

國家科學及技術委員會專題研究計畫申請書

申請條碼：113WFA0112365

一、基本資料：



計畫類別 (單選)		一般研究計畫		
研究型別		整合型		
計畫歸屬		自然處		
申請機構/系所 (單位)		國立臺灣大學地質科學系暨研究所		
本計畫主持人姓名		洪淑蕙	職稱	教授
		身分證號碼		J22046****
本計畫名稱	中文	朝向接收函數全波形高解析度的陣列成像解析南台灣隱沒-碰撞過渡帶的岩石圈構造		
	英文	Toward Receiver Function Adjoint Tomography for High-Resolution Seismic Array Imaging of Lithospheric Structure in Southern Taiwan Subduction-Collision Transition		
整合型總計畫名稱		SALUTE(II): 以陣列地震學與動力學探索南台灣由隱沒至碰撞岩石圈尺度構造		
整合型總計畫主持人		洪淑蕙	身分證號碼	J22046****
全程執行期限		自民國 113 年 08 月 01 日起至民國 116 年 07 月 31 日		
研究學門	學門代碼		學門名稱	
	M0506		地震學	
<p>【請考量己身負荷，申請適量計畫】 本年度申請主持本會各類研究計畫(含預核案)共 <u>1</u> 件。(共同主持之計畫不予計入)</p>				
本計畫是否同時有其他單位提供補助項目： <input checked="" type="checkbox"/> 否； <input type="checkbox"/> 是，請務必填寫表CM05*。				
近三年內是否有執行非國科會補助之其他(含國內外、大陸地區及港澳)計畫： <input type="checkbox"/> 否； <input checked="" type="checkbox"/> 是，請務必填寫表CM14-1。				
本計畫是否為國際合作研究： <input checked="" type="checkbox"/> 否； <input type="checkbox"/> 是，請加填表IM01~IM03				
本計畫是否申請海洋研究船： <input checked="" type="checkbox"/> 否； <input type="checkbox"/> 是，請務必填寫表CM15				
1. 本計畫是否有進行下列實驗/研究：(勾選下列任一項，須附相關實驗/研究同意文件) <input type="checkbox"/> 人體試驗/人體檢體 <input type="checkbox"/> 人類胚胎/人類胚胎幹細胞 <input type="checkbox"/> 基因重組實驗 <input type="checkbox"/> 基因轉殖田間試驗 <input type="checkbox"/> 第二級以上感染性生物材料 <input type="checkbox"/> 動物實驗(須同時加附動物實驗倫理3R說明)				
2. 本計畫是否為人文處行為科學研究計畫： <input type="checkbox"/> 是(請檢附已送研究倫理審查之證明文件)； <input checked="" type="checkbox"/> 否				
3. 本計畫是否為人體試驗或人體研究計畫： <input type="checkbox"/> 是(請增填研究中的性別考量檢核表CM16)； <input checked="" type="checkbox"/> 否				
本計畫是否申請高效能計算資源： <input checked="" type="checkbox"/> 否； <input type="checkbox"/> 是，請務必填寫表CM17				
計畫連絡人		姓名： <u>洪淑蕙</u> 電話：(公) <u>233664956-302</u> (宅/手機) <u>0927239209</u>		
通訊地址		台北市羅斯福路四段一號 台灣大學地質學系		
傳真號碼		23636095	E-MAIL	shung@ntu.edu.tw

計畫主持人簽章：_____

日期：_____

二、研究計畫中英文摘要：請就本計畫要點作一概述，並依本計畫性質自訂關鍵詞。

計畫中文關鍵詞	陣列地震學, 接收函數, 共同轉換點疊加成像, 全波形層析成像, 接收函數層析成像, 震波速度不連續面, 莫氏不連續面, 大陸岩石圈隱沒, 弧陸碰撞, 臺灣造山帶
計畫英文關鍵詞	array seismology, receiver function, CCP image, full waveform adjoint tomography, receiver function adjoint tomography, seismic velocity discontinuity, Moho, continental lithosphere subduction, arc-continent collision, Taiwan orogen
計畫中文摘要	<p>本計畫為南台灣岩石圈和抬升陣列實驗 (SALUTE) 第二期為期三年的整合型計畫之子計畫一, 旨在進一步利用高解析度的接收函數全波形成像技術探究南台灣和其東部海域隱沒-碰撞過渡帶底下複雜的岩石圈構造。第一年計畫將著重在改善P和S波接收函數的品質, 應用共振去除濾波器壓制在海水層和低速沉積層多重反射訊號, 以提高震波不連續面轉換波相的一致性。同時, 將採用全波形成像方法的開源程式碼應用到密集的SALUTE陣列所記錄的遠震體波波形 (FWAT) 和接收函數波形(RFAT)資料, 進行震波速度和密度構造的成像工作。第二年將完成建立FWAT和RFAT的實際運算操作流程, 並使用機器學習自動定位方式協助建立南台灣地區完整的地震目錄, 結合區域地震的P和S波到時和遠震體波走時殘差, 進行聯合速度構造成像, 以作為全波形反演的參考初始模型。最後一年的目標是根據FWAT和RFAT高精確和高解析度的全波形反演技術建立SALUTE陣列底下三維的岩石圈速度構造模型, 並透過已知的速度模型進行解析度測試以評估模型的準確性。SALUTE的研究發現在科學上可對該地區複雜的隱沒-碰撞構造和演化過程的了解做出重要貢獻, 並提供評估南台灣地震災害風險的重要參考依據。</p>
計畫英文摘要	<p>The Southern Array for the Lithosphere and Uplift of Taiwan Experiment (SALUTE) project proposes a three-year extension to further investigate the subduction-collision transition zone in southern Taiwan and its eastern offshore region. In the first year, the focus is on refining the quality of P and S receiver functions (RFs), implementing a resonance removal filter to suppress reverberations and enhance waveform coherence. Simultaneously, the groundwork for full-waveform adjoint tomography (FWAT) begins with the adoption of open-source code and collaboration with experts. Year two involves establishing FWAT and receiver function adjoint tomography (RFAT) workflows, creating a comprehensive earthquake catalog using machine learning, and incorporating onset-picked P and S arrival times from local earthquakes and frequency-dependent teleseismic traveltimes residuals for joint seismic tomography. The final year aims to conduct FWAT and RFAT for high-resolution imaging, with thorough resolution tests and model accuracy assessments. The findings of the SALUTE project can make significant contributions to understanding the complex subduction-collision structures and evolutionary processes in the region, providing crucial reference for assessing earthquake disaster risks in southern Taiwan.</p>
計畫概述	<p>請概述執行本計畫之目的及可能產生對人文、社會、經濟、學術發展等面向的預期影響性(三百字以內)。 ※此部分內容於獲核定補助後將逕予公開</p>
	<p>第二期SALUTE整合計畫旨在持續進行海陸聯合的SALUTE陣列布放, 以收集更完整密集的地震和周遭噪訊連續記錄用於研究南台灣大陸岩石圈隱沒至弧陸碰撞帶底下的高解析度詳細的震波速度構造, 包含上下地殼界面, 地殼-地函不連續面, 岩石圈-軟流圈邊界等, 以及地殼和上部地函速度異質變化, 非均向特性, 散射和非彈性衰減性質, 並透過這些地震觀測結果作為約束, 結合地球動力學模擬全面了解隱沒-碰撞過程的驅動機制和對台灣造山帶的影響。</p>

三、研究計畫內容（以中文或英文撰寫）：

- （一）研究計畫之背景。請詳述本研究計畫所要探討或解決的問題、研究原創性、重要性、預期影響性及國內外有關本計畫之研究情況、重要參考文獻之評述等。如為連續性計畫應說明上年度研究進度。
- （二）研究方法、進行步驟及執行進度。請分年列述：1.本計畫採用之研究方法與原因及其創新性。2.預計可能遭遇之困難及解決途徑。3.重要儀器之配合使用情形。4.如為須赴國外或大陸地區研究，請詳述其必要性以及預期效益等。
- （三）預期完成之工作項目及成果。請分年列述：1.預期完成之工作項目。2.對於參與之工作人員，預期可獲之訓練。3.預期完成之研究成果（如實務應用績效、期刊論文、研討會論文、專書、技術報告、專利或技術移轉等質與量之預期成果）。4.學術研究、國家發展及其他應用方面預期之貢獻。
- （四）整合型研究計畫說明。如為整合型研究計畫請就以上各點分別說明與其他子計畫之相關性。

3.1 Background and Progress of Proposed Study

Southern Taiwan and its eastern offshore region lie at a critical intersection where the Eurasian continental plate (EUP) undergoes subduction beneath the Philippines Sea Plate (PSP), contemporary with the oblique collision of the Luzon volcanic arc (LVA) atop the overriding PSP (Malavieille et al., 2002) (Fig. 1). Due to the oblique configuration of the WSW-ENE trending passive margin of the EUP and N-S trending LVA, and the NW-directed relative plate convergence, the collision initiated in northern Taiwan and propagated SSWward at a rate of ~ 60 km/Ma (Suppe, 1984; Byrne and Liu, 2002). This led to the closure of the Luzon forearc basement and the accretion of the forearc and arc onto the Eurasian continental margin, forming the Coastal Range in eastern Taiwan and closing the Luzon forearc basin and basement north of 22.5° . South of this latitude, the Luzon forarc-arc domain is currently indenting the Central Range and deforming against the accretionary wedge formed by the subduction of the South China Sea (SCS) plate and the Luzon forearc basement (Chi et al., 2003; Malavieille et al., 2019). This process causes significant shortening in the forearc basin and contributes to the growth of the wedge by incorporating orogenic sediments and collision complexes from the emerged southern Taiwan mountain belt (Lester et al., 2013).

Under the NSTC-funded three-year integrative proposal from 2021 to 2024, we conducted the Southern Array for the Lithosphere and Uplift of Taiwan Experiment (SALUTE) in this transition zone for the comprehensive investigations of the complex subduction-collision structures, processes, and driving dynamics involved in the early stage of the Taiwan orogeny. The SALUTE array, initiated in late-October 2021, mainly comprised the E-W and N-S transects, currently with a total of 29 closely-spaced broadband stations positioned across the southern Taiwan orogenic belt and arc-collision suture zone, along with 11 ocean bottom seismometers deployed at 8 sites in eastern offshore Taiwan (Fig. 1).

In sub-project 1, we focus on exploring seismic discontinuous features such as the Moho, intracrustal interfaces, and lateral and depth extent of the subducted Eurasian lithosphere under the array using teleseismic receiver functions as imaging probes. P receiver function is a time series mainly composed of P-to-S-converted waves that reverberate in discontinuous interfaces, such as the basement, Moho, LAB beneath a station. It is simply calculated by deconvolving the incoming vertical or longitudinal (L) component from radial or Q (SV) component of teleseismic P waves to remove common source and path effects (e.g., Langston, 1979). The calculation is usually carried out either in time-domain iterative deconvolution (Ligorria and Ammon, 1999) or frequency-domain wave-level deconvolution (Langston, 1979).

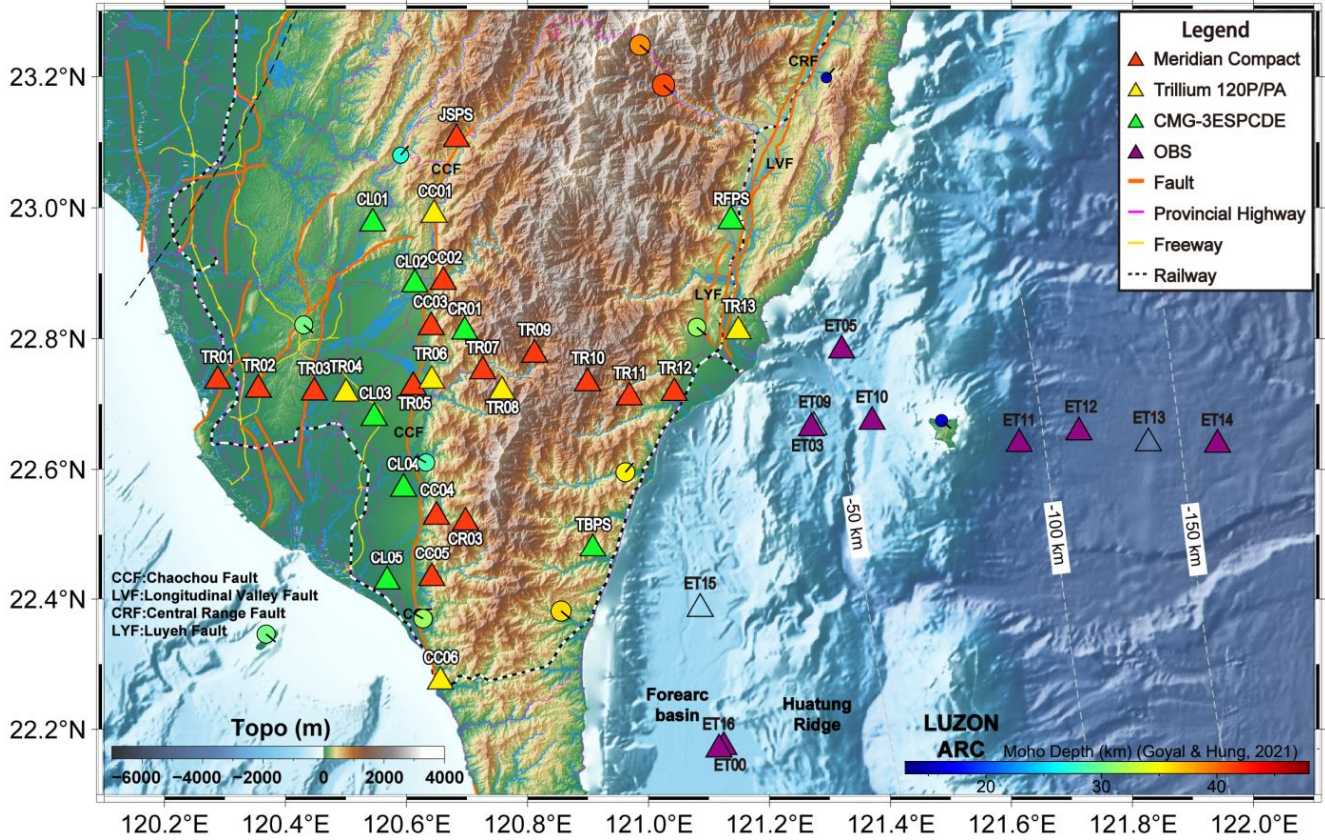


Fig. 1. Topographic map showing the configuration of the amphibious SALUTE array in southern Taiwan and adjacent offshore regions. Colored circles denote the Moho depths determined by H-V stacking of P and S RFs at permanent stations (Goyal and Hung, 2021). The radius and black lines of the circles correspond to the average horizontal offset distance of the Ps conversion points from the location of each station and the main backazimuth of the P RFs used in the Moho depth estimate.

We first select events of moment magnitude $M_w \geq 5.5$ and epicentral distance between 30° and 95° from IRIS global earthquake catalog. For each event, we window the waveforms on the three components between -300 and 1000 sec relative to the corresponding P-wave arrival time and apply a demean, detrend and bandpass filter of 0.05-2 Hz. The windowed waveforms on the original Z-N-E components are rotated to those on P-SV-SH components by free-surface transformation (Kennett, 1991) using near-surface V_p and V_s values obtained from Lee et al. (2023). Then we perform the frequency-domain deconvolution and then apply the inverse Fourier transform to obtain P receiver function in time domain, $d^{RF}(t, p)$, (Park and Levin, 2000),

$$R(t, p) = \mathcal{F}^{-1} \left[\frac{G_{SV}^*(\omega, p) G_z(\omega, p)}{G_z^*(\omega, p) G_z(\omega, p) + w(\omega)} \right], \quad (1)$$

where $G_{SV}(\omega, p)$ and $G_z(\omega, p)$ are the Fourier transformed P and SV waveforms for each given event with a slowness p , the superscript * represents the complex conjugate, and $w(\omega)$ refers to an added white noise or water level for stabilizing deconvolution (Langston, 1979). Additionally, a low-pass Gaussian filter is applied to suppress the high-frequency noise in the resulting receiver functions. After several trial and error exercises to compliment the accuracy and stability, we specify water level at 0.01 and the Gaussian width at 2.5, which yields the amplitude spectrum of the applied Gaussian filter equal to 0.1 at frequency of 1.2 Hz, equivalent to a pulse width of ~ 1 s. Subsequently, all the obtained P RFs are plotted as a function of the event's backazimuth and subjected to visual inspection. We carefully select those RFs with coherent waveforms and high signal-to-noise ratios time series for further processing in the common conversion point (CCP) stacking. Fig. 2

illustrates the waveforms of the P RFs for selected individual events, along with the corresponding stacked trace shown on the top at land station TR05 and OBS station ET12.

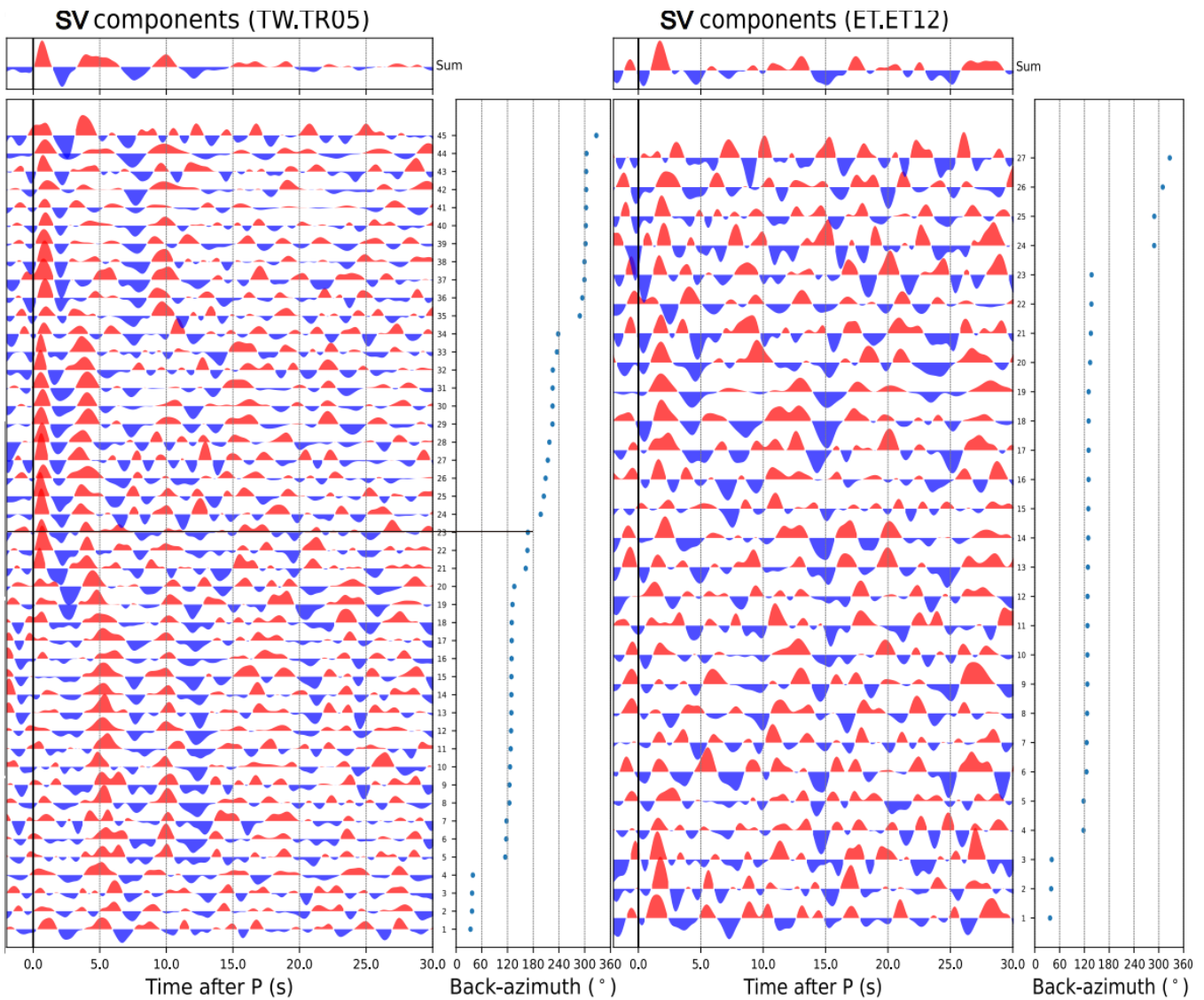


Fig. 2. P RFs at land station TR05 (left panel) and OBS station ET12 (right panel) plotted with increasing backazimuth, calculated by deconvolving P from S component traces in wavevector reference frame. The water level and gaussian width are set as 0.01 and 2.5, respectively.

Given that the main W-E transect has the longest array aperture and dense station coverage, traversing the hyperextended Eurasian continental margin, subducting Eurasian continental lithosphere, the emerged southern Taiwan orogenic belt-Central Range, arc-continent collision suture in eastern Taiwan, and the eastern offshore Luzon forearc and arc domain, we first focus on mapping seismic discontinuity features along this 2-D linear transect. We specifically include the data recorded by the on-land and offshore SALUTE stations, as well as permanent BATS and CWB broadband stations located within 10 km on both sides of the transect.

Prior to the common-conversion-point (CCP) stacking, we correct the arrival-time difference between a given P-to-s converted phase and direct P, i.e., differential Ps-P arrival time, due to velocity heterogeneities above the conversion interface at a given depth (Xu et al., 2018) derived from a 3D velocity tomography model (Huang et al., 2014), calculated along each Ps ray path in 1-D IASP91 model. The corrected time series of the P RFs are then converted from the time to depth axis in every 10-km depth interval. Finally, we perform the common-conversion point stack (Dueker and Sheehan, 1997) of all the time-to-depth-migrated RFs by

applying a weighted stack of Ps amplitudes piercing at common bins with various sizes adapted by the first Fresnel zone ($\sim\sqrt{\lambda L}$). A python-based package of SeisPy provided by Xu and He (2023) has been utilized to generate our CCP stacking image.

In Fig. 3, we illustrate the locations of P-to-s piercing points at depths of 30, 60, 90, and 120 km, projected on the surface for all the PRFs used in our CCP stacking. We also present an example of time-to-depth migrated P RFs at station TR05, obtained by stacking in every 5° back-azimuth bin overlapped by 2.5° . The stacked RF plot, shown as a function of central backazimuth of each bin, highlights a clear vertical offset of Ps phases by approximately 10 km across the backazimuth of 0 or 180 degrees, parallel to the strike of the Chaozhou Fault.

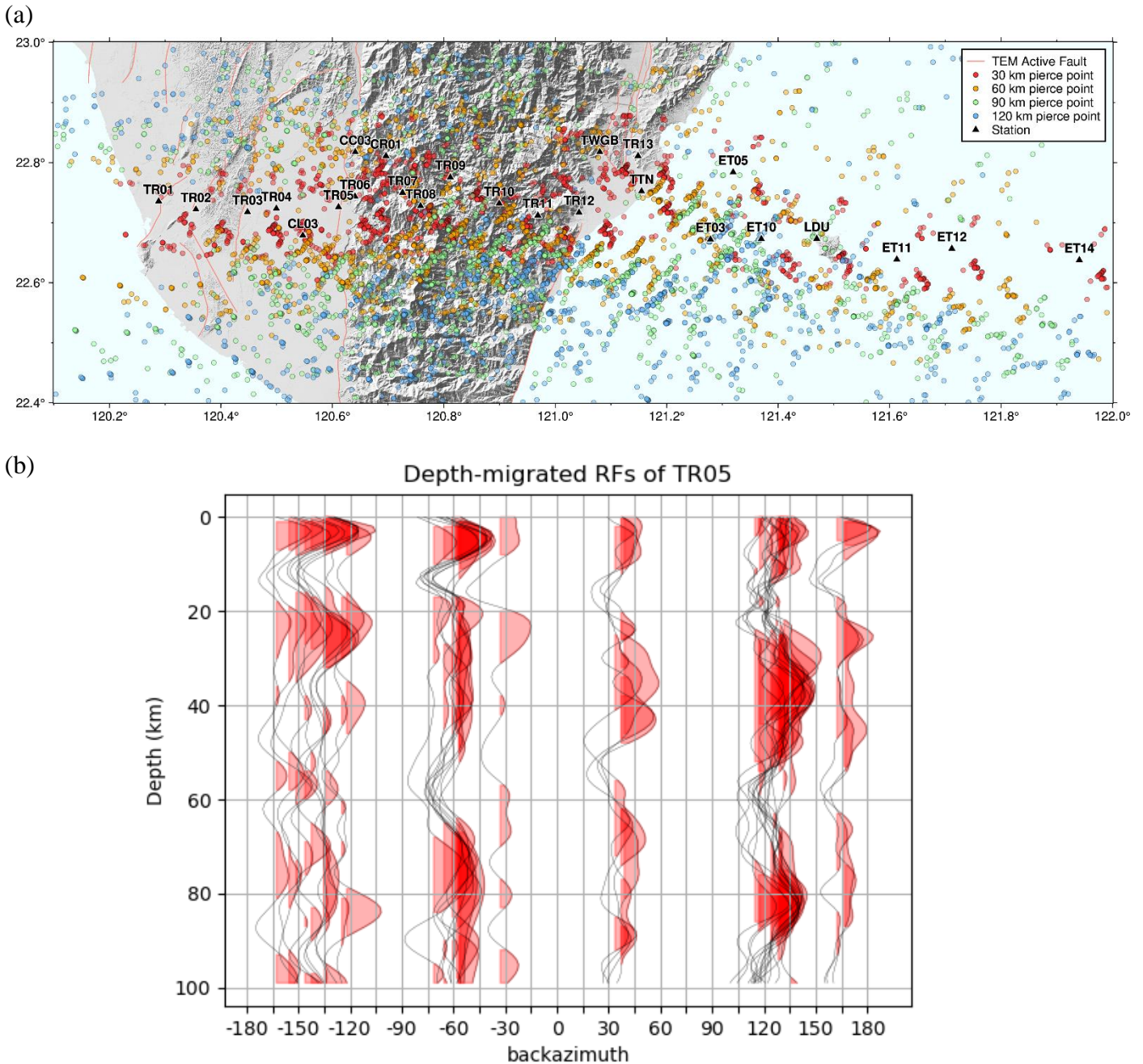


Fig.3. (a) Locations of P-to-s piercing points at depths of 30, 60, 90, and 120 km, denote by red, orange, green, cyan colored dots, projected on the topographic map. (b) Time-to-depth migration of P RFs plotted as a function of backazimuth for station TR05.

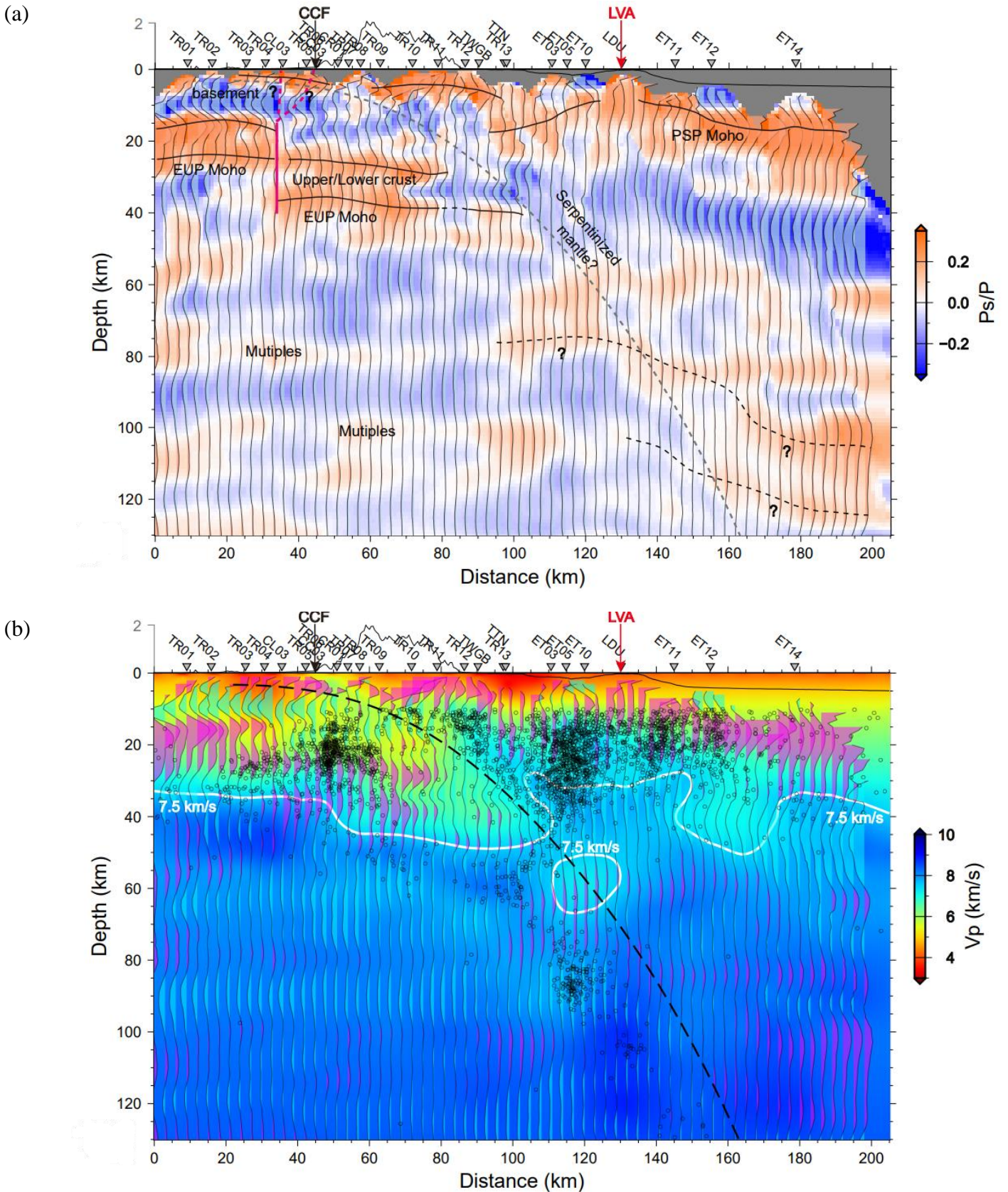


Fig. 4. (a) CCP stacking image of P RFs along the E-W transect with no vertical exaggeration below sea level. Red and blue colors represent the interfaces with sharp impedance contrast increasing and decreasing with depth, respectively. Dashed line denotes the isodepth slab contour from Slab 2.0 (Hayes, 2022). (b) Comparison of CCP image with P-wave velocities from 3D tomography model (Huang et al., 2014). Open circles indicate earthquakes with local magnitude $ML \geq 2.5$, located within 10 km on each side of the CCP profile

In Fig. 4 (a), the CCP stacking image along the W-E transect is presented, with red-orange colors indicating the large positive Ps/P amplitude ratios, suggestive of sharp interfaces or discontinuities where seismic velocity and/or density experiences an abrupt increase with depth. Conversely, blue colors correspond to large “negative” Ps/P amplitude ratios, indicating a sudden decrease in seismic velocity or density with depth. The solid black lines represent our interpreted discontinuous features associated with the basement, the interface between the upper and lower crust and the Moho of the Eurasian crust before and after subduction. In Fig. 4(b), we compare the resulting CCP image with P-wave velocity structure along the W-E transect from the 3D tomographic model (Huang et al., 2014) and seismicity with local magnitude $ML \geq 2.5$ projected within 10 km on both sides of the W-E transect.

The preliminary CCP image suggests that the upper/lower crust interface and the Moho beneath the western coastal plain of southern Taiwan are at depths of about 15 km and 25 km, respectively. The relatively thin crust, particularly the lower crust, implies that prior to subduction the Eurasian crust at the continent-ocean transition zone has been substantially stretched and thinned by continental rifting extension. The Moho is found to be nearly vertically offset by ~ 10 km beneath station CL03, located about 10 km west of the Chaochou Fault (CcF), not directly beneath the CcF as suspected in the previous study (Goyal and Hung, 2021). The sudden deepening of the Moho coincides with the location where a cluster of deeper seismicity appears. Additionally, our CCP image reveals an east-dipping Moho associated with the subducted Eurasian slab beneath the Central Range and eastern offshore region. Meanwhile, the interface between the upper and lower crust vanishes as the subducted Eurasian lithosphere advances beyond the eastern coast of Taiwan. This observation may suggest tracts of relatively buoyant subducted continental crust has been highly deformed, separated from the underlying lithospheric mantle, and exhumed to the surface during the collision (Tirel et al., 2013), as revealed in the scenario of geodynamic models (E. Tan, personal communications).

Despite the detailed unraveling of lateral undulation of the Moho and upper crust/lower crust interface in the southern Taiwan subduction-collision transition from the CCP image, challenges persist in imaging the continuity and dipping geometry of the Moho of the subducted Eurasian slab, particularly at depths ranging from 40-100 km beneath the collisional suture zone in eastern Taiwan and the offshore shortened Luzon forearc and arc regions. One of the difficulties in achieving the CCP image with desired high resolution in eastern Taiwan and its offshore area is the limited number and relatively coarse coverage of “good” receiver functions provided by the key OBS stations. Up-to-date, each OBS site of the amphibious SALUTE array only lasted for less than one-year recording, contributing to the challenges. Furthermore, OBS data intrinsically exhibit higher noise levels compared to land stations due to tilt and compliance noise induced by ocean-bottom currents (Kuo et al., 2015), as well as water reverberations bouncing back and forth between the ocean surface and bottom, similar to sediment reverberations observed at stations situated atop low-velocity sedimentary layers which tend to obscure the Moho-converted Ps phases as seen in some of P RFs recorded at our land and OBS stations (Fig. 5) (e.g., Yu et al., 2015; Zhang and Olugboji, 2021). The former noise, usually present at frequencies lower than 0.05 Hz, has a negligible influence on higher-frequency P wave and its coda, while the high-frequency signals of Ps conversions overprinted by water, sediment, and crustal reverberations can substantially degrade the resolution and accuracy of the CCP image.

The other cons and limitation of the CCP stack approach are the assumption that discontinuous features are at least locally horizontal, which may not hold true in the structurally complex settings such as the steeply-dipping subducted slabs and faults and laterally disrupted interfaces. These complexities are evident at the juncture of the subduction-collision zone offshore southeastern Taiwan. In addition to passively wait for large-

magnitude events occurring in suitable distance range recorded by the recurrently deployed OBS stations in the next phase of the SALUTE project, we propose a two-fold strategy to address these challenges and enhance seismic images in this sub-project. Firstly, we aim to increase the numbers and quality of useful RFs by employing a resonance removal filter developed by Yu et al. (2015). This filter is designed to suppress water and sediment reverberations in RFs. Secondly, we plan to apply innovative teleseismic receiver function or full waveform adjoint tomography techniques (e.g., Tong et al., 2014; Monteiller et al., 2015; Kan et al., 2022; Xu et al., 2023) to directly invert for 2D or 3D variations of compressional wave speed, shear wave speed and density beneath the SALUTE array. These advanced tomography methods necessitate high-performance computing clusters to numerically simulate high-frequency synthetic seismograms of teleseismic P and S waves. To minimize the misfit between observed and synthetic waveforms and efficiently converge to the best-fitting and reasonably robust models, the highly-nonlinear iterative inversion relies on a good starting model. Therefore, prior to performing full waveform or RF adjoint tomography, we will conduct the traveltime-based tomography for P-wave and S-wave velocity models using the combined dataset of onset-picked high-frequency traveltime residuals of local earthquakes and cross-correlation measured finite-frequency traveltime residuals of teleseismic events. The subsequent section briefly introduces the principles and methodologies of the reverberation removal filter and adjoint tomography.

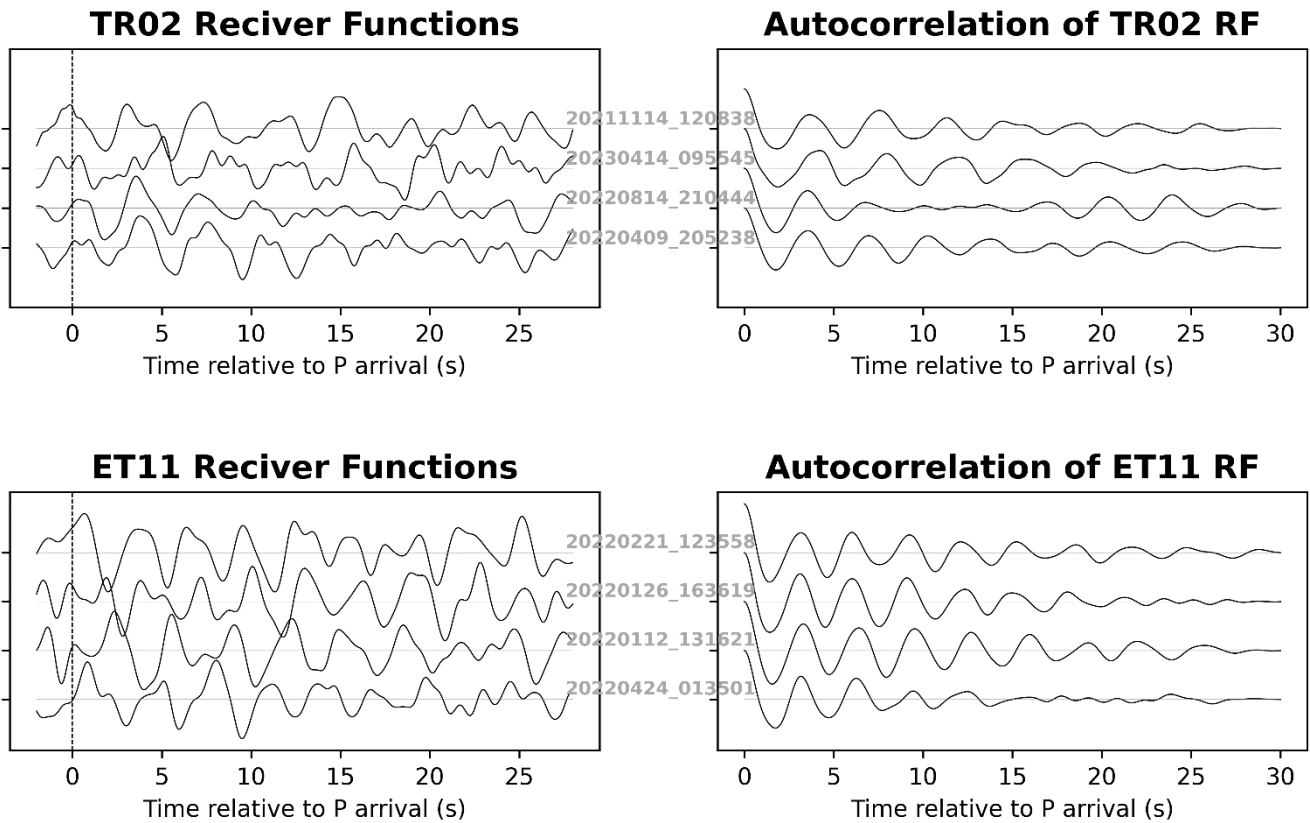


Fig 5. (Left) Examples of noisy P receiver functions commonly observed at the on-land station TR02 situated in a sediment-rich area and the OBS station ET11 on the deep ocean floor (left) that mask the Moho-converted Ps phases. (Right) The corresponding normalized autocorrelation functions showing similar decaying cosine sinusoids.

3.2 Methodology

3.2.1 Resonance Removal Filter

For an OBS station sitting on the ocean floor with a low-velocity sedimentary cover overlain by a water column, the source-deconvolved receiver function is expressed as (e.g., Zhang and Olugboji, 2021),

$$R(t) = \sum_{n=0}^{\infty} (-r_0)^n \tilde{R}(t - n\Delta t), \quad (2)$$

where R and \tilde{R} are the receiver functions with and without the presence of a sedimentary layer or water column, respectively, r_0 is the strength of reverberations, n denotes the n th multiple, and Δt the two-way travel time of reverberations. Eq. (2) in the frequency domain is written as (Backus, 1959):

$$R(f) = \tilde{R}(f) \sum_{n=0}^{\infty} (-r_0)^n e^{-i2\pi f n \Delta t} = \tilde{R}(f) (1 + r_0 e^{-i2\pi f \Delta t})^{-1}. \quad (3)$$

The term $(1 + r_0 e^{-i2\pi f \Delta t})^{-1}$ on the right-handed side of eq. (3) serves as a linear filter that induces the reverberation effect. Its reciprocal, $(1 + r_0 e^{-i2\pi f \Delta t})$, is the corresponding reverberation removal filter in the frequency domain, employed to eliminate resonant waves trapped in a water column or sediment layer.

To apply the reverberation removal filter to actual RF data, it is crucial to accurately determine the two parameters: the strength of reverberations r_0 and two-way travel time Δt . Yu et al. (2015) presented a straightforward approach to estimate these two parameters by calculating the normalized autocorrelation function of RFs. Ideally, the amplitude and time delay of the first trough on the autocorrelation function provide estimates of r_0 and Δt , respectively (see Fig. 6). For real RF data, Zhang and Olugboji (2021) suggest estimate these two parameters empirically by fitting a decaying sinusoid to the autocorrelation function of the RF in the time domain (Cunningham and Lekic, 2019),

$$AC(t) = R(t) \otimes R(t) \approx c e^{-at} \cos\left(\frac{\pi t}{\Delta t}\right), \quad (4)$$

where t is the lag time of the autocorrelated RF, Δt the half-period of the oscillation, c the amplitude at zero lag time, and a the decay constant. The half-period of the oscillation is precisely the travel time of the S reverberation; therefore, $r_0 = AC(\Delta t)$.

3.2.2 Receiver function Adjoint Tomography and Teleseismic Full Waveform Adjoint Tomography

As previously discussed, the CCP stacking may encounter challenges in imaging 3-D subsurface discontinuous structures marked by sharp lateral undulations and strong velocity heterogeneities. In recent years, with the progress and accessibility of high-performance computational hardware and software, the innovative, computationally-intensive but physically-accurate full-waveform tomography techniques combining full waveform inversion, adjoint method, time-reversal imaging, and finite-frequency or banana-doughnut theory (Tromp et al., 2015; Liu and Tromp, 2008) have drawn much attention in the community of both active and passive source seismology. They have found widespread applications in constructing regional-scale, high-resolution images of velocity and density structures simultaneously beneath dense seismic arrays using their recorded body and/or surface waveform records (Monteiller et al., 2015; Wang et al., 2021a, 2021b; Kan et al., 2022).

To overcome the limitations of the classical RF-imaging methods, a recent study of de Jong et al. (2022) has derived 2-D finite frequency misfit kernels of P RFs based on the general wave equation and adjoint method, which provide the the integration of RF-based objective function with a RF full waveform inversion workflow. Following the methodology and workflow, Xu et al. (2023) introduced an inversion scheme termed receiver function adjoint tomography (RFAT) for high-resolution seismic imaging with dense arrays. Instead of utilizing finite-frequency misfit kernels of teleseismic broadband P waveforms and directly inverting them for velocity

and density models with a nonlinear iterative algorithm, they propose that the removal of event-varying source time functions from teleseismic body waves by deconvolution results in RF waveforms with higher maximum frequency content than original broadband waveforms. By stacking RFs with similar backazimuths and ray parameters and employing the associated finite-frequency misfit kernels of stacked RFs, RFAT demonstrates the strength and capability in resolving sharp, steep and laterally disrupted discontinuous features and strongly heterogeneous velocity structures. The RFAT adopts a hybrid numerical solver integrating the spectral-element method to simulate wave propagation in an arbitrary 3D box model for the targeted region and 1-D frequency-wavenumber (FK) method to calculate the incident wavefield in a 1-D reference Earth model outside the target box model (Tong et al., 2014). The following briefly outlines the principles of RFAT, based on the derivation of Xu et al. (2023).

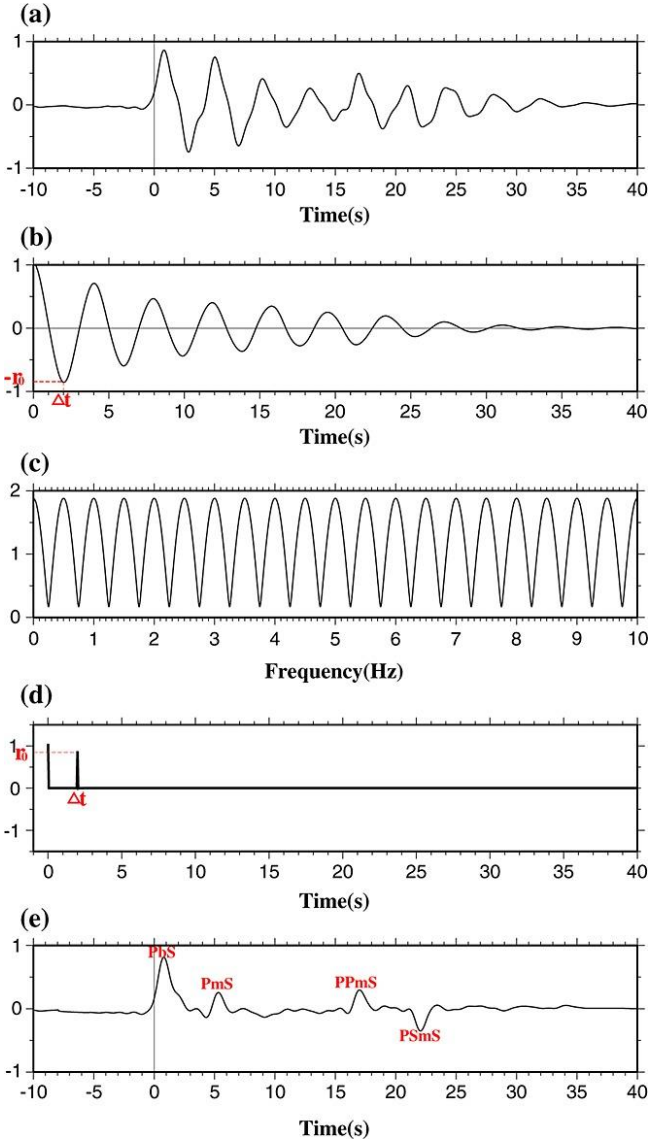


Fig. 6. Synthetic RF to illustrate how to determine the two parameters, r_0 and Δt , corresponding to the strength and two-way traveltime of sediment reverberations. Note that the first peak delayed by about 1 s r represents the P-to-s converted phase from the bottom of the sedimentary layer. (b) Autocorrelation of the RF shown in Figure 5a. (c) A resonance removal filter in with $r_0 = 0.8$ and $\Delta t = 2.0$ s in the frequency domain. (d) Same as Figure 5c but in the time domain. (e) Resulting RF after applying the resonance removal filter (obtained from Figure 2 of Yu et al. (2015)).

For P-RF inversion, we define the objective function χ as the waveform misfit between N sets of observed P-RFs, R^{obs} , and corresponding synthetic P-RFs, R^{syn} , calculated in a given parameterized velocity and density model \mathbf{m} ,

$$\chi = \frac{1}{2} \sum_{i=1}^N \int_0^T W(t) \omega_i [RF_i^{\text{syn}}(\mathbf{x}_r, \mathbf{m}, t) - RF_i^{\text{obs}}(\mathbf{x}_r, t)]^2 dt, \quad (5)$$

where \mathbf{x}_r represents the position of the receiver, $W(t)$ is the time window function, and ω_i the weight of the i -th RF data. The perturbation of the misfit $\delta\chi$ induced by infinitesimal perturbations in P-wave speed (α),

S-wave speed (β), and density (ρ) can be expressed as,

$$\delta_\chi = \int (K_\alpha \delta \ln \alpha + K_\beta \delta \ln \beta + K_\rho \delta \ln \rho) d^3 \mathbf{x}, \quad (6)$$

where K_α , K_β , and K_ρ are the sensitivity kernels with respect to the model parameters of α , β , and ρ , respectively. The sensitivity kernels in an arbitrary model can be numerically constructed by integrating the interaction field between the forward and adjoint wavefields. The adjoint wavefield is obtained by assigning time-reversed adjoint sources at receiver locations and propagating backward in time to the source. For the inversion of observed RFs, the adjoint sources, defined by the derivative of the misfit function with respect to the corresponding synthetic RFs (Tromp et al., 2005), in the frequency domain can be derived based on Parseval's theorem,

$$F_R^\dagger(\mathbf{x}, \omega) = \frac{\Delta \widehat{RF}(\mathbf{x}_r, \mathbf{m}, \omega)}{\mathbf{u}_Z^*(\mathbf{x}_r, \mathbf{m}, \omega)} \delta(\mathbf{x} - \mathbf{x}_r)$$

$$F_Z^\dagger(\mathbf{x}, \omega) = -\frac{\Delta \widehat{RF}(\mathbf{x}_r, \mathbf{m}, \omega) \widehat{\mathbf{u}}_R^*(\mathbf{x}_r, \mathbf{m}, \omega)}{\widehat{\mathbf{u}}_Z^*(\mathbf{x}_r, \mathbf{m}, \omega)} \delta(\mathbf{x} - \mathbf{x}_r), \quad (7)$$

where $\Delta \widehat{RF}$ is the difference between the synthetic and observed P RFs in the frequency domain, $\widehat{\mathbf{u}}_R$ and $\widehat{\mathbf{u}}_Z$ correspond synthetic displacements on the radial and vertical components in the frequency domain, respectively, and the superscript * and δ represent the complex conjugate operator and the Kronecker delta function, respectively. Alternatively, with a time window $W(t)$ applied, the adjoint sources in the time domain are given by

$$f_R^\dagger(\mathbf{x}, t) = W(t) [\Delta RF(\mathbf{x}_r, \mathbf{m}, t) \oslash \mathbf{u}_Z(\mathbf{x}_r, \mathbf{m}, T - t)] \delta(\mathbf{x} - \mathbf{x}_r)$$

$$f_Z^\dagger(\mathbf{x}, t) = -W(t) [\Delta RF(\mathbf{x}_r, \mathbf{m}, t) \circledast \mathbf{u}_R(\mathbf{x}_r, \mathbf{m}, T - t) \oslash (\mathbf{u}_Z \circledast \mathbf{u}_Z)(\mathbf{x}_r, \mathbf{m}, T - t)] \delta(\mathbf{x} - \mathbf{x}_r), \quad (8)$$

where T represents the time length of $W(t)$, the symbols \circledast and \oslash represent convolution and deconvolution operators, respectively. A comprehensive workflow of RF adjoint tomography (RFAT) is detailed in Section 2.2 of Xu et al. (2023). Figure 7 provides an illustration of the application of 3-D RFAT for dense array image in SE Asia obtained from Xu et al. (2023).

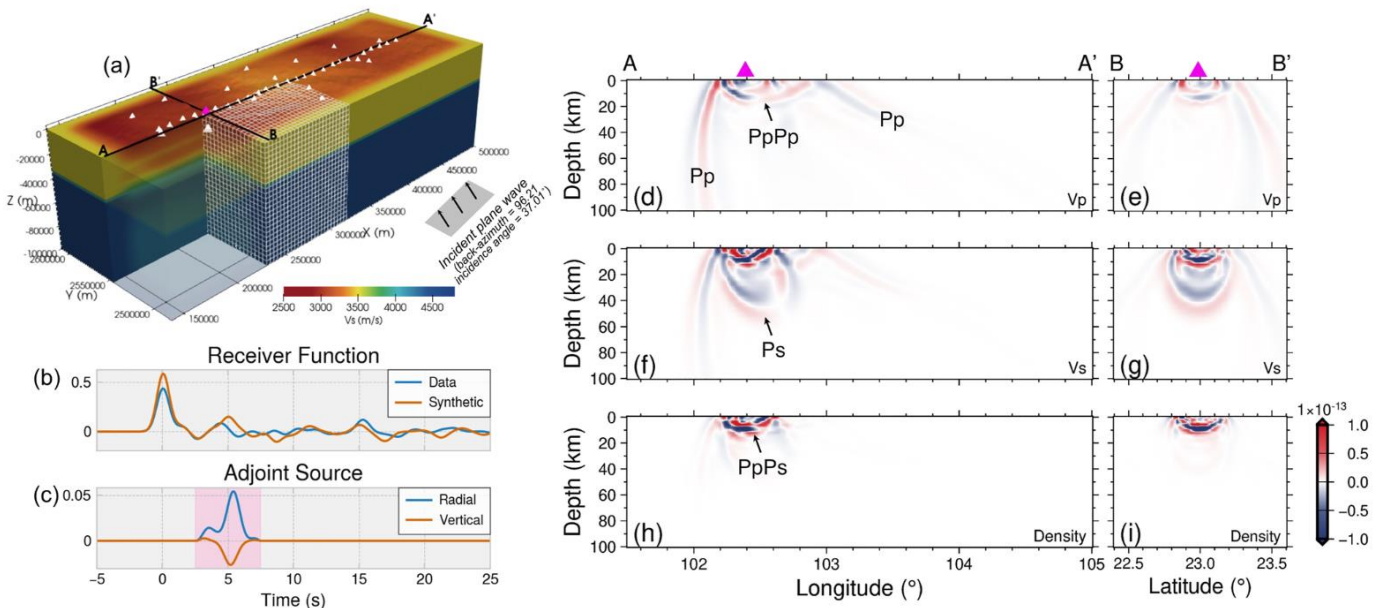


Fig. 7. (a) The computational domain and model setup for the 3-D RF adjoint tomography under a dense seismic array with stations denoted by white triangles). (b) An example of observed (cyan line) and synthetic (orange line) P RFs at station denoted by magenta triangle in (a), (d), and (e). (c) The adjoint sources windowed around Pms phase on the radial (cyan line) and vertical components (orange line). The narrow time window selected in this specific example is used for better demonstrating the sensitivities of the Moho-converted Ps wave and its primary crustal multiple, PpPp wave, with respect to V_p , V_s , and density perturbations along the AA' and BB' profiles shown in (a) (obtained from Figure 2 of Xu et al. (2023)).

3.3 Work Plan and Products

Year 1: 2024-2025

In the first year, the work will continue to establish a workflow for careful investigations of potential factors affecting the quality of both P and S RFs and improvement of the RF quality especially for stations in thick sediment-covered areas and OBS stations before applying them to the classical RF imaging results including the H-k and H-V stacking to resolve the Moho depth and average crustal velocity properties under each SALUTE station and the CCP stack imaging to map discontinuous features such as the Moho and lithosphere-asthenosphere boundary (LAB) along the main W-E transect traversing the southern Taiwan subduction-collision juncture and the N-S transect along the Chaochou fault. The purpose is to ensure the reliability of the obtained features for subsequent geological and geodynamic interpretations, paving the way for publishing robust research outcomes. The tasks include:

(1) Evaluate consistency and differences in RFs obtained through different deconvolution techniques including time-domain iterative deconvolution (Ligorria and Ammon, 1999), frequency-domain water-level deconvolution (Langston, 1979), and more sophisticated multi-taper spectral coherence approach (Park and Levin, 2000).

(2) Implement a resonance removal filter based on the autocorrelation functions of RFs to automatically estimate the strength and two-way traveltimes of reverberations for individual RF traces contaminated by sediment and/or water reverberations. Apply the reverberation removal filter that best fits the autocorrelation function of each contaminated RF to suppress the resonant noise and enhance the availability of RF data for subsequent H-k stacking and CCP analysis.

(3) Utilize hierarchical agglomerative clustering to group and stack RFs with similar backazimuth and slowness to enhance waveform coherence and signal-to-noise ratios. Conduct detailed analysis on clustered RFs to identify common features and trends.

(4) Finalize the H-k and H-V stacking results and CCP stacking images and submit two papers based on these studies.

Meanwhile, we will initiate the project of full waveform adjoint tomography (FWAT) by implementing and testing the open-source code of FWAT based on a hybrid SEM-FK method (Wang, 2021). The algorithm will be used to simulate teleseismic body wave propagation forward and back in time in the 3D complex structure under a dense array and computing the waveform misfit sensitivity kernels with respect to fractional perturbations in P-wave speed, shear-wave speed, and density for FWAT.

To advance our understanding and application of FWAT, we plan to visit Prof. Kai Wang in University of Science and Technology of China in Hefei, who is a key developer of the FWAT algorithm we intend to adopt for both receiver function and full waveform adjoint tomography. He has a strong expertise in FWAT, having previously worked as a postdoc with my long-time research collaborator and colleague, Prof. Qinya Liu at University of Toronto. Prof. Liu is a pioneering expert in theory and methodology of adjoint full-waveform

tomography and has led one of the few groups globally that first introduced and applied the hybrid method to real tomography problems. Given our longstanding professional relationship and previous collaboration on various research projects, this initialization of collaboration on FWAT and RFAT is anticipated to facilitate the construction of high-accuracy, high-resolution tomographic models of P-wave speed, S-wave speed and density structures in the SALUTE-targeted region based on receiver function and full waveform adjoint tomography.

Year 2: 2025-2026

In the second year of the project, our efforts will be twofold. Firstly, we will continue our work to establish the necessary solver and workflow for Full-Wave Adjoint Tomography (FWAT) and Receiver Function Adjoint Tomography (RFAT) adapted to the unique characteristics of our SALUTE array data. The second major focus will be on revisiting the crust and uppermost mantle structures beneath the southern Taiwan region by conducting local earthquake traveltime tomography using an expanded dataset from the SALUTE array.

To facilitate these objectives, working with graduate students, we have initiated the implementation of an open-source Python toolbox for machine learning, termed the Seismology Benchmark Collection (SeisBench) (Woollam et al., 2022). This toolbox integrates dense SALUTE array data with data from existing permanent stations managed by the Central Weather Administration and BATS. Based on the deep learning models of PhaseNet and EQTransformer built in the SeisBench platform, we aim to create a comprehensive earthquake catalog for southern Taiwan, enhancing seismic event detection and location capability and accuracy, particularly for local earthquakes within the SALUTE area. .

Simultaneously, we will integrate frequency-dependent teleseismic P and S arrival-time residuals obtained through cross-correlating windowed waveforms in different frequency bands. This data will contribute to finite-frequency traveltime tomography (e.g., Hung et al., 2011), enriching our understanding of both crustal and lithospheric mantle structures. Combining local and teleseismic P and S traveltime datasets for joint tomography will further enhance both the lateral and depth resolution of the resulting 3D models. These derived 3D models can serve as reference or initial models for optimizing subsequent full-waveform and receiver function adjoint tomography.

Year 3: 2026-2027

In the final year of the project, our primary focus will be on conducting Full-Wave Adjoint Tomography (FWAT) and Receiver Function Adjoint Tomography (RFAT) to achieve high-resolution imaging of the SALUTE array. The tasks to be undertaken during this phase include:

- (1) Complete the implementation of FWAT and RFAT using the established solver and workflow adapted to SALUTE array data. Optimize parameters and settings for FWAT to ensure the accurate inversion of seismic waveforms.
- (2) Validate and fine-tune the FWAT and RFAT approach using synthetic tests with known subsurface structures and benchmarks. Conduct thorough resolution tests to assess the model resolution achieved through both FWAT and RFAT.
- (3) Finalize the tomographic images of P- and S-wave velocity and density structures resolved from RFAT and FWAT, and ensure the compatibility of the unique features inverted from high-frequency receiver functions and broadband waveforms.
- (4) Compare the derived tomographic models with existing geological and geophysical constraints, if available. Address any discrepancies or uncertainties in the tomographic models through additional sensitivity analyses.

- (5) Document the entire process of FWAT and RFAT implementation, including methodologies, parameters, and results. Prepare manuscripts to summarize key findings and contributions of the high-resolution array imaging for publication and dissemination.

3.3 Statement of Broad Impact

The SALUTE project represents an inventive effort, marking the first long-term deployment of a large-scale, dense amphibious passive broadband seismic network across the subduction-collision transition zone in southern Taiwan and its eastern offshore regions since the TAIGER project. Extending the SALUTE project and seismic array for the next three years would hold significant impacts across scientific, educational, and outreach domains.

In the perspective of scientific advances, the integrative SALUTE project is expected to yield a series of research publications that contribute significantly to the understanding of the unique subduction-collision transition zone in southern Taiwan as well as broader fundamental knowledge of continental growth and mountain building. Scientifically, the seismic imaging results in this subproject derived from this unique dataset promise to refine our understanding of crustal and lithospheric structures profoundly influenced by subduction-collision processes, paving the way for new insights and discoveries that could reshape existing paradigms.

In terms of educational outreach, the field seismic experiment conducted as part of the SALUTE project provides an exceptional opportunity for graduate students (1 undergraduate, 3 master's and 2 PhD students in this subproject) to gain invaluable hands-on experiences in a large-scale interdisciplinary research initiative. Through active participation in data collection, processing, and analysis, students will develop a diverse set of skills, ranging from fieldwork and instrumentation to advanced seismic imaging and geodynamic modeling. The studies conducted during the project will form the basis of their theses and potentially lead to scientific paper publications. Furthermore, graduate students and young postdocs actively engaged in the project will receive solid knowledge education and research training, nurturing them as the next generation of professional scientists and leaders within the Taiwan earth science community to strengthen the scientific workforce and growth of expertise in the field.

Beyond the academic community, the excitement of scientific discovery from the project's outcomes and findings can be shared through outreach programs such as popular science lectures, posters and brochures to the general public, primary and secondary school students, and communities of indigenous tribes. Additionally, the long-term, in-situ monitoring of earthquake activities in southern Taiwan through the extended SALUTE array will contribute to the establishment of a more complete database, advancing our understanding of seismogenic structures and potential seismic hazards in southern Taiwan.

References

- Byrne, T. B., & Liu, C.-S. (2002). Preface: introduction to the geology and geophysics of Taiwan. In *Geology and Geophysics of an Arc- continent Collision, Taiwan* (pp. 5–8).
- Chi, W.-C., & Reed, D. L. (2008). Evolution of shallow, crustal thermal structure from subduction to collision: An example from Taiwan. *Crustal thermal evolution from subduction to collision. GSA Bulletin*, 120(5–6), 679–690. <https://doi.org/10.1130/b26210.1>
- Dueker, K.G., and A.F. Sheehan (1998), Mantle discontinuity structure beneath the Colorado, Rocky Mountains and High Plains, *J. Geophys. Res.*, 103, 7153-7169.
- de Jong, J. H. E., Paulssen, H., van Leeuwen, T., & Trampert, J. (2022). Sensitivity kernels for receiver function

- misfits in a full waveform inversion workflow. *Geophysical Journal International*, 230(2), 1065–1079. <https://doi.org/10.1093/gji/ggac098>
- Dueker, K.G., and A.F. Sheehan (1998), Mantle discontinuity structure beneath the Colorado, Rocky Mountains and High Plains, *J. Geophys. Res.*, 103, 7153–7169.
- Goyal, A., & Hung, S. (2021). Lateral Variations of Moho Depth and Average Crustal Properties Across the Taiwan Orogen From H-V Stacking of P and S Receiver Functions. *Geochemistry, Geophysics, Geosystems*, 22(3). <https://doi.org/10.1029/2020gc009527>
- Huang, H.-H., Wu, Y.-M., Song, X., Chang, C.-H., Lee, S.-J., Chang, T.-M., & Hsieh, H.-H. (2014). Joint Vp and Vs tomography of Taiwan: Implications for subduction-collision orogeny. *Earth and Planetary Science Letters*, 392, 177–191. <https://doi.org/10.1016/j.epsl.2014.02.026>
- Hung, S.-H., Chen, W.-P., & Chiao, L.-Y. (2011). A data-adaptive, multiscale approach of finite-frequency, travelttime tomography with special reference to PandSwave data from central Tibet. *Journal of Geophysical Research*, 116(B6). <https://doi.org/10.1029/2010jb008190>
- Langston, C. A. (1979). Structure under Mount Rainier, Washington, inferred from teleseismic body waves. *Journal of Geophysical Research*, 84(B9), 4749–4762. <https://doi.org/10.1029/J084B09>
- Lester, R., McIntosh, K., Avendonk, H. J. A. V., Lavier, L., Liu, C.-S., & Wang, T. K. (2013). Crustal accretion in the Manila trench accretionary wedge at the transition from subduction to mountain-building in Taiwan. *Earth and Planetary Science Letters*, 375, 430–440. <https://doi.org/10.1016/j.epsl.2013.06.007>
- Ligorría, J. P., & Ammon, C. J. (1999). Iterative deconvolution and receiver-function estimation. *Bulletin of the Seismological Society of America*, 89(5), 1395–1400.
- Liu, D. C., & Nocedal, J. (1989). On the limited memory BFGS method for large scale optimization. *Mathematical Programming*, 45(1), 503–528. <https://doi.org/10.1007/BF01581204>
- Kan, L.-Y., Chevrot, S., & Monteiller, V. (2022). A consistent multiparameter Bayesian full waveform inversion scheme for imaging heterogeneous isotropic elastic media. *Geophysical Journal International*, 232(2), 864–883. <https://doi.org/10.1093/gji/ggac363>
- Kuo, B., Crawford, W. C., Webb, S. C., Lin, C., Yu, T., & Chen, L. (2015). Faulting and hydration of the upper crust of the SW Okinawa Trough during continental rifting: Evidence from seafloor compliance inversion. *Geophysical Research Letters*, 42(12), 4809–4815. <https://doi.org/10.1002/2015gl064050>
- Malavieille, J., Lallemand, S. E., Dominguez, S., Deschamps, A., Lu, C.-Y., Liu, C.-S., & Schnürle, P. (2002). Arc-Continent collision in Taiwan: New marine observations and tectonic evolution. *GSA Special Paper*, 443, 189–213.
- Malavieille, J., Dominguez, S., Lu, C.-Y., Chen, C.-T., & Konstantinovskaya, E. (2021). Deformation partitioning in mountain belts: insights from analogue modelling experiments and the Taiwan collisional orogen. *Geological Magazine*, 158(1), 84–103. <https://doi.org/10.1017/s0016756819000645>
- Monteiller, V., Chevrot, S., Komatitsch, D., & Wang, Y. (2015). Three-dimensional full waveform inversion of short-period teleseismic wavefields based upon the SEM–DSM hybrid method. *Geophysical Journal International*, 202(2), 811–827.
- Park, J., & Levin, V. (2000). Receiver functions from multiple-taper spectral correlation estimates, *Bulletin of the Seismological Society of America*, 80(5), 1551–1564.

- the Seismological Society of America*, 90(6), 1507–1520. <https://doi.org/10.1785/0119990122>
- Suppe, J. (1981). Mechanics of mountain building and metamorphism in Taiwan. *Memoir of the Geological Society of China (Taiwan)*, 4, 67–89.
- Tirel, C., Brun, J.-P., Burov, E., Wortel, M. J. R., & Lebedev, S. (2013). A plate tectonics oddity: Caterpillar-walk exhumation of subducted continental crust. *Geology*, 41(5), 555–558. <https://doi.org/10.1130/g33862.1>
- Tromp, J., Tape, C., & Liu, Q. (2005). Seismic tomography, adjoint methods, time reversal and banana-doughnut kernels. *Geophysical Journal International*, 160(1), 195–216. <https://doi.org/10.1111>
- Tong, P., Komatitsch, D., Tseng, T.-L., Hung, S.-H., Chen, C.-W., Basini, P., & Liu, Q. (2014). A 3-D spectral-element and frequency-wave number hybrid method for high-resolution seismic array imaging. *Geophysical Research Letters*, 41(20), 7025–7034. <https://doi.org/10.1002/2014gl061644>
- Wang, K. (2021). Full-waveform adjoint tomography package (v1.0) [Computer software]. Zenodo. <https://doi.org/10.5281/zenodo.4747811>
- Wang, K., Wang, Y., Song, X., Tong, P., Liu, Q., & Yang, Y. (2021a). Full-waveform inversion of high-frequency teleseismic body waves based on multiple plane-wave incidence: Methods and practical applications. *Bulletin of the Seismological Society of America*, 112(1), 118–132. <https://doi.org/10.1785/0120210094>
- Wang, K., Yang, Y., Jiang, C., Wang, Y., Tong, P., Liu, T., & Liu, Q. (2021b). Adjoint tomography of ambient noise data and teleseismic P waves: Methodology and applications to Central California. *Journal of Geophysical Research: Solid Earth*, 126(6). <https://doi.org/10.1029>
- Woollam, J., Münchmeyer, J., Tilmann, F., Rietbrock, A., Lange, D., Bornstein, T., et al. (2022). SeisBench—A Toolbox for Machine Learning in Seismology. *Seismological Research Letters*, 93(3), 1695–1709. <https://doi.org/10.1785/0220210324>
- Xu, M., & He, J. (2022). Seispy: Python module for batch calculation and postprocessing of receiver functions. *Seismological Research Letters*, 94(2A), 935–943.
- Xu, M., Wang, K., Chen, J., Yu, D., & Tong, P. (2023). Receiver Function Adjoint Tomography for Three-Dimensional High-Resolution Seismic Array Imaging: Methodology and Applications in Southeastern Tibet. *Geophysical Research Letters*, 50(19). <https://doi.org/10.1029/2023gl104077>
- Yu, Y., Song, J., Liu, K. H., & Gao, S. S. (2015). Determining crustal structure beneath seismic stations overlying a low-velocity sedimentary layer using receiver functions. *Journal of Geophysical Research: Solid Earth*, 120(5), 3208–3218. <https://doi.org/10.1002/2014jb011610>
- Zhang, Z., & Olugboji, T. (2021). The Signature and Elimination of Sediment Reverberations on Submarine Receiver Functions. *Journal of Geophysical Research: Solid Earth*, 126(5). <https://doi.org/10.1029/2020jb021567>
- Zhu, L., & Kanamori, H. (2000). Moho depth variation in southern California from teleseismic receiver functions. *Journal of Geophysical Research: Solid Earth*, 105(B2), 2969–2980.

二、整合型研究計畫項目及重點說明：(總計畫及子計畫之主持人均需分年填寫此表)

(一) 整合型研究計畫項目：

第一年 (113/08-114/07)：

計畫項目	主持人	服務機構/系所	職稱	計畫名稱	申請經費 (新臺幣元)
總計畫	洪淑蕙	國立臺灣大學 地質科學系	教授	SALUTE(II): 以陣列地震學與動力學探索南台灣由隱沒至碰撞岩石圈尺度構造	0*
子計畫一	洪淑蕙	國立臺灣大學 地質科學系	教授	朝向接收函數全波形高解析度的陣列成像解析南台灣隱沒-碰撞過渡帶的岩石圈構造	4,197,247
子計畫二	曾泰琳	國立臺灣大學 地質科學系	副教授	利用地震波場二維模擬與地震特性研究南台灣之岩石圈構造	2,615,292
子計畫三	林佩瑩	國立臺灣師範大學 地球科學系	助理教授	以外海寬頻地震儀擴展海陸地震網陣列展距探討台灣南部地殼及上地函之剪力波震波非均向性	2,977,834
子計畫四	譚諤	中央研究院 地球科學研究所	副研究員	從海洋到大陸：三維模型解析南部台灣海溝隱沒動力及地震生成潛力	1,731,013
合計					11,521,386

第二年 (114/08-115/07)：

計畫項目	主持人	服務機構/系所	職稱	計畫名稱	申請經費 (新臺幣元)
------	-----	---------	----	------	----------------

總計畫	洪淑蕙	國立臺灣大學 地質科學系	教授	SALUTE(II): 以陣列 地震學與動力學探索 南台灣由隱沒至碰撞 岩石圈尺度構造	0*
子計畫一	洪淑蕙	國立臺灣大學 地質科學系	教授	朝向接收函數全波形 高解析度的陣列成像 解析南台灣隱沒-碰撞 過渡帶的岩石圈構造	4,320,649
子計畫二	曾泰琳	國立臺灣大學 地質科學系	副教授	利用地震波場二維模 擬與地震特性研究南 台灣之岩石圈構造	2,654,215
子計畫三	林佩瑩	國立臺灣師範大學 地球科學系	助理教 授	以外海寬頻地震儀擴 展海陸地震網陣列展 距探討台灣南部地殼 及上地函之剪力波震 波非均向性	3,040,198
子計畫四	譚諤	中央研究院 地球科學研究所	副研究 員	從海洋到大陸: 三維模 型解析南部台灣海溝 隱沒動力及地震生成 潛力	1,731,013
合計					11,746,075

第三年 (115/08-116/07):

計畫項目	主持人	服務機構/系所	職稱	計畫名稱	申請經費 (新臺幣元)
總計畫	洪淑蕙	國立臺灣大學 地質科學系	教授	SALUTE(II): 以陣列 地震學與動力學探索 南台灣由隱沒至碰撞 岩石圈尺度構造	0*

子計畫一	洪淑蕙	國立臺灣大學 地質科學系	教授	朝向高解析度的接收 函數全波形陣列成像 南台灣隱沒-碰撞過渡 帶的岩石圈構造	5,097,926
子計畫二	曾泰琳	國立臺灣大學 地質科學系	副教授	利用地震波場二維模 擬與地震特性研究南 台灣之岩石圈構造	2,576,032
子計畫三	林佩瑩	國立臺灣師範大學 地球科學系	助理教 授	以外海寬頻地震儀擴 展海陸地震網陣列展 距探討台灣南部地殼 及上地函之剪力波震 波非均向性	2,080,318
子計畫四	譚諤	中央研究院 地球科學研究所	副研究 員	從海洋到大陸：三維模 型解析南部台灣海溝 隱沒動力及地震生成 潛力	1,731,013
合計					11,485,289

*備註：總計畫之野外差旅費及專任助理費編入子計畫一，將專職負責整合計劃的海陸聯合陣列佈站維修和資料回收等相關事宜。

(二) 整合型研究計畫重點說明：

請就下列各點分項述明：

1. 整合之必要性：包括總體目標、整體分工合作架構及各子計畫間之相關性與整合程度。

1.1 Overall Objective and Scientific Merit of the Integrative Proposal

The investigation of subduction-collision/accretion complexes and associated structures holds significant scientific merits as it provides invaluable insights into the fundamental processes of mountain building and continental growth that have shaped the Earth's geological history (Sengor et al., 1993). Understanding the dynamics at play during subduction-collision processes, including sublithospheric mantle convection and crustal/lithospheric deformation, is essential for unraveling the complex structure and evolution of the crust and mantle between interacting tectonic plates and clarifying the physical mechanisms underlying the formation of the time-space evolving orogens. Southern Taiwan and its offshore areas lie at a crucial juncture where the Eurasian continental plate (EUP) is subducting eastward beneath the Philippines Sea Plate (PSP), concurrent with the NW-directed collision and accretion of the Luzon volcanic arc (LVA) onto the overriding PSP onto the EUP margin (Fig. 1). Such unique setting makes them a natural laboratory well-suited for exploring these scientifically fundamental and captivating problems.

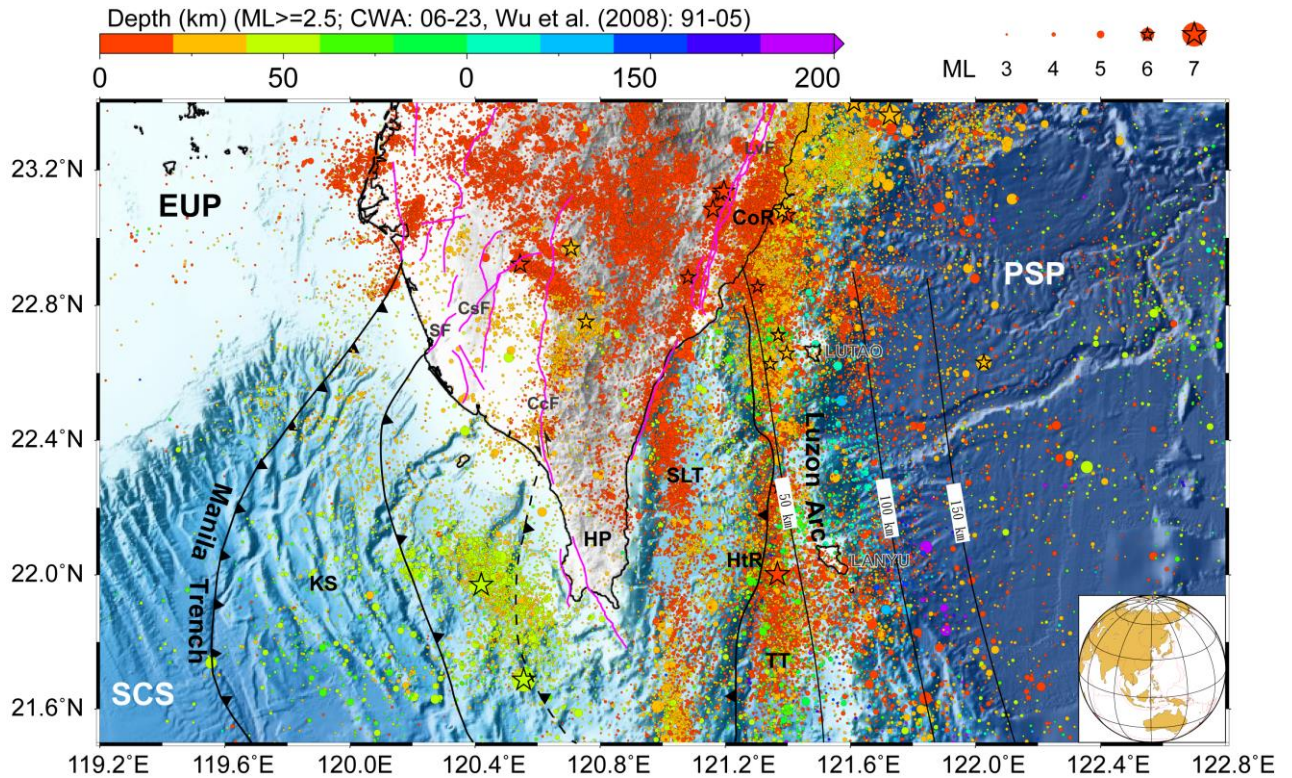


Fig. 1. Topographic and tectonic map of southern Taiwan and its offshore regions, along with seismogenic structures, faults, and seismicity with magnitude $ML \geq 2.5$. Pink lines delineate the active faults from TEM2020 model (Shyu et al., 2020), while black lines with triangles mark offshore thrust and backthrust faultings based on Lin et al. (2007) and Malavieille et al. (2021). Black lines with labels of 50-150 km indicate the isodepth contours of the subducted Eurasian plate from Slab2.0 (Hayes, 2018). Abbreviations of tectonic units and faults: KS: Kaoping Slope; HP: Hengchun Peninsula; SLT: Southern Longitudinal Trough; HtR: Huatung Ridge; TT: Taitung Trough; CsF: Chaochou Fault; CsF: Chihshan Fault; SF: Shoushan Fault.

Beyond its scientific significance, this targeted region is positioned within the growing, uplifted accretionary-orogenic wedge atop the subducted Eurasian lithosphere which has involved strong deformation partitioning in between the retroside of the wedge and LVA, along with the closure of the fore-arc basin and significant shortening of the fore-arc basement sliver beneath the PSP (Lewis et al., 2015; Malavieille et al., 2021). Shallow crustal earthquakes rupturing along the major thrusts and backthrusts, both on land and in the offshore area within the wedge, have the potential to pose significant seismic and tsunami hazards (Fig. 1). In addition to these interplate earthquakes, intraplate/intraslab earthquakes occurring within the lithospheric mantle tend to have large ratios of radiated seismic energy to moment (Preston et al., 2003). The 2006 Pingtung earthquake doublet (with a moment magnitude M_w of 7.0 and 6.9), striking SW offshore Taiwan, is an example of such seismic events and considered to nucleate along reactivated faults at a depth of ~ 40 km in the subducted Eurasian mantle lithosphere (Hu et al., 2023). The study of the seismogenesis and associated seismogenic structures for these earthquakes is not only a subject of scientific inquiry but has direct relevance of societal impacts particularly in the context of seismic hazard concerns.

Our proposed integrative project mainly aims to comprehensively investigate the evolution of the Taiwan's orogeny and seismic hazards by integrating diverse research methodologies. The overall goal is to gain a thorough understanding of the structural complexities in the juncture of

continental subduction and incipient arc collision zone and improve earthquake risk assessments in southern Taiwan.

1.2 Study Strategy and Challenge of Amphibious Broadband Seismic Array Deployment

Given the intricacies of subduction-collision processes and their associated seismic (including isotropic velocity heterogeneity, seismic anisotropy, and attenuation) and seismogenic structures in this region, a multidisciplinary approach is imperative to bridge different fields of study together and address relevant scientifically and societally important and challenging questions. To achieve these goals, a large-scale, high-density seismic campaign with extended data recording periods in the targeted study region is an essential component. Over the past three decades, various temporary arrays and seismic experiments, employing both active and passive sources, have been designed to target research problems related to the subsurface structures and geodynamic models of the Taiwan orogen (e.g., Reed et al., 1992; Kuo-Chen et al., 2012). Among these, the Formosa seismic array, deployed since 2017, is the most recent and dense passive broadband array. However, despite numerous seismic experiments in the southern Taiwan subduction-collision transition zone, most of them utilized short-period stations or geophone nodes for relatively short periods, providing insufficient seismic frequency bandwidth and long-term data coverage to illuminate some key features beneath the Taiwan orogen., particularly at greater depths and offshore regions.

To achieve high-resolution imaging of crustal and lithospheric mantle structures and to investigate source characteristics of earthquakes in the southern Taiwan subduction-collision transition, these demands had led us to initiate a 3-year integrative research project from August, 2021 to July, 2024, supported by funding from the National Science and Technology Council (NSTC) (formerly the Ministry of Science and Technology, MOST). In order to collect long-time, high-quality seismic and ambient noise data recordings with high-density station spacing, we designed a large-aperture, amphibious broadband seismic array with an average inter-station spacing of ~5-10 km, named SALUTE (Southern Array for the Lithosphere and Uplift of Taiwan Experiment). The array, strategically positioned across our focused subduction-collision transition zone, mainly forms a cross-shaped configuration. Along the main west-east transect, the array spans from west to east across the Kaohsiung area, Pingtung Plain, southern segment of the Central Mountain Range, Taitung region, and the Huatung Basin, covering a total distance of about 170 kilometers. In the north-south transect, it roughly follows the Chaochou Fault on both sides, extending northward to near the southern cross-island highway and southward to Fangshan, with a length of approximately 90 kilometers. (Fig. 2).

Starting from late-October of 2021 and continuing to the present, we have successfully deployed 29 land stations, with additional two sites scheduled for deployment in next two weeks. The simultaneous deployment of all SALUTE array stations posed challenges due to a combination of reasons, primarily resolving around the instrument availability and the delays in obtaining agreements from schools, governments, private landowners, and indigenous communities. In order to deploy stations in the challenging-to-reach yet crucial Southern Central Range, falling under the jurisdiction of government's environmental protection or conservation agencies but situated within the ancestral lands of Taiwan's indigenous people, out of respect for their autonomy, we ensure open communication with the tribal development association and present our project in a tribal meeting, seeking consensus from the tribe's community. To expand the aperture and recording continuity and duration along the main E-W transect across the Taiwan orogen, we devised a plan to recurrently deploy 8 ocean-bottom seismometers (OBSs) at

specific sites off the eastern coast of Taiwan for three consecutive years (2021, 2022, and 2023), and each deployment is anticipated to last approximately one year.

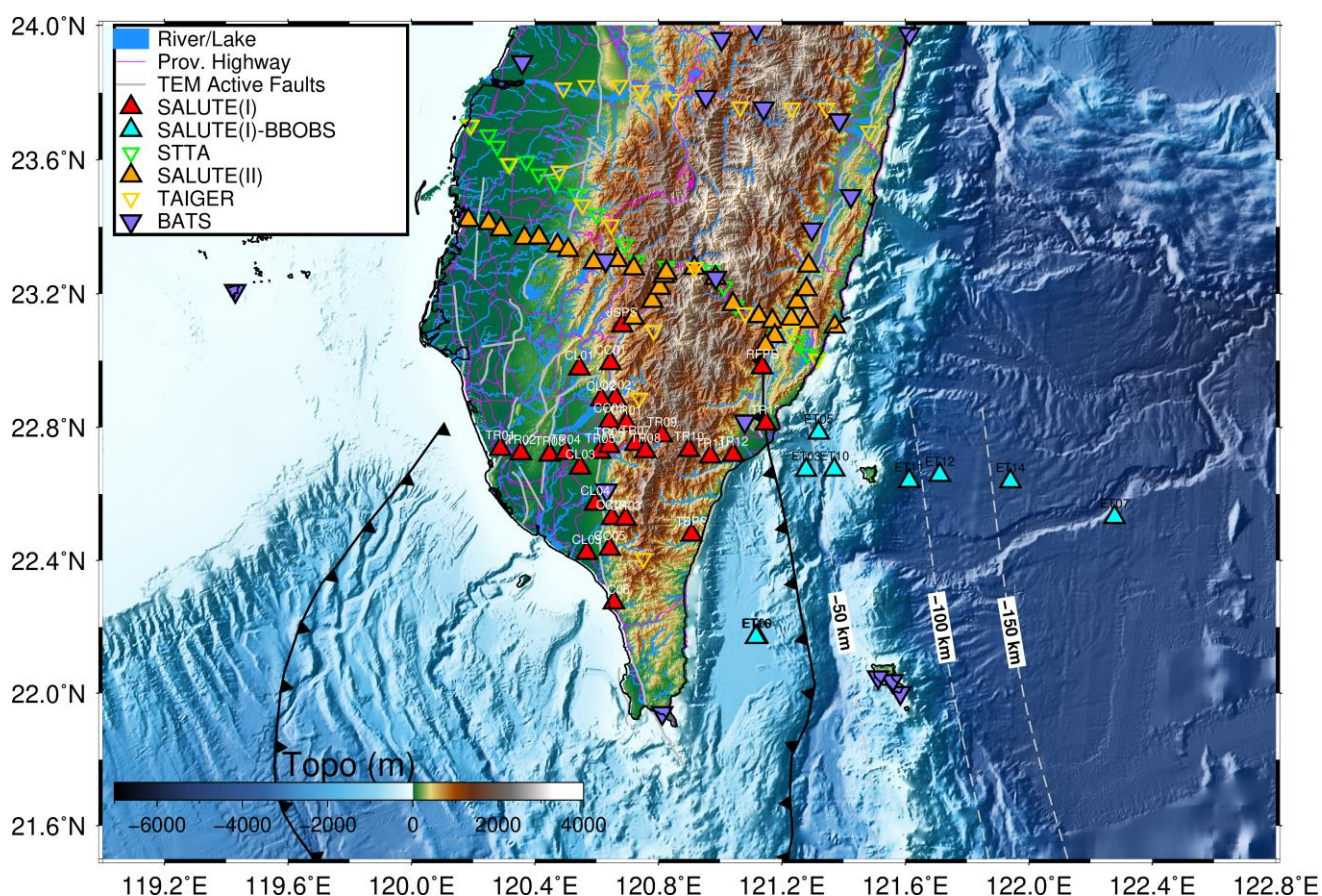


Fig. 2. Station map of the Southern Array for the Lithosphere and Uplift of Taiwan Experiment (SALUTE) in 2021-2024, shown by solid red and cyan colored triangles. Up to date, there are 29 broadband seismic stations positioned across the southern Taiwan orogenic belt and 11 ocean-bottom seismometers deployed at 8 sites in eastern offshore Taiwan. The station locations planned for the second phase of the SALUTE (II) project are denoted by solid orange triangles. Permanent BATS stations, temporary TAIGER broadband stations, and the Southern Taiwan Transect Array are marked by solid slateblue inverted triangles, open green inverted triangles, and open golden inverted triangles, respectively.

Over the past two years, our team conducted field visits approximately once in one or two months on average for the sites reachable by cars and the uninhabited sites only accessible by foot or improved SUV twice per year during dry seasons. These visits involved deploying stations, performing site maintenance, replacing disk cards, attending tribal meetings to secure indigenous community consent, and conducting on-site surveys as requested by the responsible government units. The OBS team also tried to secure 8 OBSs every year for deployment.

Despite our efforts, both onshore and offshore instruments encountered various issues due to bad weather conditions such as typhoons and floods, wild animal damage, and malfunctions in datalogger and sensors, resulting in data interruption. Moreover, unanticipated problems with OBS instrumental conditions and a low recovery rate of the second-year deployment led to the deployment of only four OBSs in the third-year experiment. Currently, data from only 5 out of the 8 OBS stations deployed in the first year are useable and overlap with data from the earliest deployed land stations. Figure 3 provides a summary of the deployment duration and data

continuity for all the 29 land stations and 8 OBSs.

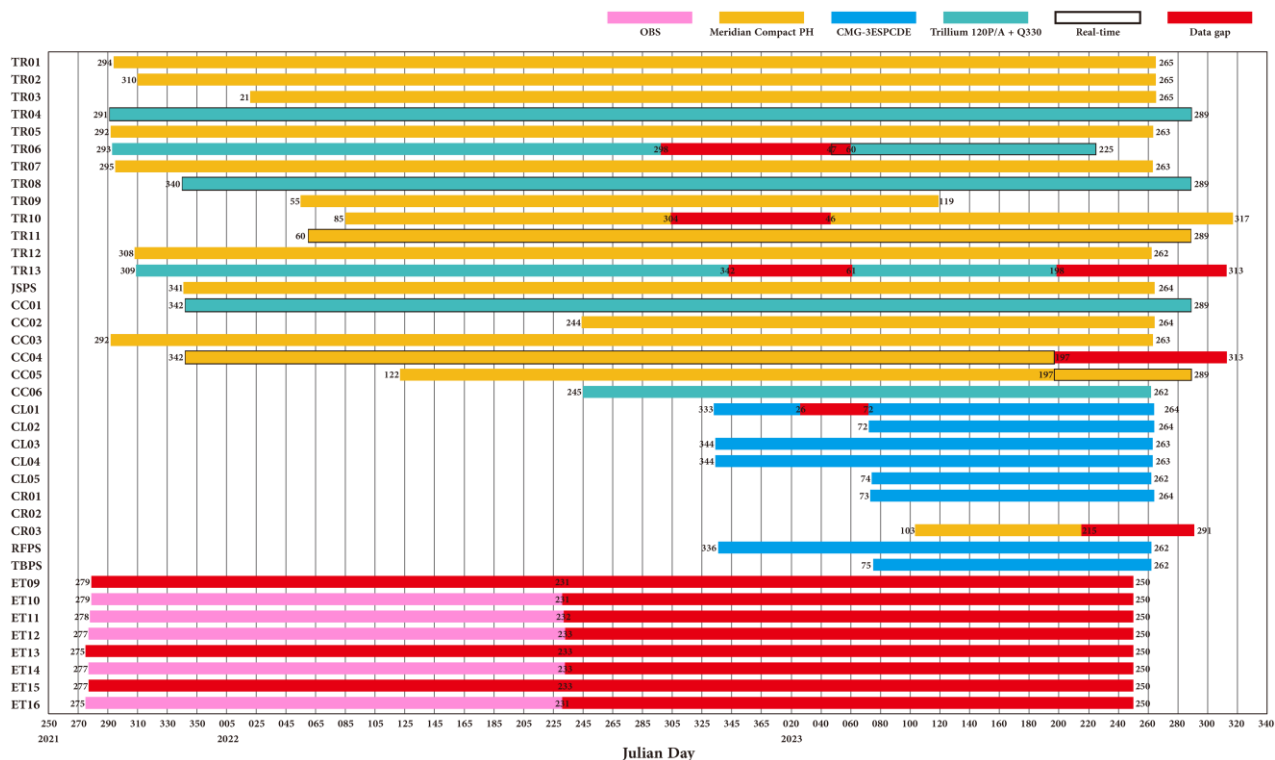


Fig. 3. Deployment duration and data continuity of 29 land stations and 8 OBSs on Julian days starting from Oct. 17, 2021 to Nov. 15, 2023. The bars are color-coded to represent the different instrument types: goldenrod for Meridian Compact, dodgerblue for CMG-3ESPCDE, cyan for Trillium 120P/A+Q330, and pink for OBSs. Stations outlined in black indicate real-time stations. The red bars highlight time periods with data gaps, reflecting the challenges faced during the deployment process, environmental conditions, and instrument-related issues.

In spite that challenging logistics have posed significant hurdles for the SALUTE experiment, the data obtained through the SALUTE array has demonstrated its high quality comparable to the well-established permanent BATS stations (Fig. 4). Preliminary observations and findings have been presented in domestic TGA meeting and international Fall AGU meeting this year (also see details in each sub-project’s proposal).

The integrative SALUTE project has demonstrated the comprehensive broadband data acquired during this endeavor would facilitate the exploration of fundamentally important scientific inquiries regarding the continental subduction and arc-continent collision and their impact on the evolution of the Taiwan orogen. To underline the significance of the SALUTE project's continuation, we use the National Science Foundation (NSF)-funded Banda arc experiment as a compelling example (Millers et al., 2016). This comparable-scale initiative, spanning five years from 2014 to 2019, deployed 30 broadband seismic stations in eastern Indonesia which is also currently undergoing arc-continent collision. The primary objectives were seismic imaging and the investigation of the collision between oceanic arc and continent lithosphere of the Indo-Australian Plate. The experiment has yielded unprecedented and invaluable data, contributing substantially to the understanding of arc-continent collision. The success of the passive seismic experiment does not only lead to profound insights into our comprehension of intricate arc-continent collision processes but also serves as a testament to the enduring scientific value derived from long-term, high-density seismic deployments.

Earthquake occurred on 2022-05-26 15:37; Mw 6.6; Latitude -22.84°; Longitude: 172.14°; Depth 15.0 km
Vertical (Z) channel in bandpass filter 0.02-0.1 Hz (10-50 seconds)

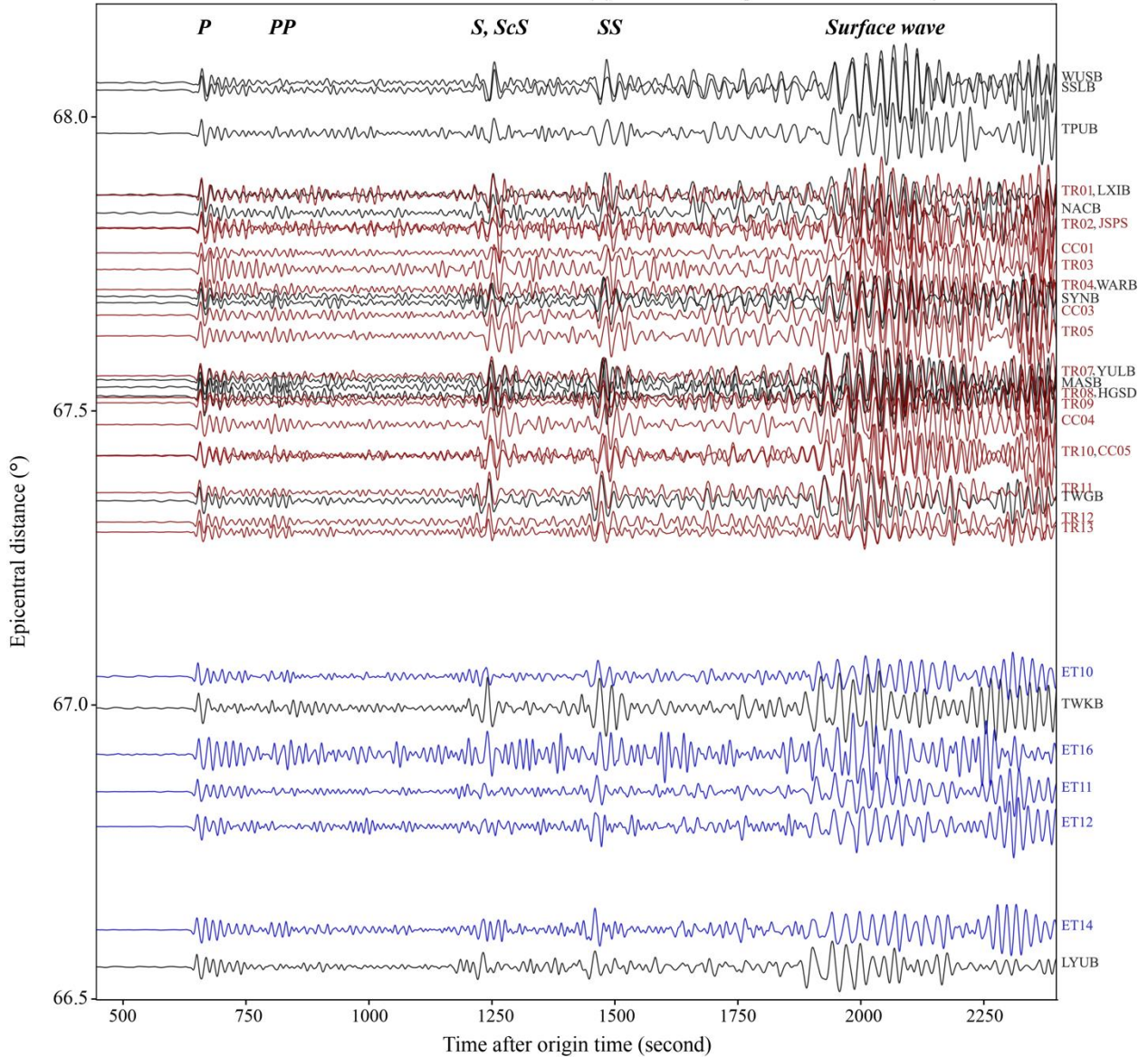


Fig. 4. Record section of bandpass-filtered displacement waveforms (10-50 s) on the vertical component for the 26 May 2022 Mw 6.6 shallow earthquake in the Fiji area recorded by SALUTE land stations (maroon lines), SALUTE BBOBSs (blue lines) and permanent BATS stations (black lines).

Inspired by the achievements of the Banda arc experiment, we propose to extend our SALUTE project and array for next three years from 2024 to 2027. Over the upcoming three years of the SALUTE project, we will seek approval for the continued utilization of broadband seismometers from TEC (Taiwan Earthquake Research Center) Instrument pool and uphold the maintenance of all the SALUTE land stations. Collaborating closely with the Institute of Earth Sciences, Academia Sinica, under the leadership of Dr. Ban-Yuan Kuo, we aim to secure the deployment of a minimum of eight OBSs annually. Our objective is to consistently record seismic data for additional two years without interruption by the entire amphibious SALUTE array. The expansive datasets will allow us to uncover intriguing details of the complex structures and dynamic processes in this transition zone and contribute to our more comprehensive and deeper understanding of the evolution of the Taiwan orogeny. Moreover, extending the funding of the SALUTE array will not only sustain the current multidisciplinary collaborations among the

sub-projects for further strengthening the scientific impact, but will also open venues for additional collaborations to address other related and unrelated studies such as deep Earth structure, seismotectonics, and seismic hazards.

In the third year, subject to the availability of funding, our intention is to relocate the amphibious seismic array northward, tracing along the NWW-SEE trending southern cross-island highway and the NNE-SSW striking Longitudinal Valley. This extension will reach beyond the northern limit where the Wadati-Benioff seismic zone associated with the eastward-subducting Eurasian lithosphere become vanishing (see Fig. 2). This strategic move aims to facilitate a comparative analysis of imaging structures beneath these contrasting subduction-collision regimes. The primary goal is to enhance our understanding of the geometry of the Eurasian slab, and to address other key questions related to the orogenic dynamics in the Taiwan region. Figure 2 displays the current configuration of the amphibious SALUTE seismic network and outlines the planned relocation of a new dense broadband array to a northern position across the Taiwan orogen in the final year of the 2nd phase of the SALUTE project. A detailed timeline and schedule for site survey and relocation of a total of 30 on-land stations are provided in Appendix A, along with the field-related budgets for both land and OBS stations listed in Appendix B and C, respectively.

1.3 Collaborative Structure and Relevance among Sub-Projects

In the forthcoming 3-year integrative proposal, each sub-project will continue to focus specific yet interconnected research themes, spanning fields from array-based, high-resolution seismic imaging, novel adjoint waveform tomography, and wavefield modeling to physics-based geodynamic modeling in this tectonically interesting and significant region. The title of each sub-project, the name of the PI, and the brief description of each sub-project are listed below.

- **Sub-project 1: Toward Receiver Function Adjoint Tomography for High-Resolution Seismic Array Imaging of Lithospheric Structure in Southern Taiwan Subduction-Collision Transition** (PI: Shu-Huei Hung, 洪淑蕙)

This subproject mainly analyzes P and S receiver functions (RFs) and employs high-resolution, array-based imaging techniques to unravel the lithospheric structures, particularly with emphasis on seismic discontinuity features such as intracrustal interfaces, Moho, and LAB (lithosphere-asthenosphere boundary) beneath the southern Taiwan subduction-collision transition zone. Toward applying the advanced adjoint RF waveform tomography method, we seek to explore detailed lithospheric structures and velocity anomalies and aim to achieve a more precise understanding and characterization of the crust and lithospheric mantle structures in the subduction-collision transition zone.

- **Sub-project 2: Investigating Lithospheric Structures under Southern Taiwan by 2-D Seismic Wavefield Simulation and Earthquake Properties** (PI: Tai-Lin Tseng, 曾泰琳)

This subproject will focus on exploring fine-scale crustal structures, such as Moho offset west of the Chaochou Fault in southern Taiwan observed by P receiver functions and in the offshore forearc wedge through the application of 2-D seismic wavefield simulation and the analysis of earthquake properties. By employing advanced waveform modeling techniques, we aim to model seismic wave interactions within the region, providing insights into the complex subsurface features. Additionally, the investigation of earthquake properties will contribute to a comprehensive understanding of the seismogenic structural characteristics and physical mechanisms of interplate/intraslab earthquakes in the continental subduction

and arc-collision setting.

- **Sub-project 3: Shear-Wave Anisotropy of the Crust and Uppermost Mantle in Southern Taiwan Using an Expanded Seismic Array of Offshore Broadband Seismometers** (PI: Pei-Ying Patty Lin, 林佩瑩)

This subproject aims to study the shear-wave anisotropy of the crust and uppermost mantle in Southern Taiwan through the utilization of an expanded seismic array comprising offshore broadband seismometers. By integrating phase velocities of surface waves across a broad range of periods from teleseismic earthquakes and inter-station noise cross correlation functions, we aim to achieve a comprehensive and detailed understanding of the directional dependence of shear-wave velocities, shedding light on the lithospheric deformation and sublithospheric mantle dynamics in this region.

- **Sub-project 4: From Ocean to Continent: 3D Modeling Subduction Dynamics and Seismogenic Potential in Southern Taiwan** (PI: Eh Tan, 譚諤)

Building upon the foundation laid in the previous 2D modeling, this subproject continues its focus on numerical geodynamic modeling in southern Taiwan and expand to more realistic 3D geometry. The emphasis remains on exploring the tectonic effects and dynamic consequences and compare those physically-realistic modeled scenarios with the crustal and lithospheric structures unveiled through seismic and field observations from sub-projects 1-3. The primary objective is to contribute to reconcile ongoing debates on the subduction-collision processes in Southern Taiwan and the evolutionary history of Taiwan orogeny.

Overall, our approach is aimed at investigating the tectonically intriguing and significant region we are exploring. The ultimate objective is to scrutinize deep, lithospheric-scale structures in detail to gain a comprehensive understanding of the physical mechanisms and driving dynamics underlying these structures. Comprising four subprojects covering the disciplines of earthquake and ambient noise seismology (sub-projects 1-3) and computational geodynamics (sub-project 4), the studies conducted in each subproject contribute to the scientific scope and objective of the integrative proposal. Collectively, these endeavors seek to address the following fundamental questions:

1. Lateral and Depth Extent of Subducted Eurasian Continental Crust: Sub-projects 1, 2, 3, 4 collectively determine the lateral and depth extent of the subducted Eurasian continental crust.
2. Shortening and Missing Portion of Luzon Forearc Basement: Sub-projects 1, 2, 3, 4 investigate the existence and fate of the shortening and missing portion of the Luzon forearc basin and basement under the collision suture zone in eastern and offshore Taiwan.
3. Seismic Evidence for the Existence of Serpentinized Mantle: Sub-projects 1, 2, 3 aim to explore seismic evidence for the presence of serpentinized mantle in the subducted Eurasian lithosphere, as predicted by geodynamic models in sub-project 4.
4. Geometry of Intracrustal and Moho Discontinuities: Sub-projects 1, 2, 4 focus on exploring the geometry of intracrustal and Moho discontinuities and plate interfaces beneath the southern Taiwan subduction-collision transition zone.
5. Chaochou Fault (CcF) and Moho Vertical Offset: Sub-projects 1, 2, 4 investigate the nature and geometry of the CcF and other possible hidden faults, and the role of the apparent Moho vertical offset observed beneath a permanent station on the CcF in facilitating the uplift of

the accretionary wedge and orogeny in southern Taiwan.

6. Seismic Anisotropic Structures and Their Implications for Lithospheric Deformation and Sublithospheric Mantle Dynamics: Sub-projects 1 and 3 use observations of body wave and surface wave arrivals to image seismic anisotropic structures, while sub-project 4's geodynamic modeling provides constraints to unravel their physical causes.
7. Seismogenic Structures and Physical Mechanisms for Interplate/Intraslab Earthquakes: Sub-projects 2 and 4 aim to unravel the seismogenic structures and physical mechanisms for spatially strain-partitioned crustal earthquakes occurring within the accretionary-orogenic wedge and deep (~40-km depth) intraslab earthquakes in the subducting Eurasian lithospheric mantle.

2. 人力配合度：包括總計畫主持人協調領導能力、各子計畫主持人之專業能力及合作諧和性。

2.1 Professional Expertise and Collaborations among Principal Investigators of Sub-projects

As being a “desk” seismologist who has focused on the analysis of seismic data and the utilization of computational seismic imaging methods, I have had the privilege of serving as the chief Principal Investigator of the integrative SAULTE project over the past three years. In this role, I have actively led the project, engaging in on-site fieldwork and collaborating with other PIs, co-PIs, research assistants, and students to contribute to the array's design and deployment. This hands-on involvement has provided me with a wealth of invaluable professional expertise and knowledge of the intricacies involved in executing the integrative project and field work. These experiences have not only deepened my understanding of the unique challenges associated with the SALUTE project but have also guided me with the insights necessary to lead the initiative into its next phase.

The complementary expertise and close interaction among the PIs leading subprojects within SALUTE is a key strength of our integrative proposal. Each sub-project's PI brings unique expertise and experience to his or her respective subproject, while sharing common research interests. This collective effort is directed towards comprehensively unraveling the lithospheric-scale structure and its dynamic evolution from subduction to collision in southern Taiwan. Regular collaboration and frequent progress discussions will be maintained to ensure optimal scientific results.

- Main and Sub-project 1:
PI Shu-Huei Hung (洪淑蕙) specializes in developing and applying innovative seismic imaging and tomographic methods, such as multiscale finite-frequency tomography (Hung et al., 2010, 2011) and joint P and S RF stacking method (Goyal and Hung, 2021a, b) to studying heterogeneous and anisotropic velocity structures and seismic discontinuities in the earth's crust and mantle from global to local scales with improved resolution and accuracy.
- Sub-project 2: PI Tai-Lin Tseng (曾泰琳) has extensive experience in large-scale broadband seismic experiments in central Tibet and the Caucasus mountain range (Tseng et al., 2009; Lin et al., 2020). She specializes in array-processing techniques to analyze earthquake source characteristics and investigate fine-scale velocity heterogeneities and discontinuous structures in the crust and mantle.
- Sub-project 3: PI Pei-Ying Patty Lin (林佩瑩) possesses extensive training and profound

expertise in denoising and analyzing OBS seismic data, specifically using dispersive surface waves to image isotropic and anisotropic structures in the oceanic lithosphere and asthenosphere beneath the ocean floor (Lin et al., 2016). She also has a wealth of experience and leadership in conducting on-board broadband OBS experiments, making her competently capable of leading efforts to deploy and recover OBS instruments proposed in our integrative project.

- Sub-project 4: PI Eh Tan (譚諤) is an expert in the development of numerical algorithms for thermo-chemical-mechanical geodynamic modeling and their application to a diverse range of scientifically significant challenges in Earth's crust and mantle dynamics. He has conducted thermo-mechanical modeling of the subduction-collision processes in the northern Manila trench, offering a plausible physical explanation for the occurrence of deep, large-magnitude intraplate earthquakes in southern Taiwan (Tan, 2020). These modeling results are of critical importance, addressing our needs for interpreting the seismic structures resulting from sub-projects 1-3.

3. 資源之整合：包括各子計畫所需各項儀器設備之共用情況及研究經驗與成果交流情況。

3.1 Instrument Resource and Collaborative Utilization

The SALUTE project emphasizes the collaborative integration of resources, involving the shared utilization of essential instruments and equipment across all sub-projects. All 30 onshore broadband stations of the SALUTE array are acquired from TEC Instrument pool, comprising three types of instruments: Meridian Compact, Trillium 120P/A & Q330S+, and CMG-3ESPCDE. Additionally, we have established a consensus and collaboration with Dr. Justin Yen-Tin Ko (柯彥廷) at Institute of Oceanography, National Taiwan University, who has provided us with four additional Trillium Compact sensors. These sensors offer the flexibility to extend and/or densify our array as needed.

PI Pei-Ying Patty Lin of sub-project 3 work closely with the OBS team in IES, Academia and Taiwan Ocean Research Institute (TORI), including the project's leading scientists, engineers and technicians to secure to secure at least 8 broadband Ocean Bottom Seismometer (OBS) instruments ready for the deployment next August and the following two years. She will lead the deployment and recovery cruises offshore SE once per year. Each broadband OBS deployment experiment allows for a maximum one-year recording period, overlapping with the time span of on-land station deployment.

3.2 Exchange of Research Experience and Outcome

The proposed amphibious broadband seismic experiments in SALUTE (I) and SALUTE (II) aim to collect an unprecedented wealth of seismic datasets in the southern Taiwan region during at least five-year deployment period. These datasets will enable PIs, co-PIs, and other collaborative researchers in the community to conduct multiscale and multiphase studies, exploring seismic velocity, anisotropy, and attenuation properties in the underlying crust and upper mantle. Additionally, researchers can investigate source characteristics of interplate and intraplate earthquakes, contributing to seismic hazard reassessment. We commit to adhering to NSTC-TEC policy, ensuring to provide the report of each site's deployment condition and data quality, archive the data at the TEC's Data Center, and make them available to the community two years after the SALUTE(I) and SALUTE(II) conclude in July, 2024 and July, 2027, respectively. This dataset will be a valuable resource for addressing various related research questions within the scientific community.

The coordination extends to regular exchange of research experiences and outcomes in order to effectively promote efficiency and collaborations among sub-projects. As a team, we presented three consecutive papers highlighting our initial seismic imaging results in southern Taiwan region using SALUTE data at the Fall AGU Meeting this December. More regular forums and workshops will be organized in the next SALUTE phase to accelerate progress toward our collective goals.

4. 申請機構或其他單位之配合度。

The feasibility of the SALUTE project relies on collaborative efforts, coordination, and support from both the applying institutions and other involved units. All tasks, from instrument requests to site surveys, station deployment and maintenance, and data archive are executed through transparent open communication, mutual assistance, shared costs and resources, and a commitment to a common goal. The applying institution actively supports the integration of various subprojects, creating an environment conducive to multidisciplinary research.

Each subproject benefits from this collaboration, as it increases the integrative project's scope, bringing together diverse perspectives, resources, support, and logistical assistance from all the applying institutions. Moreover, the collaboration within each subproject is not limited to the applying institutions; it extends to include other units contributing specific expertise and resources. This collaborative network ensures that each subproject receives valuable input and support from relevant units, greatly enhancing the overall impact of the SALUTE project.

5. 預期綜合效益。

The SALUTE project anticipates a range of comprehensive benefits that extend across scientific, societal, and educational domains. The anticipated overall benefits include:

- (1) Scientific Advance: The amphibious broadband seismic experiment is expected to provide an unprecedented dataset for multiscale and multiphase investigations of the underlying crust and upper mantle structures in southern Taiwan region. Through collaborative efforts and geodynamic modeling, the SALUTE project aims to contribute novel insights into subduction-collision structures, processes, dynamics evolution, and seismic activities in the region.
- (2) Societal Impact: The comprehensive seismic dataset and improved understanding of seismic structures will contribute to more accurate seismic hazard assessments, aiding in the development of resilient infrastructure and disaster preparedness.
- (3) Community Outreach and Education: Most stations are deployed in the campus of elementary and high schools and indigenous people's traditional territory. We promise the project will engage in community outreach and educational initiatives to disseminate general knowledge about earthquakes, tectonics, and geology of southern Taiwan and scientific findings to the local communities.
- (4) Educational Contributions: The collaborative and multidisciplinary nature of the project provides valuable training opportunities for graduate and undergraduate students. Exposure to cutting-edge seismological and geodynamic methodologies and scientific problems will prepare the next generation of researchers for careers in earth sciences.
- (5) Research Outcome Transfer: The scientific research outcomes benefiting from the new SALUTE data will be distributed widely within the scientific community through meetings, seminars and peer-review publications.

In summary, the SALUTE project is expected to advance scientific knowledge, contribute to

societal concern, and create educational opportunities for the future. These outcomes align with the goals and priorities outlined in this proposal

6. References of the Main Proposal

- Goyal, A. and S.-H. Hung (2021b). Bulk crustal properties and layered velocity structure in Fujian, SE China: Constraints from P and S receiver functions. *Front. Earth Sci.* | doi: 10.3389/feart.2021.743163.
- Goyal, A. and S.-H. Hung (2021a). Lateral variations of Moho depth and average crustal properties across the Taiwan orogen from H-V stacking of P and S receiver functions, *Geochemistry, Geophysics, Geosystem*, 22(3). <https://doi.org/10.1029/2020GC009527>.
- Hu, W.-L., Wei, S., Feng, L., Hsiao, S.-H., Ching, K.-E., and Hu, J.-C.: The 2006 Pingtung intraslab earthquake doublet offshore southwestern Taiwan: Complex normal and strike-slip faulting in the northern Manila subduction zone where the continent-oceanic transitional slab subducts, EGU General Assembly 2023, Vienna, Austria, 24–28 Apr 2023, EGU23-4603, <https://doi.org/10.5194/egusphere-egu23-4603>, 2023.
- Hung, S.-H., W.-P. Chen, and L.-Y. Chiao (2011), A data-adaptive, multiscale approach of finite-frequency, traveltimes tomography with special reference to P and S wave data from central Tibet, *J. Geophys. Res.*, 116, B06307, doi:10.1029/2010JB008190.
- Hung, S.-H., W.-P. Chen, L.-Y. Chiao, and T.-L. Tseng (2010), First multi-scale, finite-frequency tomography illuminates 3-D anatomy of the Tibetan Plateau, *Geophys. Res. Lett.*, 37, L06304, doi:10.1029/2009GL041875.
- Kuo-Chen, H., Wu, F. T., & Roecker, S. W. (2012). Three-dimensional P velocity structures of the lithosphere beneath Taiwan from the analysis of TAIGER and related seismic data sets. *Journal of Geophysical Research: Solid Earth*, 117(B6), <https://doi.org/10.1029/2011jb009108>
- Lin, A. T., Yao, B., Hsu, S.-K., Liu, C.-S., & Huang, C.-Y. (2009). Tectonic features of the incipient arc-continent collision zone of Taiwan: Implications for seismicity. *Tectonophysics*, 479(1–2), 28–42. <https://doi.org/10.1016/j.tecto.2008.11.004>
- Lewis, J. C., O'Hara, D. J., & Rau, R. (2015). Seismogenic strain across the transition from fore-arc slivering to collision in southern Taiwan. *Journal of Geophysical Research: Solid Earth*, 120(6), 4539–4555. <https://doi.org/10.1002/2015jb011906>
- Lin, C.-M., Tseng, T.-L., Meliksetian, K., Karakhanyan, A., Huang, B.-S., Babayan, H., et al. (2020). Locally thin crust and high crustal V_P/V_S ratio beneath the Armenian volcanic highland of the Lesser Caucasus: A case for recent delamination. *Journal of Geophysical Research: Solid Earth*, 125, e2019JB019151. <https://doi.org/10.1029/2019JB019151>
- Lin, P.-Y., Gaherty, J. B., Jin, G., Collins, J. A., Lizarralde, D., Evans, R. L., & Hirth, G. (2016). High-resolution seismic constraints on flow dynamics in the oceanic asthenosphere. *Nature*, 535(7613), 538–541. <https://doi.org/10.1038/nature18012>
- Malavieille, J., Lallemand, S. E., Dominguez, S., Deschamps, A., Lu, C.-Y., Liu, C.-S., & Schnürle, P. (2002). Arc-Continent collision in Taiwan: New marine observations and tectonic evolution. *GSA Special Paper*, 189–213.
- Malavieille, J., Dominguez, S., Lu, C.-Y., Chen, C.-T., & Konstantinovskaya, E. (2021). Deformation partitioning in mountain belts: insights from analogue modelling experiments and the Taiwan collisional orogen. *Geological Magazine*, 158(1), 84–103. <https://doi.org/10.1017/s0016756819000645>
- Preston, L. A., Creager, K. C., Crosson, R. S., Brocher, T. M., & Trehu, A. M. (2003). Intraslab earthquakes: Dehydration of the Cascadia slab. *Science*, 302(5648), 1197–1200. <https://doi.org/10.1126/science.1090751>.

- Reed, D. L., Lundberg, N., Liu, C. H., and Kuo, B. Y., 1992, Structural relations along the margins of the offshore Taiwan accretionary wedge : implications for accretion and crustal kinematics : *Acta Geologica Taiwanica*, v. 30, p. 105-122.
- Sengor, A. M. C., Natalin, B. A., & Burtman, V. S. (1993). Evolution of the Altaid tectonic collage and Palaeozoic crustal growth in Eurasia. *Nature*, 364, 299–306.
- Shyu, J. B. H., Sieh, K., Chen, Y.-G., & Liu, C.-S. (2005). Neotectonic architecture of Taiwan and its implications for future large earthquakes. *Journal of Geophysical Research: Solid Earth*, 110, B08402, <https://doi.org/10.1029/2004JB003251>.
- Tan, E. (2020). Subduction of transitional crust at the Manila Trench and its geophysical implications. *Journal of Asian Earth Sciences*, 187, 104100. <https://doi.org/10.1016/j.jseaes.2019.104100>
- Tseng, T.-L., Tseng, W.-P., & Nowack, R. L. (2009). Northward thinning of Tibetan crust revealed by virtual seismic profiles. *Geophysical Research Letters*, 36(24), L24304. <https://doi.org/10.1029/2009gl040457>
- Wu, Y.-M., Chang, C.-H., Zhao, L., Teng, T.-L., & Nakamura, M. (2008). A comprehensive relocation of earthquakes in Taiwan from 1991 to 2005. *Bulletin of the Seismological Society of America*, 98(3), 1471–1481. <https://doi.org/10.1785/0120070166>

Appendix B. Budget estimate for site survey and maintenance of on-land stations

架設及維護陸上地震測站之年度總預算表 (不含助理)

測站數量：31 個

第一年	27000(設備)*4 套+50000(架設)*1 趟+37500(維護)*2 趟*5 次 +3600(土地簽約金)*10+32200(高山測站維護)*2 趟*2 次
小計	NT\$697800
第二年	37500(維護)*2 趟*6 次+31200(撤站)*5 趟 +3600(土地簽約金)*10+32200(高山測站維護)*2 趟*2 次
小計	NT\$770800
第三年	27000(設備)*30 套+50000(架設)*8 趟+37500(維護)*2 趟*6 次 +31200(撤站)*5 趟+3600(土地簽約金)*10 +32200(高山測站維護)*2 趟*2 次
小計	NT\$1980800
總計	NT\$3449400

1. 硬體設施與耗材

- 地震儀與紀錄器 (自有及 TEC 借用)
- 每站所需電力等相關硬體設施及耗材 \$27,000 元 (預設太陽能板站)

設備費用	太陽能板站	價格
儀器	地震儀 紀錄器	
電力	電池(鋰電池 or 鉛酸電池)	\$6000
	太陽能板 100W (含鋁框)	\$5500
	SOLAR CONTROLLER (充電控制器)	\$6500
其他	FRP 收納箱、化學桶、圍籬等五金材料	\$9000
總計		\$27000.00



2. 野外差旅費用

- 架設測站 以一趟4個站計\$50000 元，共9趟。(Table A)
- 維護測站 以一趟15個站計\$37,500 元，共17趟。每二個月維護一次。(Table B)
- 撤站整理 以一趟6個站計\$31,200 元，共10趟。(Table C)
- 高山測站維護 以一趟1個站計\$32200 元，共12趟。(Table D)
- 土地簽約金 以1個站每年計\$3600 元，共10站。(Table E)

Table A.架設測站 (單趟 4 個，共 9 趟)

時間	2024 年 8 ~ 9 月	(第一年)1 次
	2026 年 8 ~ 11 月	(第三年)8 次
一趟架設站數：4 個	人數：3	每趟執行天數：5
項目	單價	
住宿/日	\$2000	
雜費/日	\$400	
租車/日	\$4000	
明細	2000(住宿)*3(人)*4(夜)+400(雜費)*3(人)*5(天)+4000(租車)*5(天)	
總計	\$50000	

Table B.維護測站及回收資料(單趟 15 個，維護一次 2 趟)

時間	2024 年 10 月、12 月，2025 年 2 月、4 月、6 月	(第一年)5 次
	2025 年 8 月、10 月、12 月，2026 年 2 月、4 月、6 月	(第二年)6 次
	2026 年 8 月、10 月、12 月，2027 年 2 月、4 月、6 月	(第三年)6 次
一趟巡迴站數：15 站	人數：2	每趟執行天數：5
項目	單價	
住宿/日	\$2000	
雜費/日	\$400	
租車/日	\$3500	
明細	2000(住宿)*2(人)*4(夜)+400(雜費)*2(人)*5(天)+3500(租車)*5(天)	
總計	\$37,500	

Table C.撤站及整理(單趟 6 個，共 10 趟)

時間	2026 年 5 ~ 7 月(第二年，測站北移)	
	2027 年 5 ~ 7 月(第三年)	
一趟撤站數：6 個	人數：2	每趟執行天數：4
項目	單價	
住宿/日	\$2000	
雜費/日	\$400	
租車/日	\$4000	
明細	2000(住宿)*2(人)*3(夜)+400(雜費)*2(人)*4(天)+4000(租車)*4(天)	
總計	\$31200	

Table D.高山測站維護(2個高山站，單趟1個，共12趟)

時間	2024年11月，2025年3月	(第一年)2次
	2025年11月，2026年3月	(第二年)2次
	2026年11月，2027年3月	(第三年)2次
一趟維護站數：1個	人數：2	每趟執行天數：7
項目		單價
住宿/日(2日，交通日)		\$2000
雜費/日		\$400
火車/趟		\$900
嚮導費/日(5日)		\$3000
明細	2000(住宿)*2(人)*2(夜)+400(雜費)*2(人)*7(天) +900(火車)*2(趟)*2(人)+3000(嚮導費)*5(日)*1(人)	
總計		\$32200

Table E.土地簽約金(每年1簽，共10站)

時間	2024年8月 - 2025年7月(第一年)
	2025年8月 - 2026年7月(第二年)
	2026年8月 - 2027年7月(第三年)
項目	單價
租金/站/年	\$3600
明細	3600(租金/部落回饋金)
總計	\$3600

Appendix C. Budget planned for OBS stations

佈放和收回寬頻海底地震儀之年度總預算表

海洋研究船	新海研二號 NOR2 (8 位科研人員)								
航期年度	第一年 (113/08/-114/07)			第二年 (114/08-115/07)			第三年 (115/08-116/07)		
航程目的	收回 4 台 OBS 佈放 8 台 OBS			收回 8 台 OBS 佈放 8 台 OBS			收回 8 台 OBS		
品項	單價	單位	小計	單價	單位	小計	單價	單位	小計
OBS 電池組 (鋰電池和鹼性電池)	90,000	8	720,000	90,000	8	720,000	0	0	0
OBS 錨錠 (鐵座)	8,000	8	64,000	8,000	8	64,000	0	0	0
OBS 儀器運輸費	15,000	2	30,000	15,000	2	30,000	15,000	2	30,000
OBS 耗材線材	10,000	1	10,000	10,000	1	10,000	10,000	1	10,000
出海作業工作費	9,000	8	72,000	9,000	8	72,000	9,000	8	72,000
合計 (新臺幣)	-	-	896,000	-	-	896,000	-	-	112,000
總計 (新臺幣)	1,904,000								

五、申請補助經費：

- (一) 請將本計畫申請書之第七項(表CM07)、第八項(表CM08)、第九項(表CM09)、第十項(表CM10)、第十一項(表CM11)、第十二項(表CM12\CM12-1)所列費用個別加總後，分別填入「研究人力費」、「耗材、物品、圖書及雜項費用」、「國外學者來臺費用」、「研究設備費」、「國外差旅費-執行國際合作與移地研究」及「國外差旅費-出席國際學術會議」等欄內。
- (二) 管理費為申請機構配合執行本計畫所需之費用，其計算方式係依本會規定核給補助管理費之項目費用總和及各申請機構管理費補助比例計算後直接產生，計畫主持人不須填寫「管理費」欄。
- (三) 依據本會「補助延攬客座科技人才作業要點」規定提出博士級研究人員申請，請依各年度申請之名額填入下表，如於申請時一併提出「補助延攬博士級研究人員員額/人才進用申請書」(表CIF2101、CIF2102)，若計畫核定僅核定名額者應於提出合適人選後，另向本會提出進用申請，經審查通過後，始得進用該名博士級研究人員。
- (四) 申請機構或其他單位(含國內外、大陸地區及港澳)補助項目，請檢附相關證明文件。

金額單位：新臺幣元

執行年次		第一年 (113年8月 ~114年7月)	第二年 (114年8月 ~115年7月)	第三年 (115年8月 ~116年7月)	第四年	第五年
業 務 費		3,408,476	3,513,608	4,311,240		
研究人力費		2,253,176	2,355,308	1,942,940		
耗材、物品、圖書及雜項費用		1,095,300	1,158,300	2,368,300		
國外學者來臺費用		60,000	0	0		
研 究 設 備 費		50,000	0	0		
國 外 差 旅 費		220,000	280,000	140,000		
執行國際合作與移地研究		80,000	80,000	0		
出席國際學術會議		140,000	200,000	140,000		
管 理 費		518,771	527,041	646,686		
合 計		4,197,247	4,320,649	5,097,926		
博士級研究人員	國內、外 地 區	共 <u>0</u> 名	共 <u>0</u> 名	共 <u>0</u> 名	共 <u> </u> 名	共 <u> </u> 名
	大陸地區	共 <u>0</u> 名	共 <u>0</u> 名	共 <u>0</u> 名	共 <u> </u> 名	共 <u> </u> 名
申請機構或其他單位(含國內外、大陸地區及港澳)補助項目(無配合補助項目者免填)						
配合單位名稱	配合補助項目	配合補助金額	配合年次	證明文件		

1 研究計畫申請補助經費：

金額單位：新台幣元

計畫項目	申請補助 經費 年	研 究 人力費	耗材、物 品、圖書及 雜項費 用	國 外 學 者 來 臺 費 用	研 究 設 備 費	執 行 國 際 合 作 與 移 地 研 究	出 席 國 際 學 術 會 議	管 理 費	總 申 請 經 費
總計畫	1	0	0	0	0	0	0	0	0*
	2	0	0	0	0	0	0	0	0*
	3	0	0	0	0	0	0	0	0*
子計畫一	1	2,253,176	1,095,300	60,000	50,000	80,000	140,000	518,771	4,197,247
	2	2,355,308	1,158,300	0	0	80,000	200,000	527,041	4,320,649
	3	1,942,940	2,368,300	0	0	0	140,000	646,686	5,097,926
子計畫二	1	1,490,301	460,000	0	145,000	41,960	163,736	314,295	2,615,292
	2	1,504,787	460,000	0	105,000	125,680	148,280	310,468	2,654,215
	3	1,522,715	460,000	0	105,000	0	175,160	313,157	2,576,032
子計畫三	1	1,115,421	1,274,000	0	0	80,000	150,000	358,413	2,977,834
	2	1,129,650	1,274,000	0	40,000	80,000	150,000	366,548	3,040,198
	3	1,148,537	490,000	0	40,000	0	150,000	251,781	2,080,318
子計畫四	1	1,227,924	86,000	0	0	100,000	120,000	197,089	1,731,013
	2	1,227,924	86,000	0	0	100,000	120,000	197,089	1,731,013
	3	1,227,924	86,000	0	0	100,000	120,000	197,089	1,731,013
總申請 經費	1	6,086,822	2,915,300	60,000	195,000	301,960	573,736	1,388,568	11,521,386
	2	6,217,669	3,048,300	0	145,000	385,680	618,280	1,401,146	11,746,075
	3	5,842,116	3,474,300	0	145,000	100,000	585,160	1,408,713	11,485,289

*備註：總計畫之野外差旅費及專任助理費編入子計畫一，將專職負責整合計劃的海陸聯合陣列佈站維修和資料回收等相關事宜。

六、主要研究人力：

(一) 請依照「主持人」、「共同主持人」、「協同研究人員」及「博士級研究人員」等類別之順序分別填寫。

類別	姓名	服務機構/系所	職稱	在本研究計畫內擔任之具體工作性質、項目及範圍	*每週平均投入工作時數比率(%)
主持人	洪淑蕙	國立臺灣大學地質科學系暨研究所	教授	負責SALUTE陣列的規劃設置，維修和資料品質監控並引導碩博士生和博士後後分析SALUTE資料進行南台灣底下震波不連續面構造成像，剪力波分離非均性特徵和地殼衰減構造研究	70%

※ 註：每週平均投入工作時數比率係填寫每人每週平均投入本計畫工作時數佔其每週全部工作時間之比率，以百分比表示（例如：50%即表示該研究人員每週投入本計畫研究工作之時數佔其每週全部工時之百分之五十）。

(二) 如依據本會「補助延攬客座科技人才作業要點」規定申請博士級研究人員，請另填表CIF2101及CIF2102(若已有人選者，請務必填註人選姓名，並將其個人資料表(表C301~表C303)併同本計畫書送本會)。

七、研究人力費：

- (一) 凡執行計畫所需研究人力費用，均得依本會「補助專題研究計畫研究人力約用注意事項」規定，按所屬機構自訂敘薪標準及職銜，就預估專任、兼任人員或臨時工需求填寫，並請述明該研究人力在本計畫內擔任之具體內容、性質、項目及範圍，以利審查。專任人員不限學歷，包含博士級人員。
- (二) 約用專任人員，請依其於專題研究計畫負責之工作內容，所應具備之專業技能、獨立作業能力、預期績效表現及相關學經歷年資等條件，綜合考量敘薪，並檢附各機構自訂之薪資支給依據，以為本會核定聘用助理經費之參考。
- (三) 請分年列述。

第 1 年

金額單位：新臺幣元

類別	金額	請敘明在本計畫內擔任之具體內容、性質、項目及範圍 (如約用專任人員，請簡述其於計畫內所應具備之專業技能、獨立作業能力、預期績效表現及相關學經歷年資等條件)
專任人員	787,176	第四年專任助理負責整合型SALUTE計畫陸上所有測站的野外工作，包括與各相關單位聯繫，儀器測試布放，檢查維修，資料回收整理報告等。尤其每年至少需要兩次與高山嚮導徒步至少兩天以上到TR10和TR11兩測站檢查和回收資料。該助理為所有SALUTE陣列陸上測站至今仍正常運行，記錄資料品質穩定維持不中斷扮演不可取代的角色，為吸引該特殊專才人員能繼續負責第二期SALUTE計畫的野外工作，根據台大專任研究助理薪酬加給20%，提高月薪至5萬。 787,176元(含月支費用、年終獎金、勞健保費雇主負擔部分、勞工退休金雇主負擔部分) x 1名
	120,000	因本子計畫的專任研究助理提供做為整個SALUTE計畫所有子計畫共用的野外助理，本人並無另外申請經費聘任個人研究助理，須額外聘請兼任助理(月薪10000)協助個人子計畫的相關的行政工作，文書處理和經費核銷。
	50,000	實驗室工作站，PC Cluster，和磁碟陣列必須聘請電腦專業人才定期進行系統更新和設備維護工作，一年估計約50000。
兼任人員(碩士生-學習範疇)	432,000	三位碩一學生目前分擔協助野外測站維護資料回收工作，並使用SALUTE資料分別進行接收函數common-conversion point 成像，噪訊互相關函數計算提取高階表面波訊號，以及利用機器學習進行南台灣和外海地區地震的自動定位，用於之後地殼速度構造的層析像。 (月支費用 12000.00元 x 12.00月) x 3名
兼任人員(大專生-學習範疇)	72,000	聘請大專生協助野外工作和學習資料分析處理，以吸引和培養未來研究人才。 (月支費用 6000.00元 x 12.00月) x 1名
兼任人員(博士生-學習範疇)	360,000	113年度7月入學博一學生柯俊杰目前正在進行國科會大專生計畫，利用噪訊互相關函數所提取的雷利波相速度頻散曲線和SALUTE測站記錄的P波接收函數進行貝氏推論聯合反演以求得測站底下的隨深度變化的剪力波速度構造，之後進入博士班將納入其他觀測資料如P波polarization和表面波H/V比值或橢圓率進行聯合反演，以提高測站底下沉積層，地殼和最上部函數速度解析度。同時他將參與本子計畫的主要研究主題，應用adjoint waveform tomography的技術進行南台灣地區岩石圈構造高解析度的陣列成像。 (月支費用 30000.00元 x 12.00月) x 1名
兼任人員(博士候)	432,000	Lalit Arya目前為博三學生，論文主要是利用陸地和海底地震儀記錄

選人-學習範疇)		的連續記錄研究微地震的頻譜特性，來源分佈以及生成機制，並探討和氣候擾動如颱風，季風和洋流活動的關聯。研究區域為西太平洋，菲律賓和鄰近邊緣海盆，包括北沖繩海槽-琉球島弧和南台灣東部外海花東海盆SALUTE計劃涵蓋地區。 (月支費用 36000.00元 x 12.00月) x 1名
合計	2,253,176	

第 2 年

金額單位：新臺幣元

類別	金額	請敘明在本計畫內擔任之具體內容、性質、項目及範圍 (如約用專任人員，請簡述其於計畫內所應具備之專業技能、獨立作業能力、預期績效表現及相關學經歷年資等條件)
專任人員	817,308	第五年專任助理負責整合型SALUTE計劃陸上所有測站的野外工作，包括與各相關單位聯繫，儀器測試布放，檢查維修，資料回收整理報告等。尤其每年至少需要兩次與高山嚮導徒步至少兩天以上到TR10和TR11兩測站檢查和回收資料。該助理為所有SALUTE陣列陸上測站至今仍正常運行，記錄資料品質穩定維持不中斷扮演不可取代的角色，為吸引該特殊專才人員能繼續負責第二期SALUTE計劃的野外工作，根據台大專任研究助理薪酬加給20%，提高月薪至5萬2000。 817,308元(含月支費用、年終獎金、勞健保費雇主負擔部分、勞工退休金雇主負擔部分) x 1名
	120,000	因本子計劃的專任研究助理提供做為整個SALUTE計劃所有子計劃共用的野外助理，本人並無另外申請經費聘任個人研究助理，須額外聘請兼任助理(月薪10000)協助個人子計劃的相關的行政工作，文書處理和經費核銷。
	50,000	實驗室工作站，PC Cluster，和磁碟陣列必須聘請電腦專業人才定期進行系統更新和設備維護工作，一年估計約50000。
兼任人員(碩士生-學習範疇)	432,000	三位碩二學生目前分擔協助野外測站維護資料回收工作，並使用SALUTE資料分別進行接收函數common-conversion point 成像，噪訊互相關函數計算提取高階表面波訊號，以及利用機器學習進行南台灣和外海地區地震的自動定位，用於之後地殼速度構造的層析像。 (月支費用 12000.00元 x 12.00月) x 3名
兼任人員(大專生-學習範疇)	72,000	聘請大專生協助野外工作和學習資料分析處理，以吸引和培養未來研究人才。 (月支費用 6000.00元 x 12.00月) x 1名
兼任人員(博士生-學習範疇)	408,000	博二生柯俊杰預計完成貝氏推論聯合反演SALUTE測站底下速度構造並寫成文章投稿發表。同時將全力投入參與本子計劃的主要研究主題，學習如何應用adjoint waveform tomography的技術進行南台灣地區岩石圈構造高解析度的陣列成像。 (月支費用 34000.00元 x 12.00月) x 1名
兼任人員(博士候選人-學習範疇)	456,000	Lalit Arya為博四學生，預計完成博士論文並發表論二篇文章。研究主要是利用陸地和海底地震儀記錄的連續記錄研究微地震的頻譜特性，來源分佈以及生成機制，並探討和氣候擾動如颱風，季風和洋流活動的關聯。研究區域為西太平洋，菲律賓和鄰近邊緣海盆，包括北沖繩海槽-琉球島弧和南台灣東部外海花東海盆SALUTE計劃涵蓋地區。 (月支費用 38000.00元 x 12.00月) x 1名
合計	2,355,308	

類別	金額	請敘明在本計畫內擔任之具體內容、性質、項目及範圍 (如約用專任人員，請簡述其於計畫內所應具備之專業技能、獨立作業能力、預期績效表現及相關學經歷年資等條件)
專任人員	860,940	第六年專任助理負責整合型SALUTE計畫陸上所有測站的野外工作，包括與各相關單位聯繫，儀器測試布放，檢查維修，資料回收整理報告等。尤其每年至少需要兩次與高山嚮導徒步至少兩天以上到TR10和TR11兩測站檢查和回收資料。該助理為所有SALUTE陣列陸上測站至今仍正常運行，記錄資料品質穩定維持不中斷扮演不可取代的角色，為吸引該特殊專才人員能繼續負責第二期SALUTE計畫的野外工作，根據台大專任研究助理薪酬加給20%，提高月薪至5萬5000。 860,940元(含月支費用、年終獎金、勞健保費雇主負擔部分、勞工退休金雇主負擔部分) x 1名
	120,000	因本子計畫的專任研究助理提供做為整個SALUTE計畫所有子計畫共用的野外助理，本人並無另外申請經費聘任個人研究助理，須額外聘請兼任助理(月薪10000)協助個人子計畫的相關的行政工作，文書處理和經費核銷。
	50,000	實驗室工作站，PC Cluster，和磁碟陣列必須聘請電腦專業人才定期進行系統更新和設備維護工作，一年估計約50000。
兼任人員(碩士生-學習範疇)	360,000	聘僱三位新的碩士學生分擔協助野外測站維護資料回收工作，並使用SALUTE資料分析其他相關的地震速度構造模擬，逆推，地震定位，震源機制，地震地體構造等研究。 (月支費用 10000.00元 x 12.00月) x 3名
兼任人員(大專生-學習範疇)	72,000	聘請大專生協助野外工作和學習資料分析處理，以吸引和培養未來研究人才。 (月支費用 6000.00元 x 12.00月) x 1名
兼任人員(博士生-學習範疇)	480,000	博三生柯俊杰預計通過博士候選人資格考，並繼續投入參與本子計畫的主要研究主題，應用adjoint waveform tomography的技術進行南台灣地區岩石圈構造高解析度的陣列成像以及開發其他研究課題。 (月支費用 40000.00元 x 12.00月) x 1名
合計	1,942,940	

八、耗材、物品、圖書及雜項費用：

- (一) 凡執行研究計畫所需之耗材、物品(非屬研究設備者)、圖書及雜項費用，均可填入本表內。
 (二) 說明欄請就該項目之規格、用途等相關資料詳細填寫，以利審查。
 (三) 若申請單位有配合款，請於備註欄註明。
 (四) 請分年列述。

第 1 年

金額單位：新臺幣元

項目名稱	說明	單位	數量	單價	金額	備註
野外費用	27000(設備包括地震儀(租用)、電力(鋰電池、太陽能板、SOLAR CONTROLLER、五金材料))*4套+50000(架設)*1趟+37500(維護)*2趟*5次+3600(土地簽約金)*10+32200(高山測站維護)*2趟*2次	1	1	697,800	697,800	詳細說明請參見計畫書。
消耗性器材	印表機黑白和彩色碳粉匣，影印紙，文具，五金，實驗室電腦室清潔用品，電線網絡線材。	1	1	60,000	60,000	
雜支	個人和實驗室成員國內差旅費，郵電費，研討會報名費或註冊費用，海報印刷費，期刊論文等影印費。	1	2	50,000	100,000	
論文發表費	預計三篇學術論文發表出版費用	1	3	60,000	180,000	
電腦使用費	購買架設於平行電腦和server主機matlab軟體license的費用。	1	1	7,500	7,500	
電腦使用費	全波形成像須使用數據方法解波動方程式，以模擬高頻地震波在任一三維複雜速度構造傳遞的合成波形並與陣列測站所觀測波形比較，不斷迭代改善模型以得到符合觀測波形的速度構造，要求計算的CPU或GPU速度和記憶體非常高，須使用國網中心的高速平行電腦資源。第一年主要進程式安裝測試，進行較小模型的運算。	1	1	50,000	50,000	
合 計					1,095,300	

第 2 年

金額單位：新臺幣元

項目名稱	說明	單位	數量	單價	金額	備註
野外費用	37500(維護)*2趟*6次 +31200(撤站)*5趟 +3600(土地簽約金))*10+32200(高山測站維 護)*2趟*2次	1	1	770,800	770,800	詳細說明請參 見計畫書。
消耗性器材	印表機黑白和彩色碳粉匣 ，影印紙，文具，五金 ，實驗室電腦室清潔用品 ，電線網絡線材。	1	1	60,000	60,000	
雜支	個人和實驗室成員國內差 旅費，郵電費，研討會報 名費或註冊費用 ，海報印刷費，期刊論文 等影印費。	1	2	50,000	100,000	
論文發表費	預計二篇學術論文發表出 版費用	1	2	60,000	120,000	
電腦使用費	購買架設於平行電腦和 server主機matlab軟體 license的費用。	1	1	7,500	7,500	
電腦使用費	全波形成像須使用數據方 法解波動方程式，以模擬 高頻地震波在任一三維複 雜速度構造傳遞的合成波 形並與陣列測站所觀測波 形比較，不斷迭代改善模 型以得到符合觀測波形的 速度構造，要求計算的 CPU或GPU速度和記憶體非 常高，須使用國網中心的 高速平行電腦資源。第二 年會開始進行實際全波形 反演，計算資源需求會大 量增加。	1	1	100,000	100,000	
合 計					1,158,300	

第 3 年

金額單位：新臺幣元

項目名稱	說明	單位	數量	單價	金額	備註
野外費用	27000(設備包括地震儀 (租用)、電力(鋰電池、 太陽能板、SOLAR CONTROLLER、五金材料 *6次 +31200(撤站)*5趟	1	1	1,980,800	1,980,800	詳細說明請參 見計畫書。第 三年預計要將 SALUTE array北移，造 成野外經費需 求大量增加。

	+3600(土地簽約金))*10+32200(高山測站維 護)*2趟*2次					
消耗性器材	印表機黑白和彩色碳粉匣 ，影印紙，文具，五金 ，實驗室電腦室清潔用品 ，電線網絡線材。	1	1	60,000	60,000	
雜支	個人和實驗室成員國內差 旅費，郵電費，研討會報 名費或註冊費用 ，海報印刷費，期刊論文 等影印費。	1	2	50,000	100,000	
論文發表費	預計二篇學術論文發表出 版費用	1	2	60,000	120,000	
電腦使用費	購買架設於平行電腦和 server主機matlab軟體 license的費用。	1	1	7,500	7,500	
電腦使用費	全波形成像須使用數據方 法解波動方程式，以模擬 高頻地震波在任一三維複 雜速度構造傳遞的合成波 形並與陣列測站所觀測波 形比較，不斷迭代改善模 型以得到符合觀測波形的 速度構造，要求計算的 CPU或GPU速度和記憶體非 常高，須使用國網中心的 高速平行電腦資源。第三 年持續進行實際全波形反 演，計算資源需求會大量 增加。	1	1	100,000	100,000	
合 計					2,368,300	

九、國外學者來臺費用：

- (一) 因執行研究計畫（亦包括「雙邊協議專案型國際合作研究計畫」）邀請國外或大陸地區學者來臺得申請本項經費。（邀請對象為諾貝爾獎級者，請另依本會補助邀請國際科技人士短期訪問作業要點申請，不隨計畫核給）
- (二) 請詳列邀請國外學者來臺之目的、必要性說明及行程等。
- (三) 請詳列預定邀請國外學者之姓名、天數及預估經費等，並檢附受邀者個人資料（C.V.）及同意書（格式不拘，以PDF上傳）。來臺停留期間8日以上者，請敘明理由。部份「雙邊協議專案型國際合作計畫」經雙方協議議定由共同合作之國外計畫下負擔其研究人員來臺之生活費或（/及）機票費者，不得於本表重覆編列。
- (四) 生活費、機票費及其他費用之標準，請依照「國家科學及技術委員會補助國外學者專家來臺從事科技合作研究活動支付費用最高標準表」規定填列（網址 <https://www.nstc.gov.tw/nstc/attachments/aa4063c5-5190-4f11-ab71-40ef46d4ccc4?>）。
- (五) 請分年列述。

第 1 年

金額單位：新臺幣元

類別	姓名及職稱 (中文/英文)	國籍	任職機構 及所在地	來臺 天數	申請補助經費			
					生活費	機票費	其他費用	小計
C	Ayush Goyal/博 士後研究員	印度	Indian Institut e of Technolo gy, Bombay	7	30,000	30,000	0	60,000
合 計								60,000

※ 邀請國外學者來臺之目的、必要性說明及行程：

Ayush Goyal是我前博士生，研究項目包括利用接收函數反演和表面波成像的探究台灣和外海地區底下構造，藉由邀請他訪問台大將開發推動台灣和印度之間的國際合作項目。

※ 邀請來臺天數 8 日以上之理由：

第 2 年

金額單位：新臺幣元

類別	姓名及職稱 (中文/英文)	國籍	任職機構 及所在地	來臺 天數	申請補助經費			
					生活費	機票費	其他費用	小計
合 計								0

※ 邀請國外學者來臺之目的、必要性說明及行程：

※ 邀請來臺天數 8 日以上之理由：

第 3 年

金額單位：新臺幣元

類別	姓名及職稱 (中文/英文)	國籍	任職機構 及所在地	來臺 天數	申請補助經費			
					生活費	機票費	其他費用	小計

					生活費	機票費	其他費用	小計
合 計								0

※ 邀請國外學者來臺之目的、必要性說明及行程：

※ 邀請來臺天數 8 日以上之理由：



भारतीय प्रौद्योगिकी संस्थान मुंबई
पवई, मुंबई- 400 076, भारत

Indian Institute of Technology Bombay
Powai, Mumbai-400 076, India

दूरभाष/Phone : (+91-22) 2572 2545

फैक्स/Fax : (+91-22) 2572 3480

वेबसाईट/Website: www.iitb.ac.in

IIT Bombay

To: Professor Shu-Huei Hung
Department of Geosciences
National Taiwan University
Taipei 106, Taiwan

December 29, 2023

Dear Professor Shu-Huei Hung,

Hope this letter finds you well. I am delighted with our research endeavors in recent years, including the work on Moho Depth estimation beneath Taiwan orogeny using Receiver Functions and Multiscale Teleseismic Rayleigh wave Tomography across Taiwan and offshore regions. I look forward to more discussion and collaborative projects with your team, extending such advanced seismic imaging methods to both India and Taiwan in the near future. To facilitate our further collaboration, it would be immensely helpful if I could plan a visit to Taiwan sometime in the coming year. I leave the arrangement details to you, and I look forward to more fruitful research initiatives that may result from it.

Sincerely,

Ayush Goyal, PhD
Email: fromayush@gmail.com
Institute Post-Doctoral Fellow
Department of Earth Sciences
Indian Institute of Technology Bombay
Powai, Mumbai 400076,
India

十、研究設備費：

- (一) 凡執行研究計畫所需單價在新臺幣一萬元以上且使用年限在二年以上與研究計畫直接有關之各項設備屬之。各類研究設備金額請於金額欄內分別列出小計金額。
- (二) 購置設備單價在新臺幣二十萬元以上者，須檢附估價單。
- (三) 若申請機構及其他機構有提供配合款，請務必註明提供配合款之機構及金額。
- (四) 儀器設備單價超過新臺幣六十萬元(含)以上者，請詳述本項設備之規格與功能(諸如靈敏度、精確度…等)，其他重要特性與重要附件，以及申購本設備對計畫執行之必要性。本項設備若獲補助，主持人應負維護保養之責，並且在不妨礙個人研究計畫或研究群計畫之工作下，同意提供他人共同使用，以避免設備閒置。
- (五) 計畫主持人執行本項研究計畫，如欲申請購置單價新臺幣壹千萬元(含)以上之大型儀器，請填表CM10-1。該項設備若獲本會核定補助新臺幣壹千萬元(含)以上，則單獨核給一個規劃計畫，主持人須遵守本會大型儀器之管考規定。
- (六) 經本會補助之大型儀器，儀器資訊須公開於本會全球資訊網之跨部會服務平台「貴重儀器開放共同管理平台」(<https://www.nstc.gov.tw/folksonomy/instrument?l=ch>)。
- (七) 請分年列述。

第 1 年

金額單位：新臺幣元

類別	設備名稱 (中文/英文)	說明	數量	單價	金額	經費來源	
						本會補助 經費需求	提供配合款之機 構名稱及金額
儀器及資 訊設備	筆電/Notebook	因SALUTE測站數目多，通常需兩組人馬分工進行維護資料回收，需要購買另一台專業防水筆電。	1	50,000	50,000	50,000	
合 計					50,000	50,000	

第 2 年

金額單位：新臺幣元

類別	設備名稱 (中文/英文)	說明	數量	單價	金額	經費來源	
						本會補助 經費需求	提供配合款之機 構名稱及金額
合 計					0	0	

第 3 年

金額單位：新臺幣元

類別	設備名稱 (中文/英文)	說明	數量	單價	金額	經費來源	
						本會補助 經費需求	提供配合款之機 構名稱及金額
合 計					0	0	

十一、國外差旅費-執行國際合作與移地研究：

- (一) 計畫主持人及參與研究計畫之相關人員因計畫需要必須與國外合作研究、從事實驗、田野調查、採集樣本或使用國外研究設施等移地研究得申請本項經費。
- (二) 請詳述預定各出國人員之出國行程、預估經費、天數及地點。部份「雙邊協議專案型國際合作計畫」經雙方協議議定由共同合作之國外計畫下負擔我方研究人員到訪之生活費者，不得於本表重覆編列。
- (三) 生活費、機票費及其他費用之標準，請依照行政院頒布之「中央各機關（含事業機構）派赴國外進修、研究、實習人員補助項目及數額表」規定填列（網址 <http://law.dgbas.gov.tw/LawContent.aspx?id=FL020312>）。
- (四) 請將所列各項費用換算為新臺幣，並註明估算匯率。
- (五) 請分年列述。

第 1 年

金額單位：新臺幣元

申請補助費用		
經費類別	預估經費	詳述預定各出國人員之出國行程、預估經費、天數及地點
赴國外	80,000	王凱教授是adjoint waveform tomography全波形反演技術的專家，參與程式的開發並發表許多文章應用到加州，阿拉斯加，西藏等複雜構造的速度成像。其個人碩士期間曾訪問台大和我進行有限頻走時成像的合作研究，目前任教於中國科大，預計帶博士生訪問他10天，討論如何將SALUTE波形資料應用adjoint waveform tomography的技術進行高解析的成像研究合作。
合計	80,000	

第 2 年

金額單位：新臺幣元

申請補助費用		
經費類別	預估經費	詳述預定各出國人員之出國行程、預估經費、天數及地點
赴國外	80,000	王凱教授是adjoint waveform tomography全波形反演技術的專家，參與程式的開發並發表許多文章應用到加州，阿拉斯加，西藏等複雜構造的速度成像。其個人碩士期間曾訪問台大和我進行有限頻走時成像的合作研究，目前任教於中國科大，預計帶博士生訪問他10天，討論如何將SALUTE波形資料應用adjoint waveform tomography的技術進行高解析的成像研究合作。
合計	80,000	

第 3 年

金額單位：新臺幣元

申請補助費用		
經費類別	預估經費	詳述預定各出國人員之出國行程、預估經費、天數及地點
合計	0	

十二、國外差旅費-出席國際學術會議：

- (一) 計畫主持人及參與研究計畫之相關人員參加國際學術會議得申請本項經費。
- (二) 請詳述預定參加國際學術會議之性質、預估經費、天數及地點。
- (三) 機票費、生活費及其他費用之標準，請依照行政院頒布之「國外出差旅費報支要點」規定填列（網址<https://law.dgbas.gov.tw/LawContent.aspx?id=FL017584>）。
- (四) 請詳述計畫主持人近三年參加國外舉辦之國際學術會議論文之發表情形。（包括會議名稱、時間、地點、發表之論文題目、補助機構，及後續收錄於期刊或專書之名稱、卷號、頁數、出版日期）
- (五) 請分年列述。

第 1 年

金額單位：新臺幣元

出席國際學術會議			
出席國際學術會議人數	共 1 名	金 額	140,000
費用說明	2024 Fall AGU Meeting or EGU Meeting or SSA meeting 會議性質：AGU和EGU為每年舉行一次規模最大的國際地球科學年會，各地震學，地體構造，地球動力學相關領域的學者都會與會互相交流；SSA這是較集中在地震學有關的主題，如震波成像，地震震源，構造地震災害等研究。 地點：AGU in Washington D. C., US；EGU in Vienna, Austria；SSA in Baltimore, US 預估經費：5天 NT\$140,000 x 1人		
近三年論文發表情形	2021-2023: Hyunsun Kang; Younghee Kim; Shu-Huei Hung; PeiYing Patty Lin; Takehi Isse; ; Hitoshi Kawakatsu; Sang-Mook Lee; Hisashi Utada; Nozomu Takeuchi; Hajime Shiobara; Hiroko Sugioka; Seung-Sep Kim. (2023), Upper Mantle Seismic Velocity Structure beneath the Oldest Pacific Seafloor using Finite-frequency Tomography. AGU Fall Meeting 2023, held in San Francisco, id. D113B-0022. Tzu-Chi Lin; Gregor Hillers; Shiann-Jong Lee; Shu-Huei Hung. (2023), Seismic Velocity Contrast Along the Longitudinal Valley Fault System, Taiwan, from Analysis of Fault Zone Head Waves and Direct P Arrivals. AGU Fall Meeting 2023, held in San Francisco, id. S14A-08. Lalit Arya; Shu-Huei Hung; Ramakrushna Reddy; Ban-Yuan Kuo; Ching-ren Lin. (2023), Source Characterization of Microseismic Noise in the Northern Okinawa Trough-Ryukyu Arc-Trench System from Ocean Bottom Seismometer Observations. AGU Fall Meeting 2023, held in San Francisco, id. S43C-0386. Yu-Pin Lin; Shu-Huei Hung. (2023), Seismic Attenuation Tomography in Southern Taiwan Using Amphibious SALUTE Array. AGU Fall Meeting 2023, held in San Francisco, id. T21D-0220S. Hsiu-Cheng Yeh; PeiYing Patty Lin; Hsin-Ying Yang; Tai-Lin Tseng; Chih-Ming Lin; Shu-Huei Hung; Eh Tan; Chau-Ron Wu. (2023) Shear Velocity Structures in Southern Taiwan Revealed by Surface Wave Tomography Using Amphibious SALUTE Array. AGU Fall Meeting 2023, held in San Francisco, id. T21D-0221. Shu-Huei Hung; Shih-Chi Shao; Jun-Jie Ke; Ramakrushna Reddy; Tai-Lin Tseng; PeiYing Patty Lin; Eh Tan. (2023), Exploring the Lithospheric Structure in Transition Between the Eurasian Plate Subduction to Luzon Arc Collision Using Amphibious SALTUE Array.		

	<p>AGU Fall Meeting 2023, held in San Francisco, id. T21D-0224. Walid Ben Mansour; Douglas Wiens; Valerie Maupin; Andreas Richter; Shu-Huei Hung; Sergio Eduardo Barrientos. (2023), 3-D seismic velocity structure of the Patagonian slab from multi-scale finite frequency body wave tomography. AGU Fall Meeting 2023, held in San Francisco, id. T21F-02573</p> <p>Chen, Ji-Ching ; Tan, Eh ; Hung, Shu-Huei. (2022), Origin and Evolution of Flat Slab Subduction: Insights From Numerical Modeling of Thermo-Mechanical Behavior. AGU Fall Meeting 2022, held in Chicago, IL, 12-16 December 2022, id. DI32C-0024.</p> <p>Kang, Hyunsun ; Kim, Younghee ; Hung, Shu-Huei; Lin, PeiYing ; Isse, Takehi ; Shiobara, Hajime; Kawakatsu, Hitoshi ; Lee, Sang-Mook ; Utada, Hisashi ; Takeuchi, Nozomu; Sugioka, Hiroko. (2021), Seismic Velocity Structure of Upper Mantle Beneath the Oldest Pacific Ocean Basin: Insights from Finite-frequency Tomography. AGU Fall Meeting 2021, held in New Orleans, LA, 13-17 December 2021, id. DI45E-10.</p>
--	--

第 2 年

金額單位：新臺幣元

出席國際學術會議

出席國際學術會議人數	共 1 名	金 額	200,000
費用說明	<p>2025 Fall AGU Meeting and 2025 AOGS 會議性質：AGU為每年舉行一次規模最大的國際地球科學年會，各地震學，地體構造，地球動力學相關領域的學者都會與會互相交流。AOGS 則是亞洲每年舉行一次規模最大的國際地球科學年會，涵蓋整個地球，大氣，海洋，太空等領域。 地點：AGU in New Orleans, US; AOGS in Singapore 預估經費：5天 NT\$120,000 x 1人+80000x1人</p>		
近三年論文發表情形	<p>2022-2023: Hyunsun Kang; Younghee Kim; Shu-Huei Hung; PeiYing Patty Lin; Takehi Isse; ; Hitoshi Kawakatsu; Sang-Mook Lee; Hisashi Utada; Nozomu Takeuchi; Hajime Shiobara; Hiroko Sugioka; Seung-Sep Kim. (2023), Upper Mantle Seismic Velocity Structure beneath the Oldest Pacific Seafloor using Finite-frequency Tomography. AGU Fall Meeting 2023, held in San Francisco, id. DI13B-0022. Tzu-Chi Lin; Gregor Hillers; Shiann-Jong Lee; Shu-Huei Hung. (2023), Seismic Velocity Contrast Along the Longitudinal Valley Fault System, Taiwan, from Analysis of Fault Zone Head Waves and Direct P Arrivals. AGU Fall Meeting 2023, held in San Francisco, id. S14A-08. Lalit Arya; Shu-Huei Hung; Ramakrushna Reddy; Ban-Yuan Kuo; Ching-ren Lin. (2023), Source Characterization of Microseismic Noise in the Northern Okinawa Trough-Ryukyu Arc-Trench System from Ocean Bottom Seismometer Observations. AGU Fall Meeting 2023, held in San Francisco, id. S43C-0386. Yu-Pin Lin; Shu-Huei Hung. (2023), Seismic Attenuation Tomography in Southern Taiwan Using Amphibious SALUTE Array. AGU Fall Meeting 2023, held in San Francisco, id. T21D-0220S. Hsiu-Cheng Yeh; PeiYing Patty Lin; Hsin-Ying Yang; Tai-Lin Tseng; Chih-Ming Lin; Shu-Huei Hung; Eh Tan; Chau-Ron Wu. (2023) Shear</p>		

	<p>Velocity Structures in Southern Taiwan Revealed by Surface Wave Tomography Using Amphibious SALUTE Array. AGU Fall Meeting 2023, held in San Francisco, id. T21D-0221.</p> <p>Shu-Huei Hung; Shih-Chi Shao; Jun-Jie Ke; Ramakrushna Reddy; Tai-Lin Tseng; PeiYing Patty Lin; Eh Tan. (2023), Exploring the Lithospheric Structure in Transition Between the Eurasian Plate Subduction to Luzon Arc Collision Using Amphibious SALTUE Array. AGU Fall Meeting 2023, held in San Francisco, id. T21D-0224.</p> <p>Walid Ben Mansour; Douglas Wiens; Valerie Maupin; Andreas Richter; Shu-Huei Hung; Sergio Eduardo Barrientos. (2023), 3-D seismic velocity structure of the Patagonian slab from multi-scale finite frequency body wave tomography. AGU Fall Meeting 2023, held in San Francisco, id. T21F-02573</p> <p>Chen, Ji-Ching ; Tan, Eh ; Hung, Shu-Huei. (2022), Origin and Evolution of Flat Slab Subduction: Insights From Numerical Modeling of Thermo-Mechanical Behavior. AGU Fall Meeting 2022, held in Chicago, IL, 12-16 December 2022, id. D132C-0024.</p> <p>Kang, Hyunsun ; Kim, Younghee ; Hung, Shu-Huei; Lin, PeiYing ; Isse, Takehi ; Shiobara, Hajime; Kawakatsu, Hitoshi ; Lee, Sang-</p>
--	--

第 3 年

金額單位：新臺幣元

出席國際學術會議			
出席國際學術會議人數	共 1 名	金 額	140,000
費用說明	<p>2026 Fall AGU Meeting 會議性質：AGU為每年舉行一次規模最大的國際地球科學年會，各地震學，地體構造，地球動力學相關領域的學者都會與會互相交流。 地點：AGU in San Francisco, US 預估經費：5天 NT\$140,000 x 1人</p>		
近三年論文發表情形	<p>2023: Hyunsun Kang; Younghee Kim; Shu-Huei Hung; PeiYing Patty Lin; Takehi Isse; ; Hitoshi Kawakatsu; Sang-Mook Lee; Hisashi Utada; Nozomu Takeuchi; Hajime Shiobara; Hiroko Sugioka; Seung-Sep Kim. (2023), Upper Mantle Seismic Velocity Structure beneath the Oldest Pacific Seafloor using Finite-frequency Tomography. AGU Fall Meeting 2023, held in San Francisco, id. D113B-0022.</p> <p>Tzu-Chi Lin; Gregor Hillers; Shiann-Jong Lee; Shu-Huei Hung. (2023), Seismic Velocity Contrast Along the Longitudinal Valley Fault System, Taiwan, from Analysis of Fault Zone Head Waves and Direct P Arrivals. AGU Fall Meeting 2023, held in San Francisco, id. S14A-08.</p> <p>Lalit Arya; Shu-Huei Hung; Ramakrushna Reddy; Ban-Yuan Kuo; Ching-ren Lin. (2023), Source Characterization of Microseismic Noise in the Northern Okinawa Trough-Ryukyu Arc-Trench System from Ocean Bottom Seismometer Observations. AGU Fall Meeting 2023, held in San Francisco, id. S43C-0386.</p> <p>Yu-Pin Lin; Shu-Huei Hung. (2023), Seismic Attenuation Tomography in Southern Taiwan Using Amphibious SALUTE Array. AGU Fall Meeting 2023, held in San Francisco, id. T21D-0220S.</p> <p>Hsiu-Cheng Yeh; PeiYing Patty Lin; Hsin-Ying Yang; Tai-Lin Tseng; Chih-Ming Lin; Shu-Huei Hung; Eh Tan; Chau-Ron Wu. (2023) Shear</p>		

	<p>Velocity Structures in Southern Taiwan Revealed by Surface Wave Tomography Using Amphibious SALUTE Array. AGU Fall Meeting 2023, held in San Francisco, id. T21D-0221.</p> <p>Shu-Huei Hung; Shih-Chi Shao; Jun-Jie Ke; Ramakrushna Reddy; Tai-Lin Tseng; PeiYing Patty Lin; Eh Tan. (2023), Exploring the Lithospheric Structure in Transition Between the Eurasian Plate Subduction to Luzon Arc Collision Using Amphibious SALTUE Array. AGU Fall Meeting 2023, held in San Francisco, id. T21D-0224.</p> <p>Walid Ben Mansour; Douglas Wiens; Valerie Maupin; Andreas Richter; Shu-Huei Hung; Sergio Eduardo Barrientos. (2023), 3-D seismic velocity structure of the Patagonian slab from multi-scale finite frequency body wave tomography. AGU Fall Meeting 2023, held in San Francisco, id. T21F-02573</p>
--	--

十四、近三年內執行本會之所有計畫

計畫名稱 (本會補助者請註明編號)	計畫內擔任之工作	起迄年月	補助或委託機構	執行情形	經費總額
以陣列地震學與動力學探索南台灣由隱沒至碰撞岩石圈尺度構造整合型研究—總計畫暨子計畫一—以陣列遠震接收函數解析南台灣隱沒-碰撞過渡帶岩石圈不連續面構造 (3/3)(112-2116-M-002-005-)	主持人	2023/08/01~ 2024/07/31	國家科學及技術委員會	執行中	3,161,000
以陣列地震學與動力學探索南台灣由隱沒至碰撞岩石圈尺度構造整合型研究—總計畫暨子計畫一—以陣列遠震接收函數解析南台灣隱沒-碰撞過渡帶岩石圈不連續面構造 (2/3)(111-2116-M-002-040-)	主持人	2022/08/01~ 2023/10/31	國家科學及技術委員會	已結案	3,025,000
探索地球系統：太平洋遠征 (3/3)(111-2123-M-001-006-)	共同主持人	2022/08/01~ 2024/07/31	國家科學及技術委員會	執行中	7,060,000
以陣列地震學與動力學探索南台灣由隱沒至碰撞岩石圈尺度構造整合型研究—總計畫暨子計畫一—以陣列遠震接收函數解析南台灣隱沒-碰撞過渡帶岩石圈不連續面構造 (1/3)(110-2116-M-002-010-)	主持人	2021/08/01~ 2022/10/31	國家科學及技術委員會	已結案	2,798,000
探索地球系統：太平洋遠征 (2/3)(110-2123-M-001-007-)	共同主持人	2021/08/01~ 2023/12/31	國家科學及技術委員會	執行中	7,500,000
利用週遭噪訊尾波解析臺灣地殼非均質散射和非彈性吸收衰減性質(II)：多重時間窗分析和衰減成像(109-2116-M-002-010-)	主持人	2020/08/01~ 2021/10/31	國家科學及技術委員會	已結案	2,220,000
探索地球系統：太平洋遠征 (1/3)(109-2123-M-001-005-)	共同主持人	2020/08/01~ 2022/12/31	國家科學及技術委員會	已結案	7,500,000
合 計					33,264,000

十四、近三年內執行非本會之所有計畫

(請務必填寫近三年執行非國科會補助之其他(含國內外、大陸地區及港澳)計畫)

計畫名稱 (本會補助者請註明編號)	計畫內擔任之工作 (主持人、共同主持人或其他)	起迄年月	補助或委託機構	國別	執行情形	經費總額
南投縣廬山地區地下三維地質模型建置	協助地震儀器架設佈站和資料分析	2023/04/19 ~2024/12/31	經濟部地質調查及礦業管理中心	中華民國	執行中	0
合 計						0

113 年度自然處專題計畫主持人近五年研究成果

姓名： 洪淑蕙 職稱： 教授 服務機關系所： 台大地質科學系

一、請簡述近五年代表性研究成果(含儀器或關鍵技術開發等實務應用面向)之個人重要貢獻(至多一頁)。

In the last five years, my research has spanned various facets of earthquake and ambient noise seismology, with a primary focus on seismic imaging and tomography. They include the following aspects: (1) Leading a team to deploy a dense, amphibious seismic array comprising over 30 broadband stations in southern Taiwan and its eastern offshore regions—a critical zone situated in the transition from continental subduction to arc-continent collision. (2) Adopting multiple seismic observables recorded by the SALUTE array and seismic imaging methods to unravel detailed seismic structures in these region, including receiver function imaging for the Moho and other discontinuous features, shear wave splitting for seismic anisotropy, tomographic inversion of shear wave velocity and attenuation structures of the crust and uppermost mantle. Initial results were presented at the 2023 Fall Meeting (Hung et al, 2023; Lin, Hung et al., 2023; Yeh et al., 2023). (3) Applying joint H-V stacking of P and S receiver functions to robustly determine the Moho depth and average crustal properties in Taiwan and Fujian, SE China (Goyal and Hung, 2021a, b); and teleseismic Rayleigh wave tomography to unravel 3D shear wave velocity structure beneath Taiwan (Goyal, Hung et al., to be submitted, 2024). (4) Collaborating with domestic and international researchers to apply finite-frequency traveltome tomography to study crustal and upper mantle heterogeneity beneath various tectonic settings, including the northern Okinawa Trough, oldest Pacific seafloor (Kang, Kim, Hung et al., 2023) and the Cordillera-Craton Transition of SW Canada (Chen et al., 2019, 2020). I have also contributed to the scientific community by making my codes for multiscale finite-frequency traveltome tomography openly accessible on GitHub at <https://github.com/shung302/BDFFT>. (5) With a master student, employing ambient noise and coda-wave interferometry technique to monitor the spatiotemporal variations of the crustal velocity induced by 2018 Hualien earthquake sequence and other seasonal and hydrological fluctuations (Chen et al., in preparation). (6) Working with French scientists and master students to use earthquake and noise-derived coda waves to investigate scattering attenuation and absorption structure in Taiwan and Kyushu, Japan (Margerin, Calvet, Hung, 2023; Wu et al., in preparation); (6) With the student, developing fast automatic phase picking and event location algorithm applied to the 2018 Hualien foreshock-mainshock-aftershock sequences (Chang, Hung, Chen, 2019).

二、近五年內(2019/1/1~2023/12/31)已出版之最具代表性研究成果至多6篇，擇其中5篇電子檔上傳。(請依序填寫：姓名,著作名稱,發表年份,期刊,卷數,頁次，並以*號註記該篇所有的通訊作者)

1. Kang, H., Y. Kim*, S.-H. Hung, P.-Y. P. Lin, T. Isse, H. Kawakatsu, S.-M. Lee, H. Utada, N. Takeuchi, H. Shiobara, H. Sugioka, & S.-S. Kim (2023). Seismic velocity structure of upper

mantle beneath the oldest Pacific seafloor: Insights from finite-frequency tomography.
doi:10.1029/2022GC010833

2. M. Calvet*, L. Margerin, & **S.-H. Hung** (2023). Anomalous attenuation of high-frequency seismic waves in Taiwan: Observation, model and interpretation. <https://doi.org/10.1029/2022JB025211>.
3. Goyal, A., & **S.-H. Hung*** (2021b). Bulk crustal properties and layered velocity structure in Fujian, SE China: Constraints from P and S receiver functions. *Frontiers in Earth Science*, 857.
4. Goyal, A., & **S.-H. Hung*** (2021a). Lateral variations of Moho depth and average crustal properties across the Taiwan orogen from H-V stacking of P and S receiver functions. *Geochemistry, Geophysics, Geosystems*, 22(3), e2020GC009527.
5. Chen, Y., Gu*, Y. J., Heaman, L. M., Wu, L., Saygin, E., & **Hung, S.-H.** (2020). Reconciling seismic structures and Late Cretaceous kimberlite magmatism in northern Alberta, Canada. *Geology*, 48(9), 872–876. <https://doi.org/10.1130/g47163.1>
6. Chang, Y.-H., **S.-H. Hung***, Y.-L. Chen (2019). A fast algorithm for automatic phase picker and event location: Application to the 2018 Hualien earthquake sequences, *Terr. Atmos. Ocean. Sci.*, 30, 1-14, doi: 10.3319/TAO.2018.12.23.0.

三、近五年內獲獎情形及重要會議邀請演講至多 5 項。

Invited Talk entitled “Moho Depth and Bulk Crustal Properties in Taiwan and Fujian Areas: Constraints from P and S Receiver Functions in 第五屆 TEC 年會, January 2022.

四、近五年內其他資料：擔任國際重要學術學會理監事、國際知名學術期刊編輯或評審委員等。

Reviewers for peer-review journals including BSSA, JGR, GRL, EPSL, G-cubed, Frontiers in Earth Sciences, Nature Communications, and Earth and Planetary Physics.

五、研發成果智慧財產權及其應用績效：

1. 專利：請填入近五年內核准之有效專利。「類別」請填入代碼：(A)發明專利(B)新型專利(C)新式樣專利。

類別	專利名稱	國別	專利號碼	發明人	專利權人	專利核准日期	國家科學及技術委員會計畫編號

2. 技術移轉：(近五年內完成簽約者)

技術名稱	專利名稱	授權單位	被授權單位	簽約日期	權利金, 衍生利益金等	國家科學及技術委員會計畫編號

--	--	--	--	--	--	--

3.獲選本會「未來科技展」參展之技術：

技術名稱	參展年度	國家科學及技術委員會計畫編號