

## Research Paper

# Fault model and slip distribution of the 2025 $M_W$ 6.0 Chiayi earthquake in southern Taiwan, China, constrained by InSAR observations

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## ABSTRACT

On January 20, 2025, an  $M_W$ 6.0 earthquake occurred in Chiayi County, southwestern Taiwan, China. In this study, we utilize Sentinel-1 data to investigate the coseismic ground displacement and fault slip model of this event. Here, we present the geodetic fault model of the 2025 Chiayi earthquake. While both east-dipping and west-dipping fault models can adequately reproduce the InSAR observations, the east-dipping model was found to better align with the quasi-east-west and quasi-vertical deformation fields derived from decomposing Interferometric Synthetic Aperture Radar (InSAR) ascending and descending orbits, the characteristics of interseismic deformation, and the tectonic features of the seismic region. The best-fitting east-dipping uniform-slip model shows that the seismogenic fault is characterized as a reverse slip striking  $336.2^\circ$ , dipping northeastward. The fault's upper boundary is buried at a depth of 8.0 km, with a dip angle of  $27.6^\circ$  and a slip angle of  $61.6^\circ$ . Calculations of Coulomb stress changes reveal that regions experiencing positive changes are primarily concentrated at the northeast and southwest extremities of the Chiayi earthquake rupture, as well as in the northwest and southeast lobes flanking the rupture zone.

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## 1. Introduction

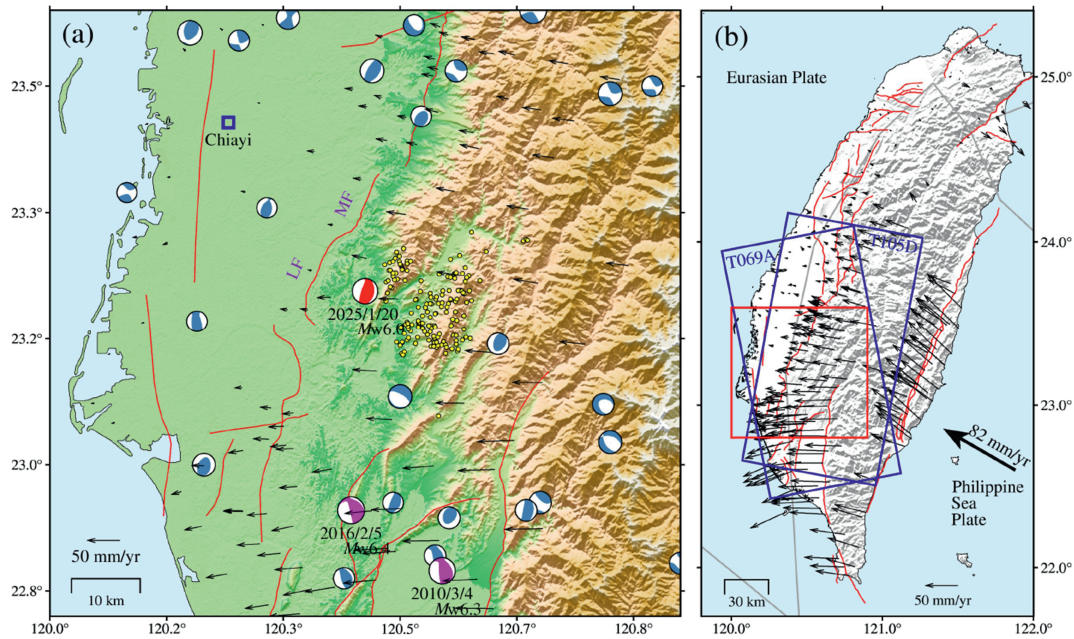
On January 20, 2025, a magnitude 6.0 earthquake struck Chiayi in southwestern Taiwan, China (Fig. 1), an island located at the convergent boundary of the Philippine Sea Plate and the Eurasian Plate, which collide at a rate of approximately 8.2 cm/yr. According to United States Geological Survey (USGS) analysis, this event occurred at 16 km focal depth, with an epicentral position 38 km southeast of Chiayi city. The focal mechanism reveals reverse fault

motion, consistent with the compressional stress field driving crustal contraction in Taiwan region's southwestern fold-and-thrust belt [1]. The closest historical earthquake to the Chiayi event and with a magnitude greater than 6 is the  $M_W$ 6.4 Meinong earthquake that occurred in 2016, which is 35 km southeast of the epicenter of this Chiayi earthquake. Previous studies on the Meinong earthquake have proposed that explaining the geodetic and seismological observations of this event necessitates the involvement of two distinct fault slips: a primary fault with a strike of west-northwest to east-southeast and a shallow subsidiary fault with a strike of southwest to northeast [2]. Notably, the primary fault orientation contrasts with the majority of identified southwest-northeast-striking active faults in southwestern Taiwan, China, whereas the shallow fault aligns seismotectonically with the dominant structural trends observed in this region.

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**Fig. 1.** Tectonic context of the Chiayi earthquake (January 20, 2025). The blue focal mechanism solutions represent historical seismic events and the red beach ball denotes the 2025 Chiayi earthquake sourced from the Global Centroid Moment Tensor (GCMT) [3]. Both magenta focal mechanism solutions denote 2016  $M_w$ 6.4 Meinong earthquake and the 2010  $M_w$ 6.4 Jia-Shian earthquake, respectively. The yellow dots represent the aftershocks one month after the earthquake. The black velocity vectors depict crustal motion velocities derived from Global Navigation Satellite System (GNSS) measurements during interseismic periods [4]. The red lines denote active faults; LF and MF denote Liuchia Fault and Muchiliao Fault, respectively. The blue polygons in (b) delineate the spatial coverage of Sentinel-1 image acquisition frames. The gray solid line indicates the plate boundary [5]. The red bounding box in (b) highlights the area in (a).

The 9-year interval between the Chiayi earthquake and the 2016 Meinong event highlights potential intraplate stress reloading cycles, with preliminary W-phase moment tensor solutions (nodal 1:  $198^\circ/56^\circ/92^\circ$  and nodal 2:  $15^\circ/34^\circ/87^\circ$  for strike/dip/rake) reported by the USGS indicating a composite rupture process involving both reverse and strike-slip components. The first nodal plane of Chiayi event exhibits a distinct focal mechanism compared to that of the 2016 Meinong earthquake ( $299^\circ/15^\circ/45^\circ$  [6]), while the second nodal plane closely aligns with the shallow-seated fault mechanism ( $8^\circ/30^\circ/85^\circ$ ) proposed by Huang et al. [2]. Early-stage aftershock monitoring highlights a clustered spatial distribution pattern concentrated near the mainshock epicenter, with the maximum aftershock magnitude reaching 5.3.

Six years prior to the 2016 Meinong earthquake, an  $M_w$ 6.4 event (2010 Jia-Shian earthquake) occurred along a blind fault 43 km to the east, with both earthquakes exhibiting reverse faulting mechanisms under NW-SE crustal compression. This event exhibited fault parameters consistent with the primary fault of the Meinong earthquake but misaligned with the orientation of mapped active fault systems in southwestern Taiwan, China [6]. Notably, the fault strike of the Jia-Shian earthquake ( $322^\circ$ ) is approximately parallel to the plate convergence direction (approximately  $307^\circ$ ). The Meinong earthquake, located west of the Jia-Shian event, also featured a main fault misaligned with plate convergence, whereas a contemporaneous shallow seismic event aligned with convergence vectors. The subsequent 2025 Chiayi earthquake, northwest of the Meinong epicenter, demonstrated fault strike consistency with plate convergence. The progressive variation in fault orientations across these three events—from subduction-proximal (Jia-Shian) to transitional (Meinong) and subduction-distal (Chiayi)—suggests potential spatial heterogeneity in crustal stress accumulation patterns relative to the plate boundary. Consequently, precise fault

parameterization of the Chiayi earthquake provides critical constraints for understanding regional stress partitioning mechanisms.

Positioned near the Muchiliao-Liuchia fault system, the epicenter of the 2025 Chiayi earthquake lies approximately 10 km southeast of this tectonic boundary. The Muchiliao and Liuchia faults, situated along the western margin of the Chiayi Hills in southwestern Taiwan, China, constitute two active reverse-slip structures with a predominant NNE strike orientation. The Muchiliao Fault extends over 7 km, while the southern Liuchia Fault exhibits a greater length of 21 km. Both faults demonstrate evidence of late Quaternary reactivation, and recent investigations confirm that the Liuchia Fault displaces Holocene sedimentary sequences, indicating sustained neotectonic activity. A clear alignment emerges between the 2025 Chiayi earthquake's focal mechanisms and the kinematic behavior of the Muchiliao-Liuchia fault system. This congruence in both fault strike (north-northeast) and deformation style (reverse-slip) raises critical questions regarding potential genetic relationships. Specifically, two hypotheses warrant further investigation: (1) Direct rupture hypothesis: The coseismic rupture may have propagated along either the Muchiliao or Liuchia fault strands; or (2) Blind fault hypothesis: In some complex fault systems, blind faults that cannot be mapped through geomorphological observation methods are common [7–9]. The earthquake might have occurred on a previously unmapped splay fault geometrically linked to this fault system. Resolving this tectonic ambiguity requires high-resolution constraints on the earthquake's fault parameters. This study integrates ascending/descending Sentinel-1A InSAR line-of-sight (LOS) displacement with elastic half-space dislocation modeling to retrieve the fault model and slip pattern of the 2025 Chiayi event, quantifying the impact of slip redistribution on stress evolution within the seismogenic zone.



## 2. InSAR data

### 2.1. Coseismic deformation

We used Sentinel-1 InSAR observations to image the coseismic deformation field of the 2025  $M_W$ 6.0 Chiayi earthquake (Table 1). In particular, we used ascending and descending images to decompose the quasi-east-west and vertical surface displacement related to Chiayi earthquake. In this study, we used sub-swath 1 of the two frames along the ascending track 69, and sub-swath 2 of the descending track 105.

Ascending and descending coseismic interferograms were generated using GAMMA software [10] from the Single Look Complex products (SLC). Through high-precision registration of pre-earthquake and post-earthquake SLC data, followed by interferometric processing, terrain phase removal, filtering, and unwrapping, the interferometric images were finally geocoded to the WGS84 coordinate system. For the detailed InSAR processing in this study, see Appendix Text S1.

The InSAR data reveal a deformation field with an elliptical distribution, oriented from north-northeast to south-southwest (Fig. 2). The peak LOS displacements derived from ascending and descending orbit InSAR were approximately 7.1 and 6.3 cm, respectively. In the primary deformation zones, the ascending and descending LOS displacements exhibit identical signs, both positive. This indicates that ground displacement caused by this earthquake is predominantly vertical, aligning with surface deformation caused by the reverse fault mechanism as documented by the USGS. On the right side of the positive LOS displacement observation of the descending orbit InSAR, there is an obvious negative LOS displacement area, while this phenomenon is not observed in the ascending orbit InSAR. Moreover, the range of the positive LOS displacement area of the ascending orbit InSAR is significantly larger than that of the positive LOS displacement area of the descending orbit InSAR, indicating that there is an obvious horizontal displacement to the west in the surface deformation caused by this event.

### 2.2. Quasi-east-west and quasi-vertical deformation fields

In order to more intuitively display the surface deformation of the Chiayi earthquake, we used ascending and descending InSAR (ascending orbit 69 and descending orbit 105) data to invert the quasi-east-west and quasi-vertical coseismic ground displacement fields. Since the orbit of the radar satellite around the Earth is a near-polar orbit, that is, the flight direction is close to the north-south direction, the LOS observation is the least sensitive to the north-south displacement of the ground and the most sensitive to the vertical displacement of the surface, with the east-west displacement being the second most sensitive [11]. Based on this characteristic of the InSAR LOS displacement, and taking into account that the focal mechanism solution of the 2025 Chiayi earthquake shows a near north-south reverse fault earthquake event, we can assume that the contribution of the north-south displacement of the surface in the InSAR LOS direction is 0. Through the observed values from these two different perspectives of the ascending and descending orbit InSAR, the quasi-east-west and quasi-vertical coseismic deformation fields can be

inverted and obtained [12–14]. The decomposition results show that the coseismic rupture has caused significant surface uplift and westward movement (Fig. 3). The maximum uplift reaches approximately 7 cm, and the maximum westward deformation reaches 5 cm. The vertical deformation and horizontal deformation exhibit an elliptical shape distribution. The area covered by the vertical deformation is approximately twice that of the horizontal deformation area. The horizontal westward movement is predominantly situated on the western portion of the region where vertical deformation occurs, and it exhibits a significant overlapping area with the vertical deformation. From the two-dimensional surface displacement profile, it can be seen that there is an obvious westward movement at the positions from 10 km to 20 km along the profiles AB and CD; from 20 km to 30 km along the profiles, the surface uplift is dominant.

## 3. Geodetic modeling

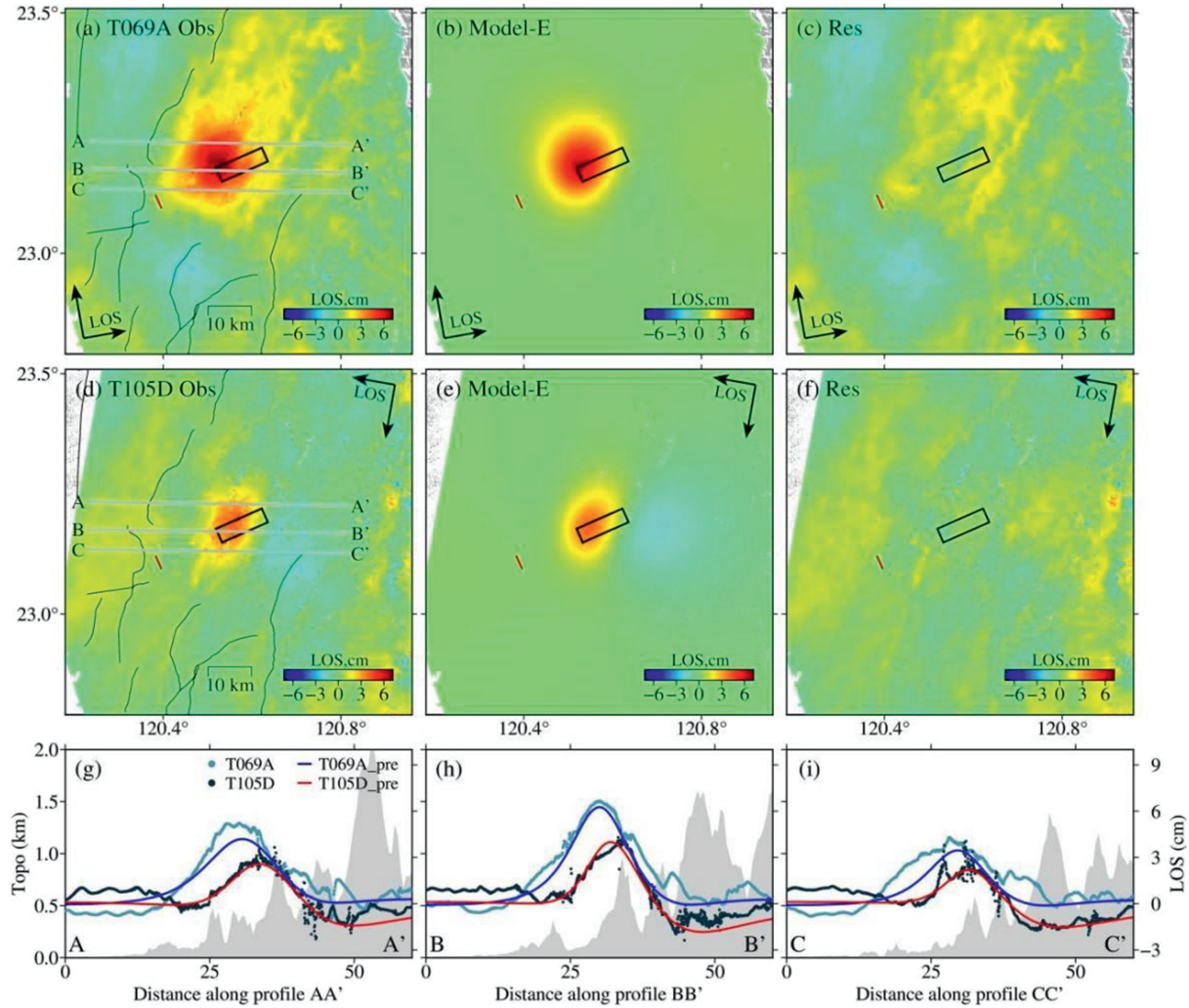
According to some previous studies, for reverse earthquakes of around  $M_W$ 6.0, the two nodal plane solutions obtained from the earthquake mechanism can generally fit the InSAR observation values well [15,16]. Taking the two focal solutions provided by the seismic agency as references, we solved the parameters for the two possible fault models. Finally, based on the tectonic characteristics of the southwest Taiwan region and some fault data and inter-seismic deformation in this area, we determine the possible fault model of this event. During the modeling of the coseismic deformation, we employed the standard two-step inversion method. First, nonlinear inversion was used to obtain the location and fault geometry, followed by a linear inversion to further estimate the slip distribution. The inversion model utilized a rectangular dislocation in elastic half-space medium [17–19]. Before modeling, we downsampled InSAR displacement maps using a quadtree sampling approach [20]. The non-linear and linear inversion with InSAR downsampling data were implemented with the Earthquake Cycle Analysis Toolkits (ECAT) software [21]. The software integrates a Sequential Monte Carlo (SMC) sampler, in which nonlinear parameters—including fault geometry, data weight scale factors (unit weight variances), and, where applicable, smoothing hyperparameters—are sampled following the strategy of Fukuda and Johnson [22]. At each sampling step, linear parameters such as slip are conditionally estimated via constrained least squares. This hierarchical approach enables efficient and robust joint inversion of fault geometry and distributed slip.

### 3.1. East-dipping fault model

The best-fitting east-dipping fault model with uniform slip shows that the seismogenic fault is characterized as a reverse slip striking  $336.2^\circ$ , dipping northeast of east (Table 2). The fault's upper boundary is buried at a depth of 8.0 km, with a dip angle of  $27.6^\circ$  and a rake of  $61.6^\circ$ . This finding aligns with the first nodal plane of the focal mechanism solution provided by the USGS. With an average uniform slip of 0.9 m and rigidity value of 30 GPa, the estimated seismic moment is calculated as  $1.23 \times 10^{18}$  N·m, equivalent to  $M_W$ 6.0. After extending the uniform slip model and dividing it into small rectangular patches for linear inversion, the results indicate that the main slip area is concentrated within a

**Table 1**  
Details of SAR images used in this study.

| Satellite  | Track | Flight direction | Reference (YYYY/MM/DD) | Secondary (YYYY/MM/DD) |
|------------|-------|------------------|------------------------|------------------------|
| Sentinel-1 | 069   | Ascending        | 20250109               | 20250121               |
| Sentinel-1 | 105   | Descending       | 20250111               | 20250123               |



**Fig. 2.** InSAR observations of 2025 Chiayi earthquake and inversion result of uniform east-dipping fault model. (a and d) InSAR observations. (b and e) Model prediction. (c and f) Residuals. (g–i) Fitting result of profiles AA', BB' and CC'.

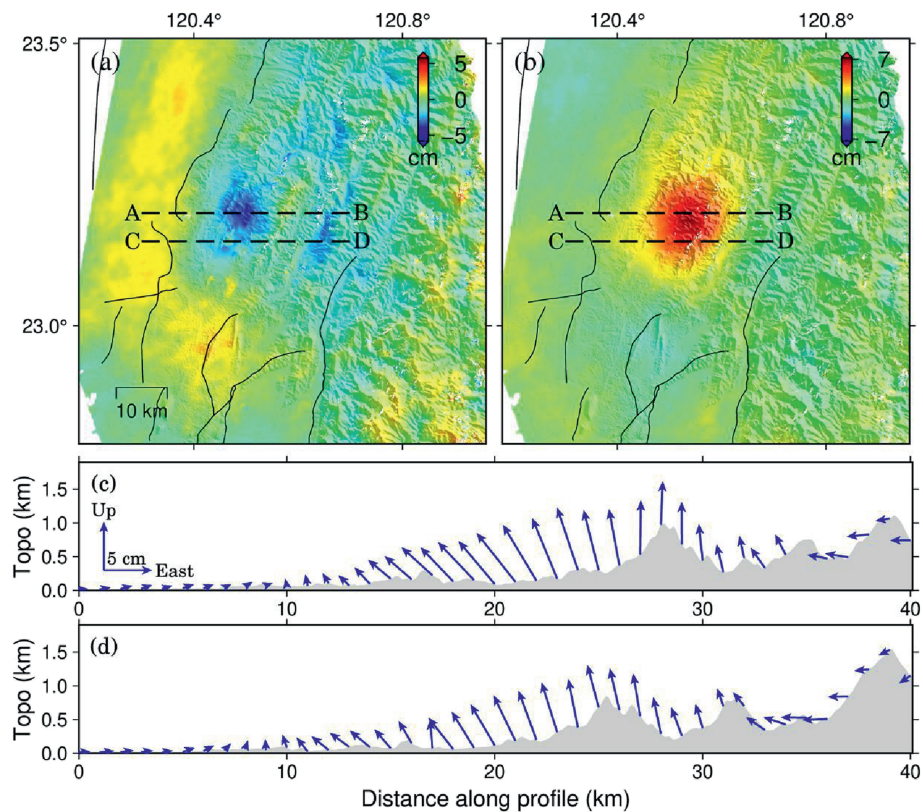
10 km  $\times$  10 km range, with a maximum slip of 0.62 m (Fig. 4). Compared with the uniform slip model, the distributed slip model does not significantly enhance data fitting (Fig. 5), suggesting that the earthquake rupture was not complex and that the simple uniform slip model can well fit the data. During the inversion process, we tested the distributed fault model by dividing the extended fault into 1 km  $\times$  1 km and 2 km  $\times$  2 km patches, respectively. We aimed to investigate whether different patch sizes would influence the inversion results. The final results indicate that the fault model divided into 1 km  $\times$  1 km patches yields greater uncertainty in the inverted fault slip, whereas the model with 2 km  $\times$  2 km patches exhibits smaller uncertainty in the inverted fault slip. Faults with 1 km  $\times$  1 km patches have much greater uncertainty of slip on each patch due to the trade-off of slip on adjacent patches. This indicates that surface InSAR data is able to resolve slip on 2 km patches at 10 km depth but not completely resolve slip on 1 km patches.

### 3.2. West-dipping fault model

The optimal west-dipping uniform-slip model indicates that the seismogenic fault features as reverse slip with a strike of 193.7°, dipping in the south to southwest direction (Fig. S1). The

fault's upper boundary is buried at a depth of 12.0 km, with a dip angle of 71.2° and a slip angle of 111.6°. The fault measures 4.6 km in length and 2.6 km in width, respectively (Table 2). This result is relatively close to the solution of the second nodal plane in the focal mechanism provided by the USGS. With a rigidity value of 30 GPa, the estimated seismic moment is calculated as  $1.23 \times 10^{18}$  N·m, equivalent to a  $M_w$ 6.1 earthquake. After expanding the uniform slip model and discretizing it into 2 km  $\times$  2 km rectangular sub-patches for linear inversion, the results indicate that the principal slip zone is concentrated within an area of 12 km  $\times$  8 km, with a maximum slip of 0.8 m (Fig. 4). Similarly, the distributed slip model does not lead to a significant further improvement in data fitting (Fig. S2).

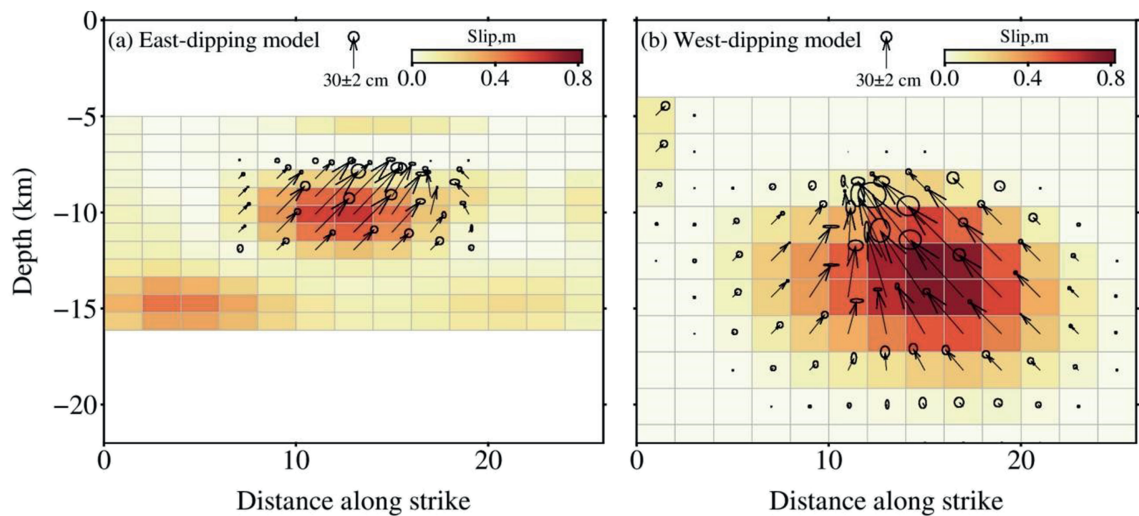
We established four fault models using InSAR observations, namely the east-dipping uniform slip model, west-dipping uniform slip model, east-dipping distributed slip model, and west-dipping distributed slip model. We have respectively provided the statistical information on the data fitting of these four models, as shown in Table S1. It can be seen from the table that the Root Mean Square (RMS) values of the data fitting for the east-dipping uniform slip model and the east-dipping distributed slip model are 4.6 mm and 4.2 mm, respectively, which are better than those of the west-dipping uniform slip model and



**Fig. 3.** Decomposed coseismic deformation field. (a) Quasi-east-west displacement field; (b) Quasi-vertical displacement field; (c) and (d) denote displacement vectors along the profile AB and CD, respectively. The black lines in (a) and (b) represent the active faults in this area.

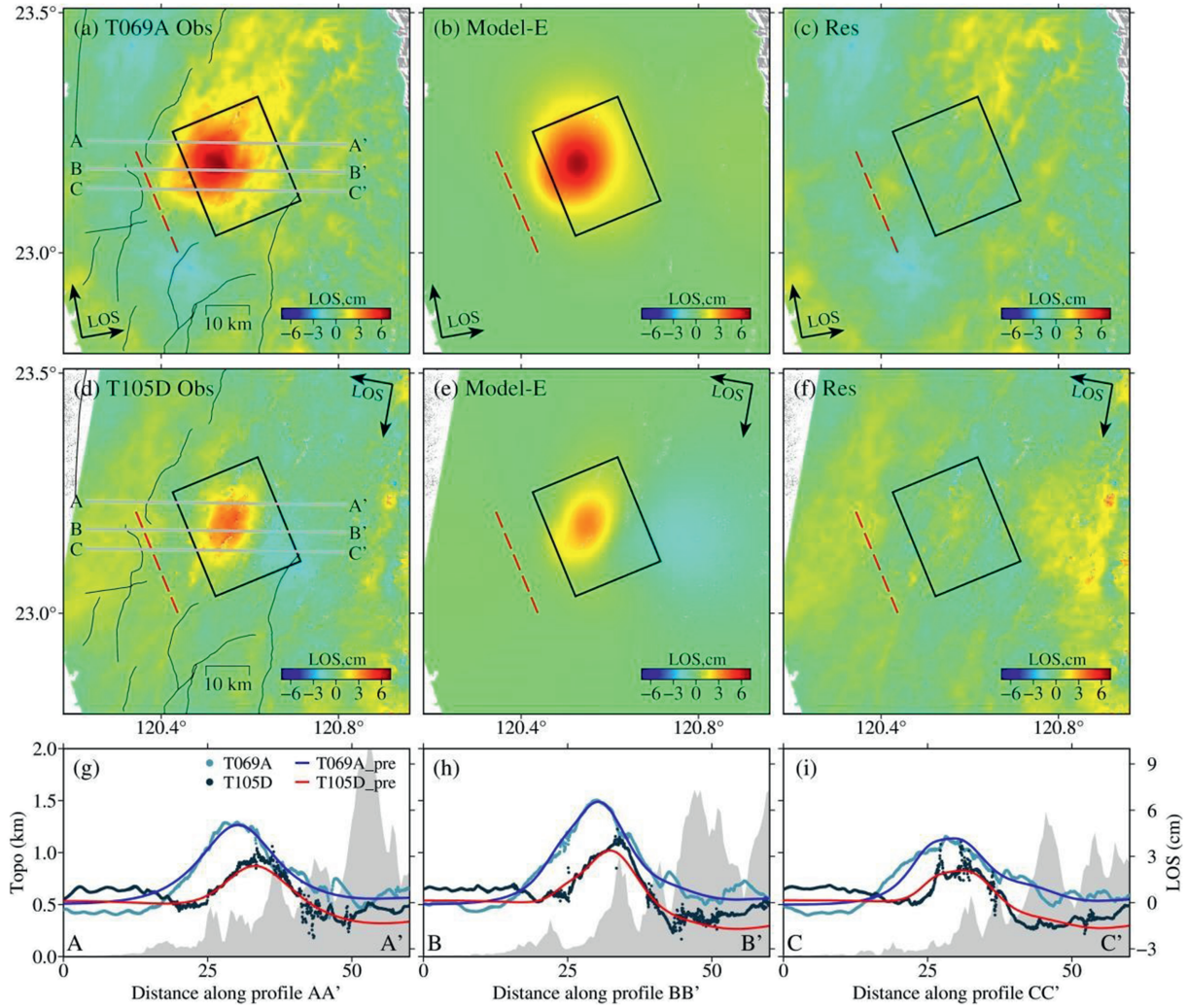
**Table 2**  
Fault parameters of the 2025 Chiayi earthquake.

| Source               | Logitude (°)     | Latitude (°)    | Depth (km)  | Strike (°)   | Dip (°)     | Rake (°)     | Length (km) | Width (km)  | Slip (m)   | $M_W$ |
|----------------------|------------------|-----------------|-------------|--------------|-------------|--------------|-------------|-------------|------------|-------|
| USGS                 | 120.545          | 23.182          | 16          | 15/198       | 34/56       | 87/92        | –           | –           | –          | 6.0   |
| GCMT                 | 120.45           | 23.23           | 16.8        | 3/199        | 27/64       | 75/97        | –           | –           | –          | 6.1   |
| Uniform slip model-E | 120.53 [±0.1 km] | 23.16 [±0.3 km] | 8.0 [±0.2]  | 336.2 [±2.9] | 27.6 [±1.3] | 61.6 [±2.6]  | 3.5 [±0.8]  | 13.0 [±0.6] | 0.9 [±0.4] | 6.0   |
| Uniform slip model-W | 120.58 [±0.2 km] | 23.17 [±0.3 km] | 12.0 [±0.4] | 193.7 [±1.3] | 71.2 [±0.9] | 111.6 [±5.3] | 4.6 [±1.3]  | 2.6 [±0.9]  | 5.2 [±1.3] | 6.1   |



**Fig. 4.** Distributed slip model. (a) East-dipping fault model; (b) West-dipping fault model.





**Fig. 5.** Inversion result of east-dipping distributed slip model. (a,d) InSAR observations. (b,e) Model prediction. (c,f) Residuals. (g–i) Fitting result of profiles AA', BB' and CC'.

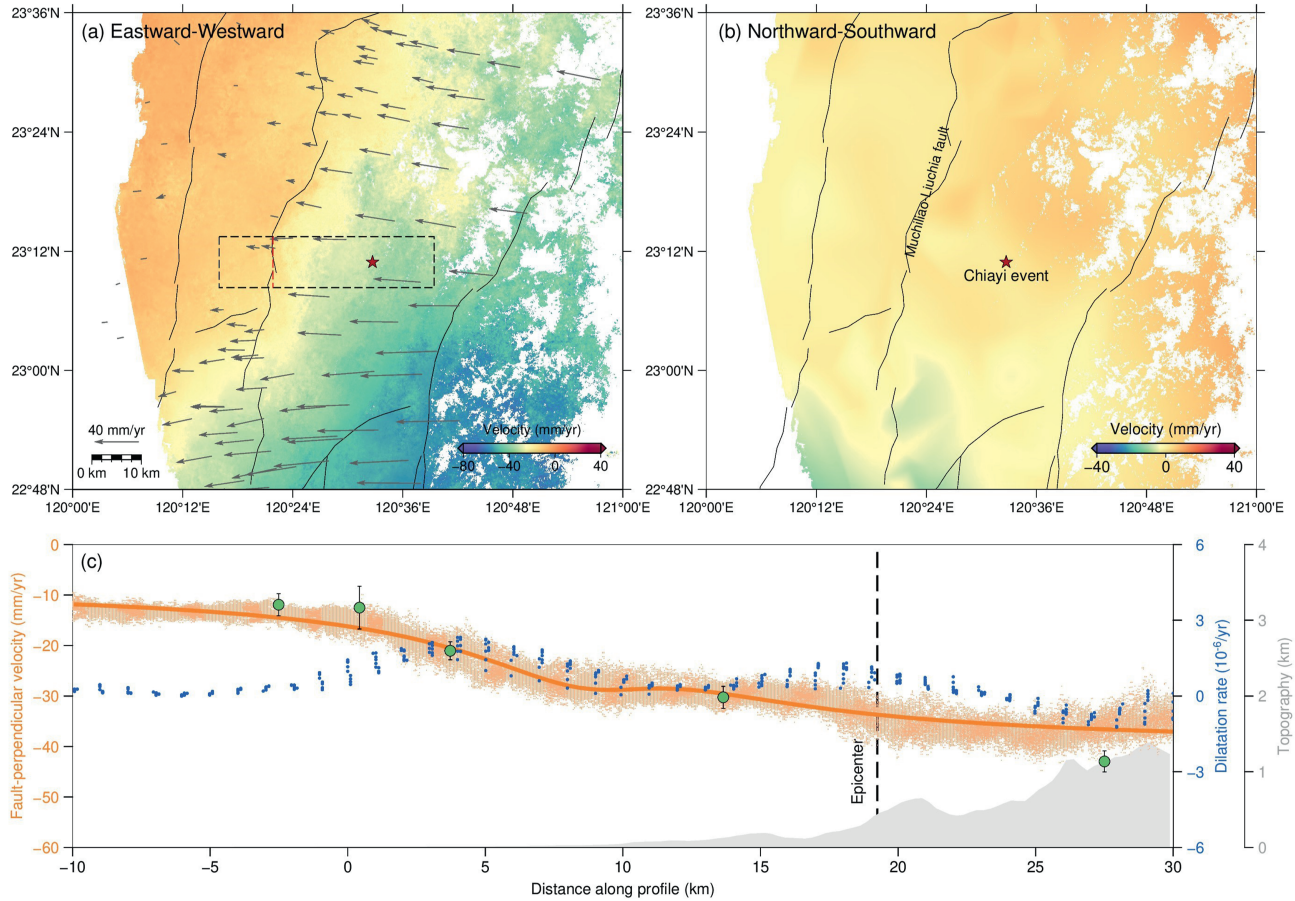
the west-dipping distributed slip model (6.8 mm and 6.5 mm). In terms of the variance reduction (VR) of data fitting, the VR of the east-dipping distributed slip model is also better, reaching 96.9%. Based on the statistical information of data fitting and other information, this study prefers the east-dipping fault model.

#### 4. Interseismic crustal velocities

To further analyze the crustal motion characteristics in the coseismic region, we collected the published crustal velocities and strain rates in Taiwan, China (Fig. 6) [4]. The horizontal velocity field reveals that the coseismic region is dominated by east-west

shortening (Fig. 6(a) and (b)). Notably, significant contractional strain has accumulated near both the Muchiliao-Liuchia fault and the Chiayi epicentral region (Fig. 6(a) and (b)). Furthermore, we utilized a two-dimensional (2D) edge dislocation model [23] to invert fault parameters of the Muchiliao-Liuchia fault, such as dip-slip rates, dip angles, locking depths, and fault locations. Given that the nearly north-south trending fault is predominantly characterized by contractional deformation [4], we only used the fault-perpendicular velocities ( $V_{\text{perpendicular}}$ ) across the Muchiliao-Liuchia fault, which are derived from the horizontal components of three-dimensional (3D) deformation field (Fig. 6(a) and (b)) [4], to invert the kinematic parameters. The inversion model is governed by the following equation:

$$\begin{cases} V_{\text{perpendicular}}(x) = \frac{b}{\pi} \sum_{h=0}^{+\infty} \left[ \cos \delta \arctan \left( \frac{x - s \cos \delta}{s \sin \delta} \right) + \sin \delta (s - x \cos \delta) \frac{s}{R_0^2} \right] \\ R_0^2 = (x - s \cos \delta)^2 + s^2 \sin^2 \delta \end{cases} \quad (1)$$



**Fig. 6.** Interseismic velocity field and profile analysis. The east-west and north-south components of interseismic velocity fields are illustrated in (a) and (b), respectively. The epicenter of the Chiayi event is denoted by a red star. Black and red dashed lines denote the locations of the profile and the fault profile, respectively. (c) Fitting results for the profile. Green dots with error bars represent fault-perpendicular GNSS velocities. Orange points indicate fault-perpendicular InSAR velocities across fault. Orange line indicates estimated velocities using a 2D edge dislocation model. Black dashed line represents the estimated epicenter locations. Blue points represent the dilatation rate, with positive and negative values indicating contraction and extension, respectively.

where  $V_{\text{perpendicular}}$  is the fault-perpendicular velocity at distance  $x$ ;  $x$  represents the perpendicular distance from the fault trace;  $b$  denotes the fault dip-slip rate;  $\delta$  is the dip angle;  $h$  is the locking depth;  $s$  is the variable of integration along the dip direction.

Subsequently, we applied a Bayesian framework using the ensemble Markov Monte Carlo Sampler [24] to derive probability density functions (PDFs) for all parameters. Each inversion underwent  $2 \times 10^6$  iterations in total, where the initial 80% of iterations were excluded as part of the burn-in phase. The final solutions were derived from calculating the posterior parameters means and standard deviations, offering both optimal estimates and quantified uncertainties. The inversion results show that the Mochiliao-Liuchia fault exhibits a dip-slip velocity of  $38.6 \pm 0.6$  mm/a, with a dip angle of  $21.9^\circ \pm 0.7^\circ$ , with locking depth and fault location values of  $4.2 \pm 0.1$  km and  $0.8 \pm 0.5$  km, respectively (Fig. S3). According to the probability distribution in Fig. S3, although the dip angle exhibits correlations with fault location, dip-slip rate, and locking depth, from the perspective of specific correlation variations, the mutual influences among them are all within an acceptable range. A change in the fault dip angle from  $21^\circ$  to  $23^\circ$  will cause a change in the fault location by 0–2 km, a

change in the fault locking depth by 0–0.4 km, and a change in the dip-slip rate by 0–2 mm/a.

## 5. Discussion

### 5.1. Dip orientation

For the Chiayi earthquake with a magnitude of  $M_W 6.0$  in 2025, we utilized InSAR data to invert the seismogenic fault model, relying on the two focal mechanism solutions provided by the USGS. We established four fault models using InSAR observations, namely the east-dipping uniform slip model, west-dipping uniform slip model, east-dipping distributed slip model, and west-dipping distributed slip model. We have respectively provided the statistical information on the data fitting of these four models, as shown in Table S1. It can be seen from the table that the Root Mean Square (RMS) values of the data fitting for the east-dipping uniform slip model and the east-dipping distributed slip model are 4.6 mm and 4.2 mm, respectively, which are better than those of the west-dipping uniform slip model and the west-dipping distributed slip model (6.8 mm and 6.5 mm). In terms of the variance reduction (VR) of data fitting, the VR of the east-dipping

distributed slip model is also better, reaching 96.9%. Comparatively speaking, the west-dipping model exhibits better fitting along profile AA' than the west-dipping nodal plane. The predicted value given by the east-dipping model at the position of profile AA' is smaller than the observed value, and it is unable to restore the maximum deformation of the observed value at this position. From the perspective of data fitting alone, it cannot be determined by the geodetic data whether the seismogenic fault of this earthquake dips eastward or westward. Therefore, we made an effort to examine the dip direction of the seismogenic fault of this earthquake from diverse perspectives. From a regional tectonic standpoint, existing active fault data predominantly cluster west of the earthquake's main deformation zone, aligning closely with both the fault strike and surface trace of the InSAR-inverted east-dipping model. Viewed from the InSAR coseismic deformation field, the quasi-east-west and quasi-up outcomes indicate that the surface deformation caused by the earthquake is mainly governed by uplift. Simultaneously, the west side of the main uplift area exhibits an obvious westward movement, which aligns better with the surface deformation caused by the east-dipping fault model. Looking at interseismic deformation, we constructed vertical profiles following the strike directions of the fault models that dip eastward and westward respectively. Subsequently, we estimated the interseismic fault edge dislocation model with the help of the interseismic InSAR and GNSS velocity field data. The fault positions shown in the inversion results are all located on the west side of the coseismic main deformation area, indicating that there is a reverse fault at this location. The fault dip angle inverted from the interseismic data is also more consistent with the dip angle of the east-dipping model. Based on the statistical information of data fitting and other evidence, this study prefers the east-dipping fault model.

## 5.2. Coulomb stress change

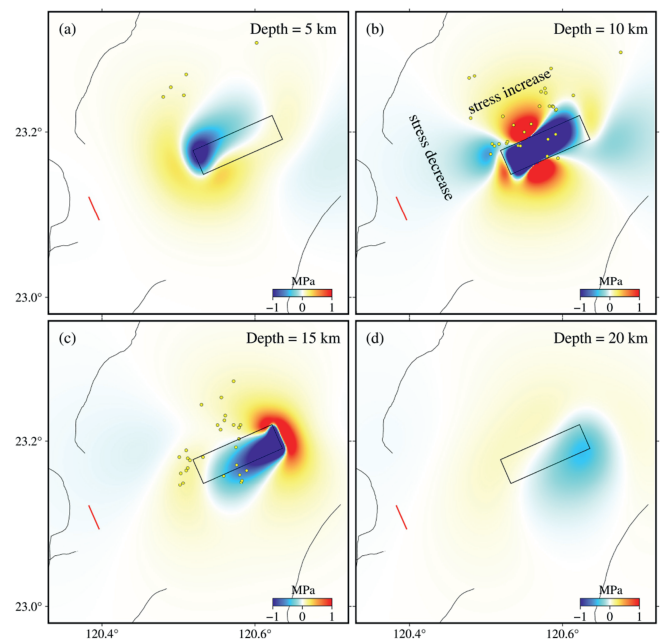
The calculations of Coulomb failure stress change ( $\Delta CFS$ ) are highly reliant on the input coseismic slip model [25]. In our study, we took the east-dipping uniform slip model of Chiayi earthquake that we derived as the input for the calculation of  $\Delta CFS$ . The calculation employed an effective friction coefficient of 0.4, and the strike of the receiving fault aligned with the direction of the mainshock. Utilizing Coulomb 3.4 software [26,27], we computed the  $\Delta CFS$  at depths of 5, 10, 15, and 20 km. The results indicate that areas with positive  $\Delta CFS$  are predominantly situated at the northern and southern ends of Chiayi earthquake rupture, as well as in the eastern and western lobes adjacent to the rupture zone (Fig. 7). As we can see, aftershocks at different depths are mainly located in areas where Coulomb stress changes have increased, indicating that the stress state around the fault of the coseismic rupture event has undergone readjustment. It is therefore necessary to pay attention to the seismic risk in regions where coseismic Coulomb stress has increased.

We use the empirical magnitude-area relations to estimate appropriate fault lengths and widths for the 2010  $M_W6.3$  Jia-Shian and 2016  $M_W6.4$  Meinong earthquakes [28]. Finally, we calculate the evolution of CFS changes for 2010  $M_W6.3$  Jia-Shian and 2016  $M_W6.4$  Meinong earthquakes. The parameters of receiver fault are set based on the nodal plane of the 2025  $M_W6.0$  Chiayi earthquake. All of our calculations of CFS changes are at a depth of 10 km, which is the location of the maximum slip of 2025 Chiayi earthquake. The calculation results indicate that the cumulative coseismic Coulomb stress changes induced by the 2010  $M_W6.3$  Jia-Shian and 2016  $M_W6.4$  Meinong earthquakes are mainly

concentrated in local areas due to their moderate magnitude (Fig. S4). Given that the Meinong and Jia-Shian earthquakes are approximately 40 km away from the Chiayi earthquake, the impact of the coseismic Coulomb stress changes generated by these two earthquakes on the epicentral area of the Chiayi earthquake is relatively small.

## 6. Conclusions

In this study, we utilize Sentinel-1 interferograms to conduct a detailed investigation into the coseismic ground displacement of the 2025  $M_W6.0$  Chiayi earthquake in southern Taiwan, China. The preferred fault model constrained by InSAR data reveals that this event took place on a northeast-dipping fault with a strike of  $336.2^\circ$  and a dip of  $27.6^\circ$ . The primary slip zone is concentrated at depths between 8 and 12 km. The rupture of the Chiayi earthquake has revealed the presence of a blind fault in this area. Our findings indicate that the strike of the fault model derived from the InSAR observation of the Chiayi earthquake is highly consistent with the strike of the Muchiliao-Liuchia fault system. Additionally, the dip value of the fault model obtained through inversion closely matches the fault dip in this region as derived from interseismic model inversion. Collectively, these observations suggest that the Chiayi earthquake primarily resulted from the mutual compression of tectonic plates, which induced stress accumulation in the region, and the accumulated stress was eventually released as an earthquake. The seismogenic fault of the Chiayi event is likely a deeply ruptured segment of Muchiliao-Liuchia fault zone. Results from Coulomb stress change calculations indicate that areas with positive  $\Delta CFS$  are predominantly situated at the northern and southern ends of the Chiayi earthquake rupture, as well as in the eastern and western lobes near the earthquake rupture zone. These stress changes may potentially reconfigure the stress accumulation state of active faults in this region.



**Fig. 7.**  $\Delta CFS$  caused by the 2025 Chiayi earthquake across various depth levels. The black rectangles and red lines depict the surface projections of fault model. The yellow dots represent the aftershocks one month after the earthquake.



## CRedit authorship contribution statement

**Guangyu Xu:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation, Conceptualization.  
**Kefeng He:** Writing – review & editing, Writing – original draft, Software, Methodology. **Longxiang Sun:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation.  
**Haiqing He:** Visualization, Validation, Investigation, Formal analysis.  
**Tengxu Zhang:** Writing – original draft, Visualization, Resources, Formal analysis.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.geog.2025.09.010>.

## References

- [1] C. DeMets, R.G. Gordon, D.F. Argus, Geologically current plate motions, *Geophys. J. Int.* 181 (1) (2010) 1–80.
- [2] M.H. Huang, H. Tung, E.J. Fielding, et al., Multiple fault slip triggered above the 2016 Mw 6.4 MeiniNong earthquake in Taiwan, *Geophys. Res. Lett.* 43 (2016) 7459–7467.
- [3] A.M. Dziewonski, T. Chou, J.H. Woodhouse, Determination of earthquake source parameters from waveform data for studies of global and regional seismicity, *J. Geophys. Res. Atmos.* 86 (B4) (1981) 2825–2852.
- [4] K.R. Franklin, M.H. Huang, Revealing crustal deformation and strain rate in Taiwan using InSAR and GNSS, *Geophys. Res. Lett.* 49 (21) (2022) e2022GL101306.
- [5] P. Bird, An updated digital model of plate boundaries, *G-cubed* 4 (3) (2003).
- [6] M. Huang, D. Dreger, R. Bürgmann, et al., Joint inversion of seismic and geodetic data for the source of the 2010 March 4, Mw 6.3 Jia-Shian, SW Taiwan, earthquake, *Geophys. J. Int.* 193 (3) (2013) 1608–1626.
- [7] K.H. Palgunadi, A.V.H. Simanjuntak, R.V. Ry, et al., Geometrically complex, relatively weak, and subcritically stressed Lembang fault may lead to a magnitude 7.0 earthquake, *Journal of Engineering and Technological Sciences* 57 (1) (2025) 129–144, <https://doi.org/10.5614/j.eng.technol.sci.2025.57.1.10>.
- [8] M.R. Daryono, G. De Gelder, A. Patria, Interpreting arc and line shapes in the fault ruptures of the 2016 Mw7.8 Kaikoura, New Zealand and the 2023 Mw7.8 and Mw7.6 East anatolian fault, Turkey-Syria earthquakes: a theoretical approach, *Journal of Engineering and Technological Sciences* 56 (6) (2024) 679–691, <https://doi.org/10.5614/j.eng.technol.sci.2024.56.6.1>.
- [9] S. Widiyantoro, P. Supendi, A. Ardianto, et al., Implications for fault locking south of Jakarta from an investigation of seismic activity along the Baribis fault, northwestern Java, Indonesia, *Sci. Rep.* 12 (1) (2022), <https://doi.org/10.1038/s41598-022-13896-6>.
- [10] U. Wegnüller, C. Werner, T. Strozzi, et al., Sentinel-1 support in the GAMMA software, *Procedia Comput. Sci.* 100 (2016) 1305–1312.
- [11] Y. Fialko, M. Simons, D. Agnew, The complete (3-D) surface displacement field in the epicentral area of the 1999 Mw7.1 hector mine Earthquake, California, from space geodetic observations, *Geophys. Res. Lett.* 28 (16) (2001) 3063–3066.
- [12] S. Fujiwara, T. Nishimura, M. Murakami, et al., 2.5-D surface deformation of M6.1 earthquake near Mt Iwate detected by SAR interferometry, *Geophys. Res. Lett.* 27 (14) (2000) 2049–2052.
- [13] Y. Wen, C. Xu, Y. Liu, et al., Deformation and source parameters of the 2015 Mw 6.5 earthquake in Pishan, Western China, from Sentinel-1A and ALOS-2 data, *Remote Sens.* 8 (2) (2016) 134.
- [14] G. Xu, C. Xu, Y. Wen, et al., The complexity of the 2018 Kaktovik earthquake sequence in the northeast of the Brooks Range, Alaska, *Geophys. Res. Lett.* 47 (19) (2020).
- [15] Z.H. Li, Locating the small 1999 Frenchman Flat, Nevada earthquake with InSAR stacking, *Journal of Geodesy and Geoinformation Science* 5 (1) (2022) 39–49.
- [16] N. Ghayournajarkar, Y. Fukushima, Determination of the dipping direction of a blind reverse fault from InSAR: case study on the 2017 Sefid Sang earthquake, Northeastern Iran, *Earth Planets Space* 72 (2020) 64.
- [17] Y. Okada, Surface deformation due to shear and tensile faults in a half-space, *Bull. Seismol. Soc. Am.* 75 (1985) 1135–1154, 1985.
- [18] E. Gunawan, W. Kongko, M. Kholil, et al., The 2019 Mw 7.0 Banten, Indonesia, intraslab earthquake: investigation of the coseismic slip, tsunami modelling and coulomb stress change, *Geoenvironmental Disasters* 9 (1) (2022), <https://doi.org/10.1186/s40677-022-00215-4>.
- [19] E. Gunawan, M. Kholil, S. Widiyantoro, Coseismic slip distribution of the 14 January 2021 Mamuju-Majene, Sulawesi, earthquake derived from GPS data, *Nat. Hazards* 111 (1) (2021) 939–948, <https://doi.org/10.1007/s11069-021-05084-y>.
- [20] S. Jónsson, H. Zebker, P. Segall, et al., Fault slip distribution of the 1999 Mw 7.1 hector mine, California, earthquake, estimated from satellite radar and GPS measurements, *Bull. Seismol. Soc. Am.* 92 (2002) 1377–1389.
- [21] K.F. He, G.Y. Xu, L.X. Sun, et al., ECAT: integrated nonlinear and linear inversion for complex fault systems and slip distribution, Zenodo, 2025, <https://doi.org/10.5281/zenodo.13730101>. Version 1.5.0.
- [22] J. Fukuda, K.M. Johnson, Mixed linear-non-linear inversion of crustal deformation data: bayesian inference of model, weighting and regularization parameters, *Geophys. J. Int.* 181 (3) (2010) 1441–1458.
- [23] S.J. Singh, S. Rani, Crustal deformation associated with two-dimensional thrust faulting, *J. Phys. Earth* 41 (2) (1993) 87–101.
- [24] J. Goodman, J. Weare, Ensemble samplers with affine invariance, *Commun. Appl. Math. Comput. Sci.* 5 (1) (2010) 65–80.
- [25] E. Gunawan, S. Widiyantoro, P. Supendi, et al., Identifying the most explainable fault ruptured of the 2018 Palu-Donggala earthquake in Indonesia using coulomb failure stress and geological field report, *Geodesy and Geodynamics* 11 (4) (2020) 252–257, <https://doi.org/10.1016/j.geog.2020.04.004>.
- [26] S. Toda, R.S. Stein, V. Sevilgen, et al., Coulomb 3.3 graphic-rich deformation and stress-change software for earthquake, tectonic, and volcano research and teaching—User guide, US Geol. Surv. Open-File Rep. 1060 (2011) 63.
- [27] Z.K. Mildon, G.P. Roberts, J.P.F. Walker, et al., Coulomb pre-stress and fault bends are ignored yet vital factors for earthquake triggering and hazard, *Nat. Commun.* 10 (1) (2019).
- [28] D.L. Wells, K.J. Coppersmith, New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement, *Bull. Seismol. Soc. Am.* 84 (1994) 974–1002.



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