出國報告(出國類別:國際會議)

赴美國夏威夷參加 2018 年亞洲大洋洲 地球科學聯合研討會

服務機關:中央氣象局地震測報中心

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派赴國家/地區:美國夏威夷

出國期間:107年5月30日至107年6月14日

報告日期:107年6月27日

摘 要

亞洲大洋洲地球科學聯合研討會(Asia Oceania Geosciences Society, AOGS)是亞洲地區規模最大之地球科學研究與應用的國際聯合研討會,此會議每年廣邀各國從事地球科學相關研究之學者,提供大家發表研究成果與互相交流的機會。

為分享本局在地震測報工作之成果,本局指派地震測報中心陳燕玲課長、羅翊菁及賴姿心 2 位技佐前往美國夏威夷參加本年度會議。陳員等 3 人於會議中以海報形式發表其個人之研究論文,論文題目分別為「A Study on the Correlation of the Stress and Earthquake Frequency-Magnitude Distribution b Value in Taiwan」、「Modeling Regional Waveforms from Explosion Source with Realistic Surface Topography」及「Determination of a local magnitude scale using earthquake data recorded by the borehole seismic network in Taiwan」,透過與會發表研究成果,就近與各國專家學者進行實質交流及觀摩,除對本局地震測報業務之發展有所助益外,亦可提升陳員等 3 人之學術研究創新及精進能力。

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一、目的

亞洲大洋洲地球科學聯合研討會(Asia Oceania Geosciences Society, AOGS)於每年夏季於亞太地區的國家輪流主辦,匯集來自世界各地關心亞太地區地球科學各個領域的學者及研究生一同參與,目的是希望能夠透由交流和討論的機會,能展現各自的研究成果,激盪出更多的火花,以解決學術界、研究機構和公眾中重要的地球科學問題,讓交流的成果在研究上得以幫助。

今年(2018)訂於 6 月 3 日至 6 月 8 日於夏威夷盛大舉行,為分享我國在地震測報工作之研發成果與觀摩各國相關之技術及經驗,本局指派地震測報中心陳燕玲課長、羅翊菁及賴姿心技佐 3 人參加透過人發表個人論文成果海報及參與最佳優秀學生論文比賽,除可展現陳員 3 人平時工作的研究成果,並與來自世界各地的專家學者在研究上交換想法與建議,不僅可促進本局地震測報作業與各國地震領域之交流,亦可提升陳員 3 人學術研究創新及精進之能力。

二、過程

本年度會議主題涵蓋大氣科學(Atmospheric Sciences)、生物科技(Biogeosciences)、水文科學(Hydrological Sciences)、跨域地質學(Interdisciplinary Geosciences)、海洋科學(Ocean Sciences)、古海洋和古氣候學(Paleoceanography and Paleoclimatology)、行星科學(Planetary Sciences)、太陽與地球科學(Solar and Terrestrial Sciences)、固態地球科學(Solid Earth Sciences)及特別演講(Special Sessions),研討會線上議程如下:

http://www.asiaoceania.org/aogs2018/public.asp?page=sessionList.htm

, 陳員 3 人主要參加固態地球科學議題之議程。

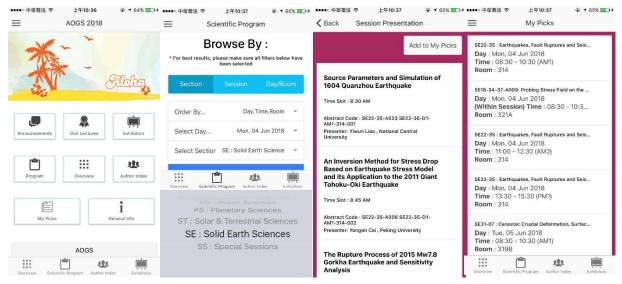
(一)參訪行程

| 日期 | 工作摘要 |
|---------------|-------------------------------|
| 107年5月30日(三) | 赴夏威夷 |
| 107年5月31日(四)至 | 搭乘華航CI2班機,21時10分起飛出發前往夏威夷,於當地 |
| 107年6月2日(六) | 時間5月30日12時45分抵達檀香山國際機場。由於航班限 |
| | 制,因此提早出發,除可提早熟悉會場附近場域,並調整 |
| | 時差及安頓各自作息以養精蓄銳參加會議。 |
| 107年6月3日(日) | 準備海報報告內容及提早去會場報到領取識別證。 |
| 107年6月4日(一) | 參與地震、斷層破裂及地震學等相關研究議題與海報。 |
| | 中午參加地震斷層破裂及地震學議題午餐(session |
| | lunch) ° |
| | 晚上參加大會reception活動。 |
| 107年6月5日(二) | 參與動態模型與機制、地震斷層破裂及地震學、利用數據 |
| | 解析地球與地震模擬等相關研究議題與海報。 |
| 107年6月6日(三) | 參與地震斷層破裂及地震學、利用數據解析地球與地震 |
| | 模擬等相關研究議題與海報。 |
| 107年6月7日(四) | 準備海報並發表個人海報、羅員及賴員參與最佳優秀學 |
| | 生論文比賽。 |
| 107年6月8日(五) | 參與地球與地震模擬等相關研究議題與海報。 |

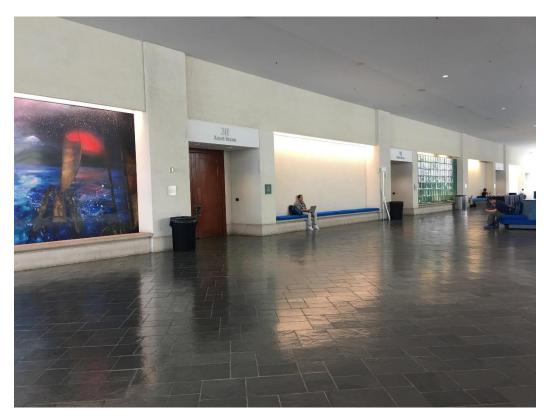
| 107年6月9日(六)至 | 陳員於會議結束後6月10日(日)返臺,搭乘華航CI1班機, |
|--------------|---------------------------------|
| 107年6月13日(三) | 14時55分起飛,於臺灣時間6月11日19時30分抵達桃桃園國 |
| | 際機場。 |
| | 羅員與賴員欲體驗夏威夷火山行程,故於6月13日(三)返 |
| | 臺,搭乘華航CI1班機,14時55分起飛,於臺灣時間6月14 |
| | 日19時30分抵達桃桃園國際機場。 |
| 107年6月14日(四) | 返回臺北 |

(二)參與有關固態地球科學(Solid Earth Science)議題的議程

近幾年各大研討會為節能減碳提倡無紙化後,以往非常厚重的紙本議程,現今都由電子 app 取代,可方便掌握議程資訊,app介面如下圖,選取好欲聆聽的議題後,可以加入「我的選擇(my picks)」,最後會有1份專屬你自己的「行程(schedule)」。



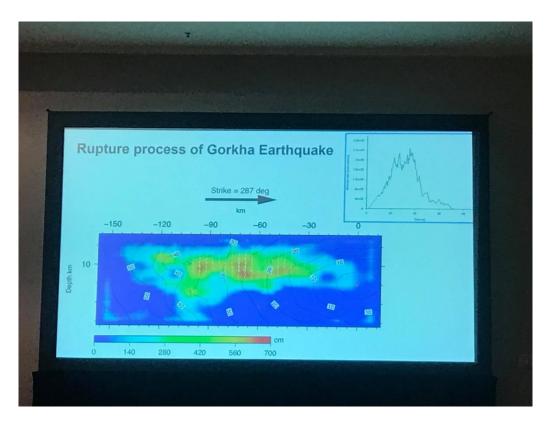
圖一、(左至右)分別為 app 主頁面、選取議程、議程內容及「我的選擇(my picks)」。



圖二、各個會議室裡面都有精彩的議題。



圖三、有關臺灣淺層速度構造的議題,講者為國震中心林哲民研究員。



圖四、與廓爾喀(Gorkha)地震有關之議題。



圖五、有關 PSHA 之議題,講者為新加坡南陽理工大學詹忠翰研究員。



圖六、有關噪聲(ambient noise)之議題,講者為猶他大學林凡奇。

(三)本局參與人員發表研究成果

1. 陳燕玲課長

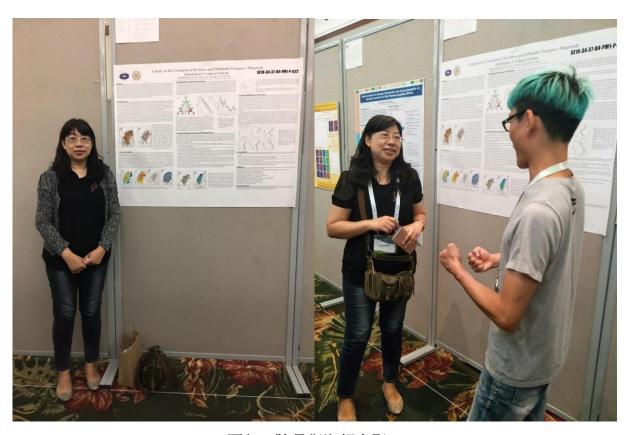
陳員發表論文的題目為「A Study on the Correlation of the Stress and Earthquake Frequency-Magnitude Distribution b Value in Taiwan」,中文題目為「臺灣地區應力與地震頻率規模分布及地震b值的相關性研究」。

上述研究使用本局地震觀測網地震目錄的343,581地震與2,640個地震震源機制解,用以描繪臺灣地震頻率規模分布與地震b值之空間變化,研究其與斷層錯動類型與地殼應力型態的相關性。地震b值的估計結果顯示,在95%的信賴區間內,各類震源機制的地震b值顯然存在著明顯的差異,逆斷層b值最低(0.82±0.02),走向滑移斷層b值居於中間(0.89±0.03),正斷層b值最高(1.03±0.09),所得結果與全球和其他區域得到相當一致的地震觀察結果。

估算臺灣3種震源機制型態的地震b值結果顯示,具有非常顯著的差異,其中逆斷層錯動型態的震源機制具有最低的地震b值,走向滑移斷層錯動型態具有中間值,正斷層

錯動型態具有最高的地震b值,這個結果與全球性或區域性地震活動的相關研究都有很好的一致性。在地震b值的側向分布研究顯示,其與主要的斷層錯動機制、地殼變形及應力型態都有非常良好的相關性。臺灣在強大的東西向縮短與差異應力作用下,造成在東臺灣和西臺灣的兩個南北走向的逆衝斷層帶,其具有較低的地震b值;在中臺灣狹長南北向的山脈內或山脈間,受到較小的拉張應力作用,主要受到走向滑移和正斷層作用,其具有較高的地震b值。在地震b值的深度分布研究顯示,地震b值隨深度單調遞減至大約於15-20公里深度終止,顯示地震b值與應力呈現反比關係,並且證實在臺灣造山帶底下具有弱質中部地殼,並存在一層脆塑性的轉變帶。

簡言之,本研究首先驗證在臺灣造山帶之地震b值與斷層錯動型態及地殼應力同樣 具有通用的對應相關。區域地震b值的變化與地殼變形及應力架構的良好相關性,充分 顯現了區域的震源構造特性。隨震源深度變化的地震b值顯示,臺灣底下的弱質中部地 殼,在約15-20公里深度,存在一層脆塑性的轉換帶。



圖七、陳員與海報合影。





A Study on the Correlation of the Stress and Earthquake Frequency-Magnitude

Distribution b Value in Taiwan

Yen-Lin Chen¹, Shu-Iluei Ilung², Juen-Shi Jiang¹, Lin-Yun Chiao³

3. Dependence b-value on faulting style We investigate the correlation of the earthquete insquency-magnitude is stitution with the syste of lauting and stress in Taison. The besides a starting of the three types of focal mechanisms show agenticant differences with the lawart for thous, intermediate for subsection of the start for the starting of the start

To stees whether the byesture veries with the leading style, we categorize the food mechanisms into three groups in a tourn's paging with the protection acceleration for this algo and what faithing beaution does not pullegate of the categories are sensitively in the protection and a pursuant foreign (1997), (19. 3a). The byesture stretched for the categories of the cate

3

regional sciencisty, Lateral distribution of the b-values above a good contablion with the predominant hauling mechanism, or stand determination and support and the total contraction of the standard contraction and standard the argent is shortening and differential stress yield the lower to values than those in the inchresser mountain angest authority the smaller connected attract and dominated by strike light and normal faults. The translation of the renonconcially determine between the stress and dominated by strike light and normal faults. The translation of the renonconcially determine places presented in virial 200 by the variety and the stress reflectionship with stress and the existence of the translationship in the work until discuss the missing contraction of the production of the production of the supportance of the translation of the work until discuss the missing contraction of the production of the place production of the production

1. Introduction

Fig. 3. (a) The Institution's transpic diagram used to chaosity the corminal strake dilt, and their rayles of their directively by him group, and red done responsively. The vertexes of the strategic correspond to the corona with the day maple of eigher mere of the open principles causes (P. M. and T) no be wortist and its other two to be interned all those with antiques intailing tolyles are, the differences of the day maples for my principle mapping and the plant of the day days are excluded. (b) Committee frequency ampairing effectiveness and estimated be state for all (A) the center normal (N), saith edg (S), and then (T) mechanisms only Obyt those between the minimum and maximum Mc (solor-filler symbols) are used in this time regression. In a houlen or stope in the Gurncharg-Blober (E. K) notation, log_a/k-a bad, between the logarithm of the canustrian minimar by a retired used of a greater several the required (Constange) of Referet. Shall, as whele used to distinct the retired of the state of the canustrians of large and shall event for both regional and gobal states. As whele used to distinct the retirement of the constant and agreement of the constant of the Power in the toble from the better man and gobal states. As whele used in the constant and suggested a unavascal inverse distinction for the Power in the toble from the state of the constant of the power and dispersant an inverse of the power of the state of dispersant an inverse of the power of the power of the control of the power as the power and the power of the power of the power as the power and constant of the power of the power as the power of the power of

Fig. 1 Topographic and tectonic map in the vicinity of Talwan. (a) Perficients with depth 50 km from 1591 to 2005 for the bi-value astimate. (b) host involvations used to investigate the dependence between bi-

Fig. 4. b-value versus rake sagle. The events with the rake ungle in the sauge of £1.5. £20°, and £2.9 are used in the localin estimate. The food mechanisms plented on the case of £20° are the annual

Lateral variations of b-value and differential stress valua and faulting tylo. Eve inharectoric units from west to east the Coastal Plain (CP), Western Ecottills IWP). Havehaham Range HMI, Central Range (CR), and Coastal Range (COR), and Coastal Range (COR), and Coastal Range

Hg. Mg) displays the lateral containes of this is value and surrond incornent tensor of the cvents within each excelleging et all of LEP's in falloude by QLS's in long-lock with the policy in the dimension Cornell, the Vivolent in regions showing the fall fall as a first representative scalar inclination and to be lower than those dominated by normal and subscript inclination. The breat is considered with a fall farmental across to press; and a discussed the presence and enclosions. The breat is considered with the breatest positions and proposition of the process positions and enclosions. The breatest form the CNR of the support of the process position and enclosions.

are riting basin extending southwestward to the lan Plan (Pt). Dotted lines: the boundaries between the lithorecomic units nar and a 2000 m isopach of the Centation sedimenty, thin gray lines; active faults.

deformation front (DF), Longitudinal Valley (DV), the collision suture zone between the EP and PSP; Okinawa Trough (OT), the back

The state contenting at selection of the contention of the leavest the contention of the contention of the leavest the contention of the contention of the leavest the contention of the leavest the contention of the contention of the leavest the contention of the content of the contention of the content of th

chonce the exerts at death's fit for between 1991 and 2015 located by the Central Weather Russau (CWB) Fig. 13, If of ZdGO earth with magnitude down to 2,6 and reliable from metaheniar from our finest-motion analysis Fig. 13). Third uses the investigate the attribute-typle dependance of the Evalue. Stay the awaret in the magnitude magn

or maximum magnitude of completeness (Mc), respectively determined by the point of the na increasment inspective magnitude curve and of the discontinuity drop in the complete to included in the branch estimete. Fig. 2 shows the lateral existence of the minimum and mastly influenced by the develore appailing of the land based CMB station has the lowest

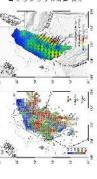
between the minimum and mas maximum curvatura in the Incoency-magnitude diagram, is num Mc. The former mostl

2. Data and method

Let.S) in the south-central and northern urban areas and the highest (*2.5) offstore easien Taleatem. The latter is related to the above the season and the highest of the activities and the season and weatherness the above the season and weatherness the above the season and weatherness the above the season and the resolve and not respond not act

ood method [Aki, 1965]

1992] and maximum likeli



pakes in Isawan. The penicipal on of focal mechanisms.

maximum (b) Me of the

Fig. 2. Labral canaltons of the minimum (a) and

Fig. 5, (a) Lateral variations of the b-values and their stardard deviations from foll in 605 as shown by other images and white contents. The food appare represents the summed moment nearor of the seems in herizonial displacements over the years of 2004-2009. Block and gray arrows indicate the directions of the principal contravescental and exclassional staticistic axes with the brights proportional to the steam rates. each exit. (b) The differential strain-rate field calculated from the difference between the two principal strain rates declared from GPS measured.

Reference
Addition, Bull Enrice Res. Inst. Tokyo Unic, 43, 235-139.
Beshiption & Robinson (1992), Data Reduction and Enric An
Cerena et al. (2002), Geol. Sec. Am., 2010), 955-938.

We thank the CWB of Telwan for the sentiquate database used in this study and Y-6. Tsal and H. Keo for discussions, his work was aupported by the Ministry of Sotence and Technology (MOSI) of Telwan.

SE18-34-37-D4-PM1-P-022



In Fig. 6, we plot the bevalue as a function of differential strain rate in easily grid shown. In Fig. 541, it is gain to the subset of institution points, there are always a neighbor contribution between them. This further condoctes the universal inverse dependence on the health of the health on the applied differential stress holds for the healthclockly very comparations. Taken

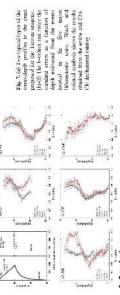
Fig. 6. b value versus differential strain rate, showing a negative correlation between them. The Mack line represents the lenst-aquates, best-fitting, line through all the

measured points.

5. Depth dependence of the b-value

Gigle et al. (2021) used quarta grain his prisonnerion plain in the series HTT or deline a linear increase of stress sith depend than the bring that the product transcriptor and either delinear and control transcriptor. The magnitude of production of the productio

serges for the Cost attacted in the Pear with a much thinner accessor cental and definite thicking, this biolises in the serges affiliated with the Chanese confirmant marginal intervents and handlesses with maginal threatest and maginal threatest with maginal threatest with maginal threatest with maginal threatest and maginal threatest with maginal threatest and maginal threatest with maginal threatest threatest and threatest and threatest access the accessor that the contraction of the continuous maginal maginal threatest maginal maginterpreters and maginal maginal maginal maginal maginal maginal m



6. Conclusion

Offices and righer in the extreme memory and the transmission of the control of t (1) The b-value dependence on the faulting style and stress holds for Taiwan with the diverse and complex deformation (2) The lower b-values are found in the two thrust zones of western and eastern Taiwan under the larger compressive

(4) Enthquakes in the riching of the same seame core in Taiwan cotally compile mixed-type for all mechanisms. It should be cautioned to use the reduced by alue extrinated from all the events within a short time window as a modified by the change of the style of faciling.

r Analysis for the Physical Sciences, 2nd Ed., McGraw-Hill Chew et a 1014, Geoppe & Act Let, 54(1), 48(1), 48(1), 54(2), 54(2), 64(4), 54(

Acknowledgement

圖八、陳員發表之海報內容

2. 羅翊菁技佐:

羅員發表論文的題目為「Modeling Regional Waveforms from Explosion Source with Realistic Surface Topography」,中文題目為「利用數值模擬的方法探討地表 地形對於爆破源的影響」,該研究並參與本次會議學生優秀論文比賽。

上述研究係利用張偉(2012)等人的方法,在研究區域建模將曲面座標(Curvilinear Coordinate)轉成卡氏座標(Cartesian Coordinate),再套入此研究區域之一維速度模型計算理論地震波形。由模擬結果可以明顯看到地表地形效應所帶來的誤差,因此地表地形在模擬中是不可忽略的。亦將模擬之波形經波速 8(公里/秒)平移過後隨著震央距排列,可以明顯看到P波及隨之而來的多重波相(multiple phase),此多重波相是因為此區域速度變化梯度太大造成的三重行為(triplication),因而產生出多重波相,本研究將利用此兩個波相的比值來判斷真實的震源深度,跟觀測資料比較厚的結果顯示,模擬之理論地震波所得的比值較接進的是深度在800-100公尺的震源深度。

最後,地震波模擬技術已是世界趨勢且在國外已經發展得很成熟,許多文章已經有利用數值模擬之理論地震波針對不同的地震參數討論,可提供觀測數據可靠的依據。共同與會之新加坡南洋理工大學的 Sehngji Wei 團隊前不久在 natural geoscience 發表了一篇利用 InSAR 針對北韓核試爆對此有更進一步的探討,羅員就近與 Sehngji Wei 討論了有關研究中位置及深度的限制,所獲之經驗對後續之研究將有很大的幫助。

SE02-A050 Modeling Regional Waveforms from Explosion Source with Realistic Surface Topography

Yi-Ching Lo12, Li Zhao3, and Shu-Huei Hung

1. Department of Geosciences, National Taiwan University, Taipei, Taiwan, 2. Central Weather Bureau, Taipei, Taiwan









3. School of Earth and Space Sciences, Peking University, China.

Simulation Configuration

strain Green tensor approach to 2017-09-03 03:30:01 UTC 6.3 41334N 129.031E The Earth's surface topography 2006-10-09 01:35:28 UTC 4.3 41.294'N 129:094'E 4.7 41.303'N 129.073'E 129.004'E 2016-01-06 01:30:01 UTC 5.1 41.300'N 129.047'E 2016-09-09 00:30:01 UTC 5.3 41.287N 129.078'E 5.1 41.299'N significant influence on the 2009-05-25 00:54:43 UTC propagation of seismic waves, which 2013-02-12 02:57:51 UTC in term leads to complexities in the we use finite difference method and recorded waveforms. In this study, Summary

six nuclear tests since 2006, with the latest in September 2017 (Table 1.) The issue of nuclear explosions by North Korea are of great public concern and has attracted much the nuclear explosion site as well as source-receiver geometry which can lead to topography near the source location on seismic waveforms. North Korea has conducted seismological interests. Our goal is to examine the topography influence surrounding investigating the effect of the surface Table 1. Recent North Korea nuclear explosions. significant effects on the recorded waveforms.

Finite Difference Method

1000

The finite-difference method (FDM, Zhang et al. (Figure 1), was adopted to compute the synthetics in local one-dimensional (1D) velocity model 2012), which uses a conforming mesh to discretize the topography on the surface and interfaces (Figure 2) with ETOPO1 topography (Figure 3).

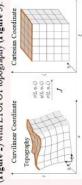


Figure 1. Schematic diagram for the curvilinear coordinate system (left) for the irregular mesh and the Cartesian coordinate system (right) for the regular mesh used by the finite-difference algorithm. Adapted from Zhang et al. (2012).

Strain Green Tensor (SGT) Approach

examine the effect on waveforms due to the Figure 2. Local 1D model (top) used uncertainty in source location and topography in the in this study. FDM computational vicinity of the source. We save the SGTs in a small mesh at vanous depths. We use the SGT approach (Zhao et al., 2006) to

volume near the location of nuclear explosion given by the USGS, using a mesh with grid sizes of 200 m horizontally and 200 m vertically. The source-time function is a Gaussian, and the FDM waveforms are accurate up to ~1.5 Hz.

Zhang W. Zhang Z. and Chan, X. (2012). Three-dimensional shorts wave numerical modelling in the presence of surface trapography by a collocated-grid faint-difference method on curtilatest grids. (Graphys. J.M. 180, 1884)? So. L. Chan, P. and Jordon, T. H. (2006). Strain Grean's tensors, reciprocity, and thair applications to seizuric sources and structure studies, Rell. Moless. Soc. Aces., 96, 178-178.

Figure 3. (Left) Locations

nuclear explosion (star, 41.334'N, 129.031'E) and GSN station MDJ (triangle, 44.617'N, 129.571'E, Δ =367.6 km). Color location of the explosion site at 0 elevation. All synthetics in this shows the ETOPO1 model of surface topography with a nominal resolution of 1 arc-(Right) Perspective views of sourcegeometry (top) and a 8x8x3 km³ volume near the explosion site in which SGTs are stored (bottom). Color stars are source locations east (red) The neighboring test sources is 500 The Green star shows the elevations of the North Korea west (blue) of the (black). minute (~1.85 km).

synthetics around the P waveforms are shifted in 8 km/s. Multiple arrivals can be seen following the Figure 4. (Left) FDM distances from 150-430 km with (black) (red) time with a wave speed of waves for a suite CII) The without topography. Synthetic Seismograms with and without Topography

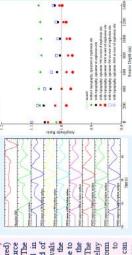
maximum amplitudes of the first two arrivals is used to constrain the the first arriving P wave due to the velocity gradient in the 1D model (Figure 2). The topography-induced delay scattering can be seen in the black traces. The ratio between maximum amplitudes source depth (Figure 6). used to constrain and topography distortion

My Mary Mary Mary Mary Mary Mary Comparison of Record and Synthetics WD source at 800 m belove surface (belove 0.3 Hz) FWD source at 1000 in below outhice (below 0.3 Hz) FWD source at 1200 m below surface (below 0.3 Hz) WD source at 100 m before unface (below 0.3 Hz) WD source at 400 m below surface (below 0.3 Hz) FWD source at 600 m below surface (balow 0.3 Hz) FWD source at surface (below 0.3 Hz) The state of the s central at Milit Photograph 3 Hot

opography and record at MDI. Traces from the top are: Unfiltered Z-component record obtained from Incorporated Research Institutions Figure 5. Comparison between synthetics computed with ETOPO1 (IRIS); low-pass filtered record with a cutoff requency of 0.3 Hz; synthetics low-pass filtered in the same way from sources at the depths of 0 m, 200 m, 400 m, and 1000 m.

study are for explosion sources.

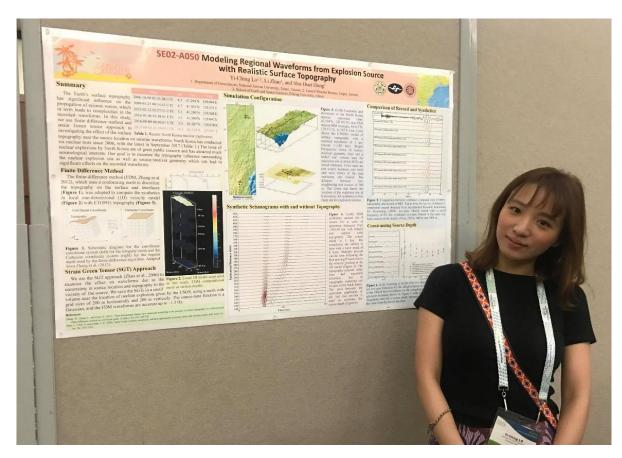
Constraining Source Depth



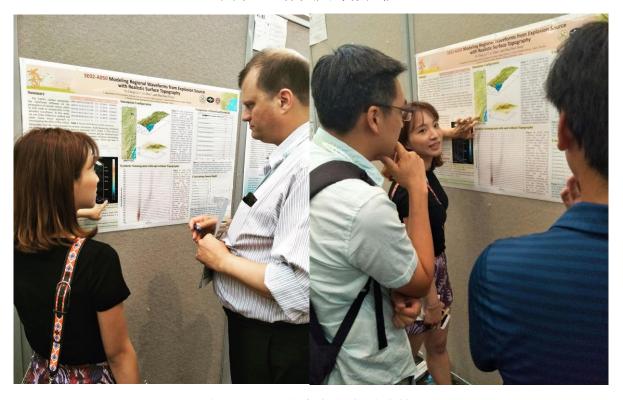
Amplitude ratio for a source depth between 800 m and 1000 m fits the value from the record the best. are low-pass filtered to 0.3 Hz. (Right) Ratios of the peak amplitudes of the filtered first two phases for the record (dash line) and for the 6 epicenter locations shown in Figure 3 with different source depths. Figure 6. (Left) Zooming in on the first two phases. All waveforms

圖十、羅員發表之海報內容

(sec)



圖十一、羅員與海報合影。



圖十二、羅員與專家學者討論熱烈。

3. 賴姿心技佐:

賴員發表論文的題目為「Determination of a local magnitude scale using earthquake data recorded by the borehole seismic network in Taiwan」,研究內容為中央氣象局為了降低地表雜訊以獲得高品質地震訊號,至 2017 年底已建置 59 個井下地震儀陣列於全臺各地,每個陣列在地表及井下各有一部強震儀,井下另有一部寬頻地震儀,透過全臺井下地震儀陣列,提昇了小規模區域型地震的監測能力、地震定位的精準度及縮短強震預警的時間。

井下地震儀大多位於數百公尺深的岩盤上,雖然有效降低地表的雜訊,但對於地 震訊號,由於場址地質條件的不同,井下站的加速度振幅會小於地表站,進一步造成地 震規模的低估,而本局現有估算地震規模的測站皆為地表站,芮氏規模衰減式也是針對 地表站,因此未來若要將井下地震儀資料納入地震規模使用,勢必要發展井下地震儀的 芮氏規模衰減式,因此本研究使用臺灣井下地震儀資料,建立第一個針對井下地震儀的 芮氏規模衰減式。

Determination of a local magnitude scale using earthquake data recorded by the borehole seismic network in Taiwan



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Institute of Earth Sciences, Academia Sinica, Taiwan Department of Civil Engineering, National Chiao Tung University Data and Methodology *** In order to acquire the high-quality seismic recordings in Taiwan, 59 borehole seismic arrays have been deployed by the Central Weather Bureau (CWB) until the end of 2017. (Fig. 1) Each borehole array includes two force balance correction function can be expressed as -logA_o= 1.553 log(r/100) - 0.001(r-100) + 3.0, with amplitude A_o in millimeters and hypocentral distance r in kilometers, showing a weak attenuation with distance. (Fig. 6) The station correction factors for the borehole stations determined in this study are smaller than the stations at the surface. (Fig. 7) We further compare the M_c surface station can be amplified also. (Fig. 3b) In the past, the attenuation function used in the calculation of local magnitude was well-builded by using the seismic records of surface stations. For a purpose of using the borehole data in determination of local magnitude (M,), it is necessary to develop a new M, attenuation equations particularly for the borehole data. In this seismometer is below the borehole accelerometer. (Fig. 2) Ideally, the background noise level of downhole station is lower accelerometers, one at the surface and other at a depth of a few ten-to-hundred (30-492) meters, as well as one broadband than the surface station. (Fig. 3a) In addition to the geology conditions, the earthquake-induced seismic signals recorded by study, we used 9022 earthquakes to report the first M. scale for borehole seismic stations. (Fig. 4, Fig. 5) The distancevalue from the borehole data with the surface data within each earthquake to investigate their correlation. (Fig. 8) Summar

Waveform recorded by borehole station The peak amplitude of the horize selsmogram for each event Simulated Wood-Anderson Selsmograms SNR > 3 Using singular value decom do the inversion ner, 1984] $S_l\delta_{ij} - a \log \left(\frac{r_{ij}}{100}\right) - b(r_{ij} - 100) = \log A_{ij} + 3.0.$ ε 2 9 $-\log A_0 = a \log \left(\frac{r}{100}\right) + b(r - 100) + 3.0$ [Richer, 1935] A repricent rail distance (km) S rempirical station correction as a special rail specialing coefficients b ranchastication to the first rail distance (km) $M_L = \log A(\Delta) - \log A_0(\Delta) + S$ 1 0 ... 0 -1 0 ... 0 pt nt i, k = 1, 2, ... m; j, l = 1, 2, ... n Œ $\sum_{k}^{m} M_k \delta_{ik} - \sum_{k}$

earthquakes occurred during 2017 in Taiwan used in this study. The sizes of the stars and circles are proportional to the magnitude. Distribution of borehole seismicarrays shown by triangles. of 9022 Epicenter Figure

Frame Relay

Borehole Seismic Array in Taiwan

Figure 5. A flowchart of deriving the first attenuation function for borehole seismic stations in Taiwan. Derive the attenuation function € $p_{ij} = -a \log(\frac{2ij}{100})$ $q_{ij} = -b(n_{ij} - 100)$ $y_{ij} = \log(A_{ij} + 3.0)$ 10

Results

300m

(black triangles) have been installed in Triwan deployed by the Central Weather Bureau (CWB) until the end of 2017, 2 stations (gray triangles) will be installed before the end of 2018.

Taiwan. There are 59 borehole seismic arrays seismic arrays

With 13943 records from 9022 events recorded by 54 borehole stations in 🛪 From the determined attenuation curve, the first M. Scale for Taiwan, the distance-correction function (attenuation curve) is obtained as borehole seismic stations is also obtained as follows $M_L = \log A + 1.553 \log r - 0.001 r + 0.79$ 3 $-\log A_0 = 1.553 \log \left(\frac{r}{100}\right) - 0.001 (r - 100) + 3.0$ Figure 2. The seismometers at surface-borehole stations. Each

9

h s 35 km & A s 80 km (7)

In Taiwan, the local magnitude is calculated using three equations proposed by Shin (1993) $M_b = \log \alpha \mp \cos n_0$, where $M_L = \log \alpha + 0.033 \log \pi + 0.00326 \pi + 1.01$ h > 35 km (9) A : spice at mald in the size of the point of the size of the point of the size of the point of the size of the $M_b = \log A + 0.83 \log r + 0.00261r + 1.07$ h < 35 km & $\Delta > 80$ km (8) $M_b = \log A + \log r + 0.00716r + 0.39$. . . Figure 6. Relationship between log As and (a) hypocentral distance for xxx all 9022 events. array includes two force behance accelerometers, one at I the surface and other inside the borehole, as well as one broadband seismometer inside the broadband seismometer inside the borehole. The downhole instruments are placed at a depth between 30 and 492 m.

PGA:0.01gal

Downhole station

PGA:0.1gal

a

Figure 7. Station corrections (a) for the stations at the surface (Lai et al., 2016) (b) for the stations at the borchole obtained in this study. (c) Histogram of the station corrections for the surface stations (left) and borchole stations (right). 9 Figure 8. Comparison of M_c from the CWB catalog and M_c determined by borehole seismit stations with the attenuation function for the 1384 events used (c) n this study.

Figure 3. (a) The background noise recorded by the surface (left) and borehole stations at a depth of 397 m (right). (b) The seismin waveform of 20180206 Hualien earthquake recorded by the surface (left) and borehole

PGA: 14gal

06 Feb 2018, EWT02, M.=6.26

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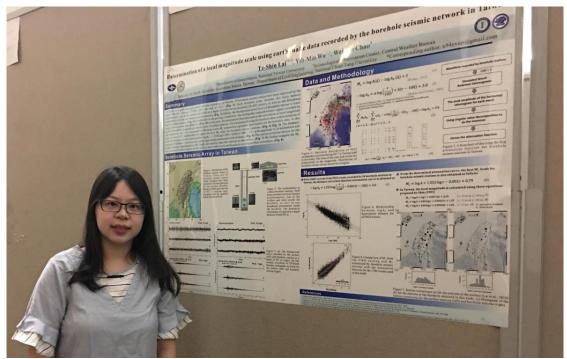
06 Feb 2018, EWT01, M_=6.26

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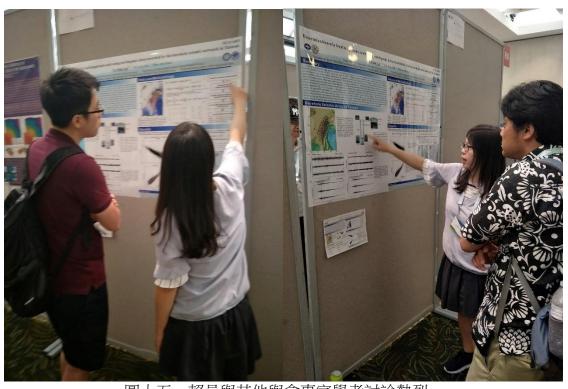
References

moningical Society of America 14, 1871–1845. of sinceffect artefacts, School East, Let., ST, 948-53. Of U. Vise, 2011, The first M, sails innorth of Vistra et, J. Ani an Earth Sci., 40, 279-236.

、賴員發表之海報內容]]] 十 画



圖十四、賴員與海報合影。



圖十五、賴員與其他與會專家學者討論熱烈。

三、心得與建議

AOGS 每年都會換不同的地方舉辦會議,集結亞太地區的專家學者共襄盛舉,除了發表有關亞太地區地球科學的議題外,並提供與會學者深入討論及交流平台,今年的 AOGS 在夏威夷舉辦,開起會來既舒服又感受到當地濃濃的海島氣息。

亞洲及太平洋地區常發生許多天然災害,AOGS 每年辦理研討會就是希望各國專家學長能齊聚一堂針對各種災害性的議題進行成果發表或討論交流。

此次有此機會參加此一盛會,除了觀摩各國專家學者之成果,透由就近討論也給予 與會人員許多研究上的建議。綜整心得與建議如下:

- 本局地震測報中心在地震發生的第一時間,快速提供地震資訊供民眾與救災單位參用,其中地震規模的估算,因時效要求並未加入地震測站修正量,建議在後續資料處理時可以考慮納入地震測站修正量用以修正地震規模,提升地震芮氏規模的精準度。
- 2. 截至 2017 年底本局已於全臺各地建置 59 個井下地震儀陣列,然臺灣現行芮氏規模的估算僅使用地表測站,並未使用井下地震站之儀器資料,賴員已建立之 1 個井下地震儀的芮氏規模衰減式,未來應可持續研究,並評估將井下地震儀資料加入地震規模估算之可行性。另外,井下地震儀的資料極為珍貴,相關的應用與研究也可透過參與國際研討會發表成果,吸收其新知與經驗並應用於臺灣之發展。
- 3. 在速度構造逆推的方法上常用噪聲(Ambient noise)訊號去逆推淺層速度構造,此次議程上,已有學者使用結合體波逆推深層速度構造的研究,對速度模型的逆推在深度上有更完整的解析,提供未來了解臺灣複雜的造山運動構造一個新的思維。

四、附錄-研討會相關照片





照片 1、攝於夏威夷國際會議中心(Hawaii Convention Center)前。



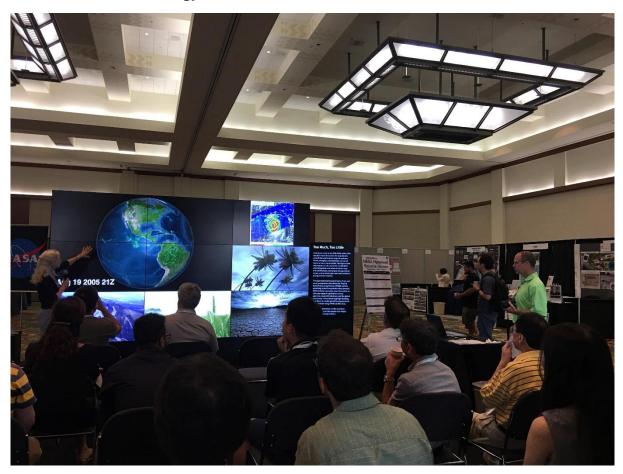


照片 2、大會報到現場及領取識別證。





照片 3、研討會現場與專家學者討論研究內容,圖左為現職新加坡南洋理工大學的Sehngji Wei,圖右為現職北京大學的Li Zhao



照片 4、會場內各地球科學領域之廠商展覽,圖為 google 的攤位。



照片 5、位於會場 Hawaii Convention Center 旁,每天從飯店走到會場必經過的 kahanamoku lagoon,是典型的海島國家。



照片 6、會議結束隔天正值夏威夷一年一度的泛太平洋節(Pan-Pacific Festival),從我們 飯店正好可以鳥瞰遊行隊伍。



照片 7、泛太平洋節(Pan-Pacific Festival)為期 3 天的年度盛事,有盛大的 Ho'olaule'a 封街派對、各式表演團體演出、草裙舞嘉年華,以及熱鬧歡騰的威基基大遊行。



照片 8、泛太平洋節(Pan-Pacific Festival)的 Ho'olaule'a 封街派對。