小林村堰塞湖潰堤洪水歷程之震動訊號分析

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國立中興大學 水土保持學系

Oct. 27, 2011

小林村複合型災害
-崩塌、堰塞壩潰歷程

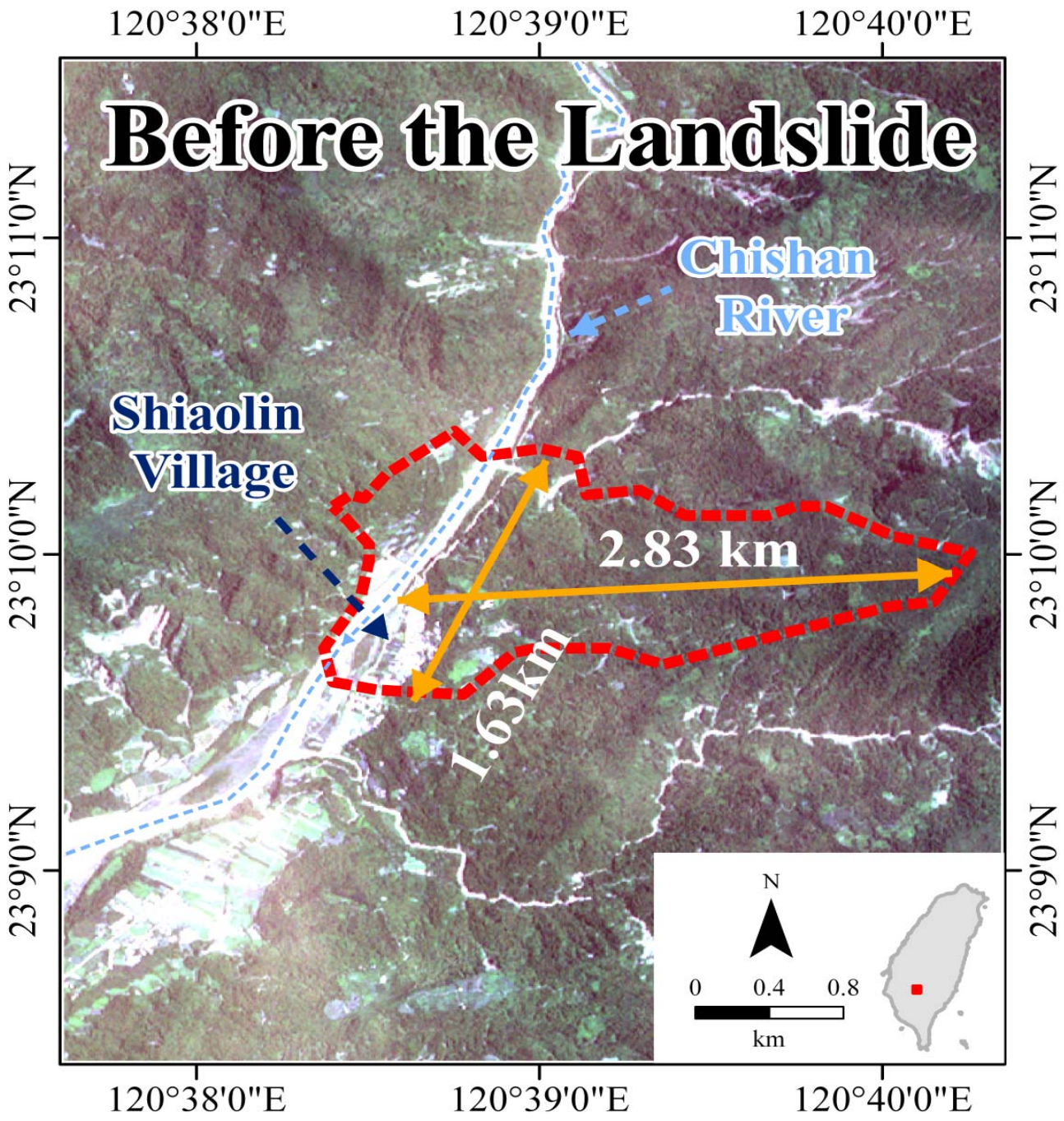
- 兩年前的8月9日那天 …
- 小林村發生複合型災害 Rock slide, rock avalanche, landslide dam breach …
- 自然界的「全尺寸試驗」，我們學到了那些教訓…?

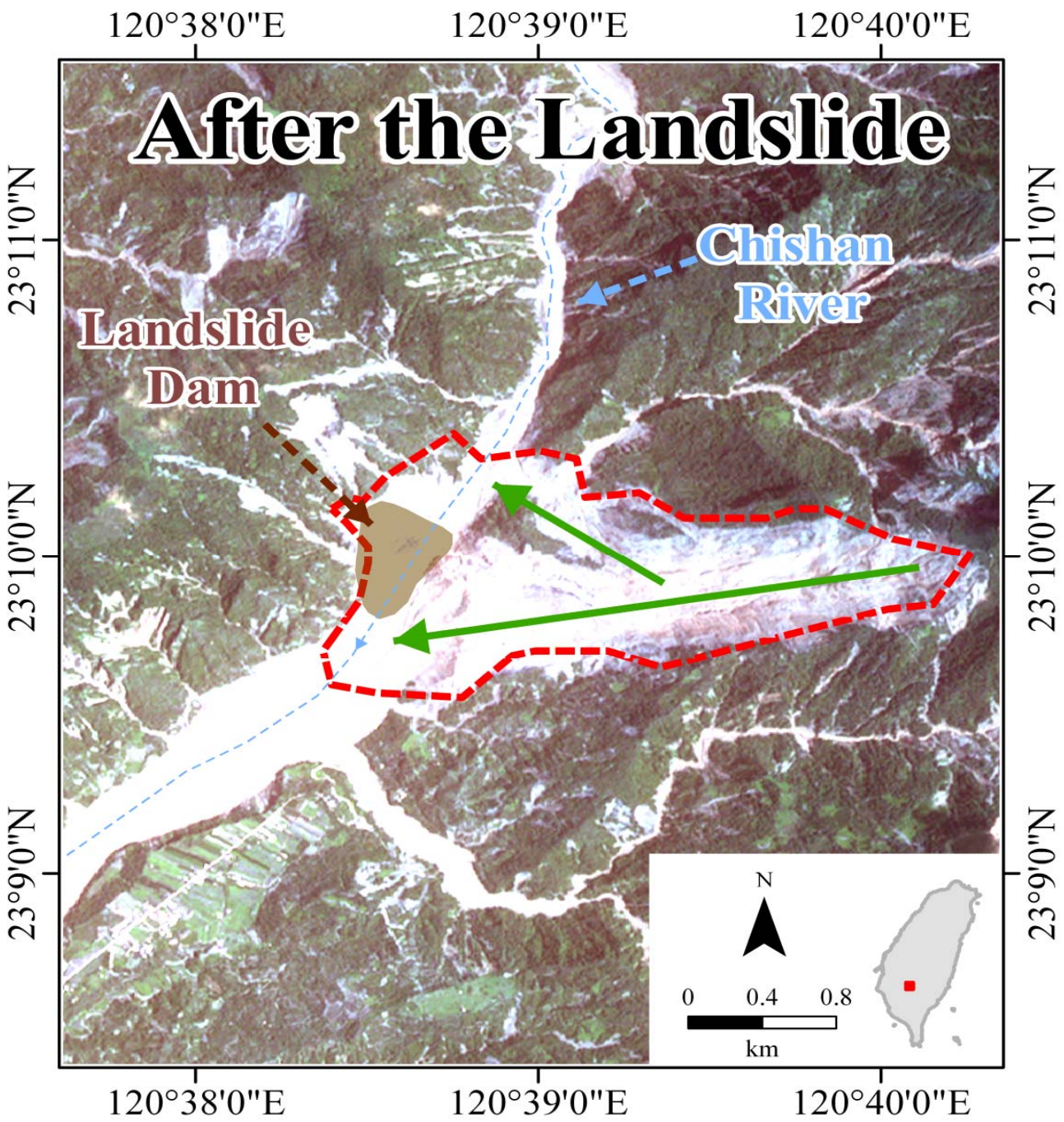
小林村複合型災害
-崩塌、堰塞壩潰歷程

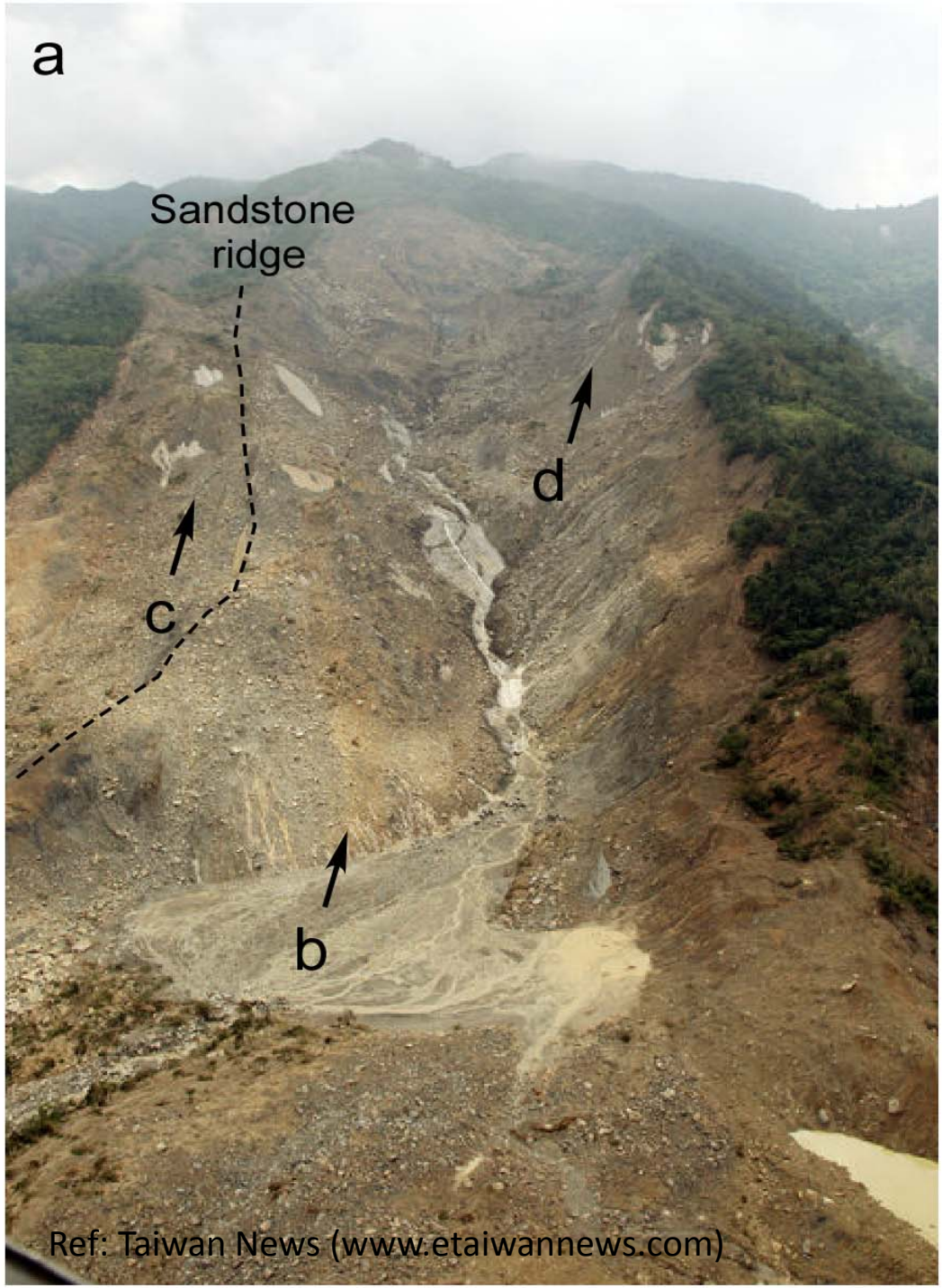
- 兩年後我們多增加瞭解了那些災害的歷程?
  - 何時堰塞湖潰堤?
  - 流速多快?
  - 洪水發生多久?
  - ...
- 從小林村獻度山岩石滑動(rock slide)與堰塞湖潰堤洪水談起...

小林村深層崩塌

- 地形與地質的調查


Before the Landslide
Chishan River
Shiaolin Village
2.83 km
1.63km
120°38'0"E
120°39'0"E
120°40'0"E
23°11'0"N
23°10'0"N
23°9'0"N
N
0
0.4
0.8
km

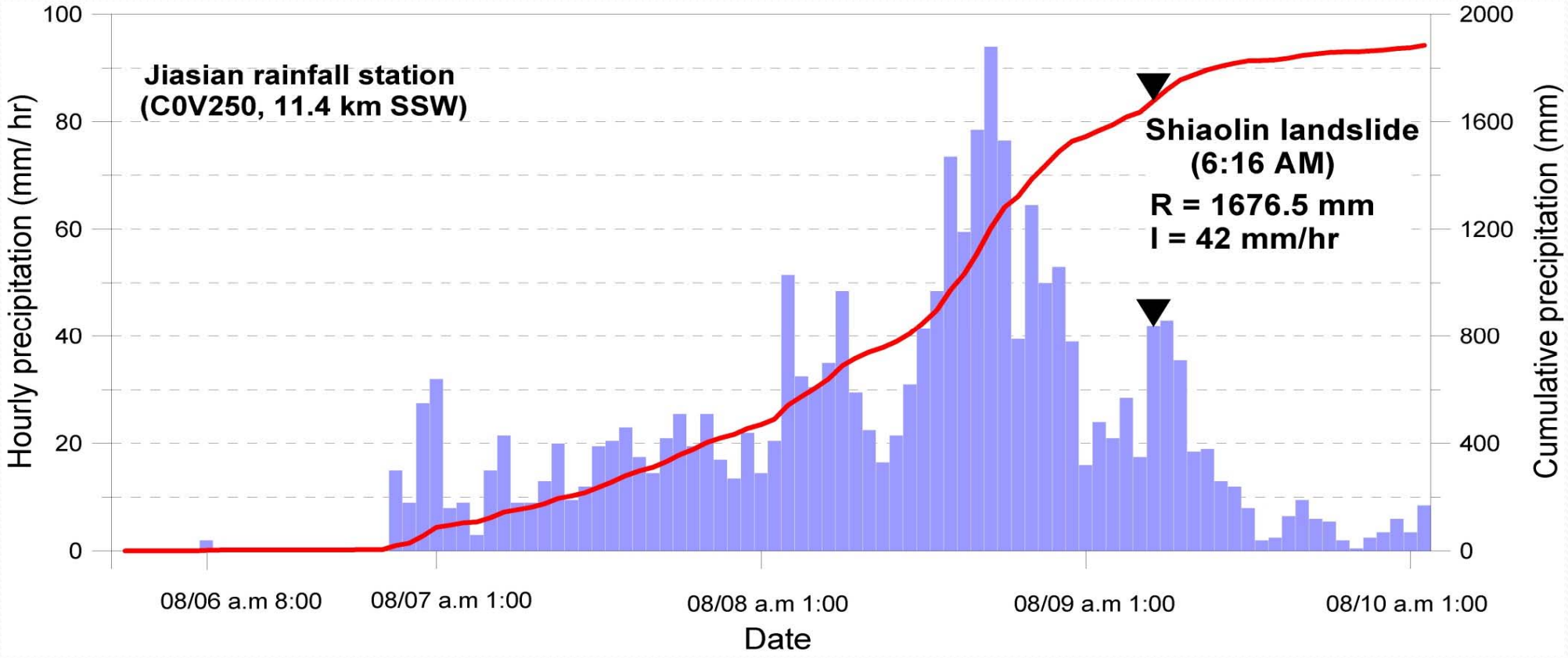

After the Landslide
Chishan River
Landslide Dam
120°38'0"E
120°39'0"E
120°40'0"E
23°11'0"N
23°10'0"N
23°9'0"N
N
0
0.4
0.8
km



Ref: Taiwan News (www.etaiwannews.com)

梯隊節理

Rainfall triggered deep-seated landslide



Ref: Central Weather Bureau

Key points - geomorphology & geology

- structural factors, weathering, and gravitational slope deformation were the underlying causes of the landslide.

- **Ching-Ying Tsou, Zheng-Yi Feng, Masahiro Chigira (2011) "Catastrophic landslide induced by Typhoon Morakot, Shiaolin, Taiwan", Geomorphology,** Volume 127, Issues 3-4, 15, April 2011, Pages 166-178, 2011. **doi:10.1016/j.geomorph.2010.12.013 (SCI).**

小林村崩塌

- 所引起之震動特性

中央氣象局
Central Weather Bureau

Geophysical Database Management System
地球物理資料管理系統

會員登入
MEMBER LOG-IN
帳號
密碼
登入
加入會員 忘記密碼

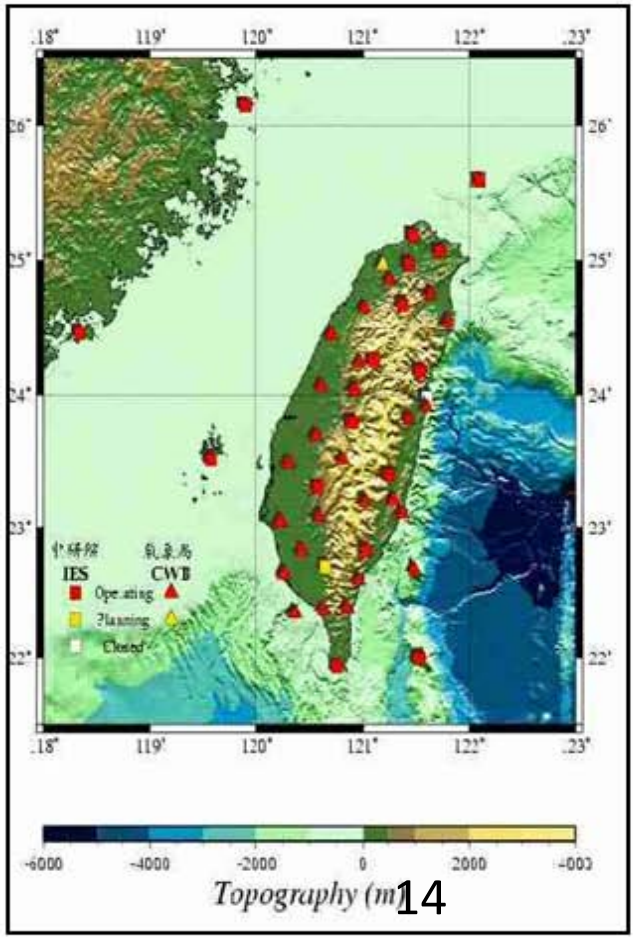
查詢與下載
歷史地震資料下載
連續地震資料下載
地震測站資料查詢
系統搜尋
即時地震觀測網
自由場強地動觀測網

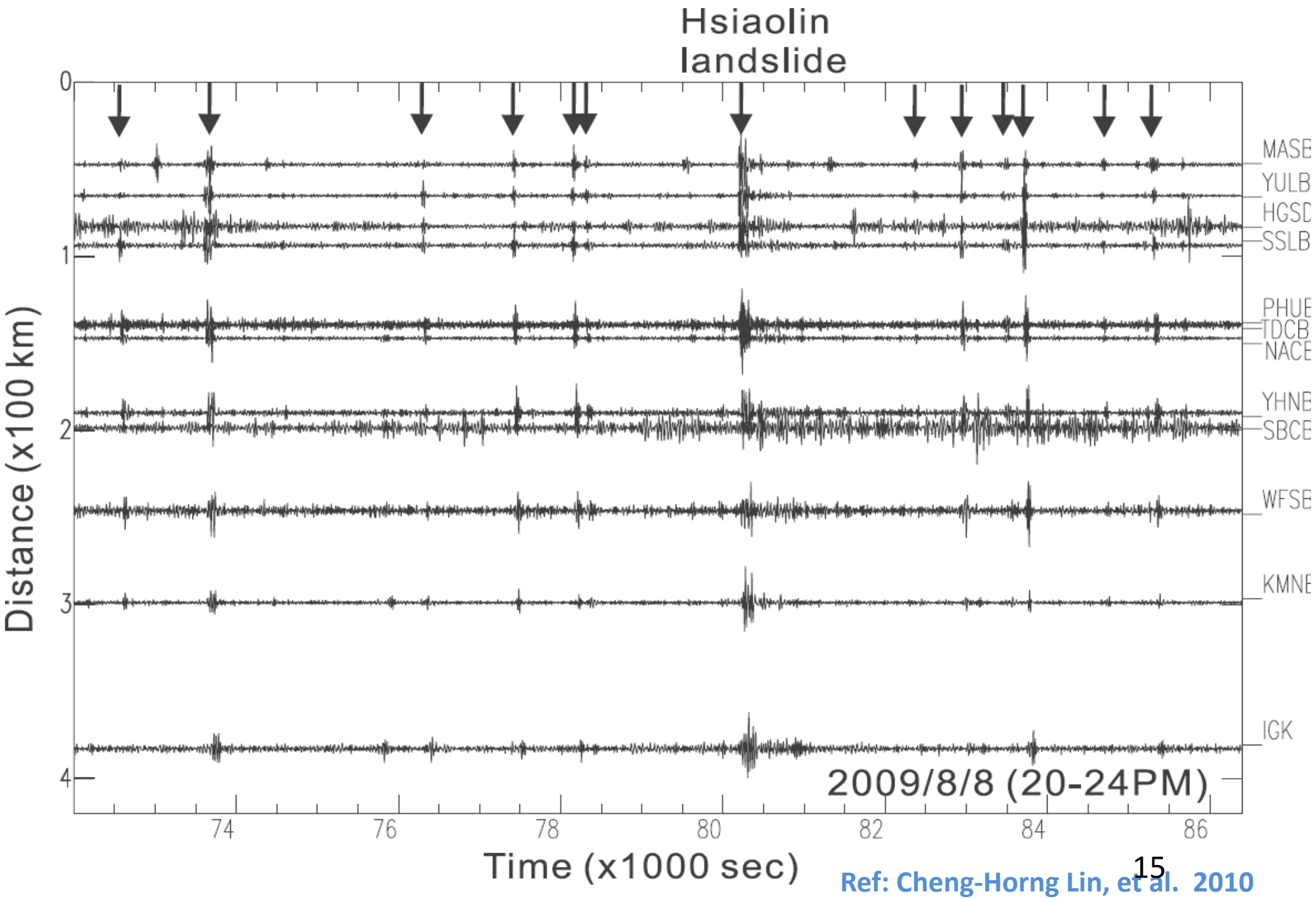
寬頻地震網

繼中研院地球科學研究所於1992年設置第一部寬頻地震儀之後，本局自2000年參與國科會「地震及活斷層研究」跨部會大型整合計劃，配合中研院及中央大學既有寬頻測站之位置，2001年設置龍潭、安塑、小琉球、旗山、永康、西林、古坑、綠島、利稻等9站；2002年設置雙連埤、六角、嘉蘭、成功、甲仙、大坪頂、阿里山、壽山、春日、鹽寮、松安等11站。並於安塑、旗山、西林、綠島、利稻、雙連埤、成功、阿里山、春日、松安等站增設強震感應器，藉以彌補測站遭遇近震及較大地震時，造成紀錄滿格之缺失。各測站所收錄之資料，藉由中華電信數據網路專線傳回本局地震測報中心之寬頻記錄系統進行處理。

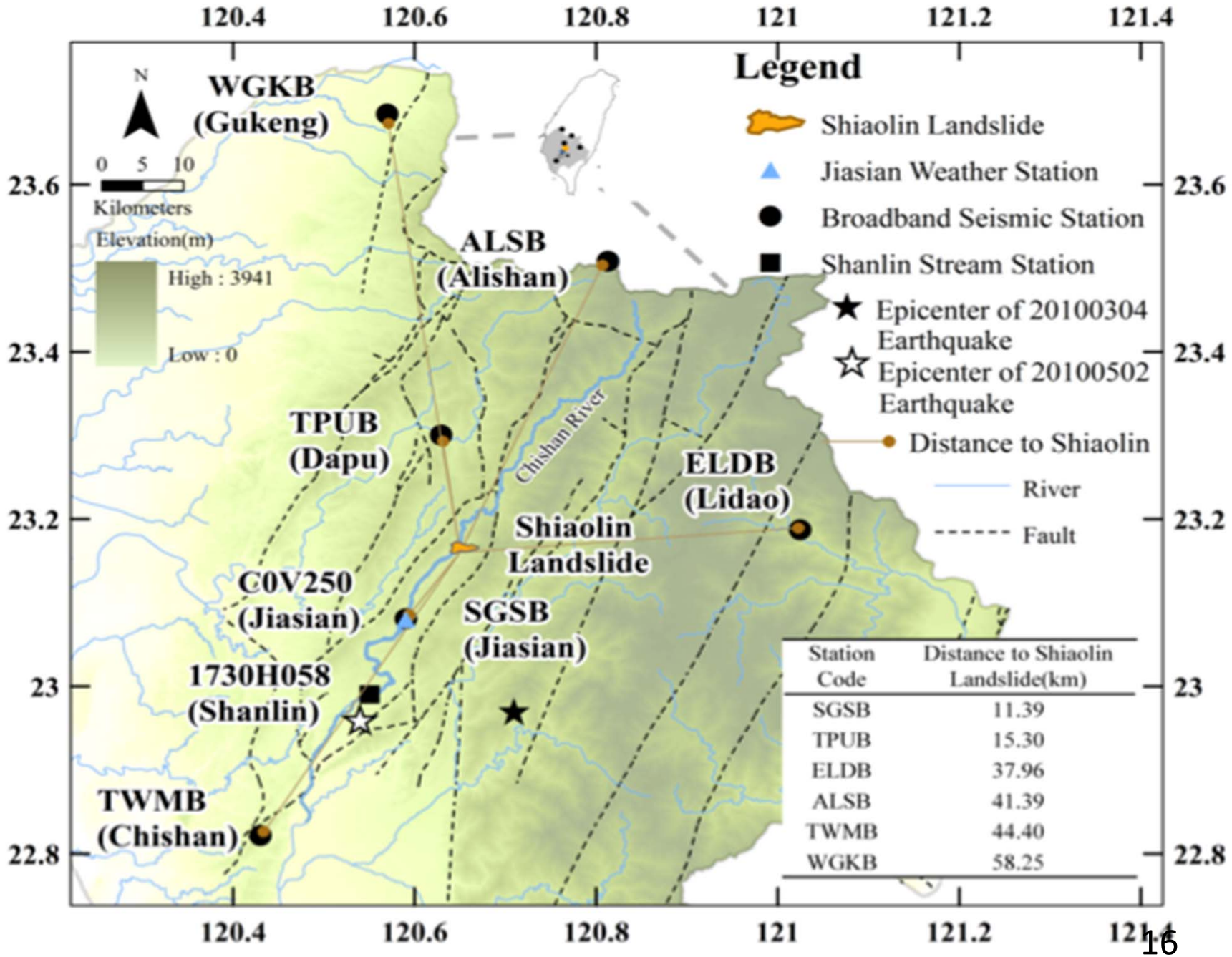
本局所設置之寬頻地震網、中研院地科所寬頻地震網以及中央大學寬頻地震站併稱為「台灣寬頻地震網(Broadband Array in Taiwan for Seismology, BATS)」(目前共計有42站)，所收錄的地震資料相互即時交換及處理，以達到資源共享之目標，其中中央大學寬頻地震站(6站)已於2003年撥交予本局管理。

由於寬頻地震儀可記錄波動的頻率範圍較為寬廣，以及其感應器較靈敏之特性，能夠記錄到內涵豐富並優質的地震波形，有效彌補加速度型與傳統窄頻式速度型地震儀記錄震波訊息之不足，進而提升地震定位與規模計算的精準度。藉由分析斷層面破裂過程之完整地震波形紀錄，更有助於了解台灣及鄰近地區大地構造與地震活動之關連性。

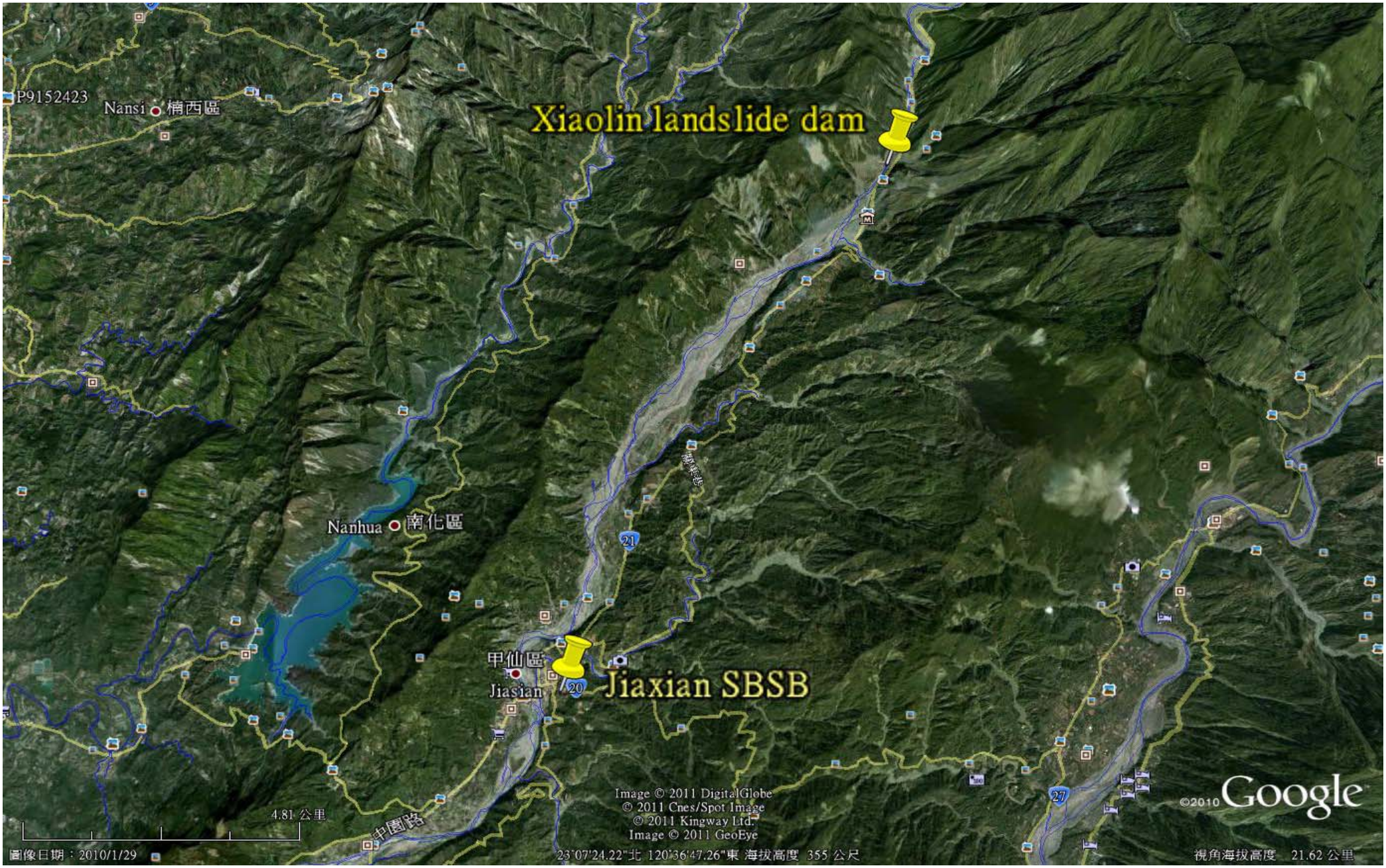


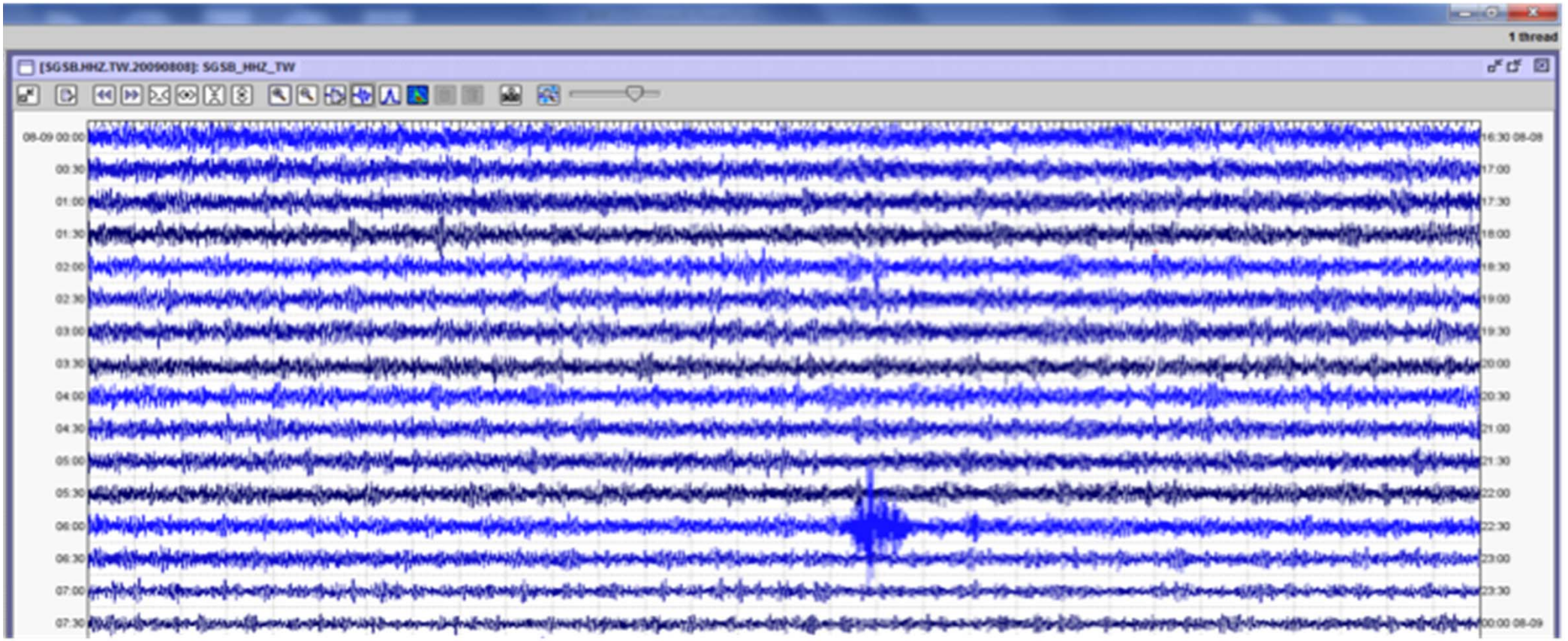


Ref: Cheng-Horng Lin, et al. 2010



Station Code	Distance to Shiaolin Landslide(km)
SGSB	11.39
TPUB	15.30
ELDB	37.96
ALSB	41.39
TWMB	44.40
WGKB	58.25

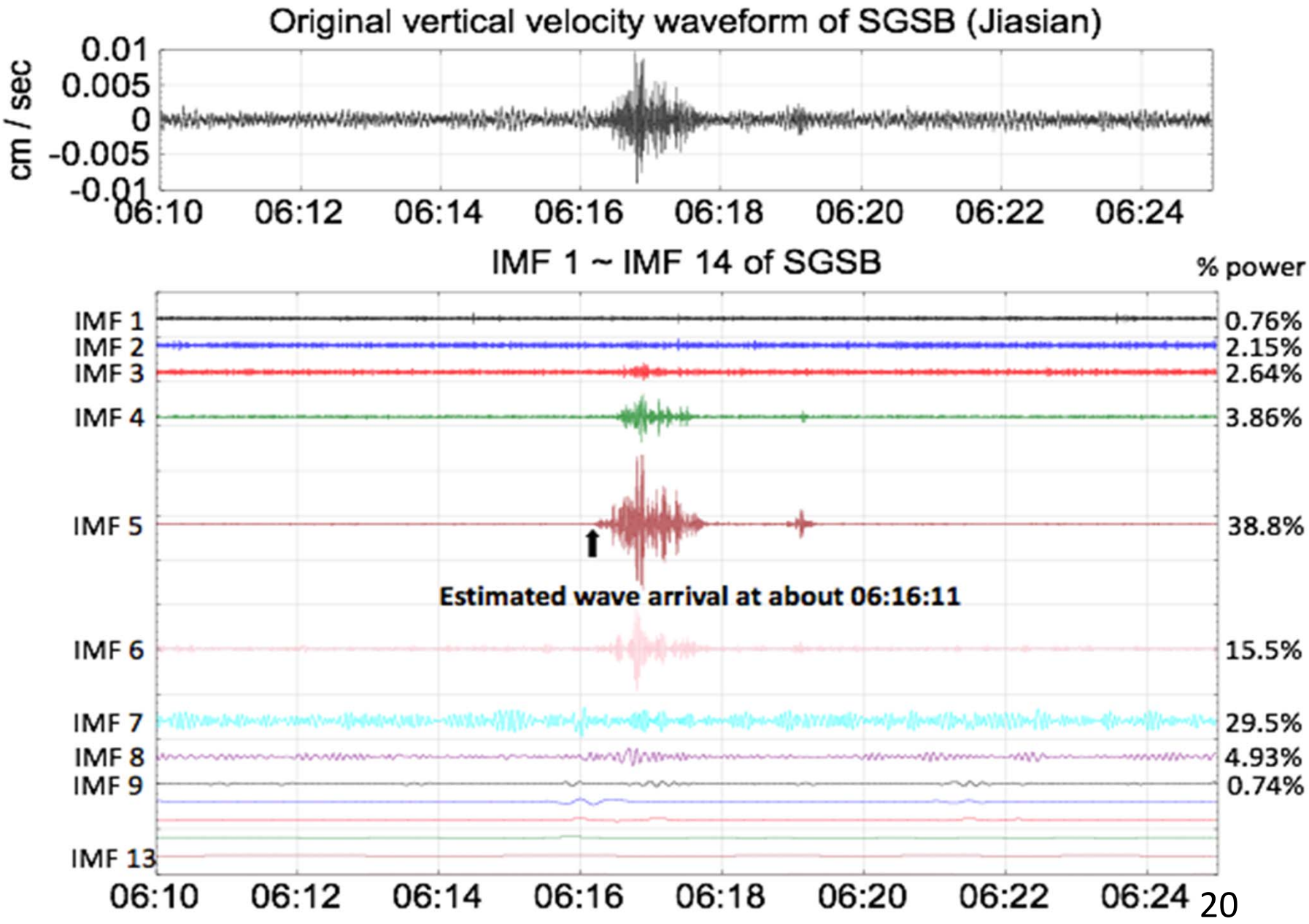

P9152423
Nansi 楠西區
Xiaolin landslide dam
Nanhua 南化區
甲仙區
Jiasian
Jiaxian SBSB
Image © 2011 DigitalGlobe
© 2011 Cnes/Spot Image
© 2011 Kingway Ltd.
Image © 2011 GeoEye
©2010 Google
4.81 公里
圖像日期：2010/1/29
23°07'24.22"北 120°36'47.26"東 海拔高度 355 公尺
視角海拔高度 21.62 公里

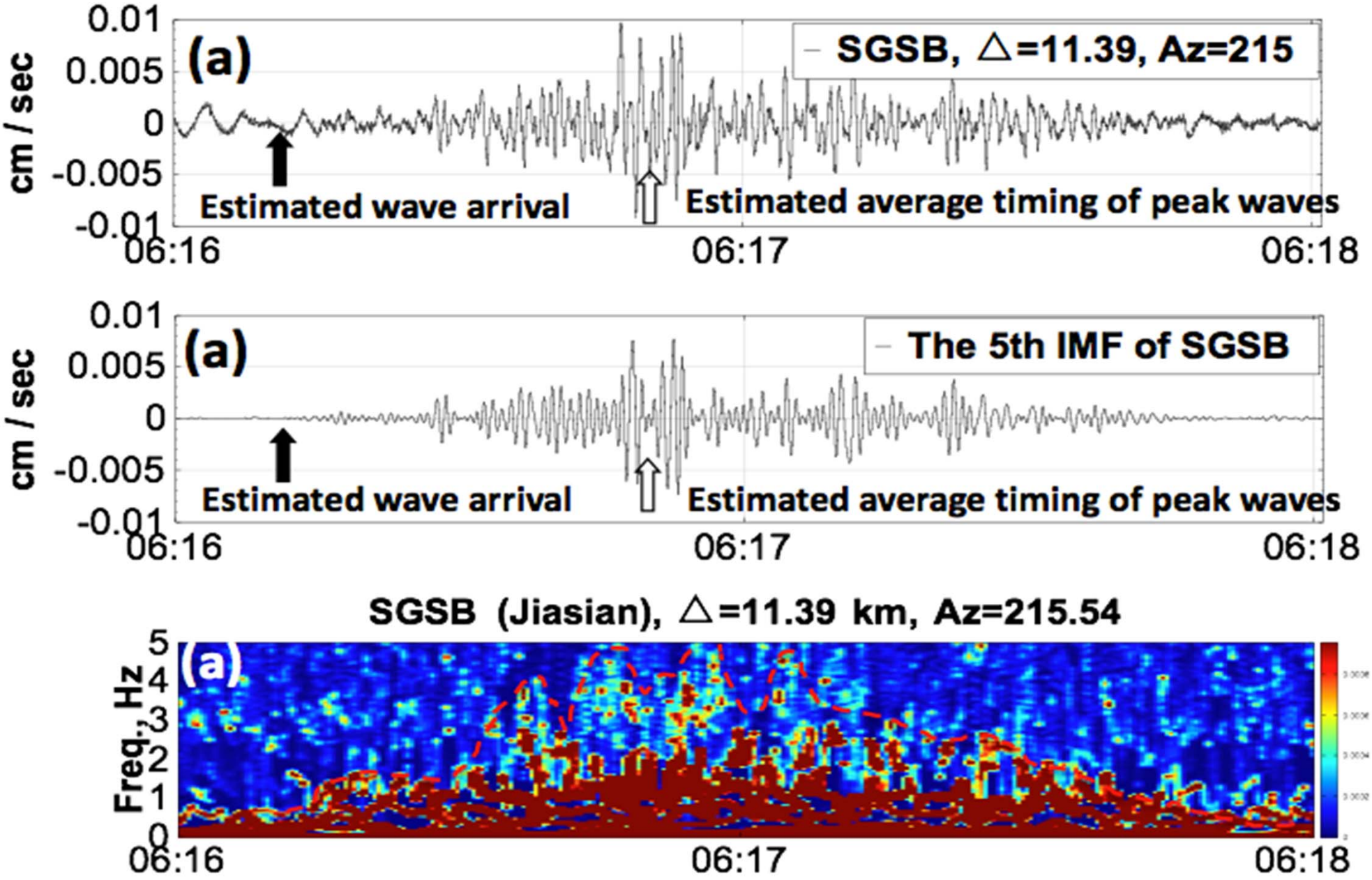

1 thread
[SGSB.HHZ.TW.20090808]: SGSB_HHZ_TW
08-09 00:00
00:30
01:00
01:30
02:00
02:30
03:00
03:30
04:00
04:30
05:00
05:30
06:00
06:30
07:00
07:30
16:30 08-08
17:00
17:30
18:00
18:30
19:00
19:30
20:00
20:30
21:00
21:30
22:00
22:30
23:00
23:30
00:00 08-09

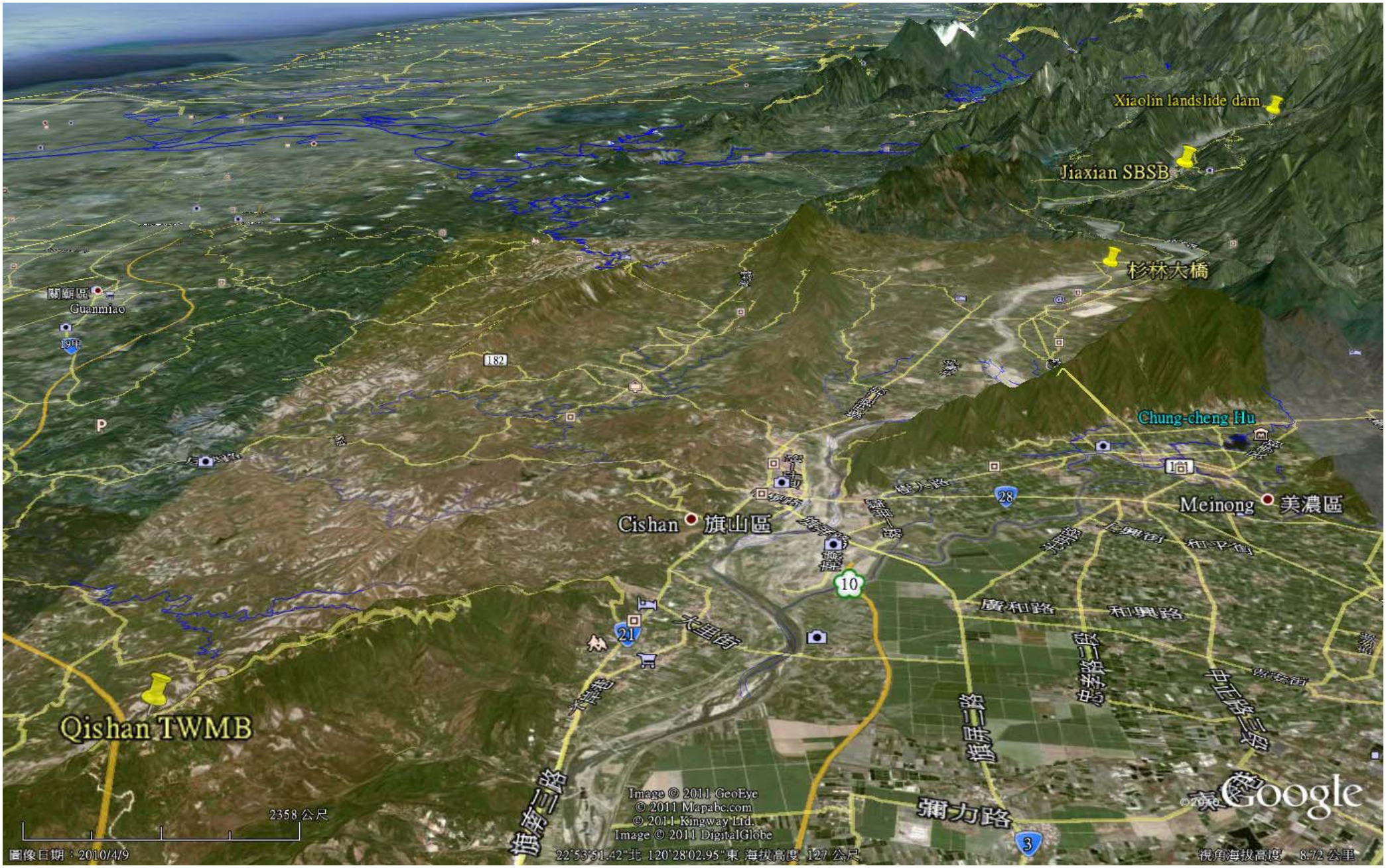
EMD & HHT

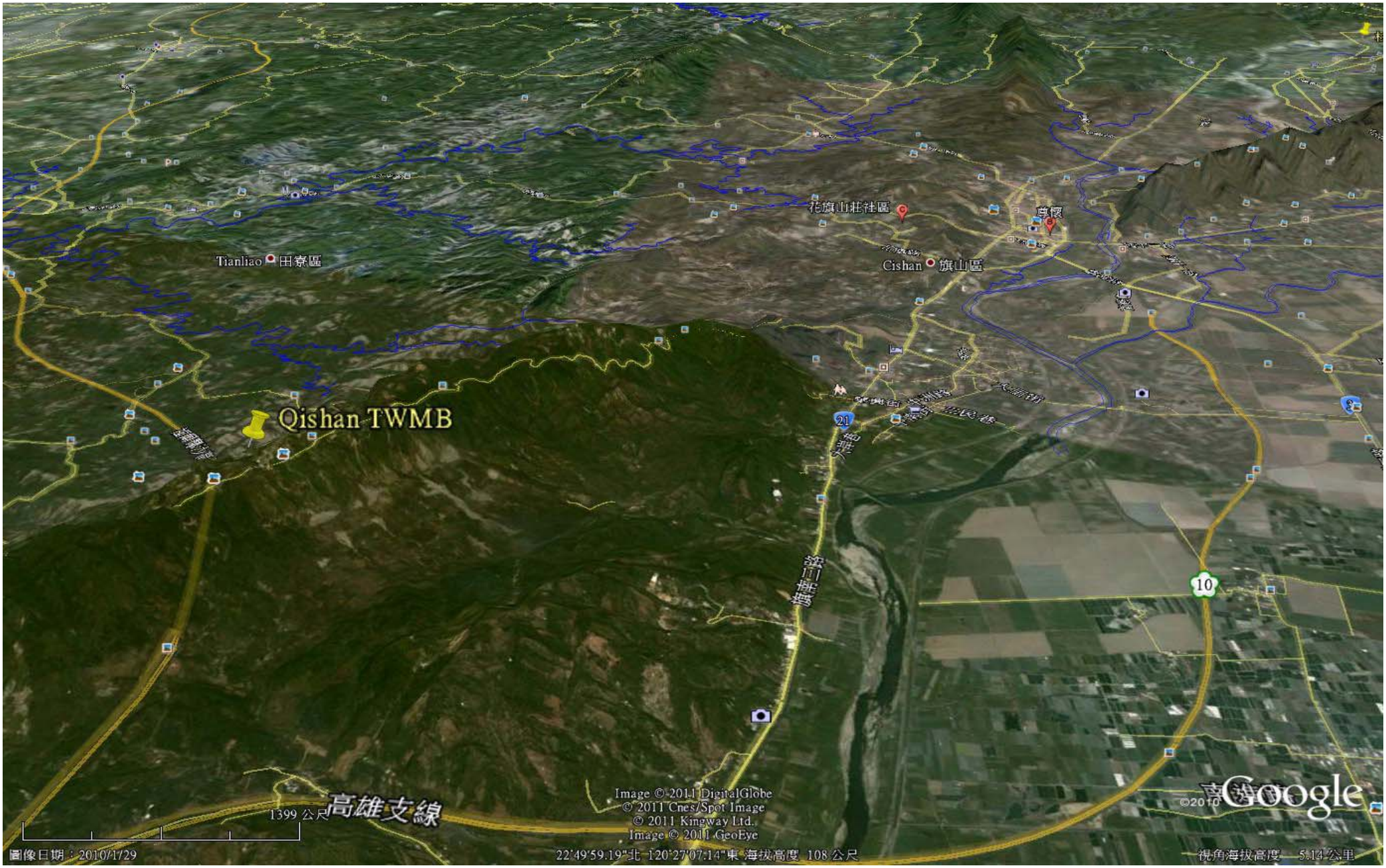
- Huang, N. E., Shen, Z., Long, S. R., Wu, M. C., Shih, H. H., Zheng, Q., Yen, N. C., Tung, C. C., and Liu, H. H.: The empirical mode decomposition and the Hilbert spectrum for nonlinear and nonstationary time series analysis, in: Proceedings of the royal society of London, series a: mathematical, Physical and Engineering Sciences, 454, 903–995, 1998.

小林村山崩寬頻震動訊號

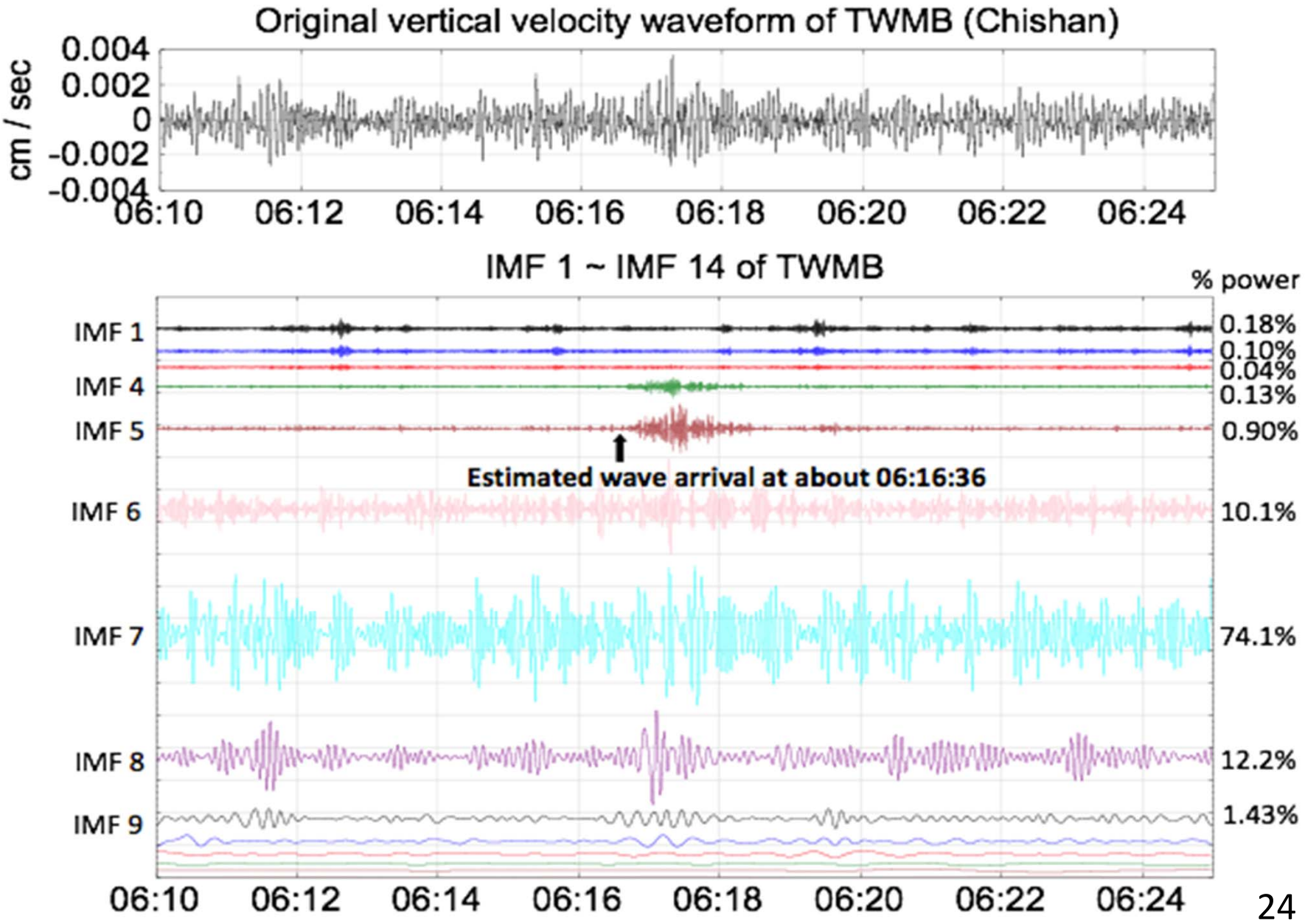


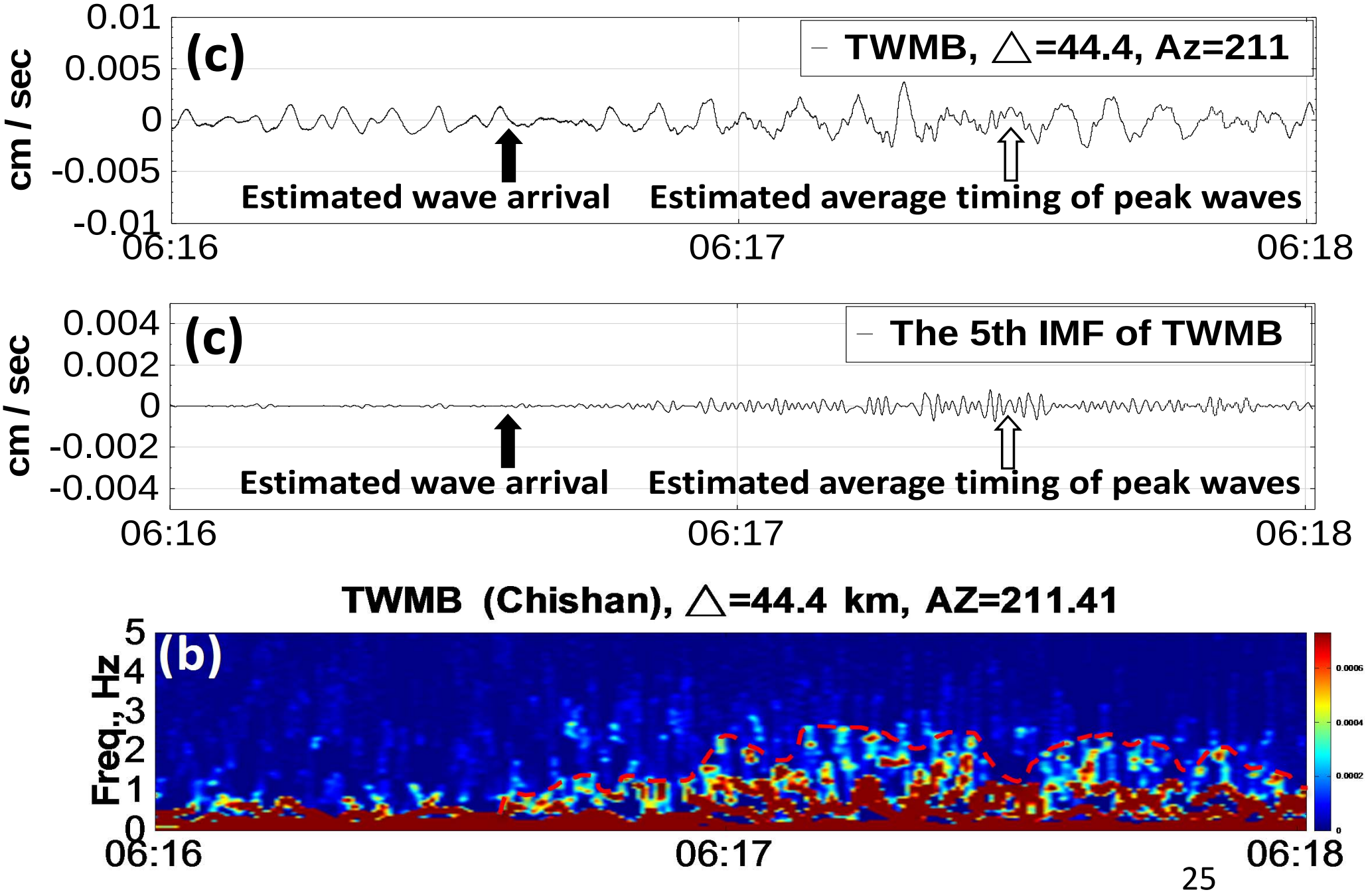

(a)
SGSB, △=11.39, Az=215
cm / sec
0.01
0.005
0
-0.005
-0.01
Estimated wave arrival
Estimated average timing of peak waves
06:16
06:17
06:18
(a)
The 5th IMF of SGSB
cm / sec
0.01
0.005
0
-0.005
-0.01
Estimated wave arrival
Estimated average timing of peak waves
06:16
06:17
06:18
SGSB (Jiasian), △=11.39 km, Az=215.54
(a)
Freq., Hz
5
4
3
2
1
0
06:16
06:17
06:18


Xiaolin landslide dam
Jiaxian SBSB
杉林大橋
Guanmiao
Chung-cheng Hu
Meinong 美濃區
Cishan 旗山區
Qishan TWMB
Image © 2011 GeoEye
© 2011 Mapabc.com
© 2011 Kingway Ltd.
Image © 2011 DigitalGlobe
Google
2358 公尺
圖像日期：2010/4/9
22°53'51.42"北 120°28'02.95"東 海拔高度 127 公尺
視角海拔高度 8.72 公里


花旗山莊社區
Tianliao 田寮區
Cishan 旗山區
Qishan TWMB
21
10
1399 公尺
高雄支線
Image © 2011 DigitalGlobe
© 2011 Cnes/Spot Image
© 2011 Kingway Ltd.
Image © 2011 GeoEye
©2010 Google
圖像日期：2010/1/29
22°49'59.19"北 120°27'07.14"東 海拔高度 108 公尺
視角海拔高度 5.14 公里

小林村山崩寬頻震動訊號




(c)
TWMB, △=44.4, Az=211
cm / sec
0.01
0.005
0
-0.005
-0.01
Estimated wave arrival
Estimated average timing of peak waves
06:16
06:17
06:18
(c)
The 5th IMF of TWMB
cm / sec
0.004
0.002
0
-0.002
-0.004
Estimated wave arrival
Estimated average timing of peak waves
06:16
06:17
06:18
TWMB (Chishan), △=44.4 km, AZ=211.41
(b)
Freq., Hz
5
4
3
2
1
0
0.0006
0.0004
0.0002
0
06:16
06:17
06:18

Key points of the LS vibration

- Empirical mode decomposition (EMD) was applied to differentiate weak surface-wave signals from noise and to estimate the surface-wave velocities in the region.
- The main frequency contents of the seismic waves caused by the Xiaolin landslide were in the range of 0.5 to 1.5 Hz.

Referee's comments

- 1ST round review comment: This is a **substantive manuscript making a significant step in the advancement of spectral decomposition techniques in geophysical/seismological time-series analysis.**
- 2nd round review comment (2011-04-25) I am happy with the substance of the manuscript and, **as previously, I regard it as a substantive manuscript making a significant contribution to the field.**

Published in Natural Hazards and Earth System Sciences

- Zheng-Yi Feng (2011) The seismic signatures of the 2009 Shiaolin landslide in Taiwan, Nat. Hazards Earth Syst. Sci., 11, 1559-1569, doi:10.5194/nhess-11-1559-2011, 25 May 2011.
- IF:1.792, 16/76=21% water resources

23 JUNE 2011

The seismic signature of a large landslide

Posted by dr-dave

Research Blogging

A little under two years ago, on 9th August 2009, Typhoon Morakot triggered a catastrophic landslide that destroyed the village of Hsiaolin in southern Taiwan, killing over 400 people. I covered this event in detail at the time and later that same year visited the site. There is a presentation about the typhoon and landslide online that can be downloaded. The journal Natural Hazards and Earth System Science has just published a paper by Feng (2011) that examines the seismic signal of the landslide. This journal is open access, so the paper can be downloaded from here.

The analysis of the seismic signals associated with

ABOUT DAVE

Dave Petley is the Wilson Professor of Hazard and Risk in the Department of Geography at Durham University in the United Kingdom. His blog provides a commentary on landslide events occurring worldwide, including the landslides themselves, latest research, and conferences and meetings.

OTHER AGU BLOGS

DAN'S WILD WILD SCIENCE JOURNAL >>

THE PLAINSPOKEN SCIENTIST >>

The analysis of the seismic signals associated with landslides is a very interesting research area at the moment. The mechanics of a landslide mean that they have a distinctly different spectral signature to that of earthquakes, meaning that very large events can be detected using global seismic arrays. This provides the possibility of the remote detection of large landslides. Furthermore, analysis of the data can provide information about the time of initiation of the movement and of the duration of the motion, which in turn can be used to analyse landslide velocity. In fact the Hsiaolin landslide demonstrates the value of such an approach – in the immediate aftermath of the Hsiaolin event there was considerable uncertainty as to whether a large landslide had actually occurred, followed by a national scandal over the tardiness of the governmental response. However, our understanding of the seismic signal of large landslides remains poor.

The Feng (2011) paper is a welcome contribution to this area, not least because Taiwan operates a remarkably dense array of strong motion instruments. This means that the seismic dataset for Hsiaolin is remarkably good. The paper examines the strong motion record from six broadband seismometers located close to the landslide. The key finding is that the landslide was clearly detectable on the strong motion instruments, and had a very different spectral signature (with the energy being concentrated at 0.5 to 1.5 Hz) to that of earthquakes of a similar magnitude. The stations located closest to the landslide indicated that the movement lasted for about 98 seconds, and movement started at 06:16 local time. However, the more distant stations produced notably less good data because of the rapid attenuation of the seismic signals.

As such, this paper is a really interesting contribution to our understanding of the seismic signature of landslides. There is some really very interesting work being undertaken by Colin Stark and Goram Ekstrom at Columbia University exploring the feasibility of a global assessment of very large landslides through remote observation via the global seismic network; this is a fascinating research area that is going to yield some great results in the next few years.

Reference

Feng, Z. (2011). The seismic signatures of the 2009 Shiaolin landslide in Taiwan *Natural Hazards and Earth System Science, 11* (5), 1559-1569 DOI: 10.5194/nhess-11-1559-2011

MOUNTAIN BELTWAY >>
THE LANDSLIDE BLOG >>
TERRA CENTRAL >>
MAGMA CUM LAUDE >>

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- Floods and landslides in Italy yesterday
- Landslides in the movies part 1 – Buster Keaton demonstrates how to survive a rockslide
- Update on the Burma flood and riverbank collapse disaster
- Remembering the Aberfan disaster – 45 years ago today
- An interesting and large landslide in Iceland

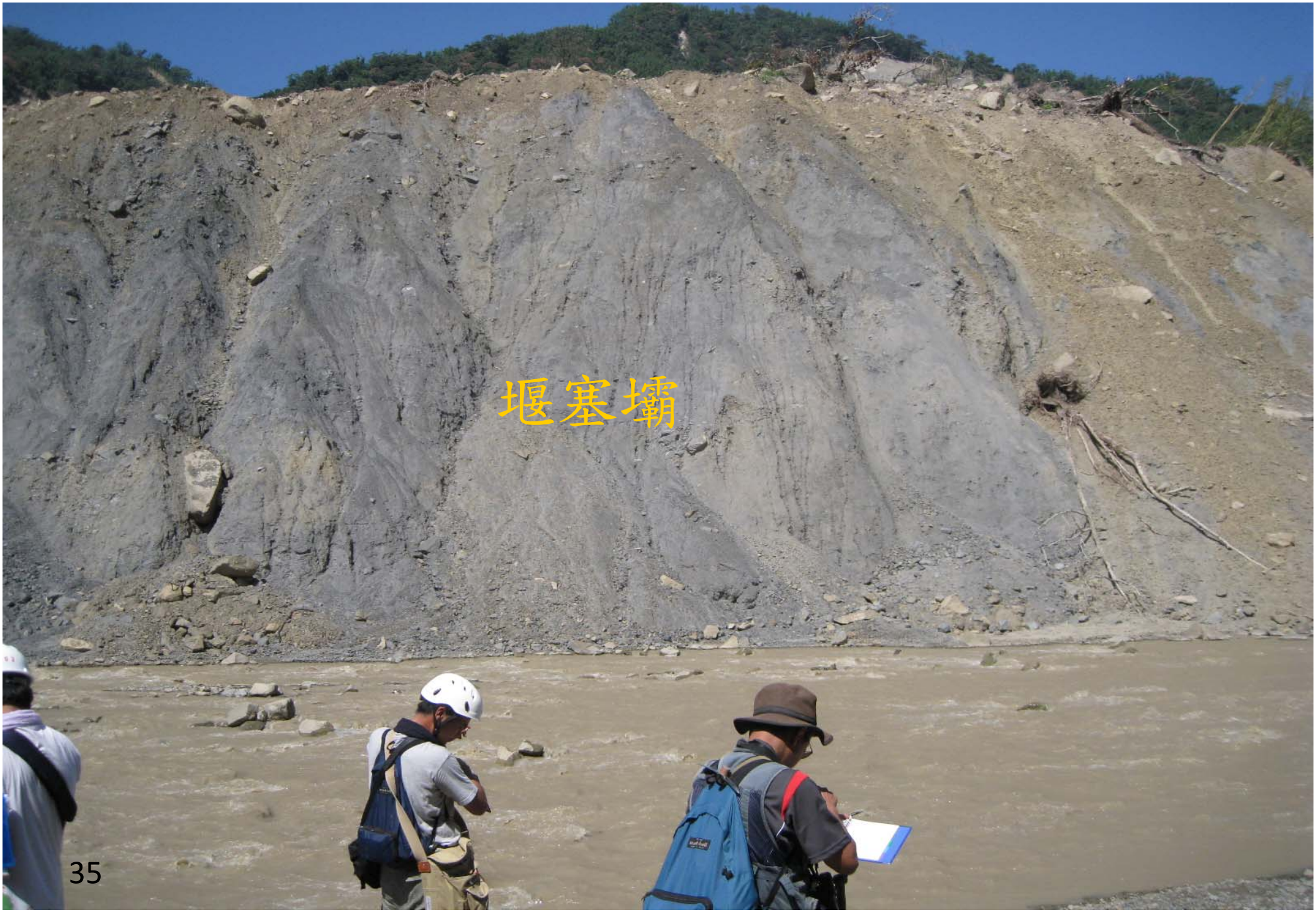
CATEGORIES
Select Category

小林村堰塞壩潰堤洪水歷程

- 小林村堰塞壩潰壩時間點
- 小林村堰塞壩潰堤洪水歷程：
  - 洪水到達時間
  - 洪水延時
  - 洪水行進速度


小林村位置


堰塞壩


堰塞壩


堰塞壩


Xiaolin lands
小林村
南化區
Nanhua
甲仙區
Jiasian
Jiaxian SBSB
甲仙
SGSB
中圍路
光華路
杉林區
杉林大橋
高雄路
3.98 公里
Image © 2011 GeoEye
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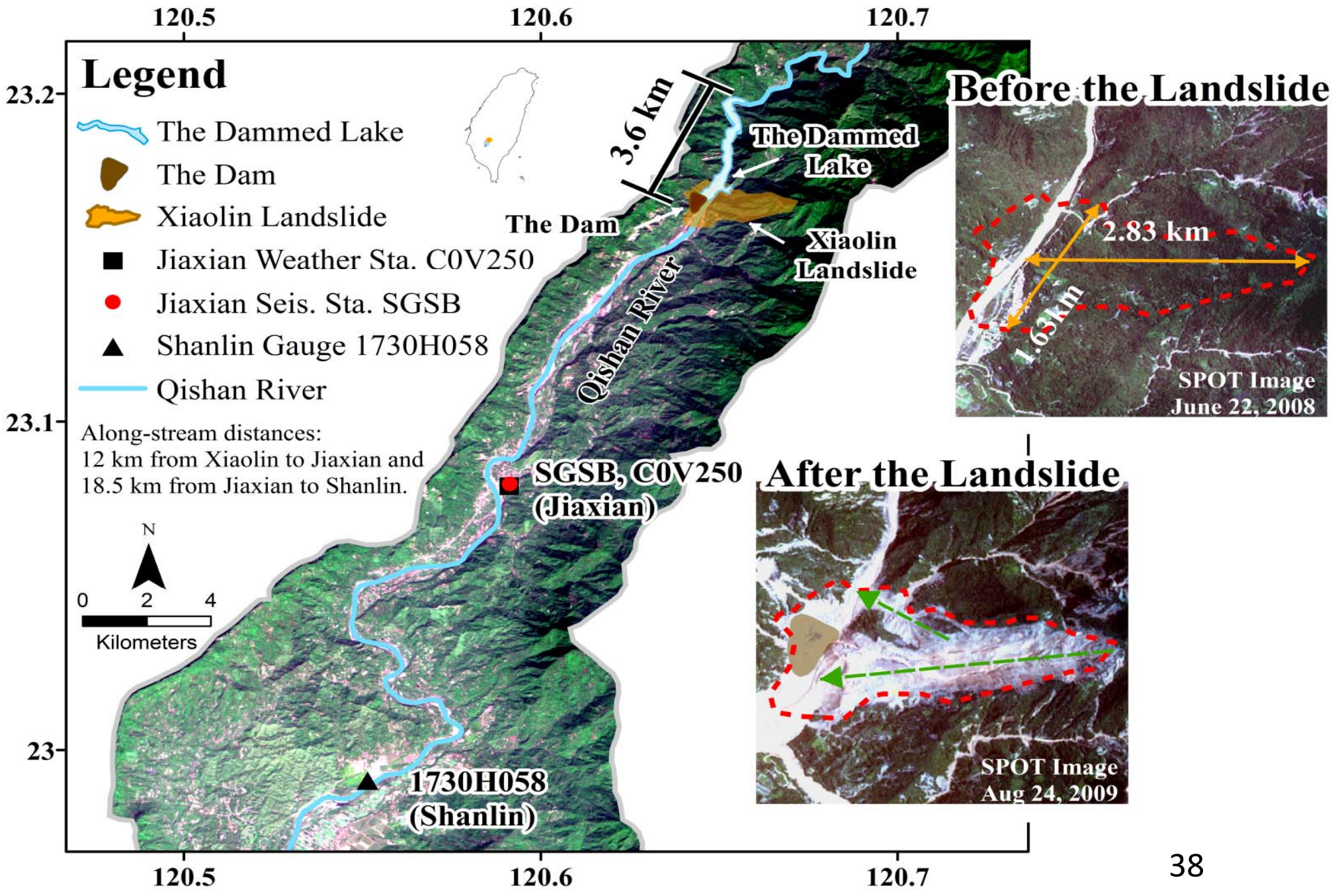
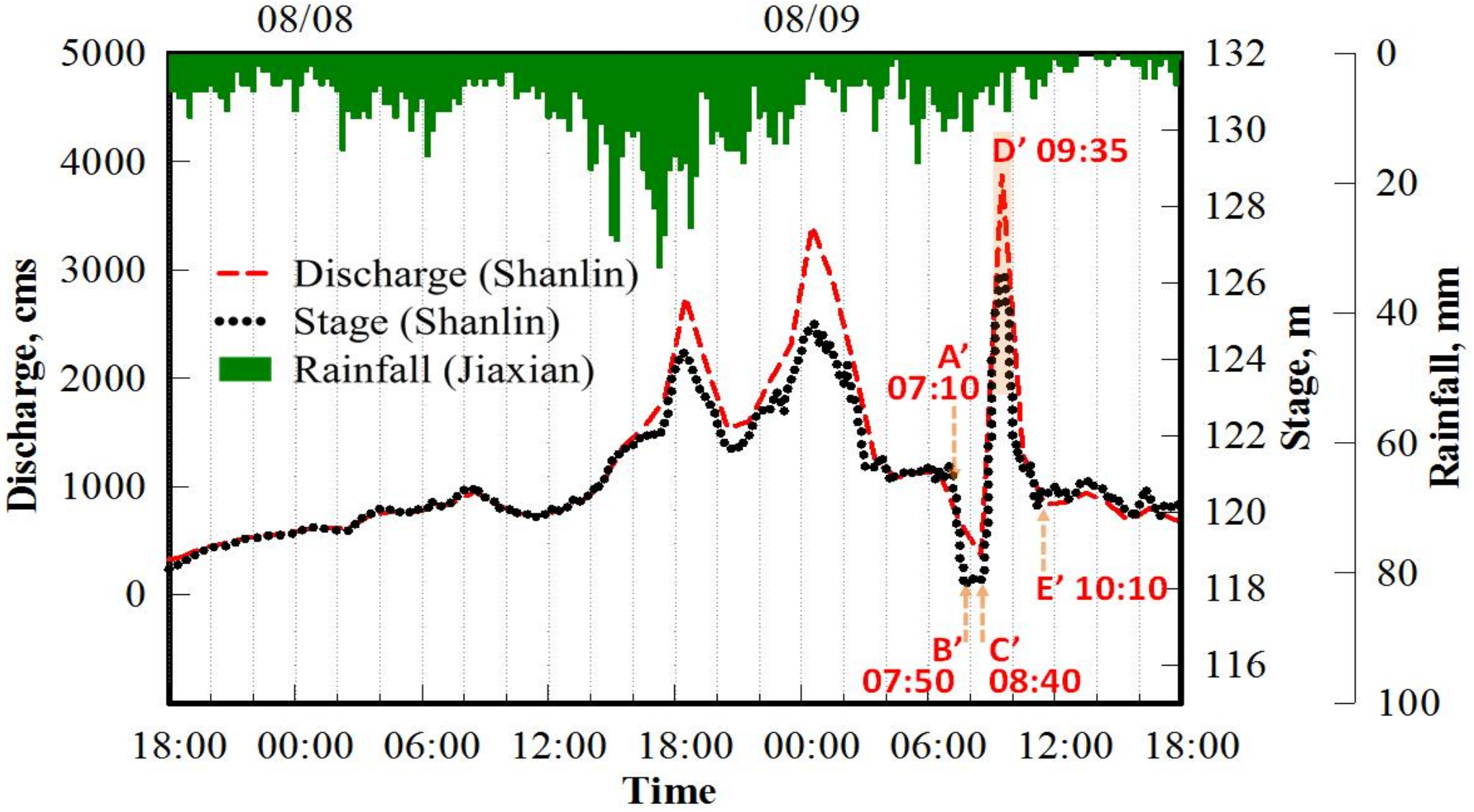
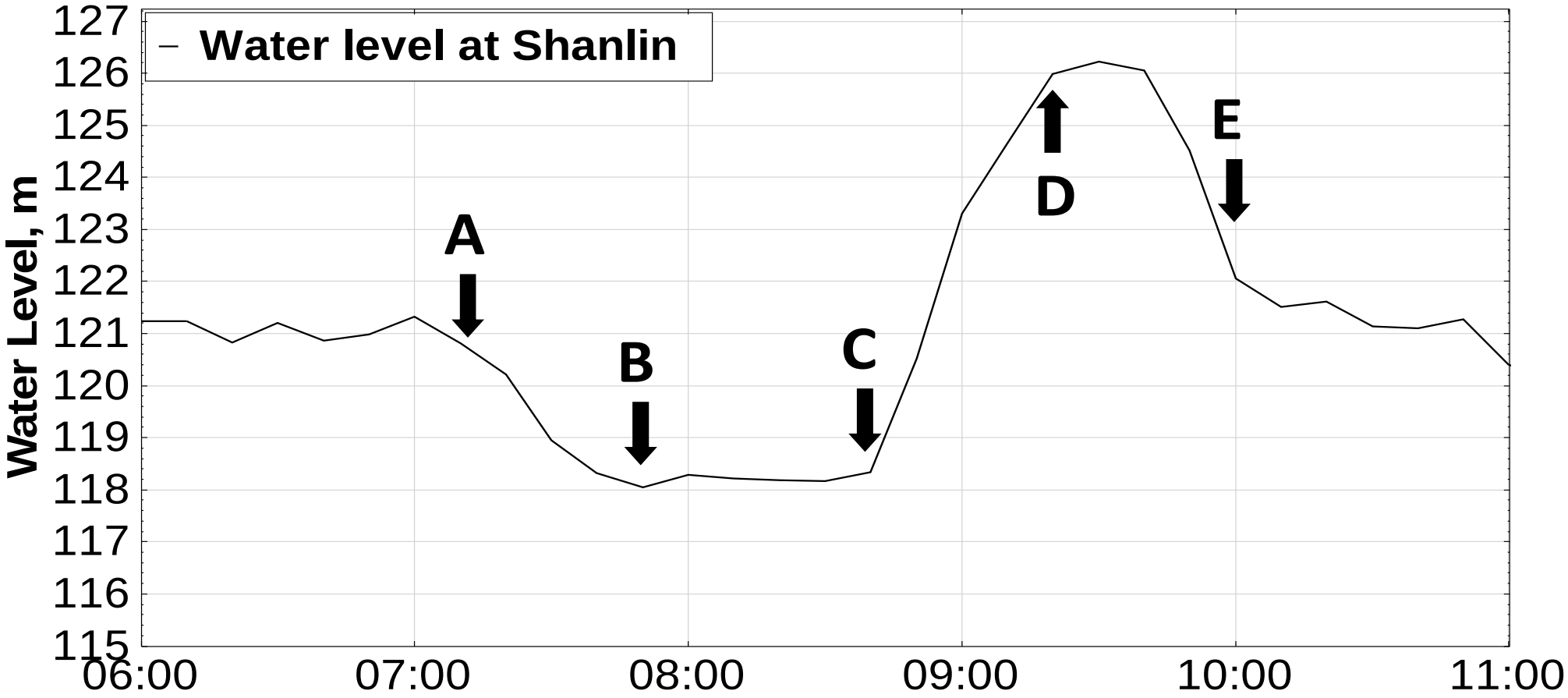
Image © 2011 DigitalGlobe
©2010 Google
圖像日期：2010/1/29
23°04'13.83"北 120°35'53.25"東 海拔高度 347 公尺
視角海拔高度 17.87 公里


120.5
120.6
120.7
23.2
23.1
23
Legend
The Dammed Lake
The Dam
Xiaolin Landslide
Jiaxian Weather Sta. C0V250
Jiaxian Seis. Sta. SGSB
Shanlin Gauge 1730H058
Qishan River
Along-stream distances:
12 km from Xiaolin to Jiaxian and
18.5 km from Jiaxian to Shanlin.
N
0 2 4
Kilometers
3.6 km
The Dammed Lake
The Dam
Xiaolin Landslide
Qishan River
SGSB, C0V250 (Jiaxian)
1730H058 (Shanlin)
Before the Landslide
2.83 km
1.63km
SPOT Image June 22, 2008
After the Landslide
SPOT Image Aug 24, 2009

杉林大橋的水位變化


08/08
08/09
Discharge, cms
Stage, m
Rainfall, mm
Time
Discharge (Shanlin)
Stage (Shanlin)
Rainfall (Jiaxian)
A' 07:10
B' 07:50
C' 08:40
D' 09:35
E' 10:10
5000
4000
3000
2000
1000
0
132
130
128
126
124
122
120
118
116
0
20
40
60
80
100
18:00
00:00
06:00
12:00
18:00
00:00
06:00
12:00
18:00


Water level at Shanlin
Water Level, m
127
126
125
124
123
122
121
120
119
118
117
116
115
06:00
07:00
08:00
09:00
10:00
11:00
A
B
C
D
E

杉林大橋


杉林大橋上游

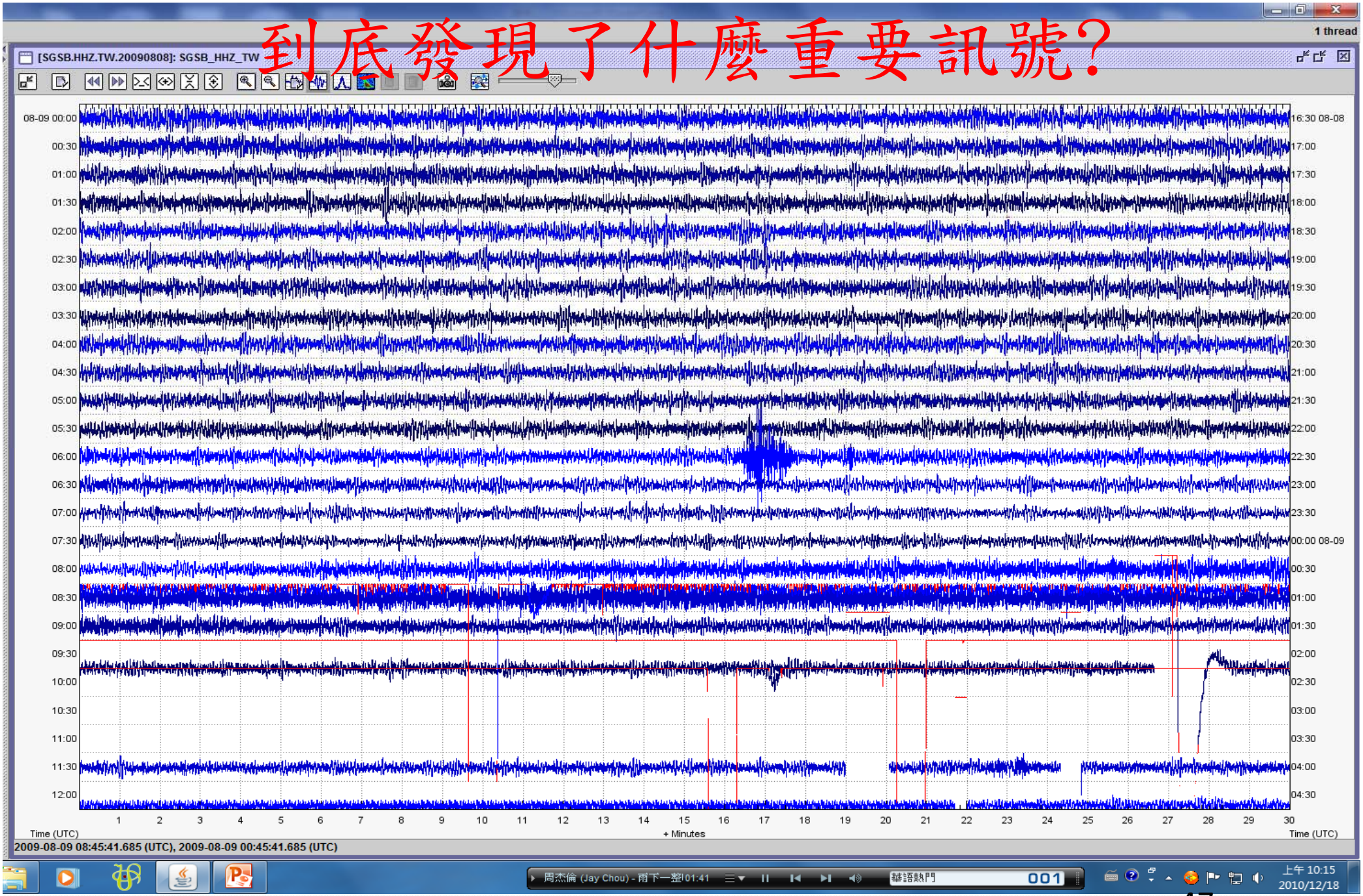

杉林大橋上游


杉林大橋下游
杉林大橋
魚苗
RA04

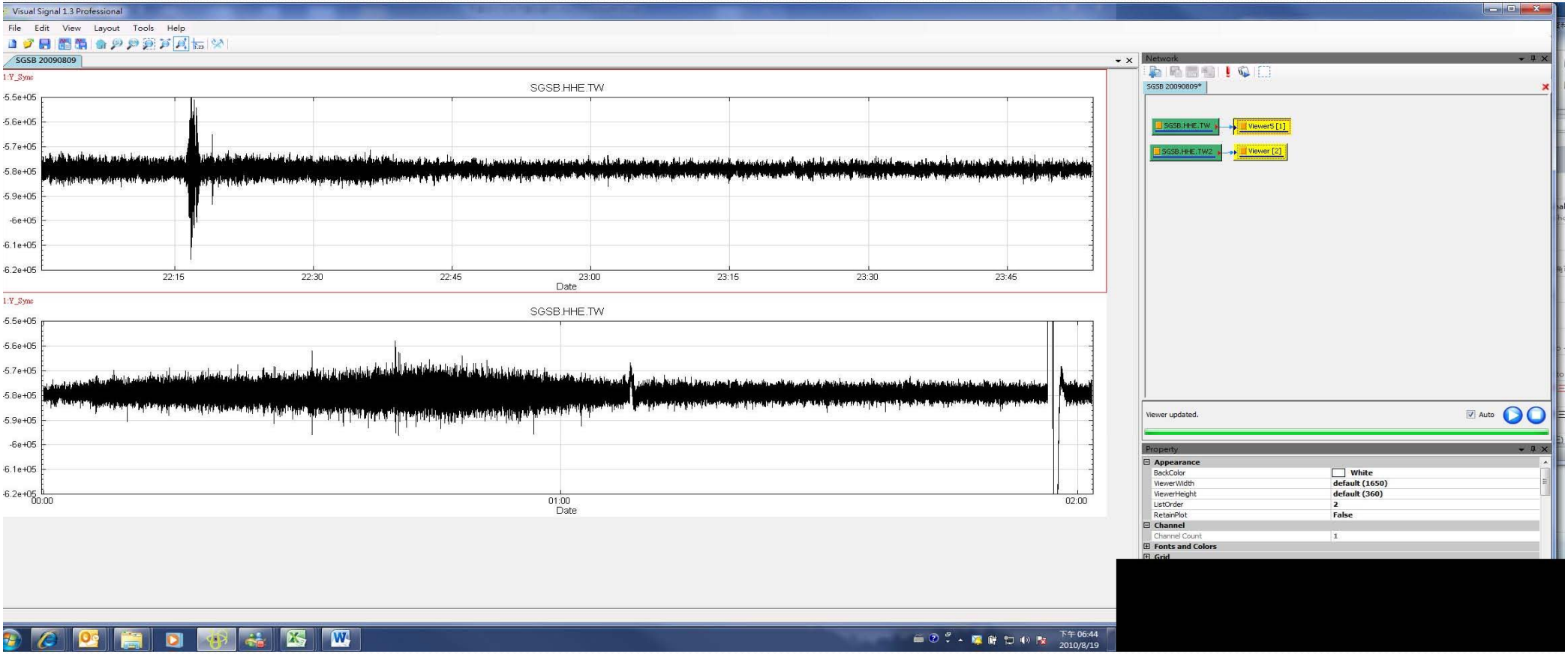
杉林大橋下游

新發現 –
甲仙寬頻測站(SGSB)
潰堤洪水訊號

到底發現了什麼重要訊號?

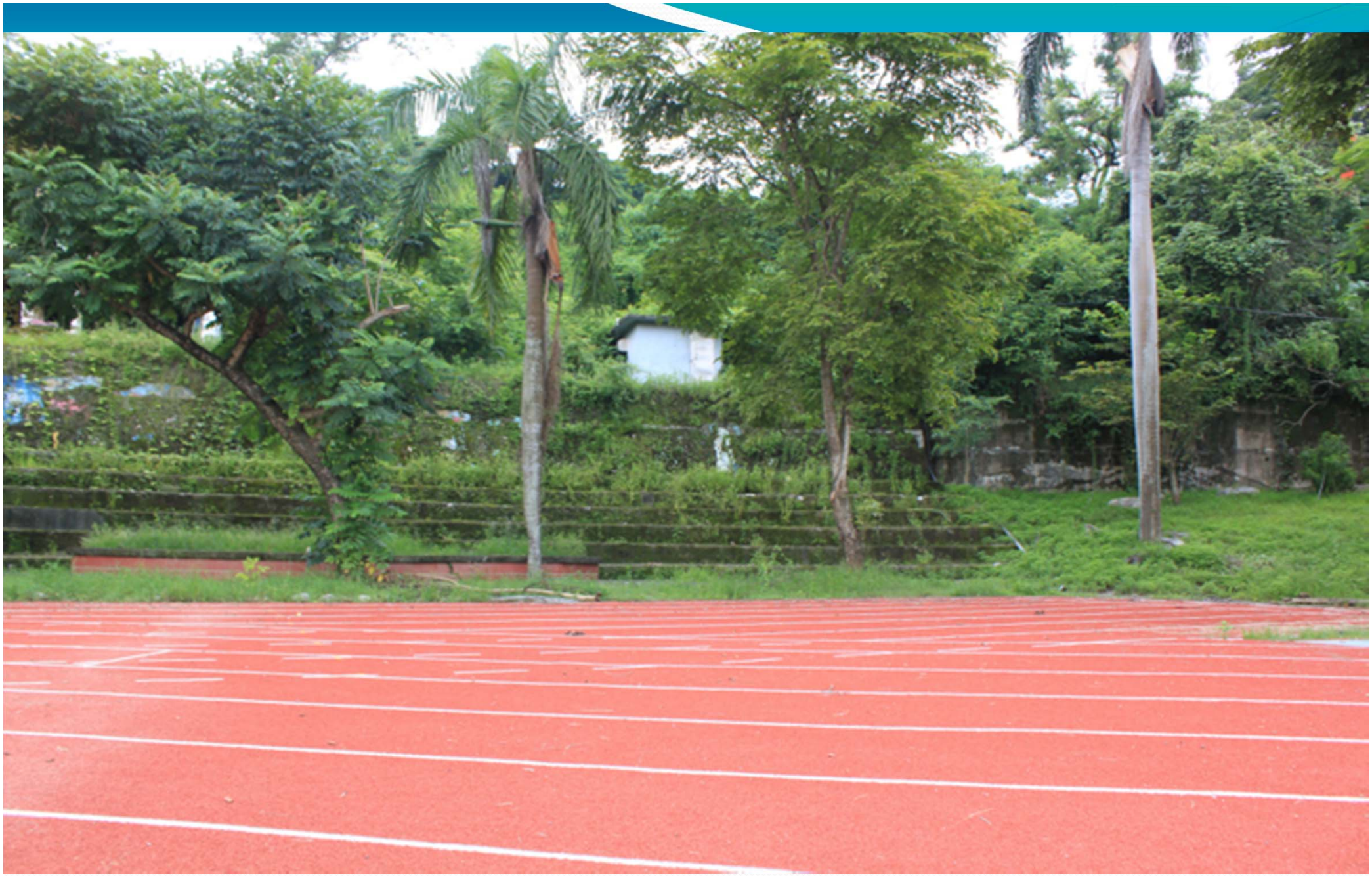


這些訊號代表何義？


Visual Signal 1.3 Professional
File Edit View Layout Tools Help
SGSB 20090809
SGSB.HHE.TW
Date
Network
SGSB 20090809*
SGSB.HHE.TW
ViewerS [1]
SGSB.HHE.TW2
Viewer [2]
Viewer updated.
Auto
Property
Appearance
BackColor
White
ViewerWidth
default (1650)
ViewerHeight
default (360)
ListOrder
2
RetainPlot
False
Channel
Channel Count
Fonts and Colors
Grid

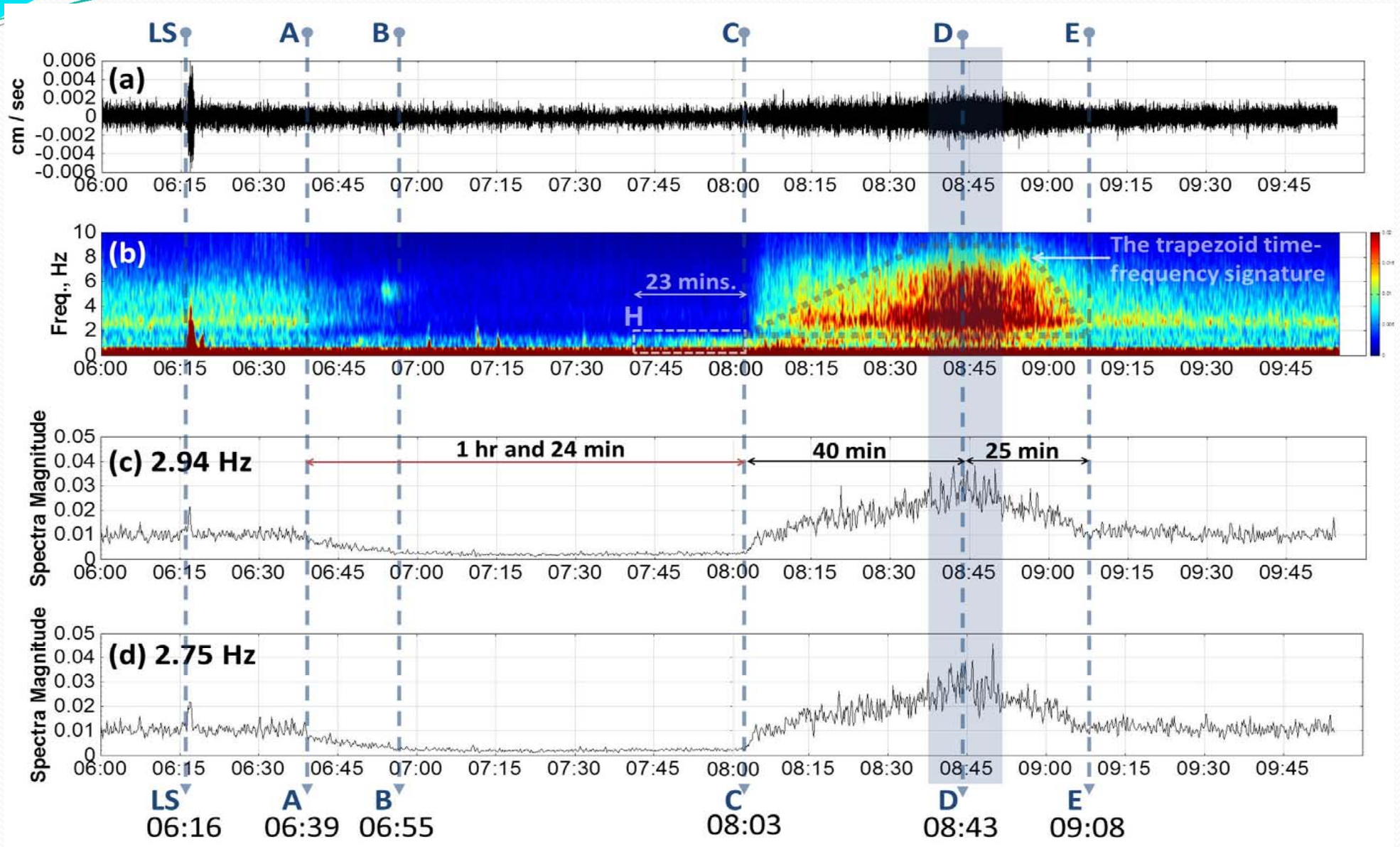

明心橋
復興路
孫竹山巷
中正路99巷
中正路78巷
高雄縣甲仙鄉立圖書館
甲仙鄉 Jiasian
甲仙分駐所
仙埔橋
甲仙國小
甲仙國中
甲仙橋
SBSB
500~600m
牽手橋
文化路
仁愛路63巷
仁愛路41巷
公館
甲仙寬頻
(SGSB


甲仙寬頻測站
(SGSB)
© 2011 Mapabc.com
© 2011 Cnes/Spot Image
© 2011 Kingway Ltd.
Image © 2011 GeoEye
©2010 Google
134 公尺
圖像日期：2010/1/29
23°04'57.59"北 120°35'13.70"東 海拔高度 251 公尺
視角海拔高度 1.04 公里

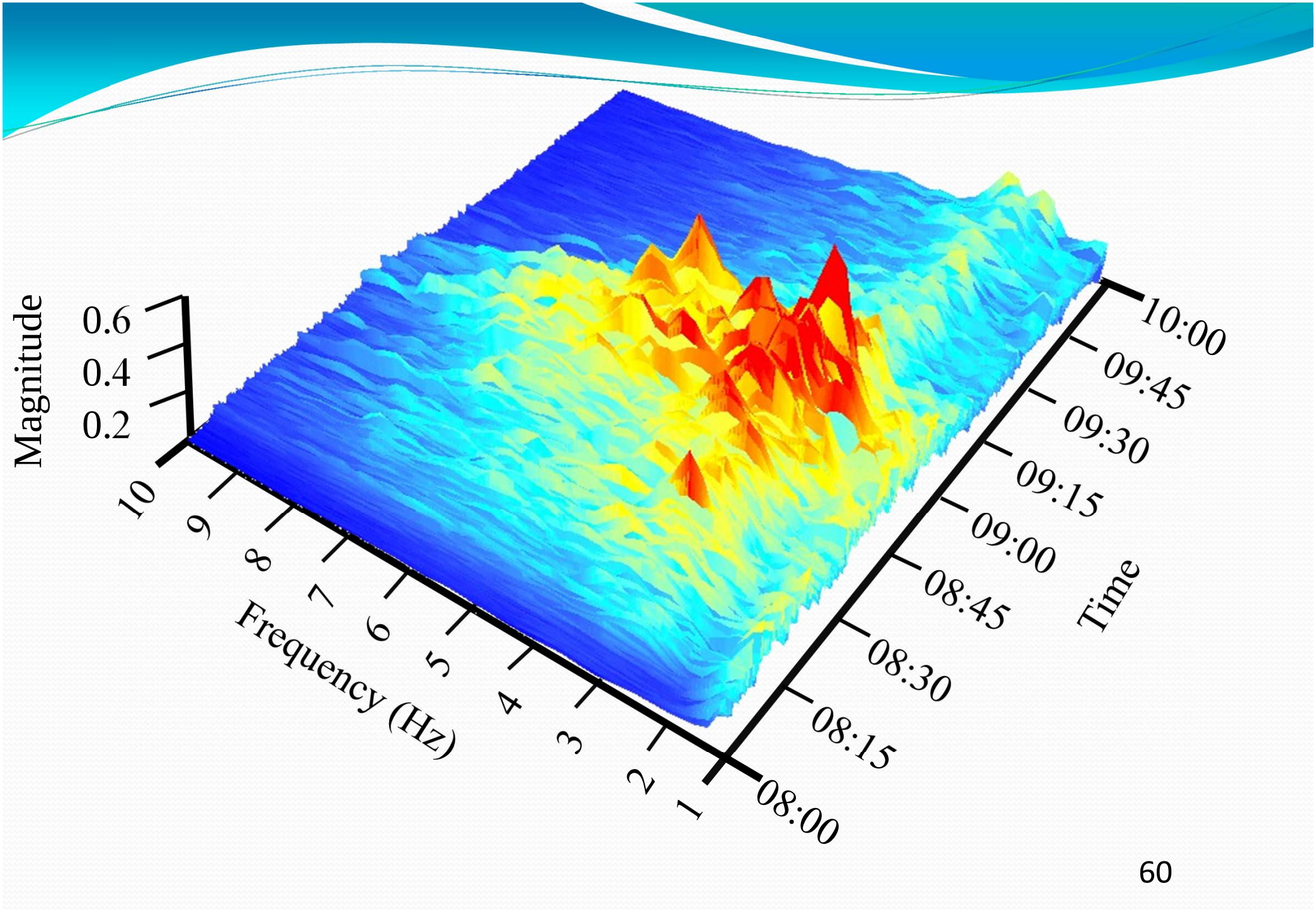


Applying HHT for the dam breach surge wave signature

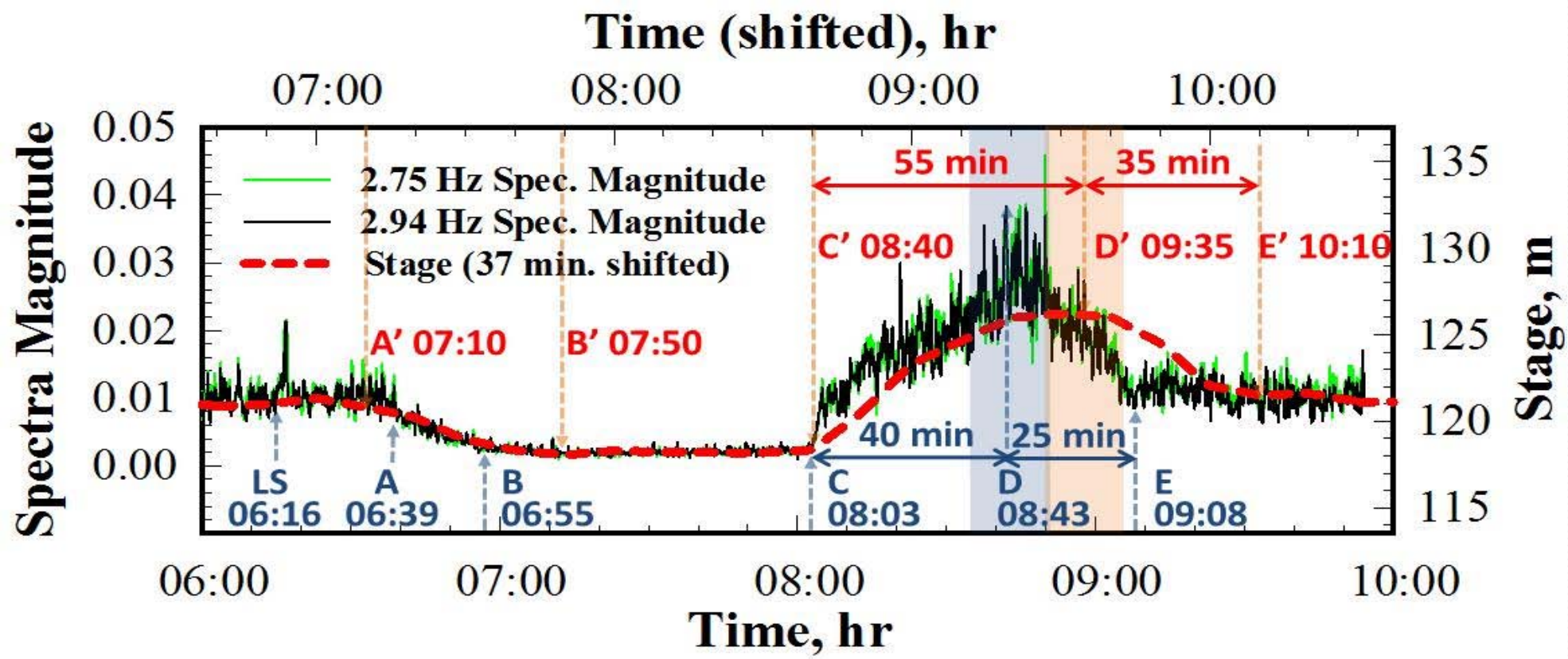
小林村堰塞湖潰堤洪水訊號



Feng, Z.-Y. (2011)


Magnitude
0.6
0.4
0.2
10
9
8
7
6
5
4
3
2
1
Frequency (Hz)
08:00
08:15
08:30
08:45
09:00
09:15
09:30
09:45
10:00
Time

小林村堰塞湖潰堤洪水訊號



Feng, Z.-Y. (2011)

Analysis and discussion

- Hydrological process of the surge wave
- flow stage
- mean speed
- discharge

崩塌與洪水的歷程	估計時間點 (2009/8/9)
LS: 獻肚山(小林)崩塌	06:16
堰塞湖全面潰堤的預估時間	**07:40**
SGSB (BATS 甲仙測站):	
A: 堰塞導致震動強度開始下降	06:39
B: 堰塞導致低震動強度	06:55
C: 震動強度開始增加	08:03
D: 高震動強度範圍	08:43
E: 潰堤洪波已消退	09:08
1730H058 (杉林橋水位站):	
A': 堰塞導致水位開始下降	07:10
B': 堰塞時的低水位	07:50
C': 水位開始增加	08:40
D': 水位最高的時候	09:35
E': 潰堤洪波已消退	10:10

Feng, Z.-Y. (2011)

小林村堰塞湖潰堤時間點

- 堰塞湖蓄滿: 7:00 am ~ 7:10 am
- 溢頂與緩慢侵蝕: 約7:10 am - 7:40 am
- 侵蝕至潰堤時間: 約20 ~ 30 分鐘
- 完全潰堤: 約7:40 am、洪水爆發

小林村堰塞湖潰堤洪水歷程

- 洪水約23分鐘後(08:03 am)到達甲仙(12 km to 小林)，洪水進退約65分鐘
- 約1小時後(08:40 am)到達杉林大橋(30.5 km to 小林)，洪水進退約90分鐘
- 洪水從甲仙到杉林橋的平均流速約為8.3 ± 0.3 m/sec
- 而小林村堰塞壩存在時間短暫，約為1小時24分鐘。

洪峰衰減現象
(Surge wave attenuation)

- **Surge wave "smearing"**
- 洪峰波高在杉林大橋 約 **8** 公尺
- 洪峰波高在甲仙? 可由甲仙寬頻訊號類比，約 10 ~12公尺
- 洪峰延時: 洪水影響甲仙大約**65**分鐘，影響杉林大橋大約**90**分鐘

潰壩洪水主要震動來源

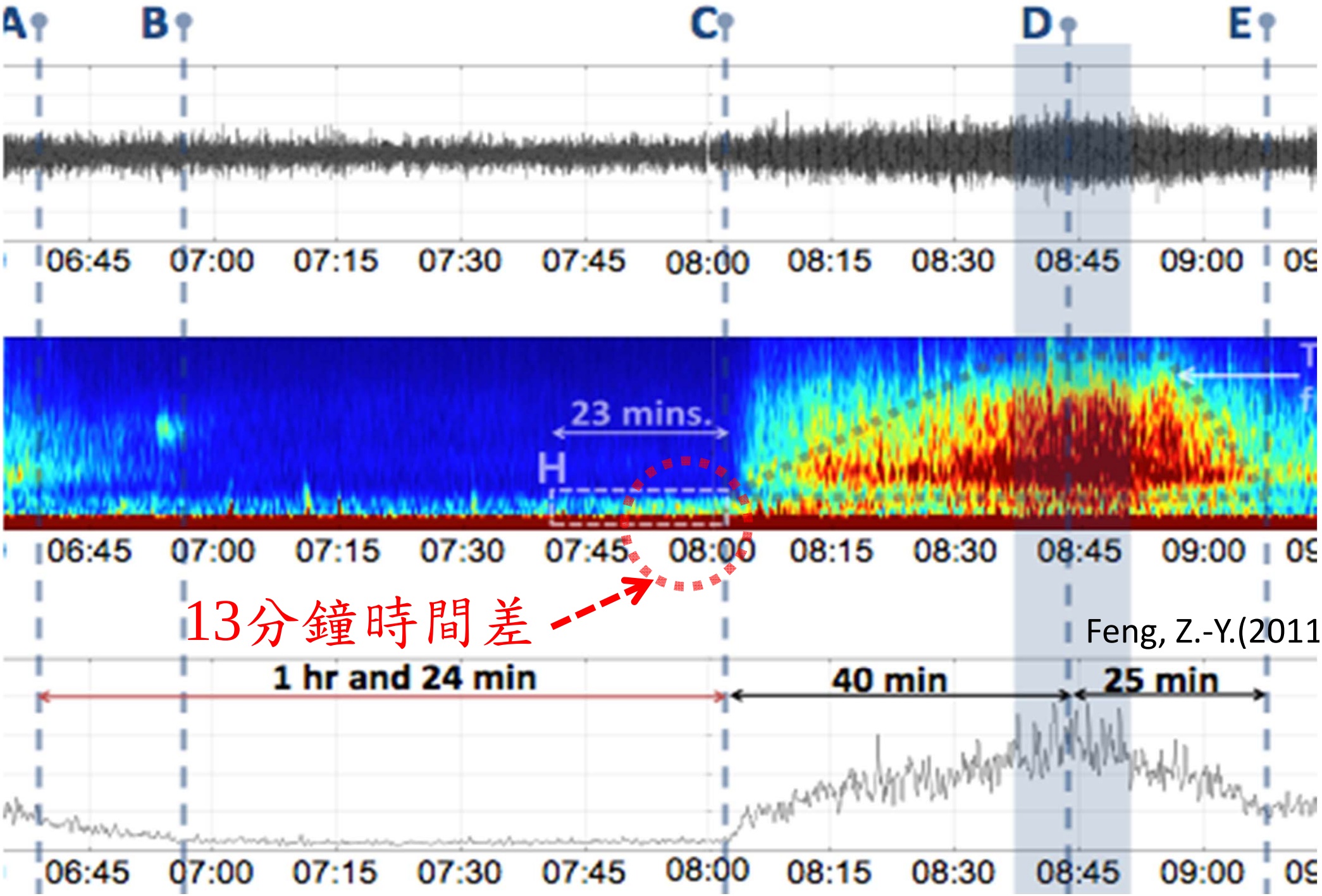
- 洪水的亂流，約2.94~2.75Hz之震動。
- 大顆粒的河床載-大部分是泥岩、頁岩、砂岩材料。可能貢獻一些額外的低頻震動訊號。但是這個貢獻難以量化，因為這些訊號可能跟低頻的洪水訊號混淆。
- 低頻的洪水訊號約為0.4~1Hz之震動，這些低頻的訊號可以傳的比較遠，因為它的衰減比較少。

震動傳遞距離

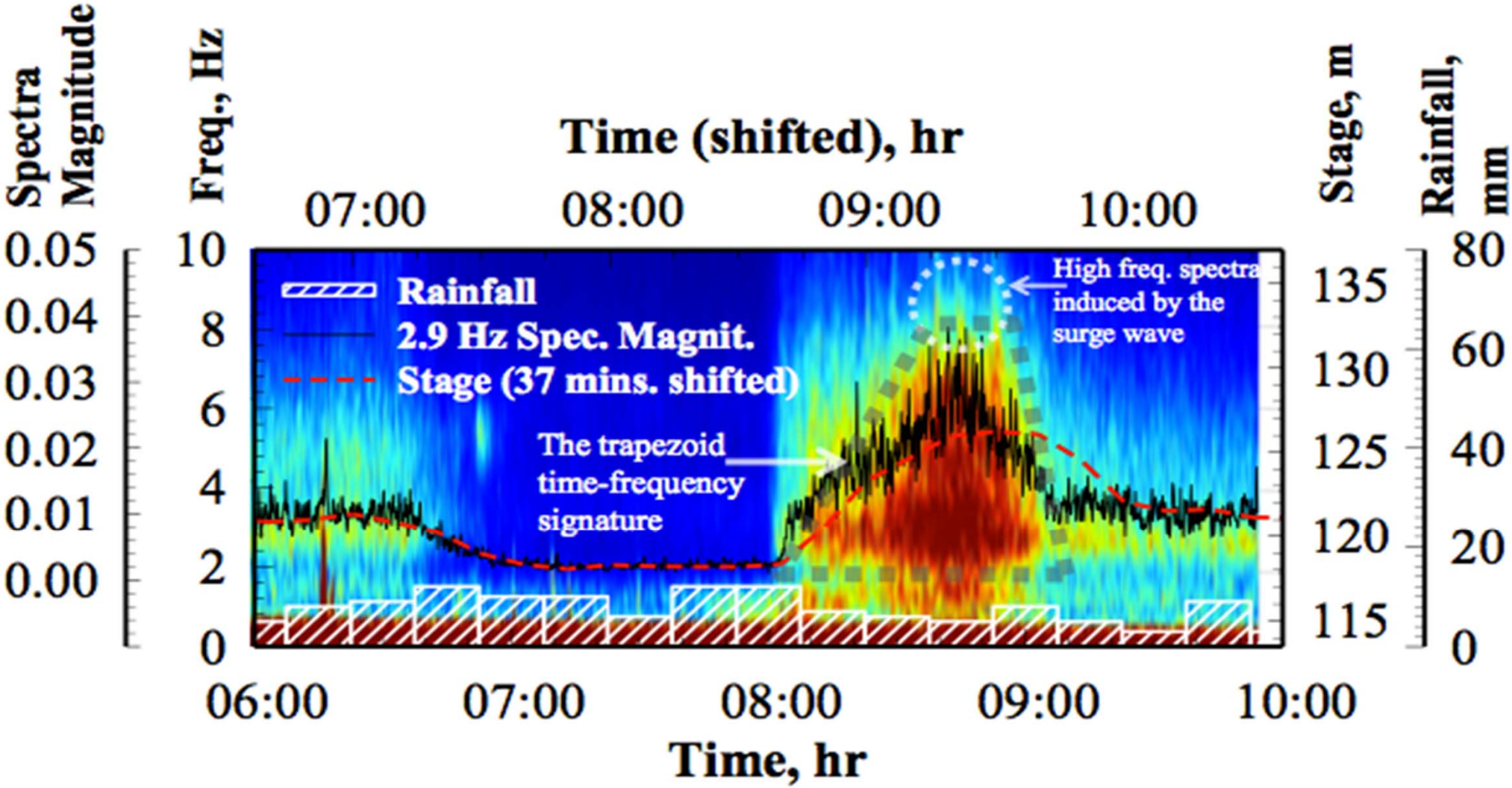
- 低頻的洪水波與河床載的震動(0.4~1 Hz)傳遞距離大約為6.5公里(13分鐘x8.3m/sec)
- 高頻的(8~10 Hz)震動傳遞距離大約為500~600公尺，這也是甲仙SGSB站到旗山溪的平均距離。

洪水預警可能性

- 如H zone所示，7點50分~8點03分有低頻的訊號出現
- 這13分鐘低頻訊號是在洪水到達之前就可以辨別出來的
- 所以這個13分鐘時間差可以用來做為預警之用，可做為撤離民眾的決策參考


A
B
C
D
E
06:45
07:00
07:15
07:30
07:45
08:00
08:15
08:30
08:45
09:00
23 mins.
H
13分鐘時間差
1 hr and 24 min
40 min
25 min

Feng, Z.-Y.(2011


Spectra Magnitude
0.05
0.04
0.03
0.02
0.01
0.00
Freq., Hz
10
8
6
4
2
0
Time (shifted), hr
07:00
08:00
09:00
10:00
Rainfall
2.9 Hz Spec. Magnit.
Stage (37 mins. shifted)
The trapezoid time-frequency signature
High freq. spectra induced by the surge wave
Stage, m
135
130
125
120
115
Rainfall, mm
80
60
40
20
0
06:00
07:00
08:00
09:00
10:00
Time, hr

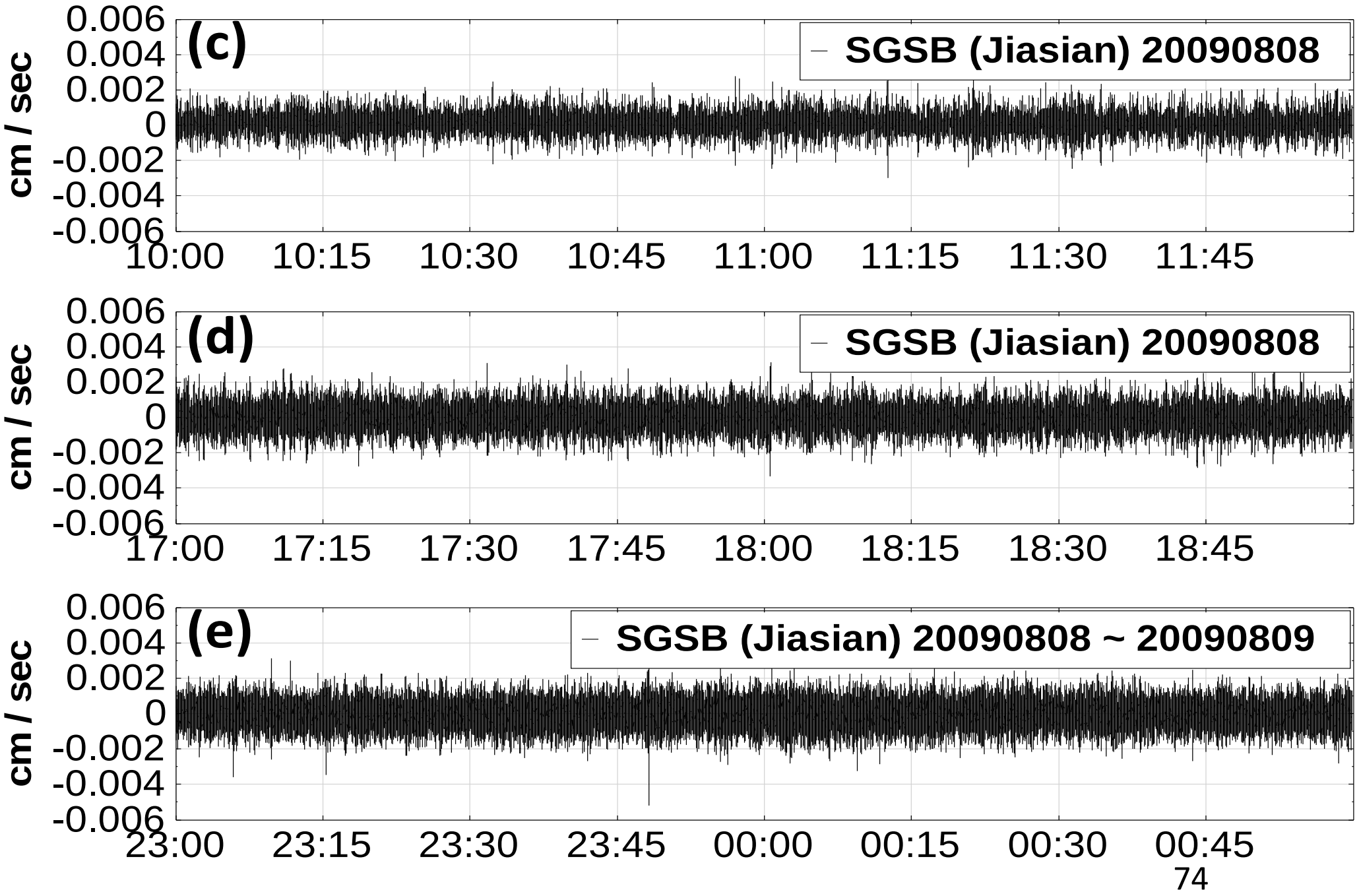
Feng, Z.-Y.(2011)

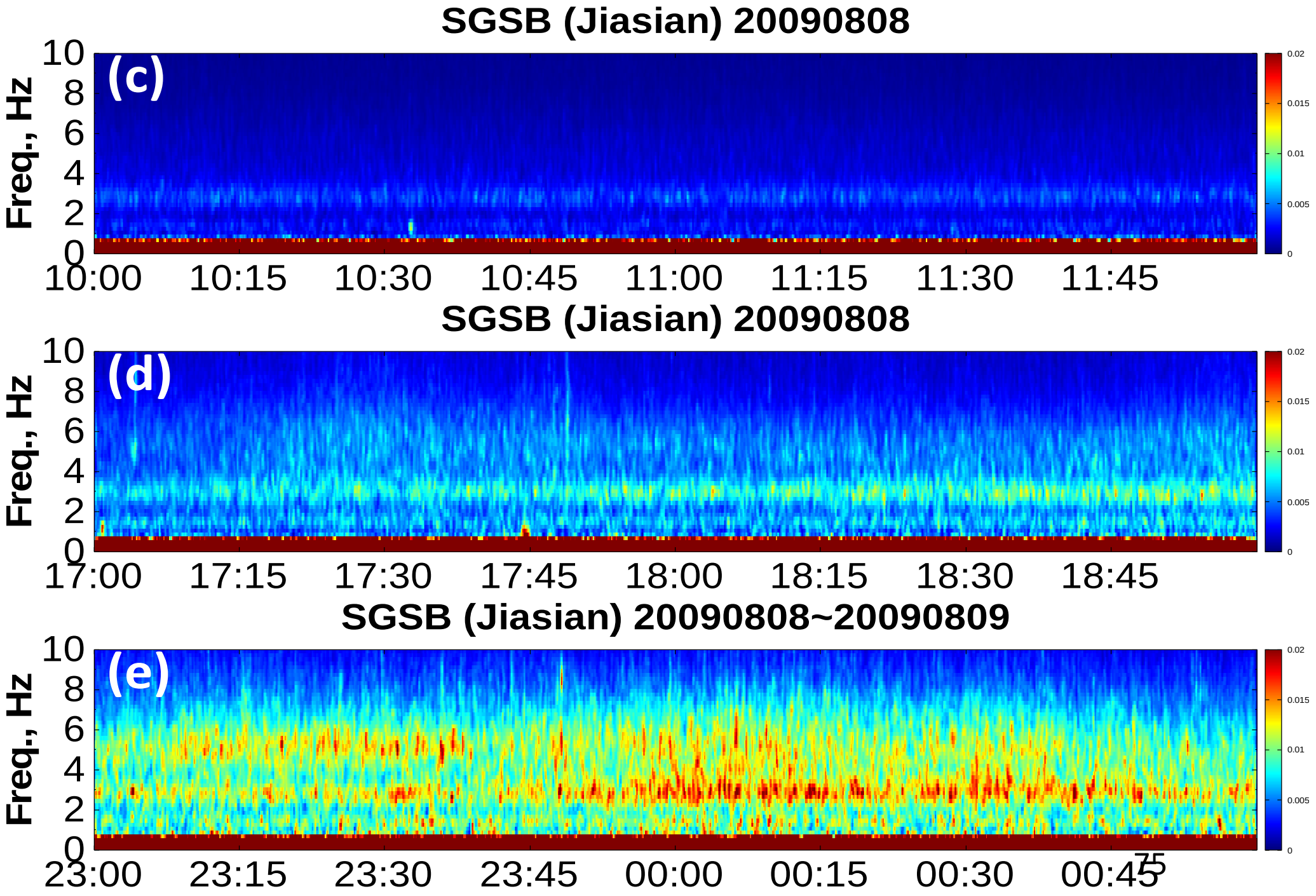
洪水時頻圖判讀

- 可以辨識一個「梯形狀」的時頻頻。
- 強大的洪水持續大約20分鐘，而造成該梯形的頻譜。
- 這與土石流或雪崩造成三角形的頻譜有所不同，因為土石流與雪崩通常不會延時太久。

Flood monitoring

- 水位 vs 震幅
- 水位 vs 頻率


(c)
SGSB (Jiasian) 20090808
cm / sec
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
10:00
10:15
10:30
10:45
11:00
11:15
11:30
11:45
(d)
SGSB (Jiasian) 20090808
cm / sec
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
17:00
17:15
17:30
17:45
18:00
18:15
18:30
18:45
(e)
SGSB (Jiasian) 20090808 ~ 20090809
cm / sec
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
23:00
23:15
23:30
23:45
00:00
00:15
00:30
00:45


SGSB (Jiasian) 20090808
(c)
Freq., Hz
10
8
6
4
2
0
10:00
10:15
10:30
10:45
11:00
11:15
11:30
11:45
0.02
0.015
0.01
0.005
0
SGSB (Jiasian) 20090808
(d)
Freq., Hz
17:00
17:15
17:30
17:45
18:00
18:15
18:30
18:45
SGSB (Jiasian) 20090808~20090809
(e)
Freq., Hz
23:00
23:15
23:30
23:45
00:00
00:15
00:30
00:45

結論

1. 發現寬頻測站的連續記錄可做為探測河川動力(river dynamics)行為的重要新來源
2. 分析結果可提供旗山溪堰塞壩潰壩洪水歷程模擬之束制條件(empirical constraint)

Referee's comments

- Reviewer #2: **I'm excited by this manuscript.** By picking the Xiaolin landslide damming of the Qishan river and the subsequent dam-breach as a focus for a seismic study of channel hydraulics, **the author has cleverly chosen a rich signal whose interpretation is straightforward and unambiguous.** In so doing the virtues of **using seismology to probe channel flow** are exemplified.

Referee's comments

- After some modification of the text **I would welcome seeing this paper in print**, and it would do the journal credit to help pioneer what **is likely to become an important new source of empirical constraint on river dynamics.** The **novelty of the method** and the unfamiliarity of seismology to hydrologists and hydraulic engineers may generate some confusion in the review process and **I encourage the editors to be steadfast** in the face of negativity should it arise.

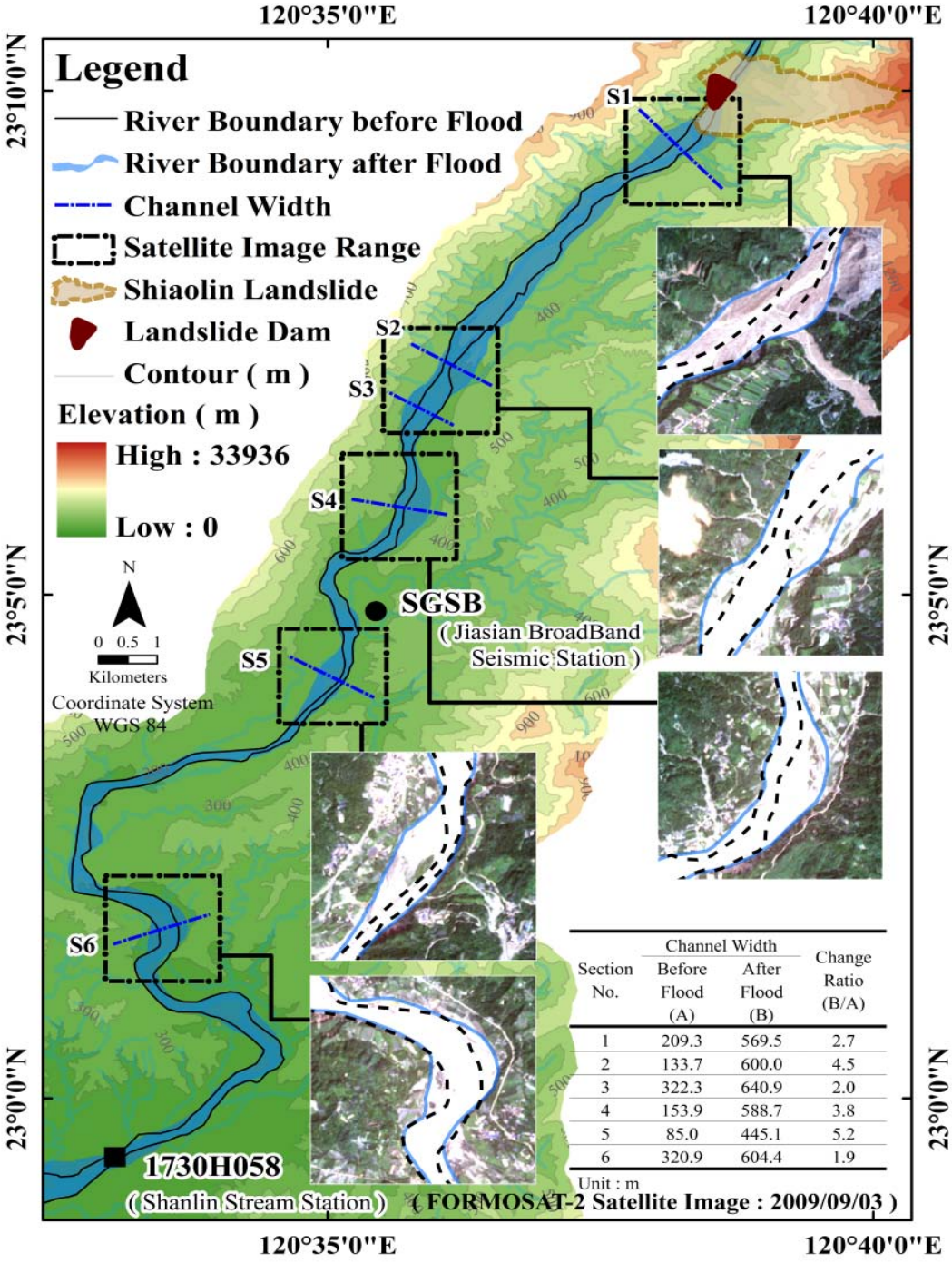
- Feng, Z.-Y. (2011) "The seismic signatures of the surge wave from the 2009 Xiaolin landslide-dam breach in Taiwan", Hydrological Processes, Sep. 6, 2011 online pub., doi: 10.1002/hyp.8239
- JCR IF= 2.068 (13%)

後續研究

- River morphology
- “Damping” of the surge wave
- Surge wave simulation

River morphology

- River morphology induced by the dam breach surge wave
  - Bed Erosion
  - Bank erosion
  - Cutting
  - Deposition
  - Meandering …



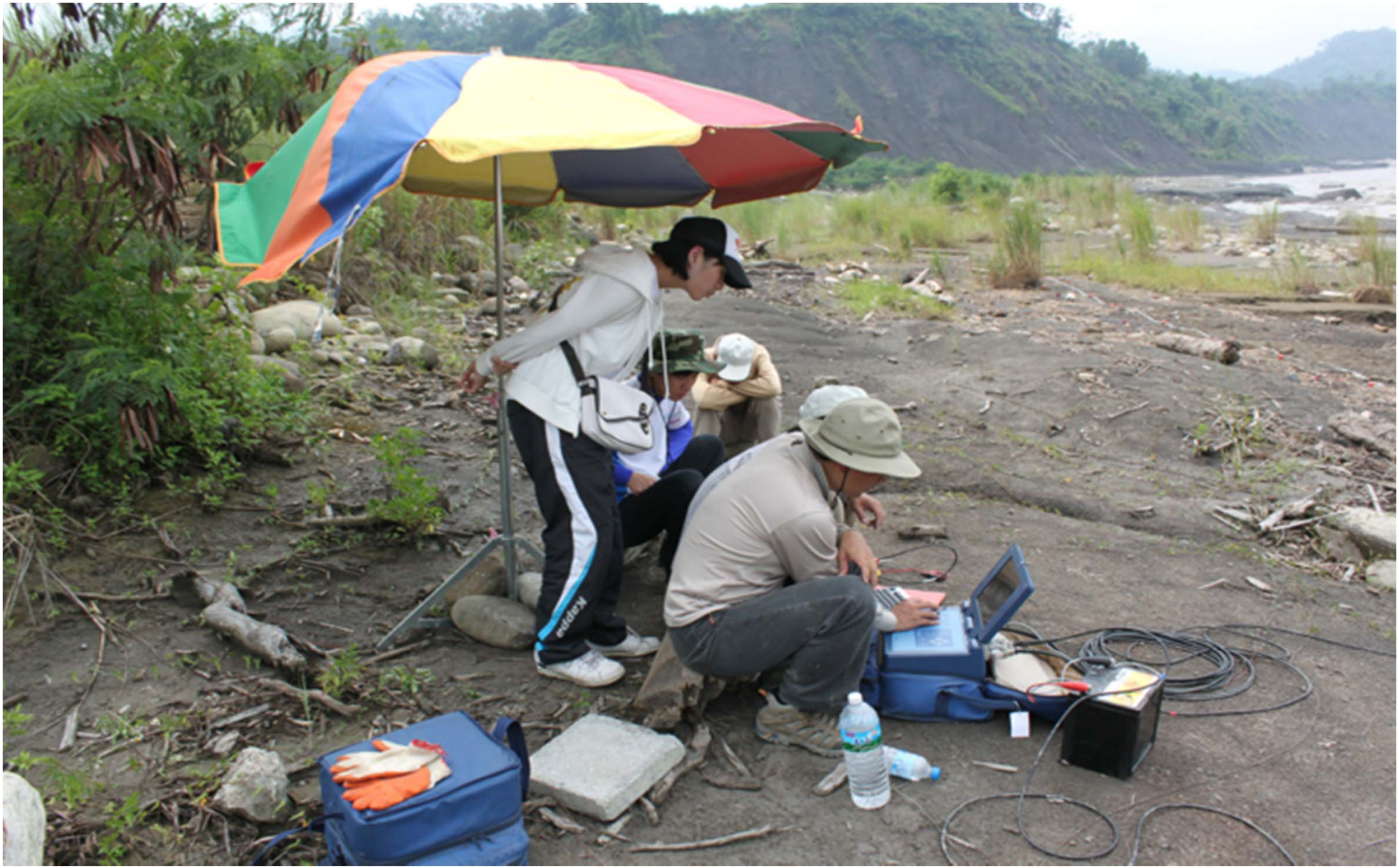
Section No.	Channel Width Before Flood (A)	Channel Width After Flood (B)	Change Ratio (B/A)
1	209.3	569.5	2.7
2	133.7	600.0	4.5
3	322.3	640.9	2.0
4	153.9	588.7	3.8
5	85.0	445.1	5.2
6	320.9	604.4	1.9

Unit : m

“Damping” of the surge wave

- how far upstream/downstream extends?
- attenuation of seismicity with distance?


206450
206600
206750
206900
207050
207200
2553650
2553500
2553350
2553200
2553050
N
甲仙大橋
測線01
測線02
測線03
0
95
190
Meters
Image © 2011 GeoEye


Kappa

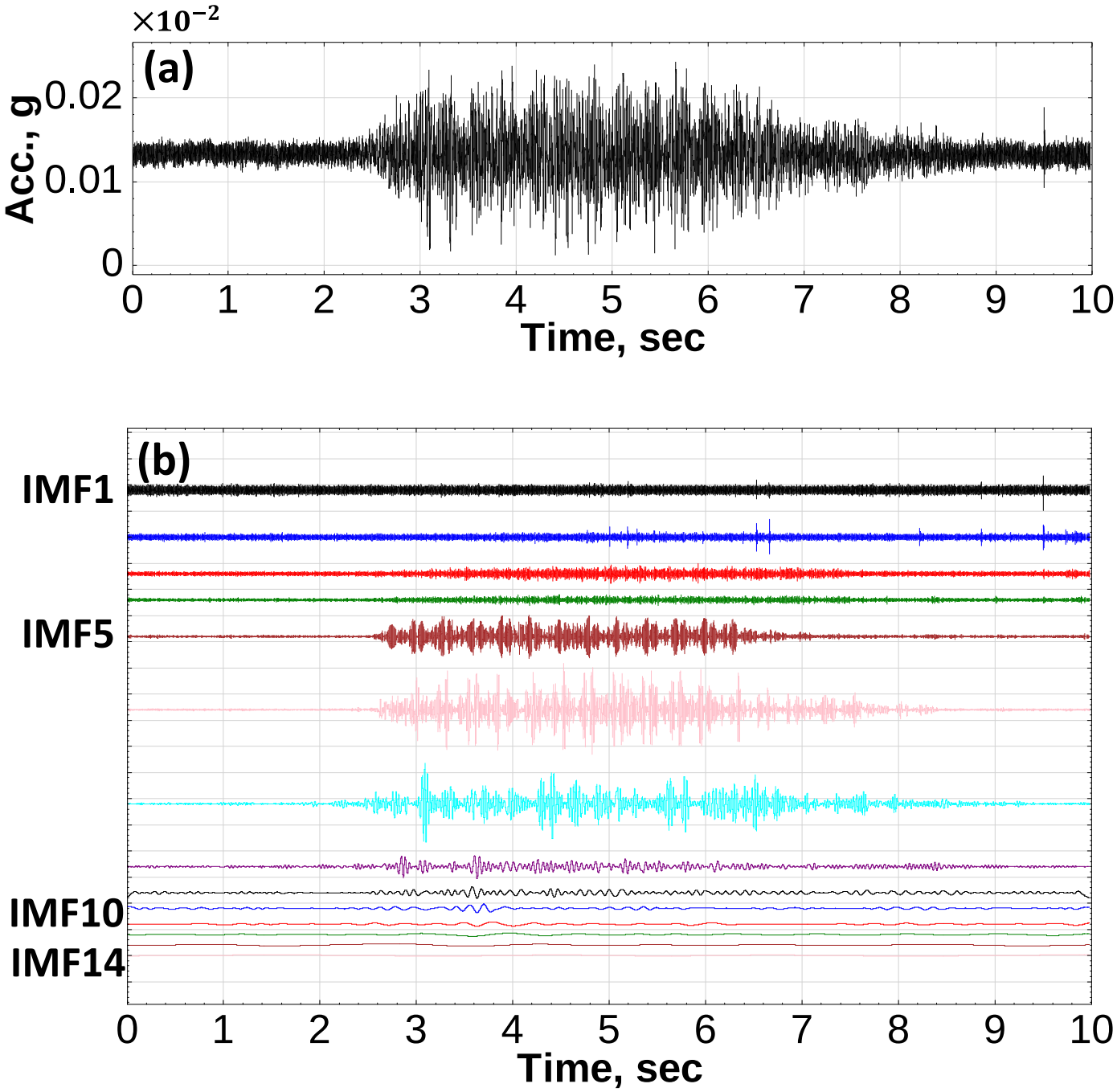
Surge wave simulation

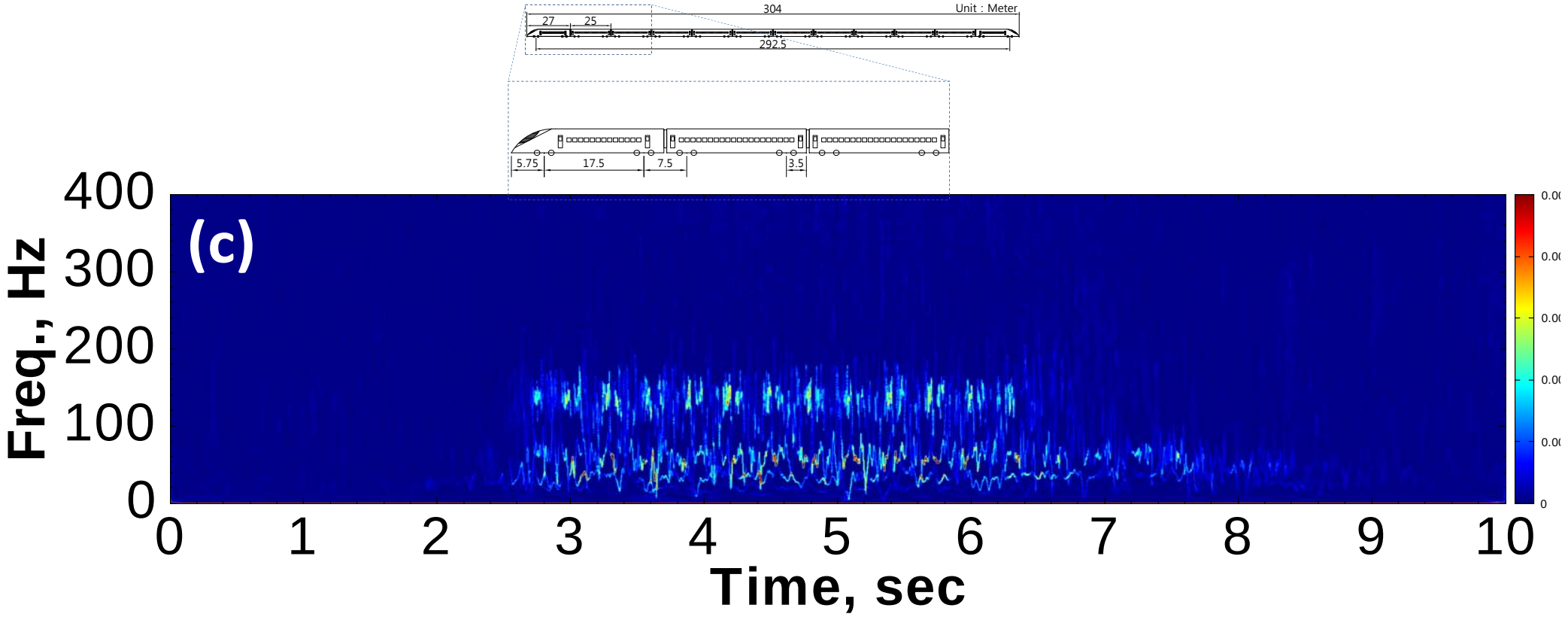
- Wave attenuation
- Bedload/sediment transportation
- Flood and bedload interation
- Flood morphology verification
- …

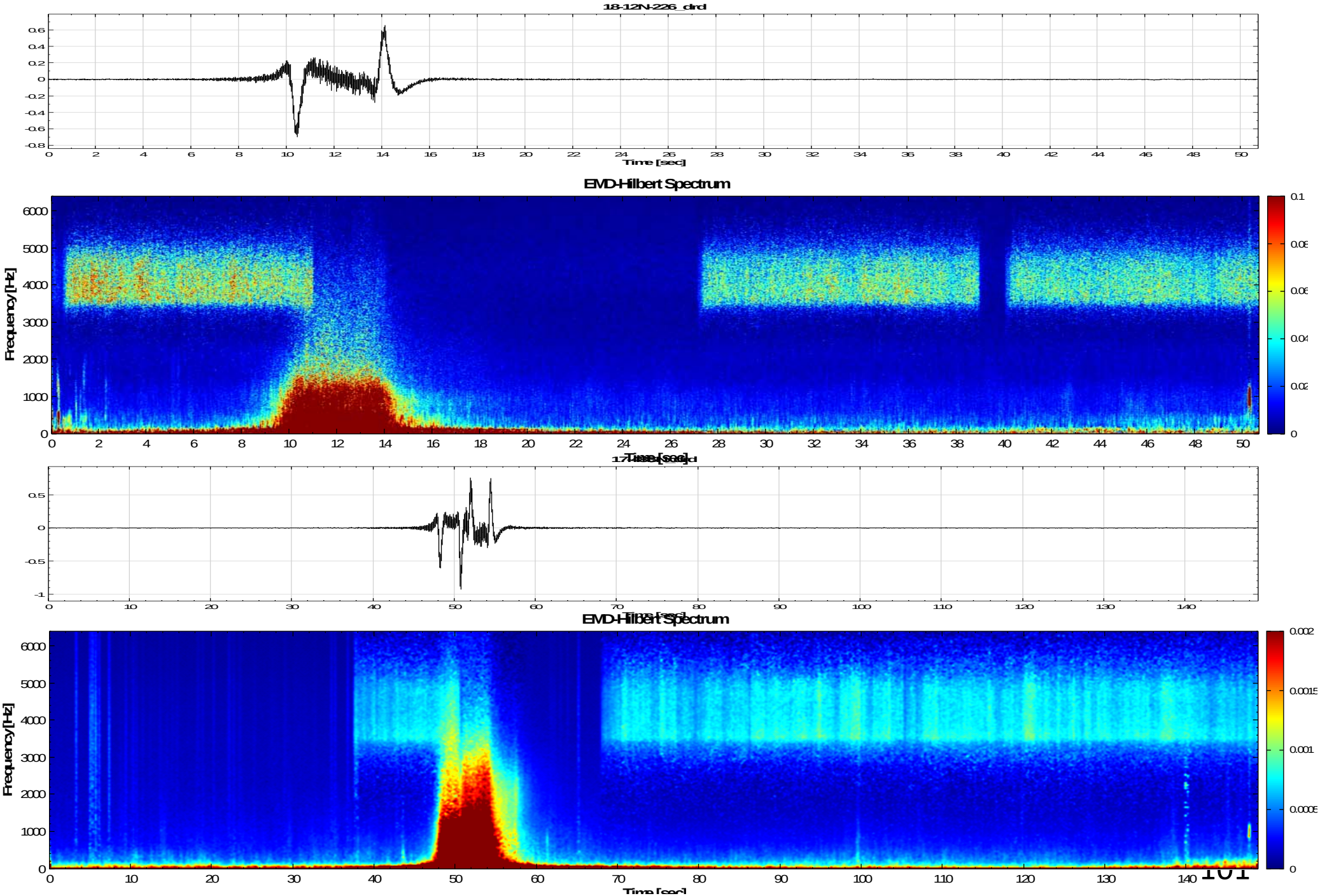
我應用HHT的研究

- 目前
  - 高速鐵路震動與噪音
- 未來
  - 高鐵沿線地層下陷之科學監測與解決方法(proposal for NSC project)
  - 大型山崩即時定位與預警系統之建置與應用(proposal for NSC project)

高速鐵路震動與噪音


×10⁻²
(a)
Acc., g
0.02
0.01
0
0 1 2 3 4 5 6 7 8 9 10
Time, sec
(b)
IMF1
IMF5
IMF10
IMF14
0 1 2 3 4 5 6 7 8 9 10
Time, sec


304
Unit : Meter
27
25
292.5
5.75
17.5
7.5
3.5
(c)
Freq., Hz
400
300
200
100
0
0
1
2
3
4
5
6
7
8
9
10
Time, sec


18-12N-226_drd
Time [sec]
EMD-Hilbert Spectrum
Frequency [Hz]
Time [sec]

自然災害防治研究室

in 國立中興大學水土保持學系

馮正一 教授
美國普渡大學 土木工程博士

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阿里山公路崩塌路段校外教學

野外調查鐵牛車上-滿載樂不可支

研究課題

- 自然災害防治、防災技術發展、防災工程設計
- 崩塌地、土石流、堰塞壩之調查、分析、監測與防治工程設計
- 崩塌震動、堰塞壩潰壩洪水之寬頻地震訊號分析與判釋
- 地球物理探測：地電阻剖面影像法(ERT)、表面波譜法震測(MASW)
- 地面型LIDAR 3D雷射掃瞄分析與應用(監測與變遷研究)
- 土石壩受地震作用之動態安全性分析、大地地震工程
- 坡地地下水流分析、土壩滲流分析

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九份二山LIDAR 3D雷射掃描

惠蓀林場人工堰塞壩地電阻剖面影像法試驗

奧萬大野溪河谷解壓節理與劈理位態量測

惠蓀林場達見砂岩層露頭Schmidt錘壓力強度量測

苗栗縣八燕坑3D雷射掃描

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- 敬請投稿
- 摘要100年10月28日前E-mail jcswc@nchu.edu.tw
- 全文100年11月25日前E-mail jcswc@nchu.edu.tw

歡迎投稿!

中華水土保持學報

jcswc@nchu.edu.tw

(申請EI 中...)

總編輯 馮正一 敬邀

崩塌、地震、洪水災害研究

Thank you very much.

敬請指教

馮正一　教授, Ph.D., P.E.

自然災害防治研究室

國立中興大學 水土保持學系

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