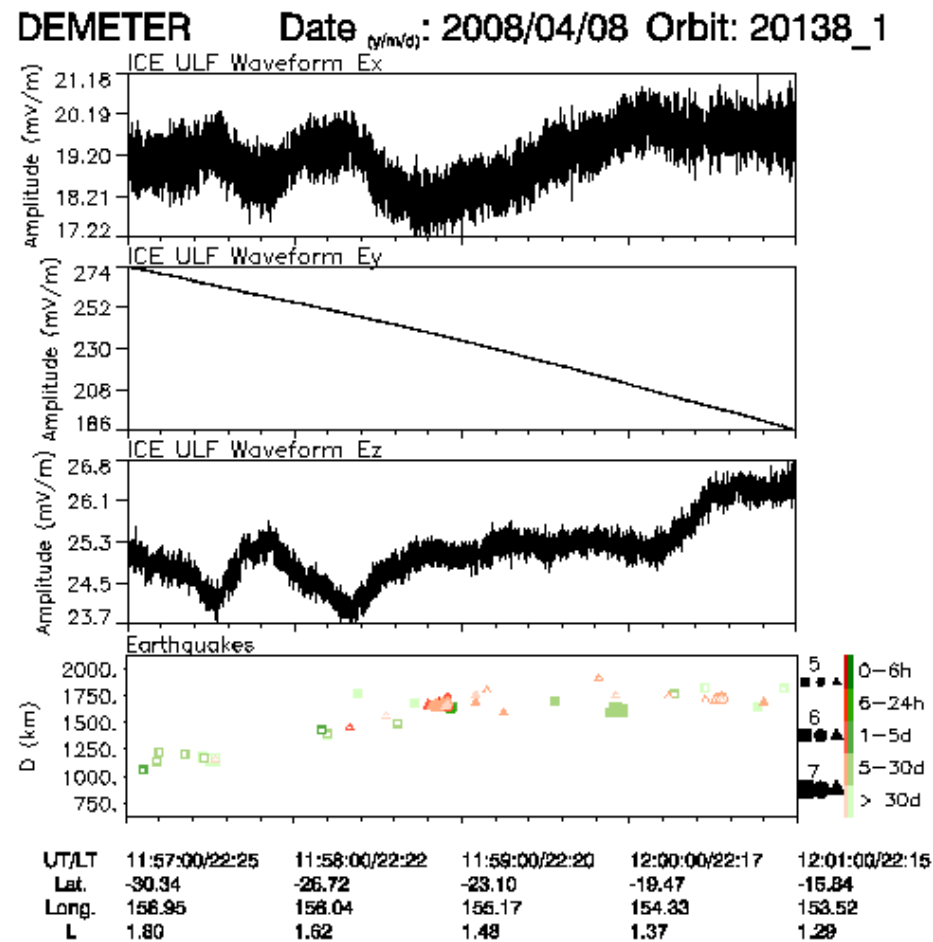
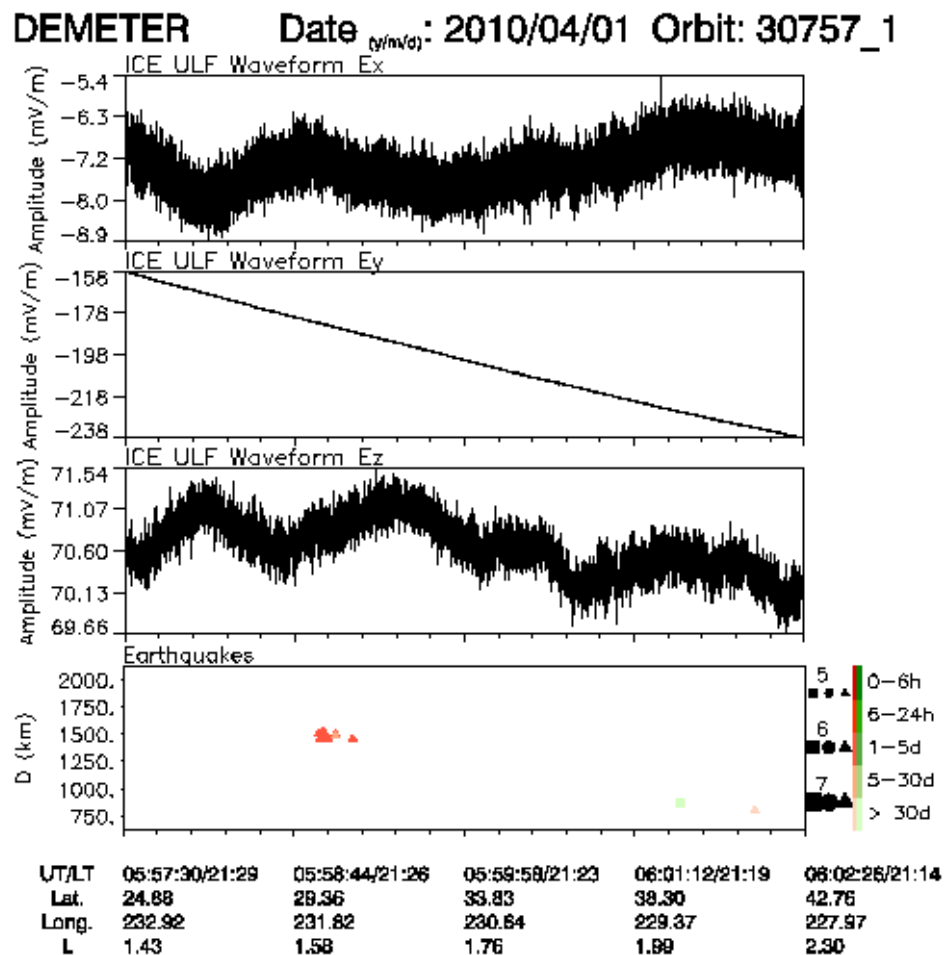
DEMETER Date (y/m/d): 2008/07/16 Orbit: 21593_1



Abnormal-shape curves in ULF electric field combing

irregular periodical signals pulse+regular waves

Typical abnormal shapes



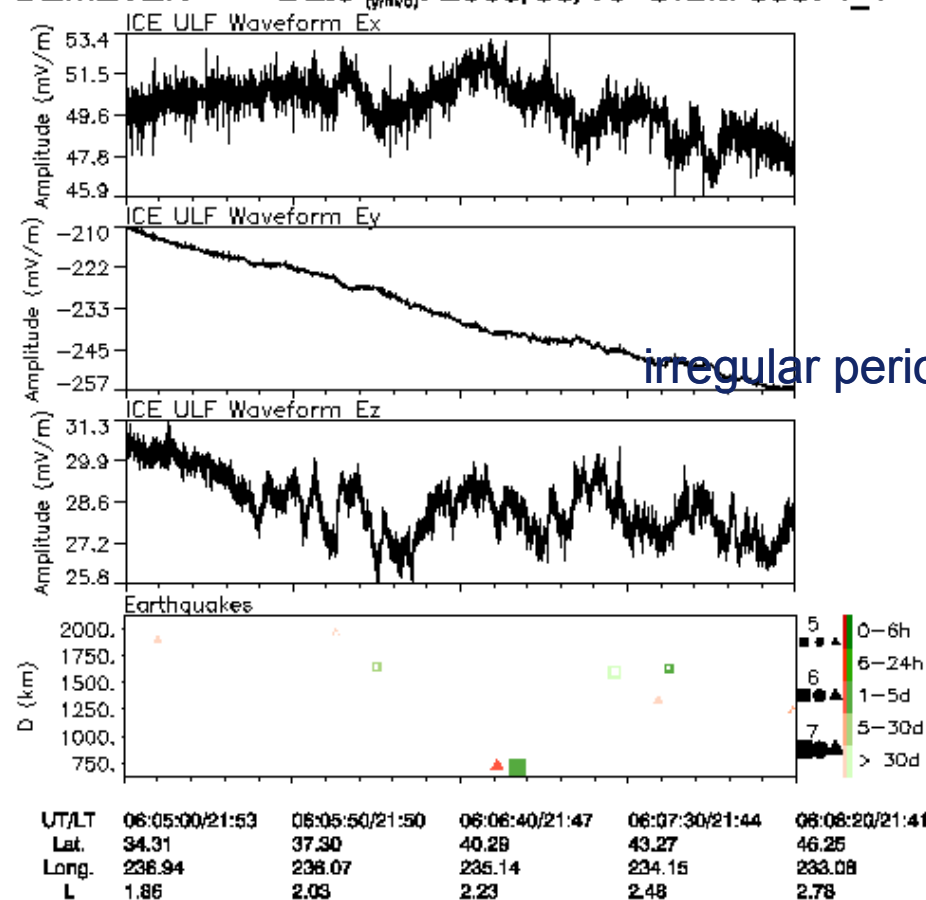
Abnormal-shape curves in ULF electric field

Long period modulation

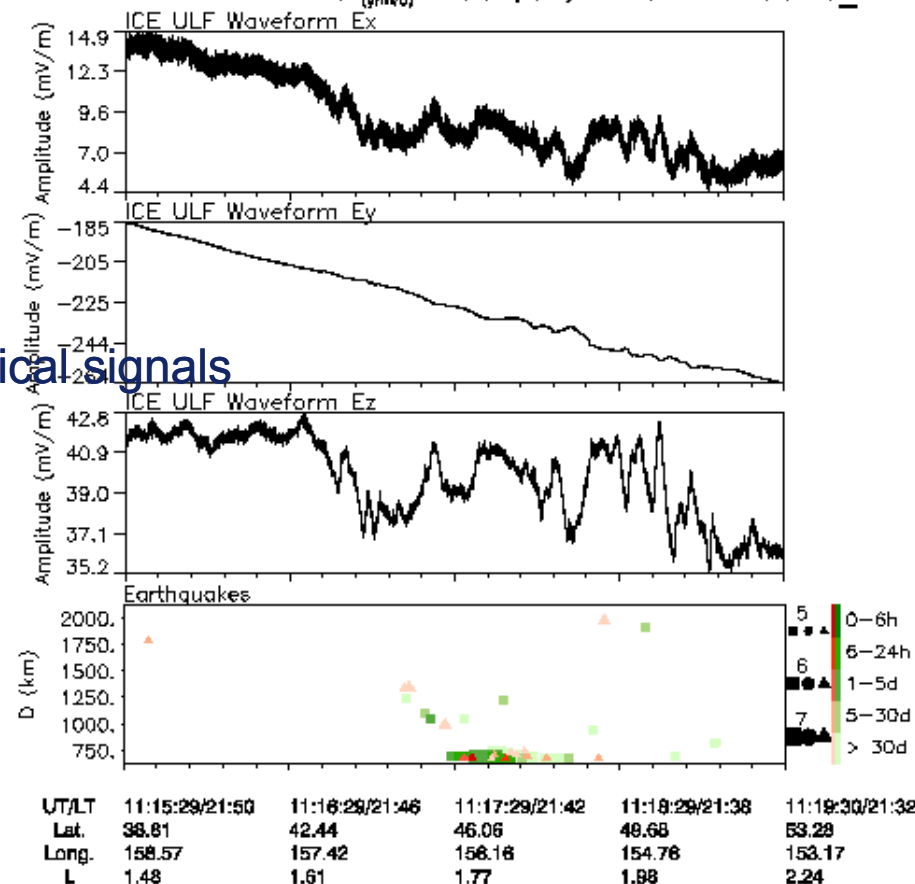
Typical abnormal shapes



DEMETER Date (y/m/d): 2005/06/16 Orbit: 05074_1



DEMETER Date (y/m/d): 2007/01/14 Orbit: 13528_1



Abnormal-shape curves in ULF electric field

Step variation+irregular waves