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臺灣造山帶西部前緣在震間期的變形與應變累積

Interseismic Deformation and Strain Accumulation Along

Western Front of Taiwan Orogen

廖冠至

Guan-Zh Liao

指導教授：莊昀叡 博士

Advisor: Ray Y. Chuang, Ph.D.

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Western Front of Taiwan Orogen

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The undersigned, appointed by the Department of Geography on 30 July 2024 have examined a Master's thesis entitled above presented by Guan-Zh Liao (R11228009) candidate and hereby certify that it is worthy of acceptance.

口試委員 Oral examination committee:

|                              |            |            |
|------------------------------|------------|------------|
| <u>莊明敬</u><br>(指導教授 Advisor) | <u>黃文正</u> | <u>鍾合和</u> |
| <u>鄧昱廷</u>                   | <u>李國興</u> |            |

系主任/所長 Director: 黃偉英

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## 摘要



造山帶是地球上地質活動最劇烈和危險的區域之一，其特點是劇烈的構造活動和褶皺逆衝。造山帶的變形前緣作為一個標誌，指示了活動構造運動和非活動構造運動之間的邊界。一般來說，變形前緣也是造山帶最活躍的構造區域，因此迫切需要對該區域進行深入了解和持續監測。

臺灣的造山帶是世界上最活躍的造山帶之一。在臺灣中部，造山帶的前緣構造是彰化斷層。據信彰化斷層最近一次引發的地震發生在 1848 年，距今已近 180 年。車籠埔地震的發生使得彰化斷層及臺灣中部造山帶的變形前緣更值得進一步調查。因此，本研究集中於彰化斷層的應變積累和地震潛勢。研究目標是整合各種大地測量數據，包括 GNSS、水準測量和 InSAR，分析地表速度，並利用地表速度的數據建立模型，以確定斷層的滑移虧損速率。

本研究發現，儘管造山活動向西推進，且彰化斷層處於最前緣，但彰化斷層並未顯示出最高的滑移虧損速率，反而是車籠埔斷層顯示出最高的滑移虧損速率。然而，車籠埔斷層剛剛進入新的地震週期，而彰化斷層已在其當前週期中持續了近 180 年。一旦彰化斷層引發地震，將對超過 300 萬人構成重大風險。因此，不能忽視彰化斷層相關的潛在危害。

**關鍵字：**彰化斷層、造山帶變形前緣、數值模型、震間期變形、地震潛勢

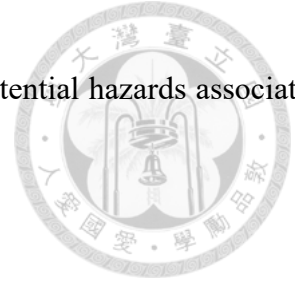
## Abstract



The orogenic belt is one of the most geologically dynamic and hazardous areas on Earth, characterized by intense tectonic activity and fold-and-thrust belts. The deformation front of the orogenic belts serves as a marker, indicating the boundary between active and inactive tectonic movements. Generally, the deformation front is also the most active structure of orogenic belts, and there is an urgent need for a thorough understanding and continuous monitoring of this region.

The orogenic belt in Taiwan, which is one of the most active orogenic belts in the world. In the central Taiwan, the frontal structure of the orogenic belt is the Changhua fault. The most recent earthquake triggered by the Changhua fault is believed in 1848, nearly 180 years ago. The out-of-sequence Chi-Chi earthquake makes the Changhua fault and the deformation front of the Taiwan central orogenic belt even more worthy of investigation. Therefore, this study focuses on the fault strain accumulation and seismic potential of the Changhua fault. This research aims to integrate varied geodetic data including GNSS, leveling, and InSAR to analyze surface velocities, and conducting a model with geodetic data to determine the slip deficit rates. It is found that despite the westward propagation of orogenic activity and the Changhua fault being at the forefront, the Changhua fault does not show the highest slip deficit rate. Instead, the Chelungpu fault shows the highest slip deficit rate. However, the Chelungpu fault has just started a new seismic cycle, whereas the Changhua fault has been in its current cycle for 176 years, posing a significant risk to over 3,000,000 people in the

event of an earthquake triggered by the Changhua fault. Therefore, the potential hazards associated with the Changhua fault should not be ignored.



**Keyword:** The Changhua fault, Deformation front, Numeric model, Interseismic deformation, Seismic Potential

# Table of Contents



|                                                                               |     |
|-------------------------------------------------------------------------------|-----|
| 論文口試委員審定書.....                                                                | i   |
| 誌謝.....                                                                       | ii  |
| 摘要.....                                                                       | iii |
| Abstract.....                                                                 | iv  |
| Table of Contents .....                                                       | vi  |
| List of Figures .....                                                         | ix  |
| List of Tables.....                                                           | xii |
| Chapter 1 Research motivation and purpose.....                                | 1   |
| 1.1 Research motivation.....                                                  | 1   |
| 1.2 Research purposes.....                                                    | 5   |
| Chapter 2 Literature review .....                                             | 6   |
| 2.1 The orogenic belt and deformation front in the world .....                | 6   |
| 2.2 The orogenic belt and deformation front in Taiwan.....                    | 10  |
| 2.2.1 The tectonic process in Taiwan .....                                    | 10  |
| 2.2.2 The tectonic process and geological setting in the central Taiwan ..... | 11  |
| 2.3 Synthetic aperture radar .....                                            | 12  |
| 2.4 Numeric model.....                                                        | 16  |
| 2.5.1 Two-dimensional model.....                                              | 17  |
| 2.5.2 Three-dimensional model .....                                           | 19  |
| Chapter 3 Study area .....                                                    | 22  |
| 3.1 Study area.....                                                           | 22  |
| 3.2 The faults in the central Taiwan .....                                    | 24  |
| 3.2.1 Changhua fault .....                                                    | 24  |

|                                                                       |    |
|-----------------------------------------------------------------------|----|
| 3.2.2 Chelungpu fault.....                                            | 30 |
| 3.2.3 Tamaopu-Shuangtung fault .....                                  | 32 |
| 3.2.4 Sanyi fault .....                                               | 32 |
| 3.2.5 Tuntzuchiaio fault.....                                         | 34 |
| 3.2.6 Chushiang fault .....                                           | 35 |
| 3.3 Geodetic slip deficit rates of faults in the central Taiwan ..... | 37 |
| 3.4 The geometry of faults .....                                      | 39 |
| Chapter 4 Data and methods .....                                      | 43 |
| 4.1 Study data.....                                                   | 43 |
| 4.1.1 GNSS .....                                                      | 43 |
| 4.1.2 Leveling .....                                                  | 44 |
| 4.1.3 SAR.....                                                        | 44 |
| 4.2 Methods.....                                                      | 45 |
| 4.2.1 Research workflow .....                                         | 45 |
| 4.2.2 Process GNSS and leveling data.....                             | 47 |
| 4.2.3 InSAR time series and velocity.....                             | 54 |
| 4.2.4 Modelling the faults in the central Taiwan.....                 | 59 |
| 4.2.5 The assessment of the moment magnitude of the faults .....      | 68 |
| Chapter 5 Results .....                                               | 69 |
| 5.1 Two-dimensional dislocation model .....                           | 69 |
| 5.1.1 Testing the lower and upper detachment.....                     | 69 |
| 5.1.2 The southern profile of 2-D model.....                          | 74 |
| 5.1.3 The northern profile of 2-D model.....                          | 75 |
| 5.2 Three-dimensional dislocation model .....                         | 80 |
| 5.2.1 The results of 3-D model .....                                  | 80 |

|                                                                            |     |
|----------------------------------------------------------------------------|-----|
| 5.2.2 3-D model testing.....                                               | 88  |
| 5.3 The moment magnitude of the faults .....                               | 96  |
| Chapter 6 Discussions.....                                                 | 99  |
| 6.1 Comparison with results of other studies.....                          | 99  |
| 6.1.1 The slip deficit rates from the 3-D model results.....               | 99  |
| 6.1.2 The moment magnitude of the faults .....                             | 100 |
| 6.2 Comprehensive assessment of slip deficit rates in three scenarios..... | 101 |
| 6.3 The impact of the Changhua fault's slip deficit rate .....             | 105 |
| 6.3.1 The impact to faults structures .....                                | 105 |
| 6.3.2 The impact to earthquake hazards.....                                | 106 |
| Chapter 7 Conclusions .....                                                | 108 |
| Reference .....                                                            | 111 |
| Appendix.....                                                              | 132 |
| Appendix A: Velocity of GNSS stations in horizontal direction .....        | 132 |
| Appendix B: Velocity of GNSS and leveling in vertical direction .....      | 145 |
| Appendix C: Velocity of InSAR in line-of-sight direction .....             | 162 |
| Appendix D: Fitting result of GNSS and leveling data .....                 | 181 |
| Appendix D1: Continuous-mode GNSS .....                                    | 181 |
| Appendix D2: Campaign-mode GNSS .....                                      | 206 |
| Appendix D3: Leveling.....                                                 | 234 |
| Appendix E: Posterior distribution of 2-D model results .....              | 254 |
| Appendix F: The 3-D model results.....                                     | 257 |

# List of Figures



|                                                                                                                      |    |
|----------------------------------------------------------------------------------------------------------------------|----|
| <b>Figure 1</b> The location of deformation front in Taiwan. (Shyu et al., 2005). .....                              | 3  |
| <b>Figure 2</b> Evolution of the central Taiwan geotectonic structures (鄧屬予，2007). .....                             | 4  |
| <b>Figure 3</b> A hierarchical classification of orogenic belts (Şengör, 2020) .....                                 | 7  |
| <b>Figure 4</b> Study area.. .....                                                                                   | 23 |
| <b>Figure 5</b> The Sanyi fault (Shyu et al., 2020) .....                                                            | 33 |
| <b>Figure 6</b> The Tuntzuchia fault (Shyu et al., 2020) .....                                                       | 35 |
| <b>Figure 7</b> The Chushiang fault (Shyu et al., 2020) .....                                                        | 36 |
| <b>Figure 8</b> The first geometry scenario of faults connection in the central Taiwan (Lee et al., 2002). ..        | 41 |
| <b>Figure 9</b> The second geometry scenario of faults connection in the central Taiwan (Yue et al.,<br>2005). ..... | 41 |
| <b>Figure 10</b> The third geometry scenario of faults connection in the central Taiwan (Lin et al., 2002).<br>..... | 42 |
| <b>Figure 11</b> The workflow of this study. ....                                                                    | 46 |
| <b>Figure 12</b> Examples of GPS and leveling time series fitting.. .....                                            | 51 |
| <b>Figure 13</b> The vertical secular velocity in the central region. ....                                           | 52 |
| <b>Figure 14</b> The horizontal secular velocity in the central region. ....                                         | 53 |
| <b>Figure 15</b> Sentinel-1 InSAR Line-of-sight (LOS) velocity (Lee, 2024, unpublished). ....                        | 55 |



|                                                                                                                    |    |
|--------------------------------------------------------------------------------------------------------------------|----|
| <b>Figure 16</b> The quadtree result for Sentinel-1 InSAR LOS velocity. ....                                       | 56 |
| <b>Figure 17</b> The quadtree result for Sentinel-1 InSAR LOS velocity with GNSS and leveling points.<br>.....     | 57 |
| <b>Figure 18</b> Study area with two profiles and two groups. ....                                                 | 63 |
| <b>Figure 19</b> The schematic diagram of three geometry assumptions. ....                                         | 67 |
| <b>Figure 20</b> The model result of optimal misfit for the lower and upper geometry of the 2-D model..<br>.....   | 72 |
| <b>Figure 21</b> The optimal geometry of the lower and upper detachment scenarios. ....                            | 73 |
| <b>Figure 22</b> The model results of optimal misfit for northern profile of the 2-D model.....                    | 78 |
| <b>Figure 23</b> The optimal geometry of the northern profile. ....                                                | 79 |
| <b>Figure 24</b> The 3-dimensional model output of the three scenarios. ....                                       | 83 |
| <b>Figure 25</b> The 3-dimensional model misfits in horizontal direction of the three scenarios. ....              | 84 |
| <b>Figure 26</b> The 3-dimensional model misfits in vertical direction of the three scenarios. ....                | 85 |
| <b>Figure 27</b> The 3-dimensional model misfits in line-of-sight direction of the three scenarios. ....           | 86 |
| <b>Figure 28</b> The trade-off curves of three scenarios.....                                                      | 87 |
| <b>Figure 29</b> The 3-dimensional model output of the three scenarios for different data. ....                    | 91 |
| <b>Figure 30</b> The trade-off curves of different smoothing parameters in the three scenarios.....                | 94 |
| <b>Figure 31</b> The 3-dimensional model output in the three scenarios for different smoothing<br>parameters. .... | 95 |



**Figure 32** The slip deficit rates across northern and southern segments..... 103

**Figure 33** The slip deficit rates in different depths across northern and southern segments. .... 104

# List of Tables



|                                                                                                                                        |    |
|----------------------------------------------------------------------------------------------------------------------------------------|----|
| <b>Table 1</b> Geologic fault slip rate of the three faults. ....                                                                      | 28 |
| <b>Table 2</b> Geodetic fault slip deficit rate of the faults. ....                                                                    | 38 |
| <b>Table 3</b> Leveling calibration reference station. ....                                                                            | 50 |
| <b>Table 4</b> Information about the SAR images used in the study.....                                                                 | 58 |
| <b>Table 5</b> Information of dataset.....                                                                                             | 58 |
| <b>Table 6</b> Initial parameter of 2-D dislocation model.....                                                                         | 62 |
| <b>Table 7</b> Initial parameter of 3-D baseline inversion model. ....                                                                 | 66 |
| <b>Table 8</b> The misfit of two scenarios from all possible combinations of fault branches. ....                                      | 70 |
| <b>Table 9</b> Slip rates and model misfit of 2-D model output from two profiles. ....                                                 | 75 |
| <b>Table 10</b> The misfit of the northern profile from all possible combinations of fault branches. ....                              | 76 |
| <b>Table 11</b> The 3-D model output of slip deficit rate and misfit in the three scenarios. ....                                      | 82 |
| <b>Table 12</b> The 3-D model output of slip deficit rate and misfit in the three scenarios for different<br>data.. ..                 | 89 |
| <b>Table 13</b> The 3-D model output of slip deficit rate and misfit in the three scenarios for different<br>smoothing parameters.. .. | 92 |
| <b>Table 14</b> The moment magnitude and the rupture area of the Changhua fault in three scenarios. ...                                | 96 |
| <b>Table 15</b> The moment magnitude and the rupture area of the Chelungpu fault in three scenarios. ...                               | 97 |



**Table 16** The moment magnitude and the rupture area of the Tamaopu-Shuangtung fault in three scenarios.....98



# Chapter 1 Research motivation and purpose

## 1.1 Research motivation

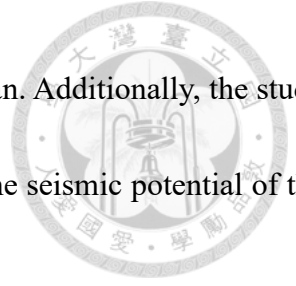
Orogenic belts are crucial regions for studying crustal deformation, where tectonic plates converge over hundreds of kilometers in length and tens of kilometers in width, leading to subduction and collision. The edges of orogenic belts often consist of fold and thrust, with the leading edge of their convergence direction known as the deformation front, marking the boundary between active continental margins and passive continental margins (Arora et al., 2011; Roberts & Bally, 2012; Huang et al., 2021). Due to the fact that orogenic belts are one of the most tectonically active regions in the world, the deformation front located at their forefront is often the epicenter of many large earthquakes. This area is prone to disasters, making it a focal point for research. Many studies focus on the deformation front of orogenic belts with the hope of not only understanding the underlying causes of disasters like earthquakes but also predicting seismic hazards in the future (Kasahara, 1979; Yu, 2004; Wu et al., 2021).

As for Taiwan, it is on an active orogenic belt where two tectonic plates converge (Ho, 1986), resulting in numerous faults and frequent earthquakes (Bonilla, 1975). The deformation front in Taiwan is located in the west (Figure 1), with the overall direction of orogeny in the central Taiwan being westward. This ongoing orogenic process has formed several parallel faults in the central Taiwan, with the Changhua fault now situated at the deformation front of the orogenic belt (Teng,



1990) (Figure 2). The most recent earthquake triggered by the Changhua fault is believed in 1848, nearly 180 years ago. Furthermore, the fault is not creeping. In other words, the Changhua fault is a fault at the deformation front and may accumulate large stress, making it a fault with highly seismic potential. However, the most recent major earthquake in the central Taiwan was the Chi-Chi earthquake in 1999, one of the largest earthquakes in a century with a magnitude of  $M_L$  7.3 or  $M_W$  7.6 (Ma et al., 1999; Chang et al., 2000). This earthquake is considered "out-of-sequence" because the Changhua fault, which is the deformation front, is not the fault triggering the earthquake. The Chi-Chi sequence alone shows that the Chelungpu fault is an active, out-of-sequence thrust (Kao & Chen, 2000). This irregular fault activity has made the Changhua fault and the central orogenic belt even more worthy of investigation.

Geodetic data has been essential for monitoring faults and the potential hazards. Utilizing geodetic data with numerical models can efficiently yield effective fault slip deficit rates (e.g., Johnson, 2013). Slip deficits are crucial data for fault monitoring (e.g., Petersen et al., 2014). In the central Taiwan, there are related studies on fault monitoring (e.g., 景國恩, 2020). However, there are some limitations of these studies. Most studies only use GNSS (Global Navigation Satellite System) data, and some of the numerical models used for monitoring do not consider vertical velocities. Therefore, this study will use more comprehensive geodetic data from the central Taiwan, combined with numerical models that incorporate three-dimensional velocities, to fully calculate the



slip deficit rates of the Changhua fault and other faults in the central Taiwan. Additionally, the study will estimate the corresponding earthquake moment magnitude to assess the seismic potential of the Changhua fault.

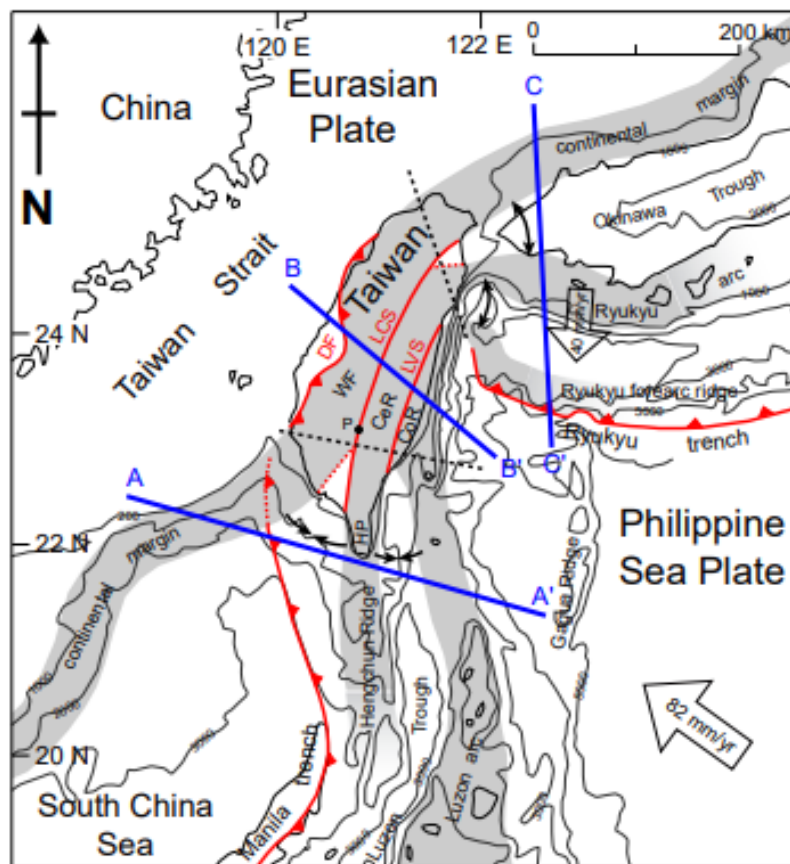


**Figure 1** The location of deformation front in Taiwan. "DF" indicates the location of deformation front (Shyu et al., 2005).

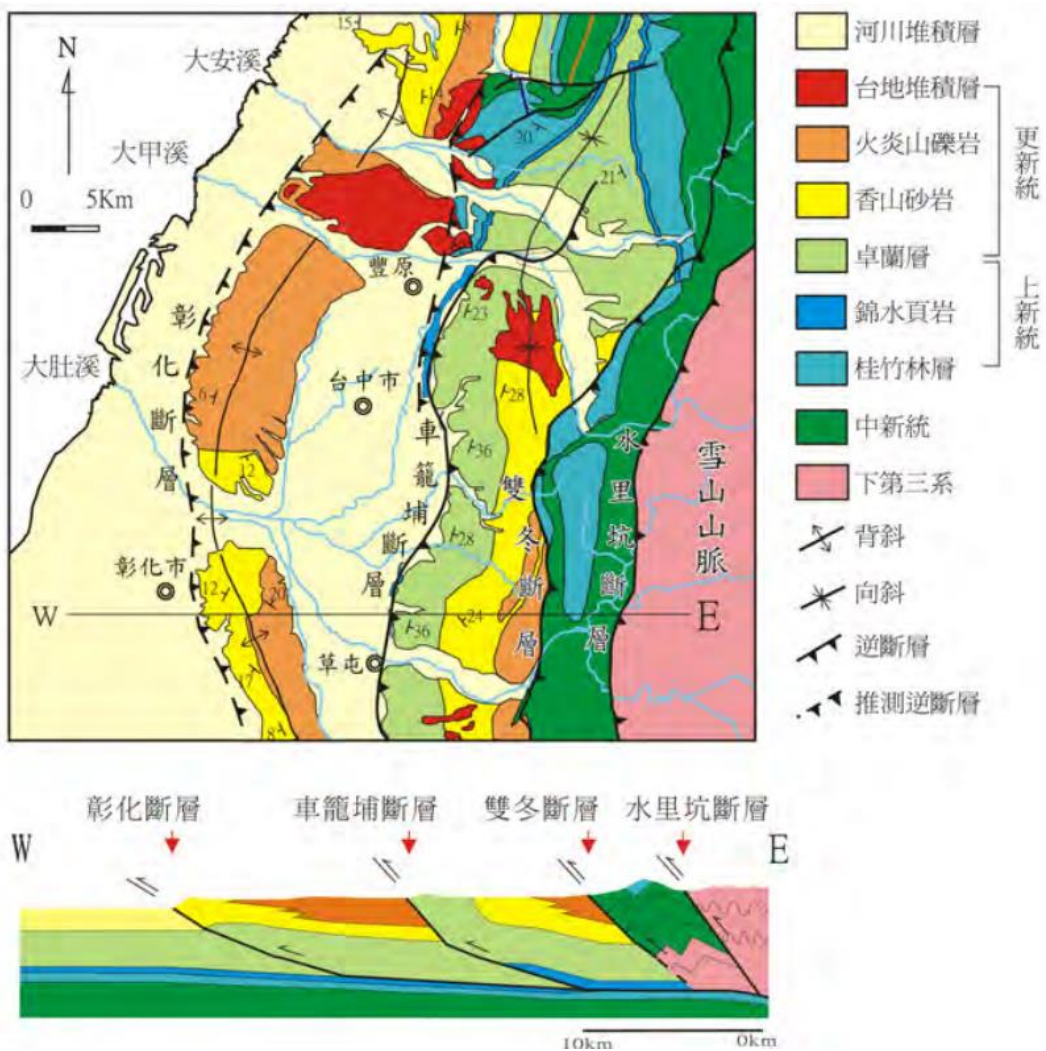


**Figure 2** Evolution of the central Taiwan geotectonic structures (鄧屬予，2007).



## 1.2 Research purposes

This research's primary objective is to integrate high accuracy geodetic data, including GPS, leveling measurements, and InSAR data. Using these data to get the velocity field in the central Taiwan during the interseismic period. This velocity field will be utilized with numerical models to gain insights into the slip deficit rates and the inferred moment magnitude of the faults in the central Taiwan, and to further assess the future seismic potential of the Changhua fault. Answers were sought to the following questions:

- (1) After the Chi-Chi earthquake, what are the slip deficit rates and their distribution of the Changhua fault and the faults in the central Taiwan during the interseismic period?
- (2) Based on this slip deficit rate, what is the earthquake potential of the Changhua fault?



## Chapter 2 Literature review

### 2.1 The orogenic belt and deformation front in the world

According to Şengör (2020), orogenic belts, formed through plate convergence, can be classified into four major categories based on the mode of convergence: collision-controlled orogens, subduction-controlled orogens, obduction-controlled orogens, transpressional-controlled orogens (Figure 3).

The first category is collision-controlled orogenic belts. Take the Himalayan region as an example. Orogenic activity in the Himalayas began around sixty million years ago and continues to this day, remaining highly active, making it a perennial focus of research. Early studies took a broader temporal and spatial perspective on the Himalayan orogenic belt and supplemented their findings with field data as a basis. These studies helped establish the direction of plate motion and delineated how this motion, led to the contact and collision of the Indo-Australian and Eurasian plates, resulting in the formation of mountain ranges and plateaus (Powell & Conaghan, 1973; Searle, 1986). Subsequently, research gradually shifted its focus to the active deformation front within the orogenic belt. Bilham et al. (1997), utilizing geodetic data such as GPS and leveling, combined with two-dimensional numerical models, calculated the slip rates in the Himalayan region. Similarly, Feldl & Bilham (2006) used geodetic data but employed different numerical models to obtain more detailed slip rates.

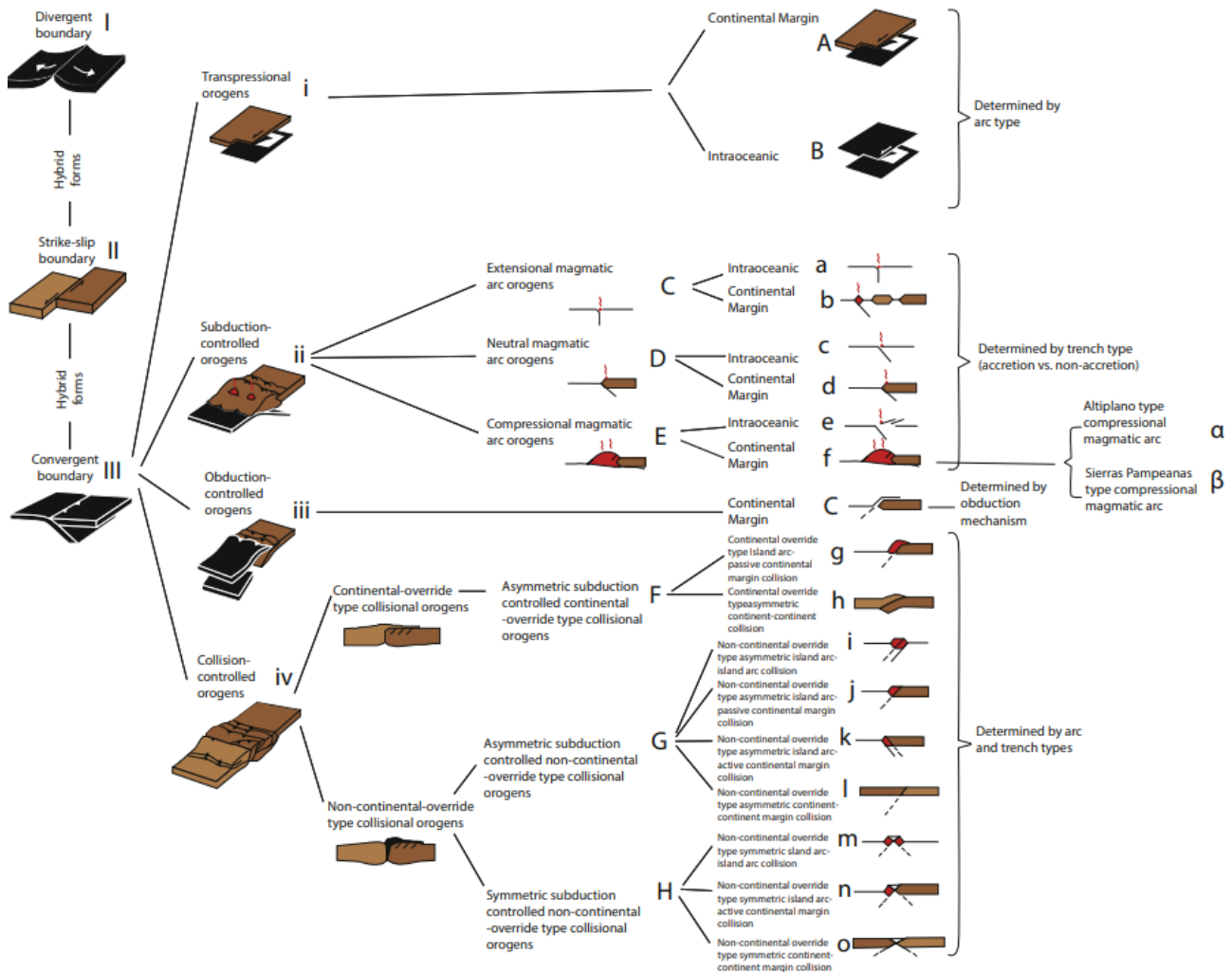
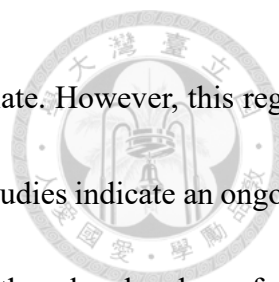


**Figure 3** A hierarchical classification of orogenic belts (Şengör, 2020)

The second category is subduction-controlled orogenic belts. Well-known examples of such subduction-dominated orogenic belts include southwestern Japan, the northwestern United States, and southern Chile (Heaton & Hartzell, 1987; Oncken et al., 2006; Faure et al., 2009). Taking the Cascadia subduction zone, located off the west coast of north America, as an example. Its main cause



is the subduction of the Juan de Fuca Plate beneath the North American Plate. However, this region has not experienced a major earthquake in over two hundred years. Many studies indicate an ongoing stress accumulation in the area. Additionally, evidences of past large earthquakes has been found through paleoseismic investigations. Consequently, the likelihood of a major earthquake recurrence in this region is not low (Atwater et al., 1995; Clague, 1997). Multiple studies have attempted to estimate recurrence intervals, and researching the deformation front of the Cascadia subduction zone is one approach to predict recurrence intervals. For instance, Hyndman & Wang (1993) used a method to constrain numerical models by examining the temperature of the crust ahead of the subduction zone deformation front, improving the accuracy of simulations. Han et al. (2016) employed Seismic reflection images to identify the structure of the oceanic crust within the Cascadia subduction zone. They used this information to discuss the interaction between the plates at the deformation front of the subduction zone and the underlying mantle's liquid and temperature-pressure conditions.

The third category is obduction-controlled orogenic belts, which are characterized by the subduction of less dense continental crust beneath denser oceanic crust at plate boundaries. This plate convergence type is less common compared to the previous two categories and often includes the appearance of ophiolites. Notable obduction-controlled orogens can be found in Central Asia, northern Oman, western Turkey, northeastern Iraq, and western Iran, all of which have evidence of obduction processes (Searle & Stevens, 1984; Alavi, 2004; Garzanti et al., 2007). Taking the Zagros



fold-thrust belt in central Asia as an example, since obduction is no longer occurring in the present, researchers rely on the exposure of unconformity and changes in the deformation front's position to determine the direction and timing of obduction. This approach allows them to reconstruct the plate movements that occurred during the obduction phase (Karim et al., 2011).

The fourth category is transpressional-controlled orogenic belts, which are characterized by oblique subduction. The lateral subduction forces associated with this type of subduction directly or indirectly influence the orientation of strike-slip faults. Consequently, these orogenic belts are typically linked to subduction zones. Examples of well-known transpressional-controlled orogens include Sumatra in Indonesia and the North Island of New Zealand (Tikoff & Teyssier, 1994; Collot et al., 1996). Using the Great Sumatran fault, controlled by the subduction zone in Sumatra, as an example. The presence of lateral components in this subduction zone leads to complex stress interactions between plates. Researchers have to rely on the position of the Sunda megathrust deformation front to define these intricate plate interactions (Sieh & Natawidjaja, 2000). Alternatively, modeling approaches with constraints from geological evidence like ancient coral fossils have been used to understand the dynamics of this region (Briggs et al., 2006).



## 2.2 The orogenic belt and deformation front in Taiwan

### 2.2.1 The tectonic process in Taiwan

Taiwan is an active orogenic belt, situated at the junction of the Eurasian Plate and the Philippine Sea Plate. The geological setting is greatly influenced by the convergence of the Ryukyu subduction zone and the Manila subduction zone, resulting in the tandem suturing of a volcanic arc and a sliver of continental crust to the continental margin (Chai, 1972; Biq, 1973; Bowin et al., 1978; Teng, 1990; Shyu et al., 2005).

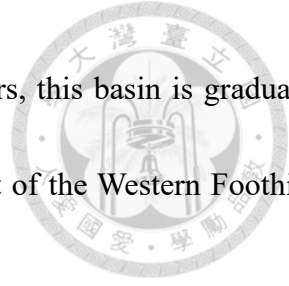
The formation process began in the middle to late Miocene due to the traction of the Manila subduction system. The ancient Pacific Plate was thrust onto the Eurasian Plate, resulting in the northward movement of the Luzon Island arc in a collision scenario. Initially, this collision occurred near the Ryukyu Island arc, and then it continued northwestward, colliding with the passive continental margin oriented in the northeast-southwest direction (Bowin et al., 1978; Suppe, 1980a; Teng, 1990). Accumulated accretionary terranes from subduction and collision gradually uplifted during the orogenic process, forming the current Central Mountain Range in Taiwan. On its eastern side, the colliding Luzon Island arc and associated accretionary terranes piled up to create the present-day Coastal Mountain Range (Chai, 1972; Suppe, 1980a; Teng, 1990). As the collision point continued to move southwestward along the continental margin, the orogenic activity shifted to the southwest of Taiwan. The stress that had initially uplifted northern Taiwan gradually diminished and



was replaced by the extensional activity behind the Ryukyu Trench. The Yilan Plain is a product of this post-orogenic extension (Lee & Wang, 1988; Kao et al., 1998). Orogenic activity continues to be active in the southwest of Taiwan, delineating the general boundaries between mountain-building and subsiding regions in northern and southwestern Taiwan. The complex arc-continent collision processes have shaped the unique tectonic structure of Taiwan. Off the northeastern coast of Taiwan, the offshore subduction zone tilts westward, where the Philippine Sea Plate subducts beneath the Eurasian Plate. In contrast, off the southwestern coast of Taiwan, the offshore subduction zone tilts eastward, with the Eurasian Plate subducting beneath the Philippine Sea Plate (Chai, 1972; Bowin et al., 1978; Suppe, 1980a; Teng, 1990). This configuration between Luzon and Taiwan forms a "Dual-Trench" pattern (Biq, 1971). To sum up, after the subduction and obduction orogeny, the main orogenic process in Taiwan is now collision-controlled (Teng, 1990; 鄧屬予, 2007).

### 2.2.2 The tectonic process and geological setting in the central Taiwan

The orogenic belt in the central Taiwan is relatively mature, with clear evidence of collision propagation (Teng, 1990; 鄧屬予, 2007). Most of the faults in the central Taiwan have a north-to-south strike and are parallel to each other because of the direction of crust collision (陳文山等, 2000). This is due to the ongoing westward propagation of orogenic activity, causing the central Taiwan to repeatedly undergo the following cycle: the weight of the mountains causes the crust at the

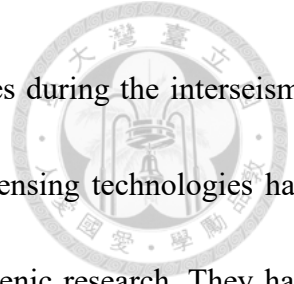


continental margin to bend downwards, forming a basin. After many years, this basin is gradually uplifted by the continuous westward thrust of the orogeny, becoming part of the Western Foothills Belt (鄧屬予, 2007).

Along the Western Foothills Belt, shallow marine rocks and sediments of the continental shelf are being uplifted to the central Taiwan through the Philippine Sea Plate was thrust onto the Eurasian Plate (Suppe et al., 1987). The stratigraphy in this region, from youngest to oldest, consists of alluvium and terrace deposits, followed by the Toukoshan Formation, which includes the Huoyenshan and Hsiangshan Facies. Beneath this lies the Cholan Formation, followed by the older and deeper Chinshui Shale, and finally the pre-Pliocene strata (Chang, 1971).

## 2.3 Synthetic aperture radar

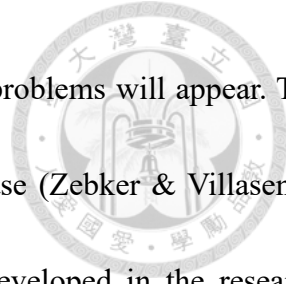
Remote sensing tools play a crucial role in studying the deformation front of mountain belts. These tools have evolved over the years, providing increasingly rich and abundant data for research in orogenic zones. They have become invaluable in various aspects of geological research. For instance, passive optical satellites like Landsat have been used to identify faults in the Tibetan Plateau (Molnar & Tapponnier, 1978). Satellite-based gravity instruments have been employed to identify shear zones within tectonic plates (Bird, 2001). Furthermore, active satellites equipped with synthetic



aperture radar (SAR) have allowed researchers to obtain surface velocities during the interseismic period (e.g., Chen & Khan, 2010; Grandin et al., 2012). These remote sensing technologies have significantly increased the quantity and quality of data available for orogenic research. They have overcome previous limitations associated with data scarcity in mountainous regions, opening up new possibilities for studying the deformation fronts of orogenic belts.

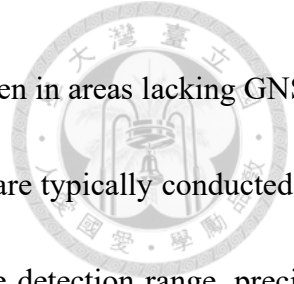
SAR offers advantages that optical satellites do not possess. SAR collects data by actively emitting radar signals and receiving the signals that bounce back from objects, making it independent of sunlight for illumination. The objects that reflect these signals are referred to as scatterers. Additionally, SAR is capable of penetrating through atmospheric moisture, avoiding interference from the troposphere. This means it can overcome issues such as cloud cover and the inability to capture images at night (Rosen et al., 2000; Hanssen, 2001).

InSAR (Interferometric Synthetic Aperture Radar) is a powerful technique that produce interference between two radar images to achieve much higher resolution than single images. After interference, the resulting data can be corrected and used for change detection. InSAR can achieve centimeter-level accuracy in certain conditions and, under specific circumstances, can even provide millimeter-level precision comparable to GNSS stations (Rosen et al., 2000; Hanssen, 2001; Cigna et al., 2021).



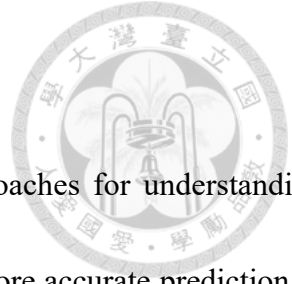
However, when it comes to assessing multi-temporal InSAR, some problems will appear. The main one is decorrelation temporal and spatial in the interferometric phase (Zebker & Villasenor, 1992). To address the time series issue, various solutions have been developed in the research community. One commonly used approach involves identifying persistent scatterers (PS) as the targets for analysis. This method selects objects with strong reflectance signals, often man-made structures like cement buildings, as persistent scatterers and performs interferometry on these points over multiple time periods. Typically, only one image is chosen as the master image for interferometry. This approach is particularly suitable for urban environments (Ferretti et al., 2001). Another technique focuses on distributed scatterers (DS). The distributed scatterers can be coherently summed to reduce the effect of random noise on the signal of interest (Osmanoğlu et al., 2016). By using distributed scatterers, the small baseline subset (SBAS) technique becomes a useful approach for handling multi-temporal InSAR. SBAS aims to minimize both spatial and temporal differences between images. With the use of small baseline interferograms, this method avoids decorrelation issues, increase the temporal sampling rate of the monitoring, and enhance the spatial coverage over the area of interest (Berardino et al., 2002).

InSAR has been used extensively to measure displacements when the events causing crustal deformation such as earthquakes, volcanic activity, and can better document the current surface movement along the fault (Hooper et al., 2012; Cavalié et al., 2008). One of the major advantages of



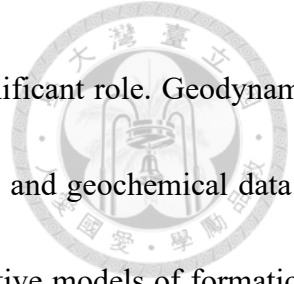
InSAR is that it provides a comprehensive view of surface deformation, even in areas lacking GNSS data. It is an excellent supplement to ground-based measurements, which are typically conducted at a limited number of locations (Rosen et al., 2000). Furthermore, the wide detection range, precise data accuracy, and high availability of SAR images offer a novel approach for analyzing surface deformation anywhere on the Earth's surface. Many studies saw the ability of InSAR data, demonstrated the possibility of integration the more traditional geodetic data like GNSS and leveling and InSAR data, and got the convince results (e.g., Wang et al., 2009; Grandin et al., 2012).

Although InSAR data can cover a broader area and provide more information, the abundance of InSAR data may cause the more precise ground-based measurements data to be relatively underweighted. Consequently, the dataset may become dominated by InSAR data. Therefore, Quadtree is a common method used to reduce InSAR data (e.g., Jónsson et al., 2002; Wright et al., 2003; Jiang et al., 2013). This method can capture the statistically significant portion of the signal with far fewer sampling points (Jónsson et al., 2002).



## 2.4 Numeric model

The numerical model stands as one of the most predominant approaches for understanding subsurface phenomena in the fields of geology and geodesy. It provides more accurate prediction of subsurface structure and allows a comprehensive understanding of relationship between the parameters of faults and its movement (Brandes & Tanner, 2014). It is so powerful that applying a numerical model to get the analytic solution about the displacement from faults becomes a standard especially at tectonic plate boundaries (Cohen, 1999). According to Brandes & Tanner (2014), numerical models have been widely applied in the fields of geology and geodesy over the past 30 years and can be categorized into three types: geometrical, kinematic, and dynamic models. Geometrical models utilize the data of geological information to build an environment of the study area. The accuracy of the dataset determines the final resolution (Brandes & Tanner, 2014). Kinematic models consider the orientation of fault plan and slip and use these data to measure in the field at exposures of faults, collect in a somewhat ambiguous form from fault-plane solutions of earthquakes, and specify the deformation magnitude (Marret & Allmendinger, 1990). Dynamic models assume that the slip of faults in the direction of shear stress resolved on the fault plane. The models require the geometrical and kinematic models as input, along with rheological information to assess stress and strains produced by the structures (Marret & Allmendinger, 1990; Brandes & Tanner, 2014).



Among the various numeric models, the dynamic models play a significant role. Geodynamic modeling provides a framework for interrogating geological, geophysical, and geochemical data at all scales, enabling the construction of thoroughly integrated and quantitative models of formation, and can be used to explain high precise geodetic data and get the convinced results (Hobbs et al., 2000; Meade & Loveless, 2009). Plenty studies use it to do the research in the seismic area (e.g., Flück et al., 1997; Connolly, 2009). Therefore, this study will focus on the dynamic model in both two- and three-dimensional models.

### 2.5.1 Two-dimensional model

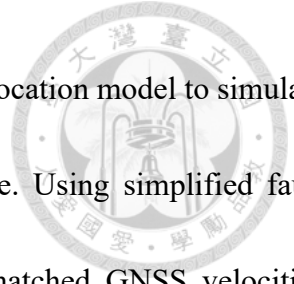
Dislocation theory is a mathematical framework used to study the effects of shear and tensile stresses induced by various fault systems within the assumed elastic half-space (Okada, 1985; Okada, 1992). It is an essential key concept for various dynamic models, allows us to understand the surface displacement, strain, and tilt caused by the stresses, and even become a standard research tool for analyzing surface deformation in orogenic belts (Cohen, 1999).

By analyzing surface displacements, the velocity field of a region, which in turn helps us infer the forces acting on faults beneath the Earth's surface, can be calculated. This information is used to determine fault geometries, estimate fault slip rates, or predict surface displacements resulting from



known fault geometries and subsurface locations. It plays a crucial role in seismic hazard assessment (Okada, 1985; Matsu'ura et al, 1986; Okada, 1992).

Matsu'ura et al. (1986) employed surface geodetic data in Hollister, California, in conjunction with the two-dimensional buried dislocation model to invert for interseismic slip rates, achieving a successful match with geological data. Bilham et al. (1997), in the Himalayan region, used the Two-dimensional buried dislocation model to match GPS and leveling data, calculating the long-term slip rates of faults. Gahalaut & Chander (1997) applied the two-dimensional buried dislocation model, along with an analysis of different fault rupture scenarios, to estimate possible fault slip rates. Vergne et al. (2001), aiming to compare the performance of different two-dimensional models, selected three models from two major categories (2-D finite element model and 2-D dislocation model). They used the Main Himalayan Thrust in the Himalayan region as the benchmark study area. The first model was relatively complex, considering the rheology of the earth's crust and mantle, the thermal structure of the lithosphere, fault geometry, and surface topography, erosion rate, and sedimentation rate within a 2-D finite element model. The second and third models both applied dislocation theory, but the former incorporated the concept of a seismic cycle model, where the steady-state plate stress equals the sum of stresses during seismic and interseismic periods. This corresponds to a back-slip dislocation model. The latter model used a two-dimensional buried dislocation model established solely based on dislocation theory, and the results indicated that all three models performed



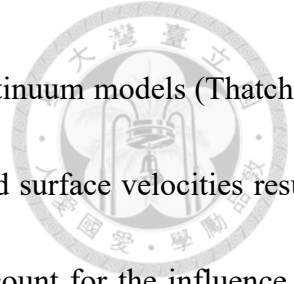
comparably. Hsu et al. (2003) also utilized the two-dimensional buried dislocation model to simulate surface displacements resulting from fault strain in an elastic half-space. Using simplified fault geometry, the two-dimensional buried dislocation model successfully matched GNSS velocities across most of Taiwan.

In conclusion, the two-dimensional dislocation model offers explanatory ability comparable to other two-dimensional models, allowing confirmation of fault geometry, including dip angle, strike, length, etc. This is particularly helpful for faults in the central Taiwan, which still show some uncertainties in geometry. Moreover, it is applicable both domestically and internationally (e.g., Bilham, 1997; Hsu et al., 2003), and yields results as good as other 2-D models (Vergne et al., 2001).

### 2.5.2 Three-dimensional model

Based on the classification by Meade & Loveless (2009), dynamic three-dimensional models can be categorized into four types: Continuum, Microplate, Fault/earthquake cycle, and Block models.

Continuum models: These models utilize spherical interpolation methods or viscous rheology to represent surface velocities. Most models in this category do not consider seismic cycles (Meade & Loveless, 2009). Additionally, research suggests that geodetic velocities are not directly related to secular velocities at depth (Hetland & Hager, 2004).



**Microplate models:** Microplate models are simplified versions of continuum models (Thatcher, 2007). They consider the movement of blocks, assuming that the observed surface velocities result from the rotation of several microplate blocks. However, they do not account for the influence of seismic cycles (Meade & Loveless, 2009).

**Fault/Earthquake cycle models:** These models incorporate seismic cycles and the layered structure of the Earth (Meade & Loveless, 2009). Shallow portions of faults are locked between earthquakes, while deeper sections creeping. Surface deformation accumulates, releasing stress during earthquakes, generating coseismic deformation, and experiencing either long or short-term post-seismic deformation before entering the next cycle (Savage, 1983). For example, Flück et al. (1997) utilized the concept of seismic cycles to establish interseismic models, inferring the impact of coseismic events in the Cascadia subduction zone. Baseline Inversion models also fall into this category. Based on the assumption that surface strain rates result from elastic deformation due to the locked parts of faults, these models infer underground slip rate deficits through changes in baselines, estimating slip rates on faults (Johnson, 2013; 景國恩等, 2018; 莊昀叡等, 2023).

**Block Models:** Block models are common three-dimensional models that combine concepts from microplate and earthquake cycle models. The underlying assumption is that strain caused by block rotation leads to long-term stability. By simulating block movements, long-term velocities for the region can be determined (Johnson, 2013). Many studies build upon this foundation,



incorporating additional factors such as internal strain within blocks (McCaffrey, 2005; Meade & Loveless, 2009) or considering time as a factor to eliminate the influence of transient events for more accurate long-term velocity estimations (McCaffrey, 2005).

Numerous studies demonstrated the complementary relationship between two-dimensional and three-dimensional models. For instance, Flück et al. (1997) developed a three-dimensional dislocation model based on the two-dimensional dislocation model by Hyndman & Wang (1995) for the Cascadia subduction zone, addressing limitations in margin observations. Freymueller et al. (2000) used a two-dimensional dislocation model to determine fault geometry and interplate forces. Building upon this, Zweck et al. (2002) discretized the interpolated plate interface depth model into rectangular tiles to compute surface displacement from stress in an elastic half-space, leading to the development of a three-dimensional dislocation model. Two-dimensional models can confirm fault geometry, calculate fault slip rates, establish geometrical and seismological constraints, serving as the basis for more detailed explanations in complex fault areas within three-dimensional models.



## Chapter 3 Study area

### 3.1 Study area

The study area is illustrated in the Figure 4. In the central Taiwan, there are three primary parallel faults, from east to west: the Tamaopu-Shuangtung fault, the Chelungpu fault, and the Changhua fault. These three faults are a result of westward orogenic movement (Lee et al., 1996). Therefore, while the primary focus of the research is the Changhua fault, discussions should also include the two faults to the east as they are integral to the overall analysis.

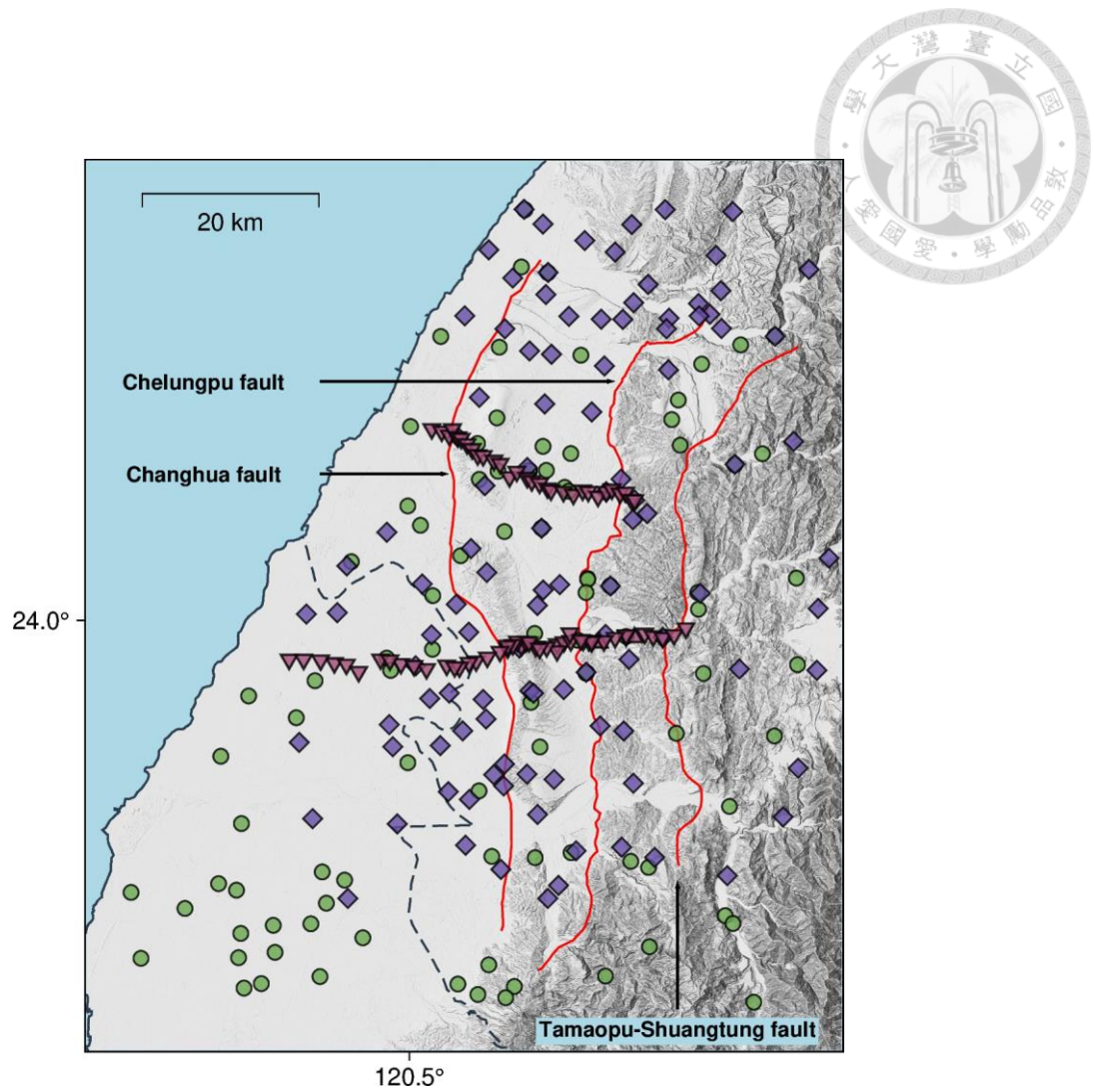


**Figure 4** Study area. Green circles are continuous-mode GPS stations. Purple Quadrilateral are campaign-mode GPS stations. Pink triangles are leveling stations. The red lines represent the faults, with the easternmost being the Tamaopu-Shuangtung fault, followed by the Chelungpu fault, and finally the Changhua fault to the west. Black dash indicates the subsidence area.



## 3.2 The faults in the central Taiwan

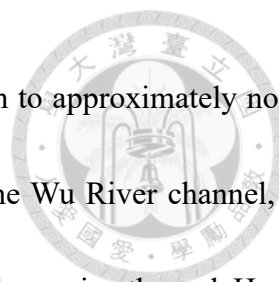
According to the survey from GSMMA (Geological Survey and Mining Management Agency, MOEA) (林啟文等，2021) and Taiwan Earthquake Model (TEM) (Shyu et al., 2016; Shyu et al., 2020), the main structures in this study area are included below.

### 3.2.1 Changhua fault

#### 3.2.1.1 The geological and geodetic setting of the Changhua fault

The Changhua fault referred to in this study corresponds to the Changhua fault within the Taiwan Earthquake Model (TEM) proposed by Shyu et al. (2016; 2020). This fault encompasses the Changhua fault from the active structures published by the Central Geological Survey, as well as its northern extension known as the Tachia fault (林啟文等，2021).

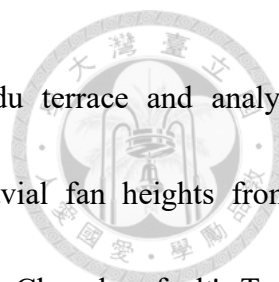
The Changhua fault primarily spans two administrative regions: Taichung City and Changhua County. Taichung City is the second most populous special municipality in Taiwan, while Changhua County is the most populous county. There are over 3,000,000 people in the two administrative district (內政部，2024). The fault runs from north to south, passing through several densely populated settlements. the Changhua fault begins in the north at the Daan River, running in a northeast-southwest direction. It passes to the west of the Tiehchan Anticline, crosses the Dajia River, and continues in a northeast-southwest direction through the western side of the Dadu terrace, reaching



the area around Shalu in the central Taiwan. It then changes its orientation to approximately north-south as it crosses the Wu River into Changhua County. After crossing the Wu River channel, the fault appears on the western side of the Pakua terrace, continuing to the south, passing through Huatan township, where it changes orientation to a northwest-southeast direction. It continues in this direction until reaching Yuanlin city. South of Yuanlin, the fault orientation shifts back to a north-south direction, extending to the south until it reaches the Choushui River.

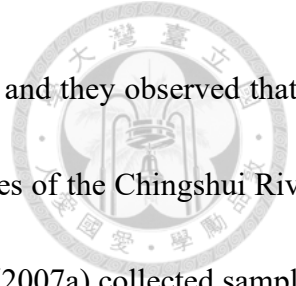
The Dadu and Pakua terrace are the primary topographical features that Changhua fault traverses, and much of the research on the fault begins with investigations in these two areas. Originally, both the Dadu and Pakua terrace were alluvial fans in the Western Foothills Belt. During the Quaternary mountain-building process, as it moved westward, the Tamaopu-Shuangtung, the Chelungpu, and the Changhua fault gradually formed. The Dadu and Pakua alluvial fans were uplifted during this period, creating the folded plateaus. Together with the western foothills, they make up the Taichung basin. The middle section of the plateau on the western side was cut through by the Dadu River, resulting in the current north-south division (Sun, 1965; Lee et al., 1996).

Research on the northern segment of the Changhua fault in Taichung city (referred to as the Tachia fault by the GSMMA) has been relatively less compared to the southern segment. 林朝榮 (1957) was the first to suggest the presence of a fault on the western side of the Dadu terrace based on topography. Shih & Yang (1985) organized relevant research and defined a classification system



for active structures. They conducted field investigations on the Dadu terrace and analyzed topographical features such as triangular facets, fault scarps, and alluvial fan heights from a geomorphological perspective, providing evidence for the existence of the Changhua fault's Tachia segment, previously referred to as the Chinshui fault. Wang et al. (2003) used shallow seismic reflection profiling to confirm that the segment formerly known as the Chinshui fault connects to the north with the Tachia fault and to the south with the Changhua segment. They suggested that this fault is a fault-bend-fold structure and has not ruptured to the surface. 林啟文等 (2008) estimated, based on the position of rock cores, that this segment of the fault is close to the surface or has already reached the ground. 陳文山等 et al. (2008), also using drilling core comparisons, estimated the vertical slip rate of this segment of the fault to be  $3.6 \pm 1.9 \text{ mm yr}^{-1}$ .

The southern section of the Changhua fault was initially inferred to exist based on topographic evidence by Tomita (1932) and 林朝榮 (1957). Chen (1978) identified it as a reverse fault through seismic reflection, noting that the fault cuts through Pliocene-Pleistocene and Miocene strata but did not extend to the surface. Subsequently, Shih & Yang (1985) confirmed the reality of the Changhua fault through investigations on the Pakua terrace. Wang et al. (2003) used shallow seismic reflection profiling and found that the northern part of the Pakua terrace has a gentler dip angle of uplifted strata, while the southern part has a steeper dip angle with more deformation, suggesting it is a fault-bend fold, and also found no surface rupture. Ota et al. (2002) estimated a slip rate of  $6.18 \pm 0.10 \text{ mm yr}^{-1}$ .



<sup>1</sup> for the Changhua fault based on DEM and radiocarbon dating evidence, and they observed that it continues southward, merging with the Chelungpu fault in the upper reaches of the Chingshui River rather than ending at the southern tip of the Pakua anticline. Simoes et al. (2007a) collected samples on-site and used optically stimulated luminescence to date them. They also gathered seismic profiles of the area and ultimately developed a folding model to estimate the shortening rate in that region. 陳文山等 (2008) determined a vertical slip rate of  $7.3 \pm 3.0 \text{ mm yr}^{-1}$  through drilling core comparisons. For the entire Changhua fault, Shyu et al. (2020) conducted field investigations of historical earthquake traces and used empirical formulas to estimate an average slip rate of  $1.77 \text{ mm yr}^{-1}$  for the Changhua fault, with a recurrence interval of 280 to 11960 years.



**Table 1** Geologic fault slip rate of the three faults.

| Source                                | Fault              | Fault slip rate (mm yr <sup>-1</sup> ) |
|---------------------------------------|--------------------|----------------------------------------|
| Ota et al. (2002) <sup>#a #b</sup>    | Changhua           | 6.18 ± 0.10                            |
| Simoès et al. (2007a) <sup>#a#c</sup> |                    | 16.3 ± 4.1                             |
| 陳文山等(2008) <sup>#b</sup>              |                    | North: 3.6 ± 1.9<br>South: 7.3 ± 3.0   |
| Shyu et al. (2020)                    |                    | 1.77 (0.90 - 6.63)                     |
| Shyu et al. (2020)                    | Chelungpu          | 6.94                                   |
| Shyu et al. (2020)                    | Tamaopu-Shuangtung | 1.00 (0.42 - 4.88)                     |

Note:

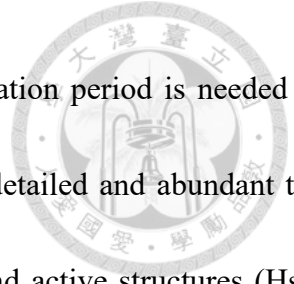
<sup>#a</sup>: Ota et al. (2002) and Simoès et al. (2007a) only analysis the south part of the Changhua fault.

<sup>#b</sup>: Both Ota et al. (2002) and 陳文山等 (2008) only estimated the vertical velocity.

<sup>#c</sup>: The rates from Simoès et al. (2007a) are the shortening rate.

### 3.2.1.2 History earthquakes of the Changhua fault

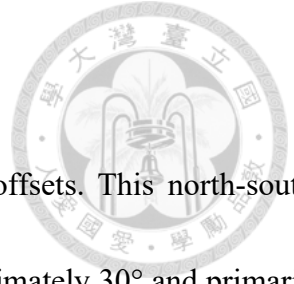
Understanding the historical activity of the Changhua fault and assessing earthquake risk is crucial for developing effective earthquake disaster prevention strategies and preparedness for possible future seismic events. Due to the inherently unpredictable nature of earthquakes, earthquake investigations are filled with uncertainties (Geller et al., 1997). Historical earthquake data can effectively provide insights into the past behavior of active structures and help in predicting future trends. Yet still the seismological observation is negligibly short when compared with the geological



time scale involved in the seismicity of a region. A much longer observation period is needed to permit a meaningful statistical treatment (Ambraseys, 1971). The more detailed and abundant the earthquake data that research involves, the better scientists can understand active structures (Hsu, 1983).

However, Taiwan did not have its first modern seismometer until December 1897. Therefore, earthquakes that occurred before this date could only be inferred from secondary sources such as local records, official correspondence, and other historical documents to estimate the timing of earthquakes and reconstruct important information like earthquake epicenters and magnitudes.

The availability of reliable historical records of earthquakes in Taiwan began during the Qing dynasty period. Based on inference, the most likely fault movement along the Changhua fault since the Qing dynasty occurred in 1848 (Lee et al., 1976; Hsu, 1983; Tsai, 1985; Cheng & Yeh, 1989), with Richter magnitude scale exceeding 6. From this, the conclusions are as follows: First, since the establishment of seismometers, there have been no records of seismic activity along the Changhua fault. Therefore, the last fault movement event may have occurred nearly 180 years ago. Second, the last potential earthquake event had a substantial magnitude, indicating that the Changhua fault has the capability to release a significant amount of energy. In the event of a fault movement, the risk of causing a disaster is high.

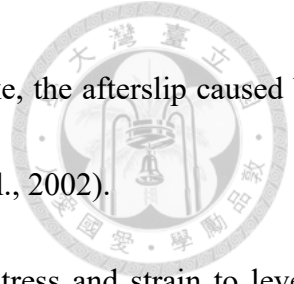


### 3.2.2 Chelungpu fault

The Chelungpu fault is a reverse fault with left-lateral strike-slip offsets. This north-south-trending fault is a 90-km structure that dips shallowly to the east at approximately  $30^\circ$  and primarily slips within and parallel to the bedding of the Pliocene Chinshui Shale (Yue et al., 2005). At its northern end near Fengyuan, it curves toward the northeast and splinters into complex branches (Ma et al., 1999). The fault's slip rate is  $6.94 \text{ mm yr}^{-1}$  with a recurrence interval of 300-1260 years (Shyu et al., 2020).

The last significant earthquake triggered by the Chelungpu fault was the 1999 Chi-Chi earthquake, one of the largest earthquakes in a century with a magnitude of  $M_L$  7.3 or  $M_W$  7.6. This event produced extensive surface ruptures along approximately 85 km of the Chelungpu fault, with displacements ranging from 1 to 8 meters (Ma et al., 1999; Chang et al., 2000).

After the 1999 Chi-Chi earthquake, the central Taiwan inevitably experienced postseismic deformation. The postseismic deformation can be mainly attributed to afterslip, pore-fluid flow, and viscous relaxation of the lower crust and upper mantle. Afterslip is a major cause of postseismic deformation but decays rapidly and occurs on faults surrounding the epicenter (Bürgmann et al., 2002; Tang et al., 2019). Afterslip can be analyzed by fitting GNSS data and incorporating it with a dislocation model to determine the afterslip distribution (e.g., Freed, 2007). Additionally, the afterslip distribution can be used to verify the fault geometry when the subsurface fault geometry remains



unclear (e.g., Hsu et al., 2002). In the case of the 1999 Chi-Chi earthquake, the afterslip caused by the earthquake continued for approximately at least three months (Hsu et al., 2002).

Large earthquakes can induce changes in pore-fluid flow, increasing stress and strain to levels comparable to stress drops on faults (Nur & Booker, 1972). The postseismic deformation resulting from pore-fluid flow can be estimated and constrained using InSAR and GNSS data through relevant models. The entire process of these pore pressure gradients, poro-elastic rebound, results in subsidence within compressional quadrants and uplift in extensional quadrants, which may persist for an extended period (Jónsson et al., 2003).

The viscous relaxation resulting from significant stress and strain changes caused by the earthquake often have long-lasting effects. Tang et al. (2019) estimated effective viscosities using power-law Burgers rheology. The effective time, same as the pore-fluid flow, is measured in years and show a decaying trend. The affected area includes the central Taiwan and potentially the entire island, with most of the activity occurring in the brittle-ductile transition zone.

Although the postseismic deformation has proven difficult to distinguish between these processes (Pollitz et al., 2001; Jónsson et al., 2003), the mostly of postseismic deformation is afterslip and it localizes to the fault zone involved in the mainshock and decays rapidly (Tang et al., 2019).

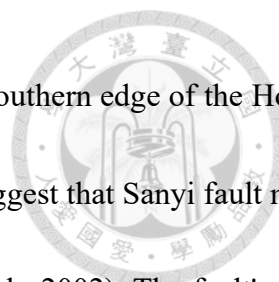


### 3.2.3 Tamaopu-Shuangtung fault

The Tamaopu-Shuangtung fault is a reverse fault, divided into two segments by the Dajia River. The northern segment, known as Tamaopu fault (何春蓀, 1959), trends northeast, extending from Wushikeng in Heping Township, Taichung County, southwest to Qingdong Village in Dongshi Town (Tamaopu). The southern segment, known as Shuangtung fault (大江二郎, 1939), trends roughly north-south, extending from Xinshe Township on the south bank of the Dajia River southward to Lugu Township in Nantou County (林啟文等, 2007). The entire fault extends for approximately 70 km. Its slip rate is  $1.00 \text{ mm yr}^{-1}$ , with a range of 0.42 to  $4.88 \text{ mm yr}^{-1}$ , and its recurrence interval is 200 to 3980 years (Shyu et al., 2020). Following the 1999 Chi-Chi earthquake, evidence indicates that the fault became active again (饒瑞鈞等, 2006).

### 3.2.4 Sanyi fault

The Sanyi fault is a westward-thrusting reverse fault. The southern segment of the fault trends northeast, then transitions to an east-west direction near Sanyi Township. The length is approximately 29.8 km. In the northern segment, between Sanyi and Dahu Township, no evidence has been found of the fault cutting through late Pleistocene strata. However, more evidence exists for the southern segment of Sanyi fault. Fault outcrops have been identified southwest of Shanghu in Sanyi Township



(林啟文等，2008) and along the northern bank of the Dajia River at the southern edge of the Houli Terrace (Shih et al., 1984). Additionally, some drilling and seismic data suggest that Sanyi fault may extend to the Fengyuan and Tanzi District (Tanaka et al., 2002; Wang et al., 2002). The fault's slip rate is  $0.97 \text{ mm yr}^{-1}$ , with a range of  $0.41$  to  $4.61 \text{ mm yr}^{-1}$ , and its recurrence interval is 230 to 5490 years (Shyu et al., 2020).

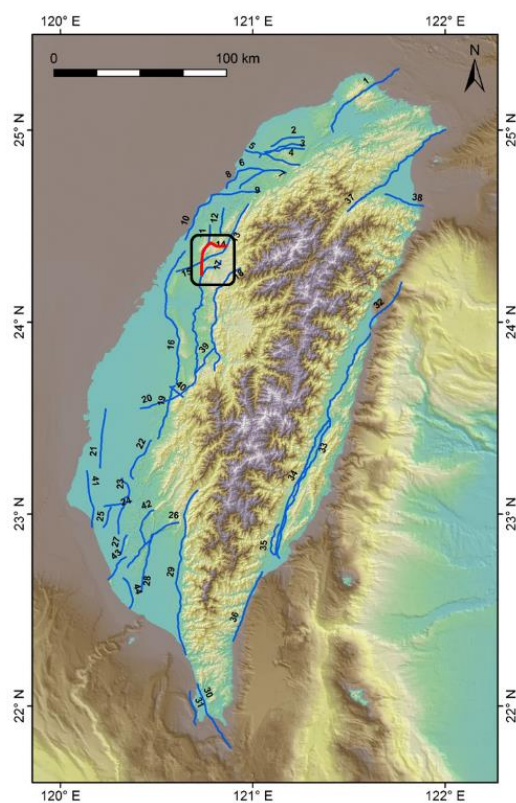


**Figure 5** The Sanyi fault (Shyu et al., 2020)



### 3.2.5 Tuntzuchiao fault

The Tuntzuchiao fault is a right-lateral strike-slip fault trending northeast. This fault caused the Hsinchu-Taichung earthquake in 1935 (Otuka, 1936). According to seismic data from 董倫道等 (2005), the Tuntzuchiao fault shows a compressional flower structure under the surface. Aside from the surface rupture caused by the 1935 earthquake, which cut through the laterite terrace deposits, no evidence of tilting or bending of strata has been observed. This suggests that the fault may have only been active once since the deposition of the laterite terrace (林啟文等, 2008). The fault has a length of 25.1 km. Its slip rate is  $0.47 \text{ mm yr}^{-1}$ , with a range of 0.23 to  $1.67 \text{ mm yr}^{-1}$ , and its recurrence interval is 470 to 4390 years (Shyu et al., 2020).

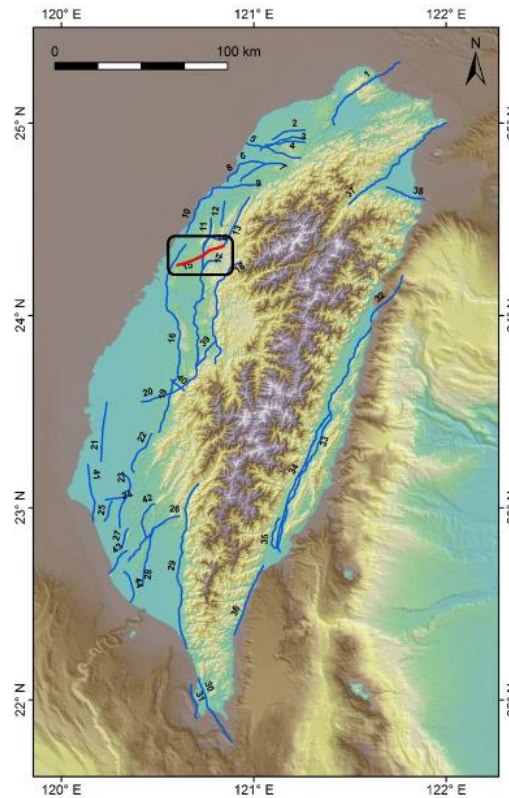


**Figure 6** The Tuntzuchiaio fault (Shyu et al., 2020)

### 3.2.6 Chushiang fault

The Chushiang fault trends roughly northeast, extends approximately 19.8 km in length, and shows both westward thrusting and right-lateral strike-slip. The southwestern end connects with the Chelungpu fault, while the northeastern end links with Shuangtung fault. The Chelungpu fault appears as two splay faults branching onto a common ramp, which further north connects only to the Chelungpu surface trace. The horizontal shortening rate is  $2.9 \pm 1.6 \text{ mm yr}^{-1}$  (Simoes et al., 2007b). Its slip rate is  $2.90 \text{ mm yr}^{-1}$ , with a range of 1.30 to  $4.50 \text{ mm yr}^{-1}$ , and its recurrence interval is 60 to 520 years (Shyu et al., 2020)

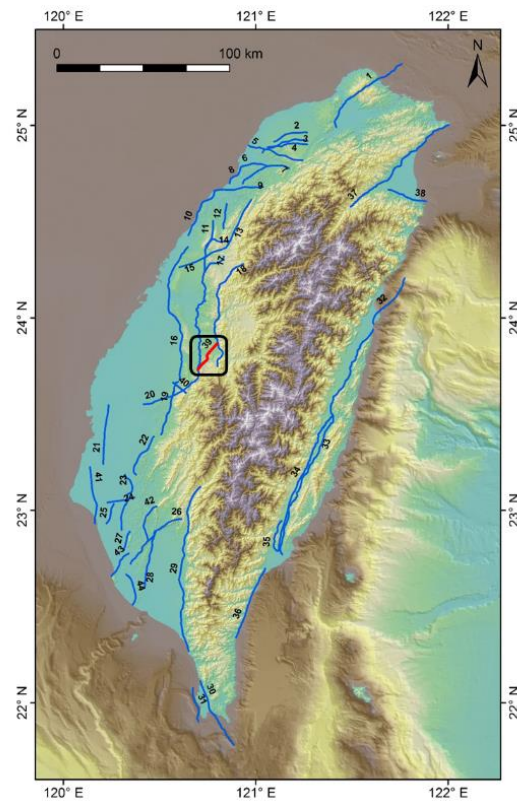
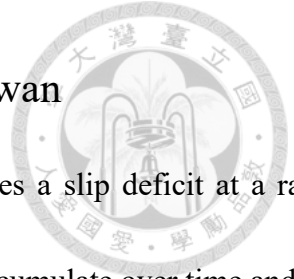


**Figure 7** The Chushiang fault (Shyu et al., 2020)



### 3.3 Geodetic slip deficit rates of faults in the central Taiwan

The seismogenic zone, situated above the locking depth, accumulates a slip deficit at a rate matching that of the deeper, freely slipping fault and the slip deficit will accumulate over time and is expected to be recovered in future earthquakes (Murray et al., 2014). Geodetic data has been essential for monitoring faults and the potential hazards. Utilizing geodetic data with numerical models can efficiently yield effective fault slip deficit rates (e.g., Johnson, 2013). In the central Taiwan, there are related studies on fault monitoring. Chang et al. (2016) apply DEFNODE model, which is one of block models, to get the slip deficit rates on faults. The dataset he used was only included GNSS data. The detailed slip deficit rates on faults are showed in Table 2. 景國恩等(2020) also use DEFNODE and Baseline Inversion model with GNSS data to estimate the slip deficit rates of the faults. Compared to the block model, the Baseline Inversion model can simultaneously consider horizontal, vertical, and InSAR line-of-sight velocities for inversion (Johnson, 2013; 景國恩等, 2018; 莊昀叡等, 2023).

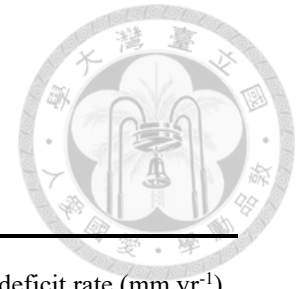


**Table 2** Geodetic fault slip deficit rate of the faults.

| Source              | Method             | Fault              | Slip deficit rate (mm yr <sup>-1</sup> ) |
|---------------------|--------------------|--------------------|------------------------------------------|
| Chang et al. (2016) | DEFNODE            | Changhua           | 0.5 ± 0.4                                |
| 景國恩等 (2020)         | DEFNODE            |                    | North: 1.3 ± 1.6                         |
|                     |                    |                    | South: 4.3 ± 5.7                         |
| 景國恩等 (2020)         | Baseline Inversion |                    | 1.7 ± 0.8                                |
|                     |                    |                    | 3.0 ± 1.4                                |
| Chang et al. (2016) | DEFNODE            | Chelungpu          | 2.3 ± 0.6                                |
| 景國恩等 (2020)         | DEFNODE            |                    | 2.4 ± 3.6                                |
| 景國恩等 (2020)         | Baseline Inversion |                    | 6.7 ± 2.0                                |
| Chang et al. (2016) | DEFNODE            | Tamaopu-Shuangtung | 1.4 ± 0.6                                |
| 景國恩等 (2020)         | DEFNODE            |                    | 1.2 ± 1.6                                |
| 景國恩等 (2020)         | Baseline Inversion |                    | 0.5 ± 0.3                                |
| Chang et al. (2016) | DEFNODE            | Sanyi              | 4.2 ± 0.8                                |
| 景國恩等 (2020)         | DEFNODE            |                    | 5.7 ± 3.3                                |
| 景國恩等 (2020)         | Baseline Inversion |                    | 3.0 ± 1.0                                |
| Chang et al. (2016) | DEFNODE            | Tuntzuchiaio       | 1.2 ± 0.8                                |
| 景國恩等 (2020)         | DEFNODE            |                    | 1.4 ± 1.6                                |
| 景國恩等 (2020)         | Baseline Inversion |                    | 1.2 ± 0.9                                |



### 3.4 The geometry of faults

According to Johnson & Segall (2004), there is an inconsistency in the subsurface faults geometry during the 1999 Chi-Chi earthquake and the inconsistency can be attributed to the ongoing controversy between "thick-skinned" and "thin-skinned" tectonics in Taiwan. Suppe is the pioneer of thin-skinned and fold-bend fold models. He applied the thin-skinned theory in Taiwan through the incorporation of shallow borehole and exploration seismic data (Suppe et al, 1987). The cross-sectional profile of the central Taiwan he proposed indicated that the dip of the fault is about  $30^\circ$ , and the detachment is shallow, not extending beyond 10 km. In contrast, thick-skinned model faults extend below 10 km in depth and lack a major detachment above which deformation is concentrated (Wu et al., 1997).

Many studies have proposed their models, and although there are many differences among them, the results consistently indicate the presence of a detachment that does not extend below 10 km, based on independent evidence (e.g., Hsu et al., 2002; Johnson & Segall, 2004). Thin-skinned tectonics may be the consensus for the central Taiwan, but the depths of the detachments remain controversial. One argument is that the detachment remains shallow, at about 5 km. In this view, the Chelungpu fault and the Taiwan Main detachment are active in parallel and may function as duplex faults linking the parallel detachment (Yue et al., 2005). The other argument posits that the Chelungpu fault rupture



extends directly from the surface down to the depth of the 1999 Chi-Chi earthquake mainshock hypocenter (Wang et al., 2000).

Additionally, the Changhua fault is a buried fault, so how it connects with other faults in the study area has been a topic of ongoing debate within the scientific community. There is general consensus that the detachment extends from east to west, progressively branching into the Tamaopu-Shuangtung fault, the Chelungpu fault, and the Changhua fault. However, there is disagreement on how the Changhua fault connects with the detachment. The main differences stem from various interpretations of the imbrications and kinematic development of faults in the central Taiwan. These interpretations can be summarized into three main scenarios of fault geometric connections.

The first geometry scenario, as shown in Figure 8, shows the detachment sequentially branched into the Tamaopu-Shuangtung fault, the Chelungpu fault, and the Changhua fault as it moves westward with the orogenic process.





The third geometry scenario, as shown in Figure 10, shows the detachment branched into the Changhua fault and then continuing to extend westward at its original depth at a low angle.

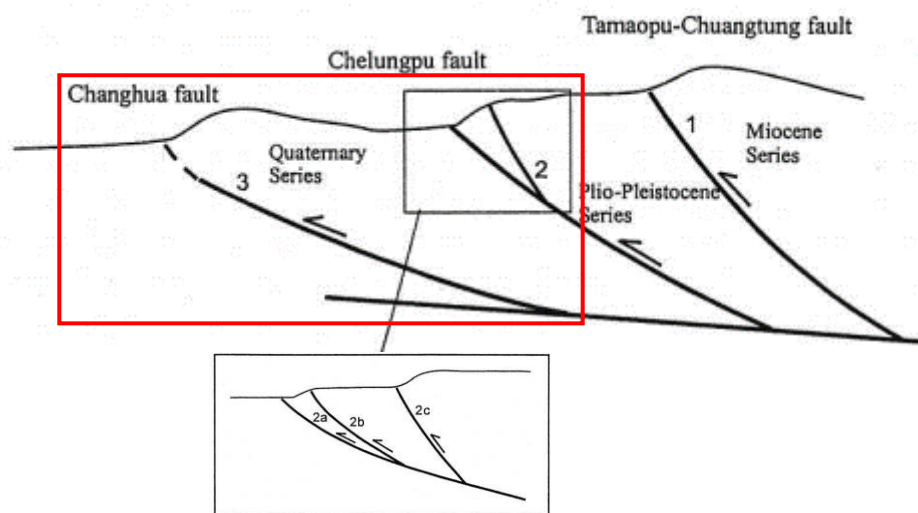


**Figure 10** The third geometry scenario of faults connection in the central Taiwan (Lin et al., 2002).



## Chapter 4 Data and methods

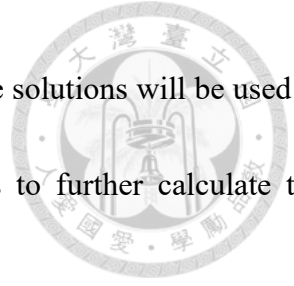
### 4.1 Study data

#### 4.1.1 GNSS

The research will utilize GNSS data, leveling measurements, and SAR (Synthetic Aperture Radar) imagery.

The GNSS data in this study were collected from continuous-mode GPS stations and campaign-mode GPS stations. There are a total of 71 continuous-mode stations with a time span ranging from 1999 to 2023, although the duration varies slightly for each station. The stations are built by different agencies, including GSMMA, CWA (Central Weather Administration), NLSC (National Land Surveying and Mapping Center), WRA (Water Resources Agency), and IES (Institute of Earth Sciences). The data from these stations are sourced from 莊昀叡等 (2023). Additionally, there are 115 campaign-mode GPS stations with data available from 2002 to 2023, also with slight variations in the time coverage for individual stations. The stations are built by GSMMA. The data from these stations are also sourced from 莊昀叡等 (2023).

莊昀叡等 (2023) used GipsyX from JPL (The Jet Propulsion Laboratory) to derive daily solutions from continuous-mode GPS stations. The workflow includes data preprocessing, orbit calculation, and parameter estimation. The results will encompass station coordinates and precision estimates derived from phase or pseudorange observation data. For campaign-mode GPS, data will



also be processed using GipsyX. Residuals and the root mean square of the solutions will be used to check for any potential impacts. This study will utilize these solutions to further calculate the velocities.

#### 4.1.2 Leveling

The leveling survey were conducted by GSMMA. The leveling data for this study were sourced from 莊昀叡等 (2023). Two leveling routes were selected within the research area, one in the north and one in the south. The northern leveling route consisted of a total of 30 stations, covering a time span of 19 years, with measurements taken from 2004 to 2022. The southern leveling route included 49 stations, spanning 22 years from 2002 to 2023. Both leveling routes had their data regularly updated annually, providing a comprehensive dataset for the study. This study will also utilize these solutions to further calculate the velocities.

#### 4.1.3 SAR

Since 2016, the European Space Agency has been implementing the Copernicus Programme, launching the Sentinel-1 satellites. These satellites provide observation images as frequently as every



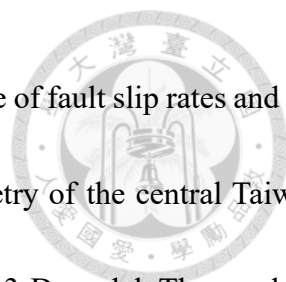
six days, significantly improving temporal resolution. Furthermore, these images are freely available to the public, ensuring high accessibility to the data (Source: <https://www.esa.int/>). The SAR images are sourced from the Alaska Satellite Facility (Source: <https://asf.alaska.edu/>) and will cover the period from 2016 to 2022 in the central region of Taiwan.

This study will not process SAR images or generate InSAR velocities. Instead, it will use the InSAR velocity field of southwest Taiwan from Lee (2024, unpublished).

## 4.2 Methods

### 4.2.1 Research workflow

To answer the research questions, the research framework was designed as shown in Figure 11. The research workflow involves several key steps. First, ground-based measurements, including GPS and leveling data, will be processed and fitted to generate the velocity data in the study area. Next, Sentinel-1 images will be conducted by ISCE (Interferometric synthetic aperture radar Scientific Computing Environment) and MintPy (Miami INsar Time-series software in PYthon) to create multi-temporal InSAR and then obtain surface velocity of the central Taiwan. The obtained surface velocity from InSAR will be combined with the ground-based measurement data. Following this, a two-dimensional dislocation model is constructed. The 2-D model is used to check the depth of the



detachment and obtain preliminary results, including the order of magnitude of fault slip rates and the range of fault locked. Once completed, the previous studies on the geometry of the central Taiwan will be summarized into three scenarios, which will then be applied to the 3-D model. The geodetic and InSAR multi-temporal data are then applied to the 3-D model to figure out the slip deficit rates and their distribution of the three faults and then use the rates to calculate the moment magnitude. and then infer the moment magnitude. Finally, the seismic potential will be assessed through these slip deficit rates and the moment magnitude.

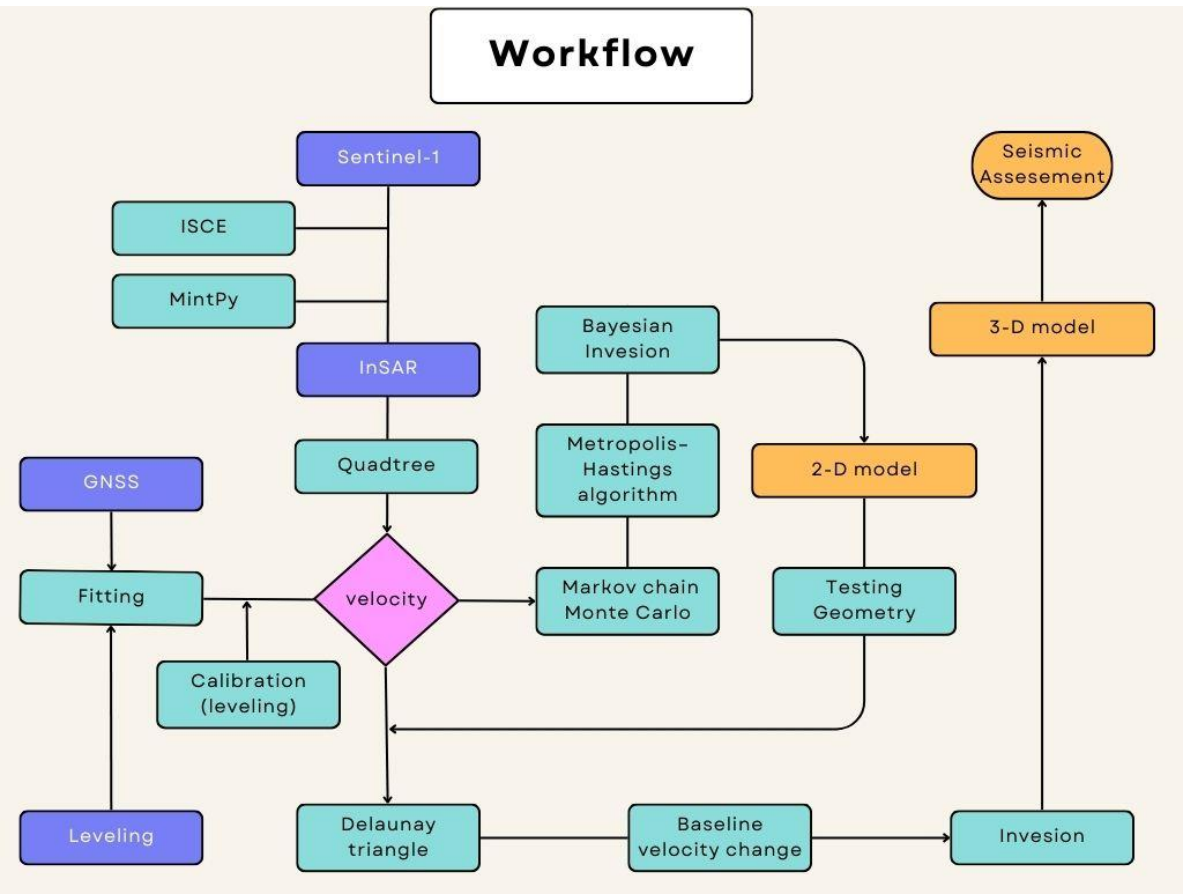


**Figure 11** The workflow of this study.



#### 4.2.2 Process GNSS and leveling data

Considering factors such as terrain and accessibility, it is often challenging to obtain subsurface geological data in regions within orogenic belts. Therefore, some studies of deformation front have shifted towards the use of geodetic tools (e.g., Bilham et al., 1997; Feldl & Bilham, 2006). These tools, such as GNSS and leveling, allow researchers to infer what is happening beneath the Earth's surface based on information collected at the surface. The GNSS demonstrate the feasibility of making precise measurements suitable for large-scale geodetic applications (Nikolaidis, 2002). The inherent precision of leveling also shows its utility as a geodetic measurement system for over a century (Vanicek et al., 1980). Thus, geodetic tools can be considered a crucial component in the study of deformation fronts and the entire orogenic belt.

However, GPS data cannot be used directly. The raw GPS time series reflects various periodic effects and singular events on the stations. For example, Bawden et al. (2001) found that due to underwater and oil pumping, there is a seasonal oscillation of 55 mm in the vertical direction and 7 mm in the horizontal direction between summer and winter. Additionally, earthquakes can result in sudden coseismic uplift, which is not relevant when calculating interseismic slip rates, which require long-term rates (Nikolaidis, 2002). Therefore, a fitting process is necessary to extract these long-term



rates, filtering out the disturbances mentioned earlier which are beyond the scope of discussion. This study will apply the formula by Nikolaidis (2002):

$$y(t_i) = a + bt_i + c \sin(2\pi t_i) + d \cos(2\pi t_i) + e \sin(4\pi t_i) + f \cos(4\pi t_i) + \sum_{i=1}^{N_s} S_i H(t_i - t_1) + p_1 \ln \left(1 + \frac{t_i - t_2}{p_2}\right) \quad (1)$$

Here  $y(t_i)$  is the position at the time  $t_i$ .  $a$  is the site position and  $b$  is the secular velocity.  $c, d, e, f$  are the coefficient of semi-annual and annual periodic motions.  $S_j$  is the amount of coseismic displacement and  $H$  is the Heaviside step function.  $p$  is the characteristic time to define the decay of logarithmic postseismic deformation.  $p_1$  is the coefficient of logarithmic postseismic deformation.  $p_2$  are the empirical time constants for the exponential decay.

Given the observation data vector  $d$ , the relationship between the observations and the model parameters is

$$Gm = d \quad (2)$$

Here the observation data is vector  $d$  with  $m$  observations,  $m$  is a vector of  $n$  model parameters, and  $G$  is a function. Then using least squares solution to determine the optimal  $m$

$$\min \sum_{i=1}^m \frac{(d_i - (Gm)_i)^2}{\sigma_i^2} \quad (3)$$

Here  $\sigma_i^2$  represents the standard deviation of the observation  $d_i$ . Hence,  $m$  will be like equation below

$$m = (G^T G)^{-1} G^T d \quad (4)$$



Additionally, use the following equation to determine the fit error, so the standard deviation will be the square root of the variation

$$Cov(m) = \sigma^2(G^T G)^{-1} \quad (5)$$

Vertical velocity data from leveling also require fitting to obtain the vertical velocities at each station. GSMMA leveling data typically use one station along each leveling route as the reference point, and all subsequent measurements are relative to this station. This means that the vertical velocity of the reference station is usually unknown but can potentially differ in direction from other stations, resulting in discrepancies between the fitted velocities and reality. To obtain non-relative velocities, external data is needed for correction. This study used GPS vertical velocity data for calibration. The method involves finding the closest corresponding GPS stations to the leveling stations and shifting the vertical velocity of the leveling station to match that of the GPS station. The same shift is applied to other stations, resulting in calibrated vertical velocities (Table 3).

The southwest of the study area suffers from severe subsidence due to agricultural and fish farming activities. It is obvious that this subsidence does not result from tectonic activities, so the GNSS data in these subsidence areas should be removed. The definition of the subsidence area will follow the contour map of cumulative subsidence in Changhua and Yunlin from 1992 to 2022. The resource comes from the Water Resources Agency, MOEA.



**Table 3** Leveling calibration reference station.

| Leveling route | Benchmark station of leveling | Benchmark station of GNSS | Distance between stations (m) |
|----------------|-------------------------------|---------------------------|-------------------------------|
| 11             | G926                          | G926 (Campaign)           | 5.4                           |
| 16 & 17        | B280                          | GS83 (Continuous)         | 5.2                           |

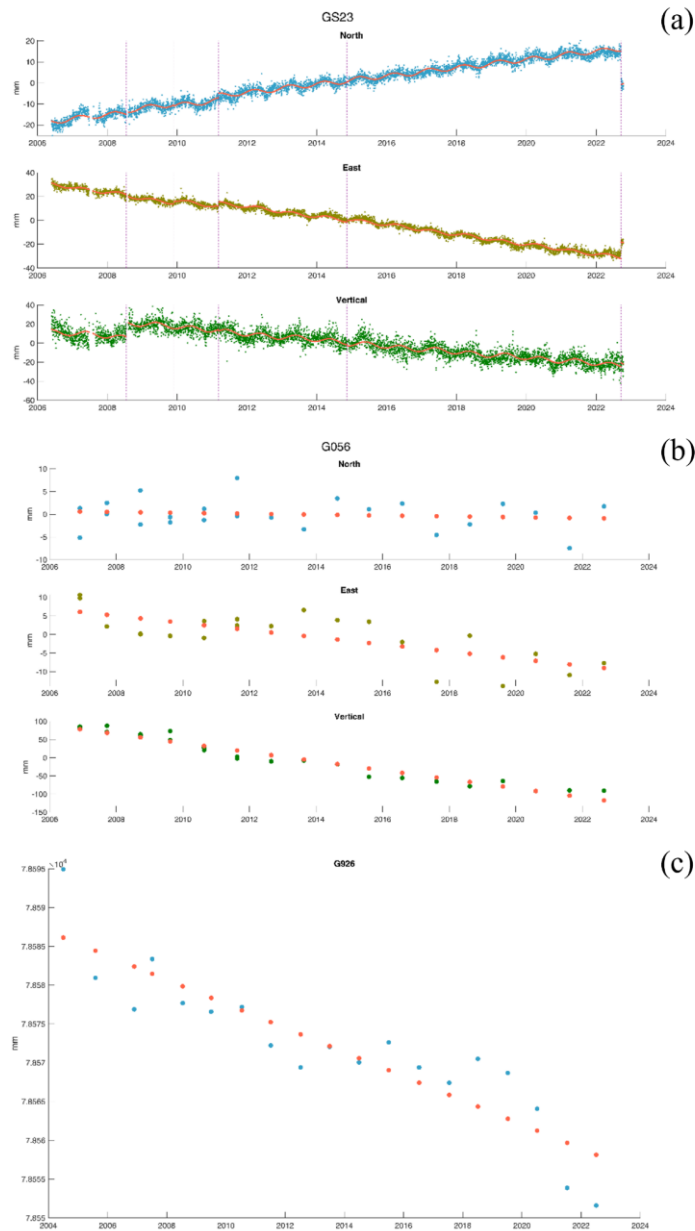


**Figure 12** Examples of GPS and leveling time series fitting. (a) Continuous-mode GPS station GS23. (b) Campaign-mode GPS station G056. (b) leveling station G926.

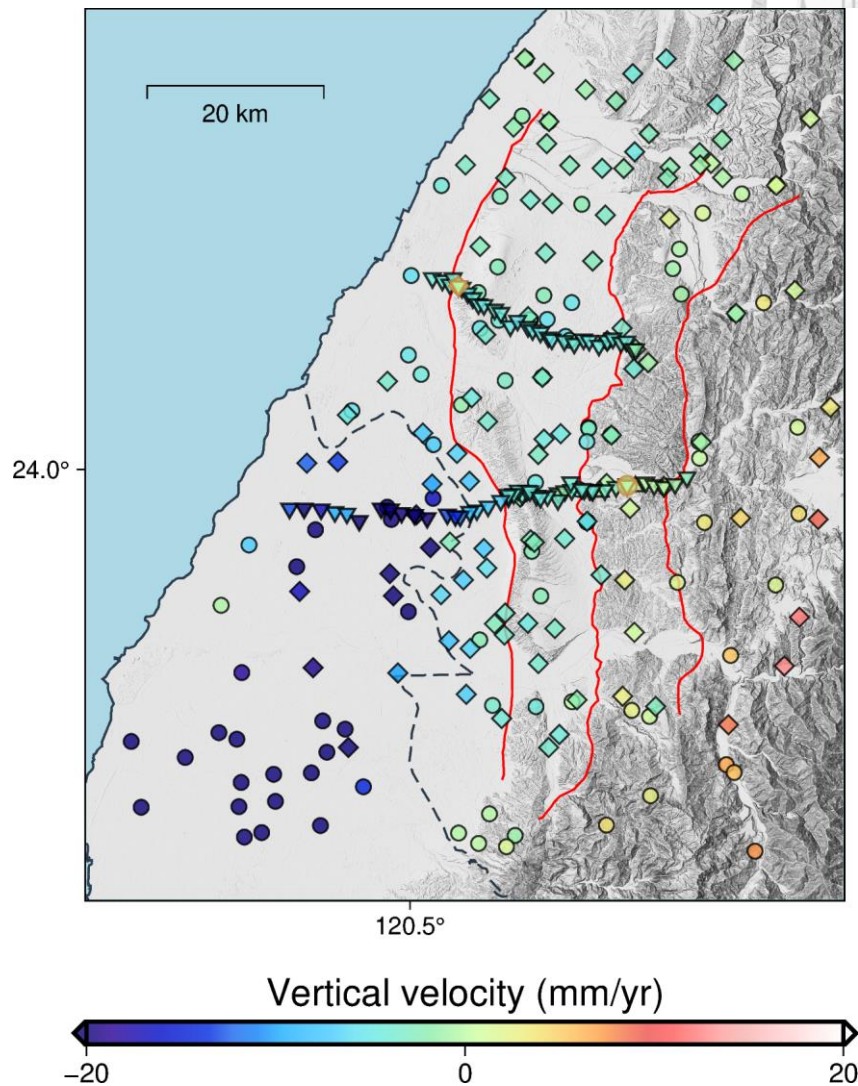


**Figure 13** The vertical secular velocity in the central region. Triangles represent leveling data, squares denote campaign-mode GPS stations, and circles indicate continuous-mode GPS stations. The orange outline signifies benchmark points for leveling data calibration. Both GPS and leveling measurement data in the figure have been fitting as secular velocity. Additionally, leveling measurement data have been corrected using information from GPS stations. Black dash indicates subsidence area.

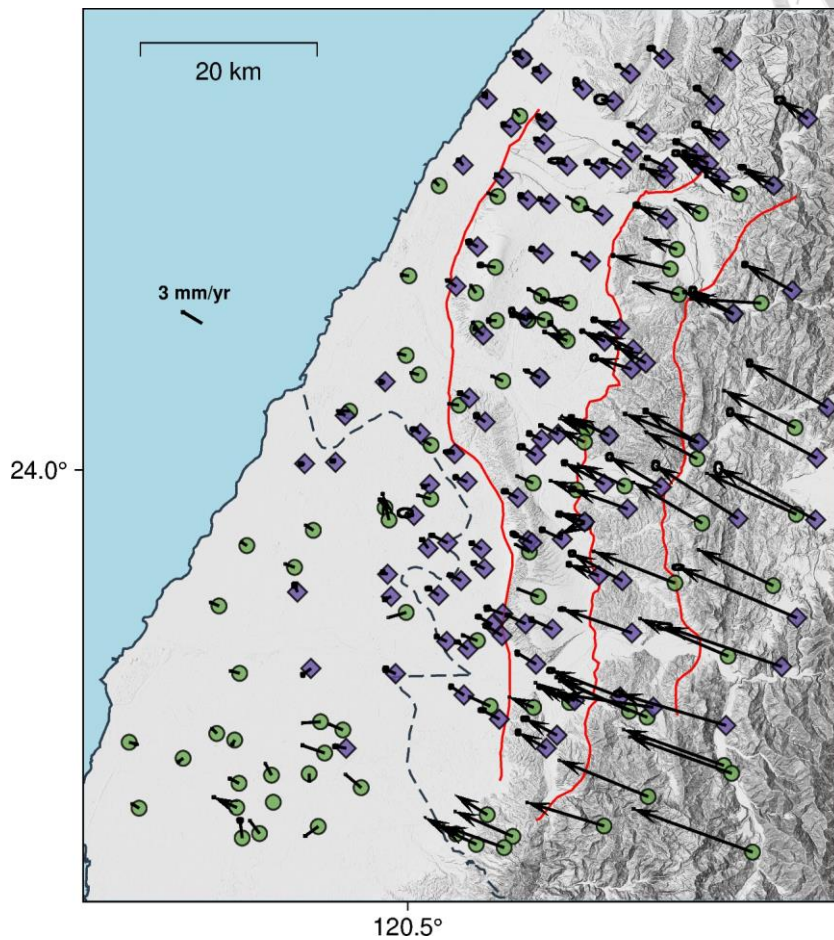


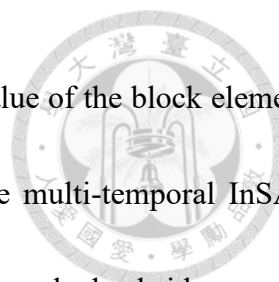
**Figure 14** The horizontal secular velocity in the central region. Green circles represent continuous-mode GPS data. Black arrows indicate continuous-mode GPS horizontal secular velocity direction. Purple Quadrilaterals represent campaign-mode GPS data. Black arrows indicate campaign-mode GPS horizontal secular velocity direction. Black dash indicates subsidence area.



#### 4.2.3 InSAR time series and velocity

The InSAR data are compiled from Lee (2024, unpublsh). After preprocess the SAR images by using ISCE (Rosen et al., 2012), Lee utilizes MintPy as the main tool for processing InSAR multitemporal data. MintPy employs SBAS as the network of interferograms to process multitemporal interferometry data. Compared to multi-temporal InSAR approaches with permanent scatters, which works perfectly in urban areas with abundant buildings and concrete structures, SBAS demonstrates its powerful ability in rural areas with less man-made structures (Hooper et al., 2012; Osmanoglu et al., 2016). It can provide precise and reliable results with InSAR and has shown its advantages over other open-source InSAR workflows and software (Yunjun et al., 2019).

InSAR data can provide broad yet precise information on surface deformation. Both the 2-D and 3-D models will incorporate line-of-sight InSAR data. Additionally, the data from the identified subsidence areas will be removed to ensure that the overall InSAR data is not affected by subsidence trends unrelated to tectonic activity. However, if all the InSAR data points are incorporated into the model used in this study, the overwhelming number of InSAR data points could result in the more precise but fewer GNSS points being weighed less. The entire output will be shown as an input of InSAR data only. In this study, the minimum sampling window was  $32 \times 32$  pixels. The threshold



value of the maximum value of the block elements minus the minimum value of the block elements is set to  $0.8 \text{ mm yr}^{-1}$ . A total of 634 observations are obtained from the multi-temporal InSAR. Considering the impact of the subsidence area, this study will remove the marked subsidence areas from the analysis. After removal, there will be a total 171 observations.

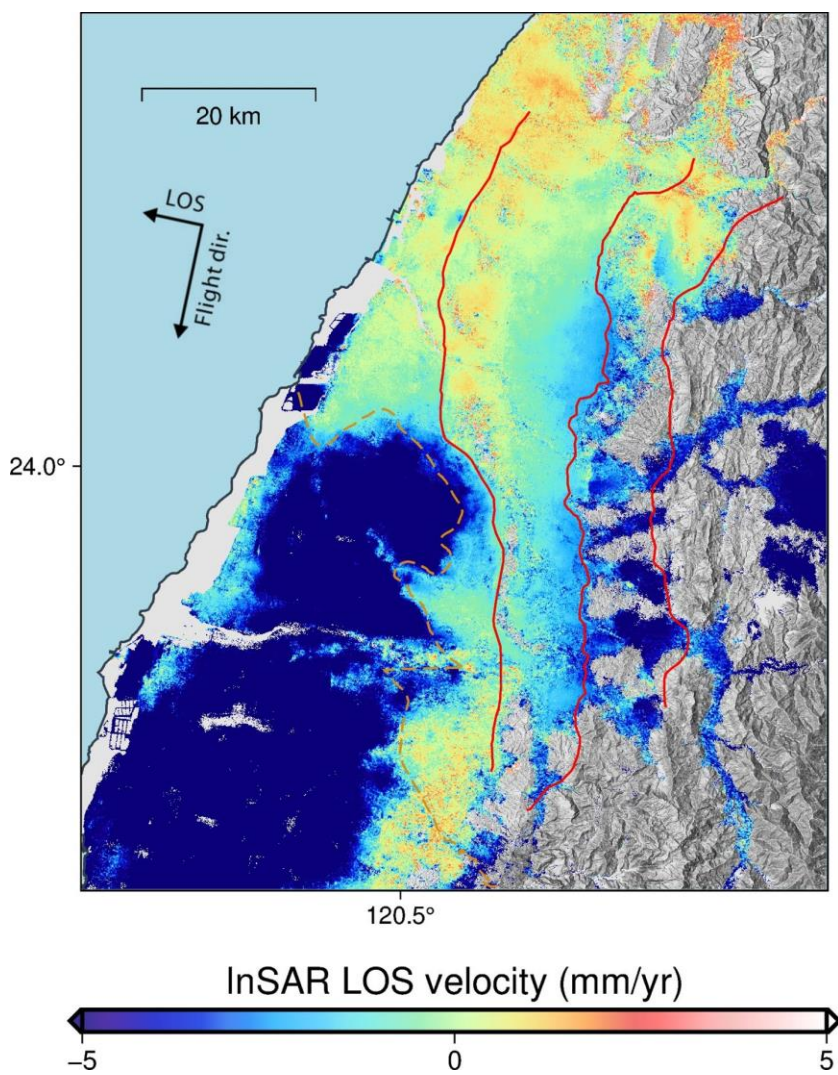


**Figure 15** Sentinel-1 InSAR Line-of-sight (LOS) velocity (Lee, 2024, unpublished). Dashed line denotes the subsidence area.

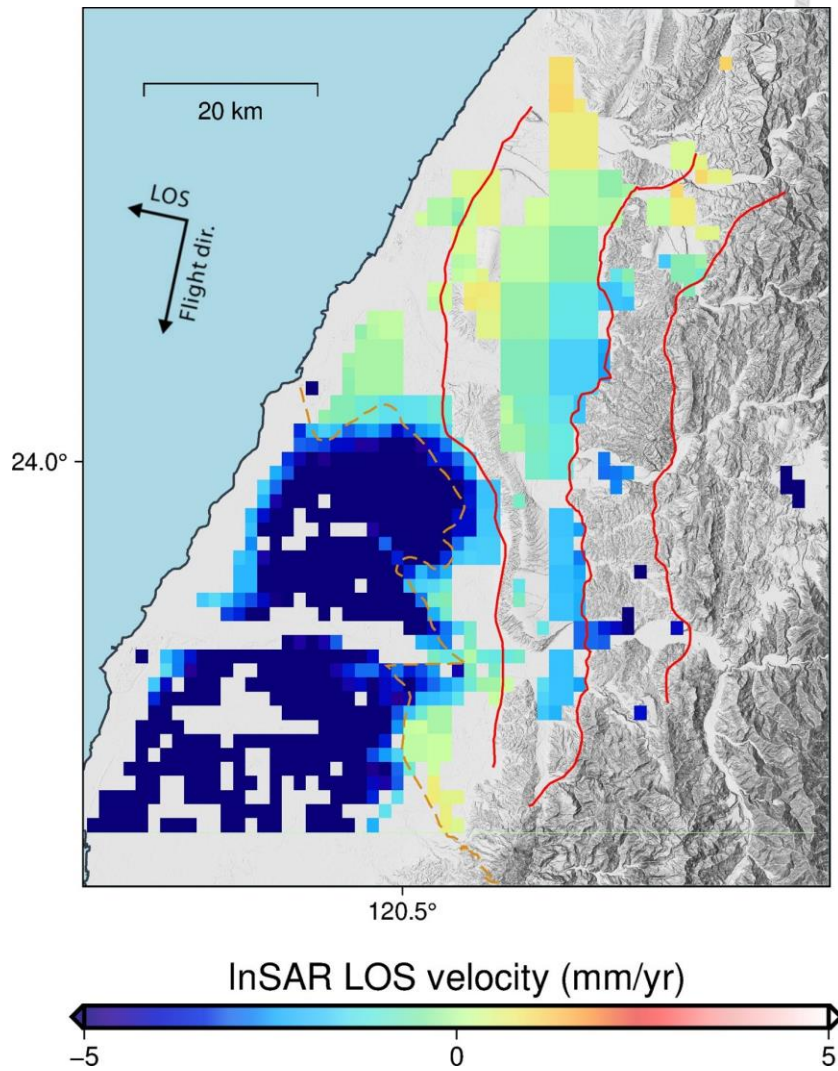


**Figure 16** The quadtree result for Sentinel-1 InSAR LOS velocity. Dashed line denotes the subsidence area.

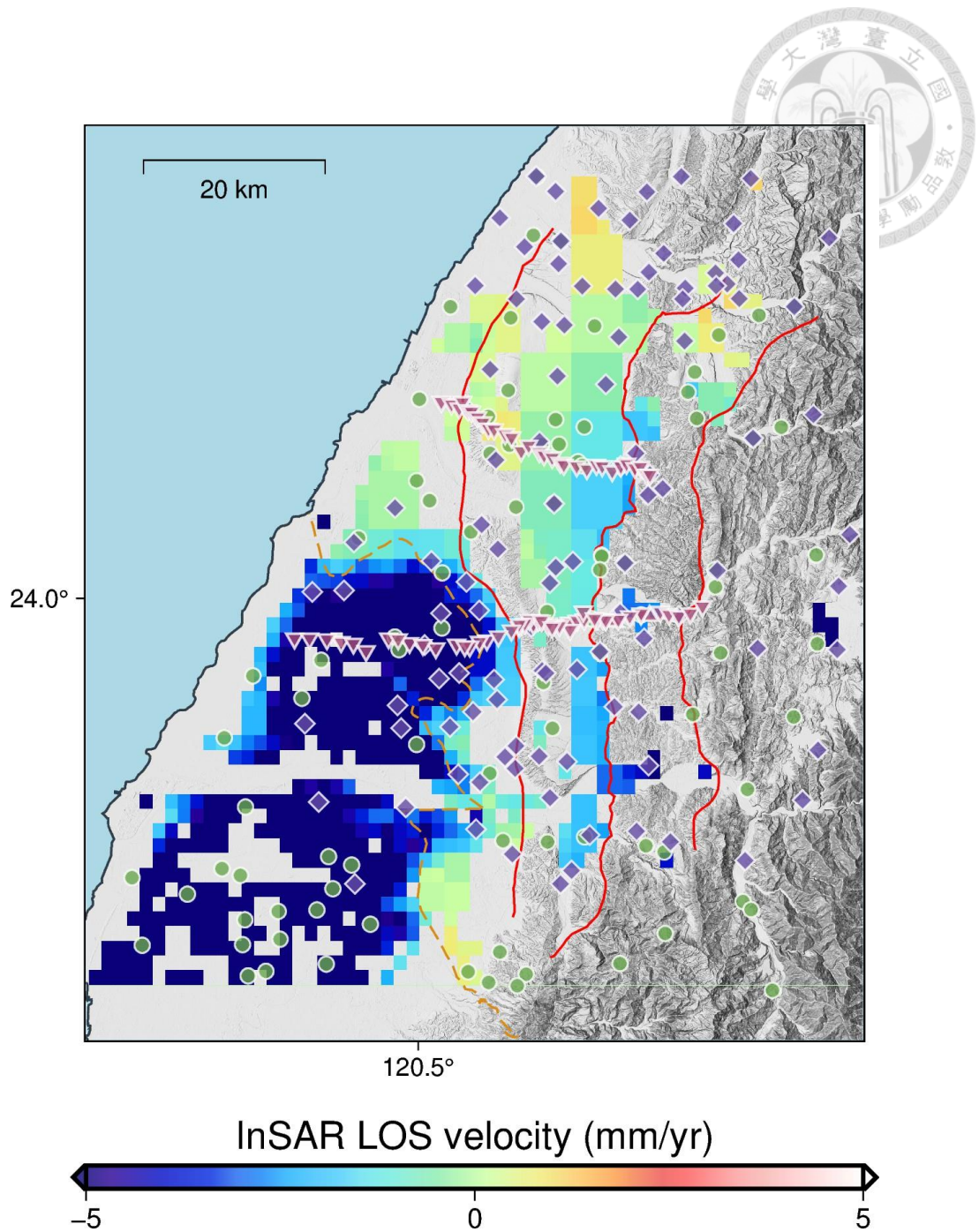


**Figure 17** The quadtree result for Sentinel-1 InSAR LOS velocity with GNSS and leveling points. Dashed line denotes the subsidence area. Triangles represent leveling data, squares denote campaign-mode GPS stations, and circles indicate continuous-mode GPS stations.



**Table 4** Information about the SAR images used in the study.

| Date      | Satellite  | Band | Wave length | Resolution | Orbit      |
|-----------|------------|------|-------------|------------|------------|
| 2014-2023 | Sentinel-1 | C    | 5.54 (cm)   | 5*20 (m)   | Descending |

**Table 5** Information of dataset.

| Data set                | Continuous GPS | Campaign GPS | Leveling | InSAR              | Total              |
|-------------------------|----------------|--------------|----------|--------------------|--------------------|
| The amount of data      | 94             | 107          | 72       | $3.49 \times 10^4$ | $3.52 \times 10^4$ |
| The amount of used data | 68             | 95           | 61       | 171                | 395                |
| Weight (%)              | 17             | 24           | 15       | 43                 | 100                |



#### 4.2.4 Modelling the faults in the central Taiwan

After reviewing the articles of Taiwan orogenic activity in Taiwan and the active faults in the central Taiwan, it is clear that the Changhua, the Chelungpu, and the Tamaopu-Shuangtung faults are the primary products of orogenic activity in the central Taiwan. The propagation of Penglai Orogen since the late Middle Miocene is toward northwest (Teng, 1990) and the Changhua fault is the at the forefront of the deformation front in the central Taiwan. Therefore, it would be more reasonable to include the other two main faults, the Chelungpu and the Tamaopu-Shuangtung, which formed prior to the Changhua fault, in this study to facilitate a comprehensive discussion of the orogenic belt in the central Taiwan. Moreover, the models need a certain level of simplification from the actual conditions, only the Changhua, the Chelungpu, and the Tamaopu-Shuangtung fault are included in the model for discussion.

##### 4.2.4.1 Two-dimensional dislocation model

The main purpose of operating the 2-D model, in addition to testing the depth of the detachment, is to preliminarily determine the order of magnitude of fault slip rates and the distribution of slip rates and ensure that subsequent discussions move in the right direction.

This study adopts the 2-D model proposed by Ching et al. (2016). Ching et al. (2016) assume that the fault geometry consists of a décollement and several branched faults, following the model by



Johnson et al. (2005). The slip rate on the décollement is the sum of the slip rates on all the branched faults, and the detachment is assumed to be creeping. Consider the probability that the fault may be locked, this model also assumes that the slip rate on the segment shallower than the locking depth is zero. Additionally, to enhance computational efficiency and substantially reduce time costs due to the model involving numerous parameters and sequential trials, the model introduces the Metropolis–Hastings algorithm of Markov chain Monte Carlo methods, which belongs to Bayesian inversion (Fukuda & Johnson, 2008; Ching et al., 2016). Starting from initial parameters, the model randomly selects parameters and calculates their posterior probabilities to determine the direction of the algorithm.

Also, based on the assumptions of the 2D model, if the fault branches are put into the 2D model, they are set to creep. If the fault branches are not in the 2D model, they are set to be locked. To determine which parts of the fault branches are locked, this study will sequentially remove fault branches and test all possible combinations of geometries to find the optimal combination for the 2-D model.

Due to the debate about the depth of detachment in the central Taiwan and its connection to the Chelungpu fault, this study will initially examine south cross-sections to test two scenarios: one where the detachment is at a shallow depth of about 5 km, and the other where the detachment extends



deeper to about 10 km. This will determine whether the lower or upper detachment scenario is more appropriate and then apply it to the northern profile.

Then considering the north-south differences in fault geometry, two cross-sections are established within the study area, and the geodetic data are divided into northern and southern groups for separate calculations. The initial fault geometry, parameters, slip rates, and fault rake are listed in the Table 6 below. The initial fault geometry inputs are based on Chang et al. (2000), Yue et al. (2005), and Shyu et al. (2020). The model misfit is defined as follows

$$||d - \hat{d}||_2^2 \quad (6)$$

$$\hat{d} = G * m$$

Here  $d$  is the observation data,  $m$  is a vector of model parameters, and  $G$  is Green's function from Okada (1985).



**Table 6** Initial parameter of 2-D dislocation model. There are geometry differences in the north-south cross-section, resulting in two sets of dip angles. Dip angles and depths of branches within the same fault are separated by slashes.

|                                      | Changhua           | Chelungpu                        | Tamaopu-Shuangtung |
|--------------------------------------|--------------------|----------------------------------|--------------------|
| Slip <sup>#a</sup>                   | 1.77               | 6.94                             | 1                  |
| Rake <sup>#b</sup>                   | 65                 | 65                               | 65                 |
| Depth [South][shallow] <sup>#c</sup> | 1.67 / 3.18 / 4.30 | 0.00 / 2.45 / 3.24 / 5.00        | 0.00 / 2.39 / 5.00 |
| Depth [South][deep] <sup>#c</sup>    | 1.67 / 3.18 / 4.30 | 0.00 / 4.00 / 5.00 / 9.50        | 0.00 / 5.00 / 9.50 |
| Depth [North] <sup>#c</sup>          | 1.67 / 3.16        | 0.00 / 0.55 / 1.68 / 2.60 / 3.16 | 0.00 / 3.72        |
| Dip [South][shallow] <sup>#c</sup>   | 30 / 15            | 50 / 25 / 15                     | 45 / 35            |
| Dip [South][deep] <sup>#c</sup>      | 30 / 15            | 50 / 20 / 50                     | 45 / 35            |
| Dip [North] <sup>#c #d</sup>         | 60                 | 45 / 40 / 25 / 15                | 45                 |

Note: #a: Shyu et al. (2020); #b: Chang et al. (2000); #c: Yue et al. (2005); #d: 黃旭燦等 (2004)

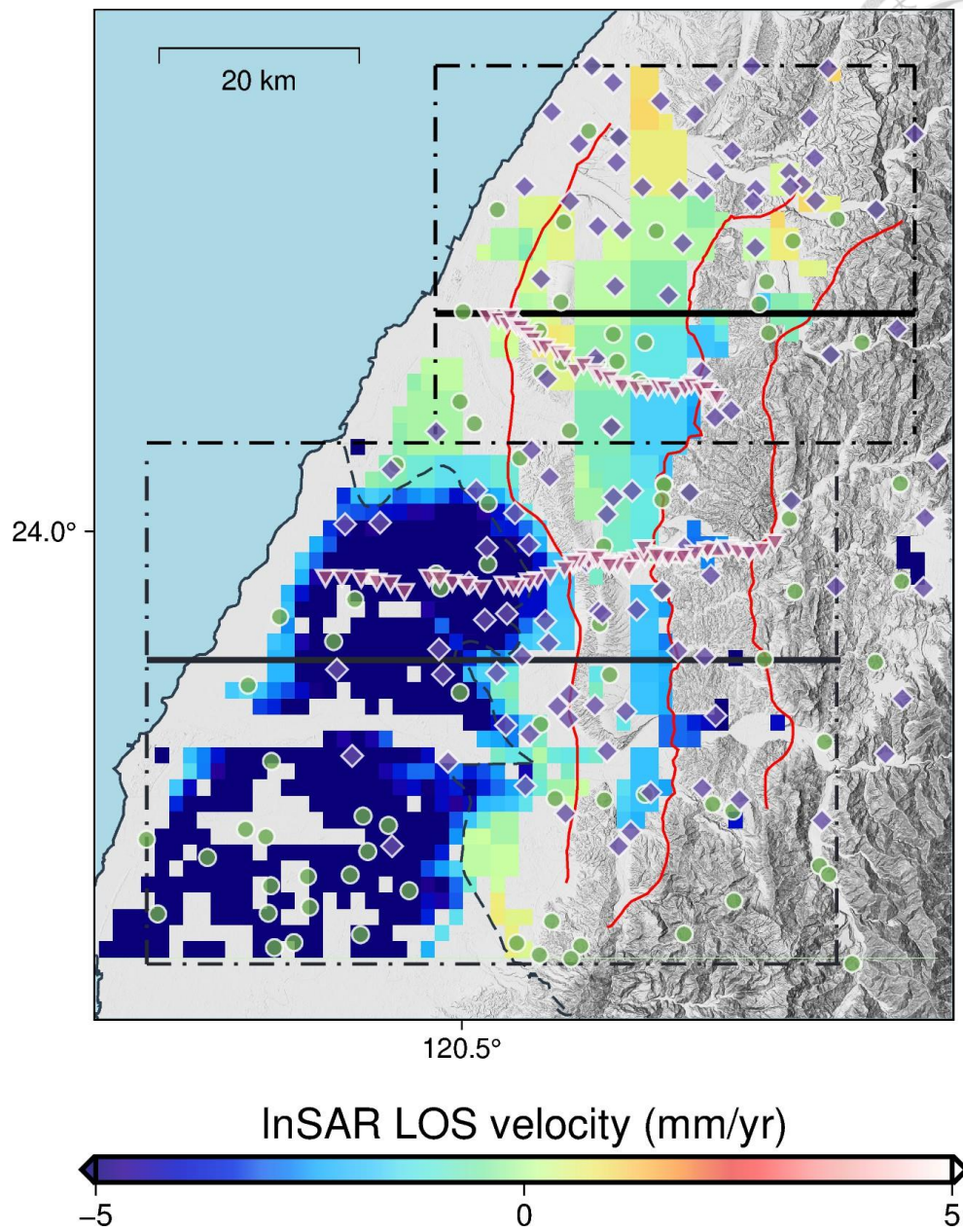


**Figure 18** Study area with two profiles and two groups. The black dotted-dashes indicate the two groups of data. The black lines represent the north and south profiles. Black dash indicates subsidence area.

#### 4.2.4.2 Three-dimensional dislocation model

The main purpose of operating the 3-D model is to figure out the slip deficit rates and their distribution of the three faults and then use the rates to calculate the moment magnitude. This study will apply the Baseline Inversion model. It can simultaneously consider horizontal, vertical, and InSAR line-of-sight velocities for inversion. The initial fault geometry and parameters are based on the classification of the fault geometry described in Chapter 3.4 and are detailed in Table 7.

This model will first apply Delaunay triangulation to create baselines from geodetic data within the study area. Then, it will convert the station velocities on the baselines into unit velocities in the direction of the baselines. These unit velocities will be subtracted to calculate the unit velocity changes, which will be used as observation data. Using the Green's function from Okada (1985), the model will invert to obtain model parameters, as shown in Equation 2, to estimate fault slip deficits based on changes in baseline lengths. Moreover, this study will use a linear least-squares solver with bounds to solve least-squares curve fitting problems of the form:

$$\min \frac{1}{2} \|A * m - \bar{d}\|_2^2 \quad (\text{Coleman \& Li, 1996}) \quad (7)$$

$$\bar{d} = \begin{bmatrix} d \\ \sigma \\ \phi \end{bmatrix}, \text{ and}$$

$$A = \begin{bmatrix} G \\ \frac{G}{\sigma} \\ \lambda L \end{bmatrix}$$

where  $d$  is the observation data,  $m$  is a vector of model parameters, and  $G$  is Green's function from Okada (1985).  $\lambda$  is a smoothing parameter.  $L$  is a finite-difference approximation



proportional to the second derivative of  $m$ .  $\phi$  is a zero vector.  $\sigma$  is the error of observation data.

The model misfit is defined as follows

$$||d - \bar{d}||_2 \quad (8)$$

$$\bar{d} = G * m$$

Additionally, this study will apply three different scenarios mentioned in Chapter 3.4. The use of varying fault geometries is not intended to determine which geometry is correct. Instead, the primary goal is to encompass the three prevailing interpretations of fault geometry in the central region. By doing so, the study aims to quantify the slip deficit for each of these fault geometry scenarios.

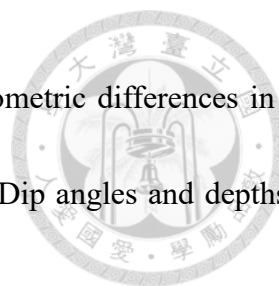


**Table 7** Initial parameter of 3-D baseline inversion model. There are geometric differences in the north-south cross-section, resulting in two sets of dip angles and depths. Dip angles and depths of branches within the same fault are separated by slashes.

|                   | Changhua           | Chelungpu                 | Tamaopu-Shuangtung |
|-------------------|--------------------|---------------------------|--------------------|
| Depth [North] #a  | 1.67 / 3.16 / 3.80 | 0.00 / 2.45 / 3.24 / 4.50 | 0.00 / 2.39 / 3.80 |
| Depth [South] #a  | 1.67 / 3.18 / 4.30 | 0.00 / 2.45 / 3.24 / 5.00 | 0.00 / 2.39 / 5.00 |
| Dip [North] #a #b | 60 / 60            | 35 / 15 / 15              | 45 / 45            |
| Dip [South] #a    | 30 / 15            | 50 / 25 / 15              | 45 / 35            |

Note: #a: Yue et al. (2005); #b: 黃旭燦等 (2004)

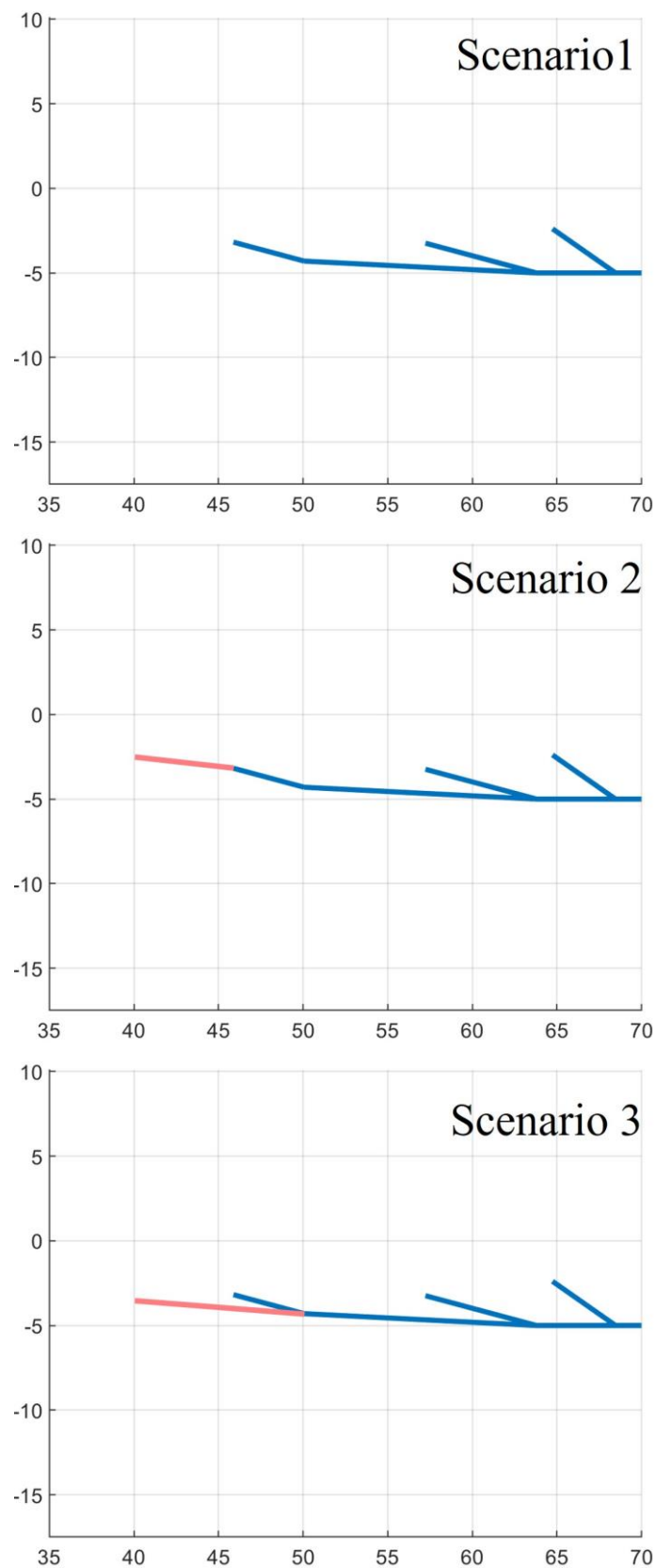


**Figure 19** The schematic diagram of three geometry assumptions.



#### 4.2.5 The assessment of the moment magnitude of the faults

After conduction the 3-D model, the moment magnitudes of the Changhua fault in three scenarios will be calculated by follow equations. First, the slip deficit rate will be converse into the average displacement  $D$  by multiple the recurrence interval from Shyu et al (2020). Then, the scalar seismic moment  $M_0$  will be calculated by:

$$M_0 = \mu AD \quad (\text{Aki, 1966}) \quad (9)$$

Here  $M_0$  is the moment of component couple of the equivalent double couple,  $\mu$  equals  $3 * 10^{11} \text{ dyne cm}^{-2}$  and  $A$  is the rupture area ( $\text{km}^2$ ).

Finally, the moment magnitudes will be calculated by

$$M_w = \frac{2}{3} \log M_0 - 10.73 \quad (\text{Hanks \& Kanamori, 1979}) \quad (10)$$



## Chapter 5 Results

### 5.1 Two-dimensional dislocation model

#### 5.1.1 Testing the lower and upper detachment

After testing all possible combinations of fault branches to determine which depth of the detachment are more reasonable and to identify which parts of the faults may be locked (Table 8), it was found that the geometry where the Changhua and the Chelungpu fault retain most branches while the Tamaopu-Shuangtung fault retains only the bottom branches has the smallest misfit in both the lower and upper detachment scenarios. Figure 20 show the model results of optimal geometry of two scenarios.

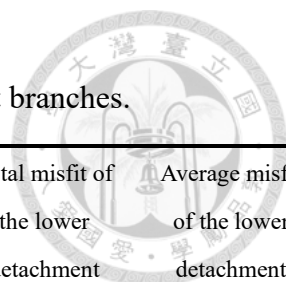


**Table 8** The misfit of two scenarios from all possible combinations of fault branches.

| Number of<br>the Changhua<br>fault branches | Number of the<br>Chelungpu<br>fault branches | Number of the<br>Tamaopu-<br>Shuangtung fault<br>branches | Total misfit of<br>the upper<br>detachment<br>scenario | Average misfit<br>of the upper<br>detachment<br>scenario | Total misfit of<br>the lower<br>detachment<br>scenario | Average misfit<br>of the lower<br>detachment<br>scenario |
|---------------------------------------------|----------------------------------------------|-----------------------------------------------------------|--------------------------------------------------------|----------------------------------------------------------|--------------------------------------------------------|----------------------------------------------------------|
| 2                                           | 3                                            | 2                                                         | 2348.5                                                 | 5.4                                                      | 2639.5                                                 | 6.1                                                      |
| <b><u>2</u></b>                             | <b><u>3</u></b>                              | <b><u>1</u></b>                                           | <b><u>2169.7</u></b>                                   | <b><u>5.0</u></b>                                        | <b><u>2341.8</u></b>                                   | <b><u>5.4</u></b>                                        |
| 2                                           | 3                                            | 0                                                         | 3066.5                                                 | 7.0                                                      | 3618.5                                                 | 8.3                                                      |
| 2                                           | 2                                            | 2                                                         | 3477.6                                                 | 8.0                                                      | 3519.7                                                 | 8.1                                                      |
| 2                                           | 2                                            | 1                                                         | 3358.3                                                 | 7.7                                                      | 3332.3                                                 | 7.6                                                      |
| 2                                           | 2                                            | 0                                                         | 4387.3                                                 | 10.1                                                     | 4821.4                                                 | 11.1                                                     |
| 2                                           | 1                                            | 2                                                         | 3323.6                                                 | 7.6                                                      | 3537.1                                                 | 8.1                                                      |
| 2                                           | 1                                            | 1                                                         | 3064.3                                                 | 7.0                                                      | 3387.3                                                 | 7.8                                                      |
| 2                                           | 1                                            | 0                                                         | 3421.8                                                 | 7.8                                                      | 4800.3                                                 | 11.0                                                     |
| 1                                           | 3                                            | 2                                                         | 2516.1                                                 | 5.8                                                      | 2573.5                                                 | 5.9                                                      |
| 1                                           | 3                                            | 1                                                         | 2253.1                                                 | 5.2                                                      | 2363.4                                                 | 5.4                                                      |
| 1                                           | 3                                            | 0                                                         | 3432.2                                                 | 7.9                                                      | 4156.2                                                 | 9.5                                                      |
| 1                                           | 2                                            | 2                                                         | 3475.3                                                 | 8.0                                                      | 3522.1                                                 | 8.1                                                      |
| 1                                           | 2                                            | 1                                                         | 3222.7                                                 | 7.4                                                      | 3323.7                                                 | 7.6                                                      |
| 1                                           | 2                                            | 0                                                         | 4294.4                                                 | 9.8                                                      | 4842.2                                                 | 11.1                                                     |
| 1                                           | 1                                            | 2                                                         | 3513.5                                                 | 8.1                                                      | 3486.9                                                 | 8.0                                                      |
| 1                                           | 1                                            | 1                                                         | 3177.3                                                 | 7.3                                                      | 3374.7                                                 | 7.7                                                      |
| 1                                           | 1                                            | 0                                                         | 3399.4                                                 | 7.8                                                      | 4799.0                                                 | 11.0                                                     |
| 0                                           | 3                                            | 2                                                         | 2808.4                                                 | 6.4                                                      | 2674.3                                                 | 6.1                                                      |
| 0                                           | 3                                            | 1                                                         | 2279.1                                                 | 5.2                                                      | 2475.9                                                 | 5.7                                                      |
| 0                                           | 3                                            | 0                                                         | 3916.9                                                 | 9.0                                                      | 4427.6                                                 | 10.2                                                     |
| 0                                           | 2                                            | 2                                                         | 3525.4                                                 | 8.1                                                      | 3534.2                                                 | 8.1                                                      |
| 0                                           | 2                                            | 1                                                         | 3376.1                                                 | 7.7                                                      | 3359.8                                                 | 7.7                                                      |
| 0                                           | 2                                            | 0                                                         | 4224.2                                                 | 9.7                                                      | 4802.5                                                 | 11.0                                                     |
| 0                                           | 1                                            | 2                                                         | 3453.7                                                 | 7.9                                                      | 3580.9                                                 | 8.2                                                      |
| 0                                           | 1                                            | 1                                                         | 3137.8                                                 | 7.2                                                      | 3407.6                                                 | 7.8                                                      |
| 0                                           | 1                                            | 0                                                         | 3389.1                                                 | 7.8                                                      | 4744.3                                                 | 10.9                                                     |
| 0                                           | 0                                            | 2                                                         | 4145.6                                                 | 9.5                                                      | 3582.9                                                 | 8.2                                                      |
| 0                                           | 0                                            | 1                                                         | 3426.7                                                 | 7.9                                                      | 3383.6                                                 | 7.8                                                      |

Note: The optimal combinations of fault branches are shown in bold and underlined.



In both fault-normal and parallel directions, both scenarios show good fits, showing a trend of increasing velocities from west to east. As for the model result of InSAR data, the upper detachment scenario fits slightly better than the lower detachment scenario on the eastern side of the Tamaopu-Shuangtung fault.

However, the main discrepancy between the model outputs of the two scenarios lies in the vertical direction, especially on the eastern side of the Chelungpu fault. In the lower detachment scenario, the model fitting show that after crossing the Chelungpu fault, the velocity increases significantly, then gradually slows down until the cross the Tamaopu-Shuangtung fault. After that, the velocity rises again at the Tamaopu-Shuangtung fault without showing a decreasing trend.

Conversely, in the upper detachment scenario, after crossing the Chelungpu fault, the velocity also increases significantly, but then gradually slows down. The velocity is slower compared to the other scenario. After crossing the Tamaopu-Shuangtung fault, the velocity increases again, but then decreases once more.

Overall, the upper detachment scenario provides a better fit of the model output, particularly in the vertical direction and with respect to data points between the Chelungpu and the Tamaopu-Shuangtung fault. The model output of the lower detachment scenario overfits the velocity data to



the east of the Chelungpu fault. Based on these results, this study will adopt the upper detachment scenario as the primary geometry for further analysis and discussion.

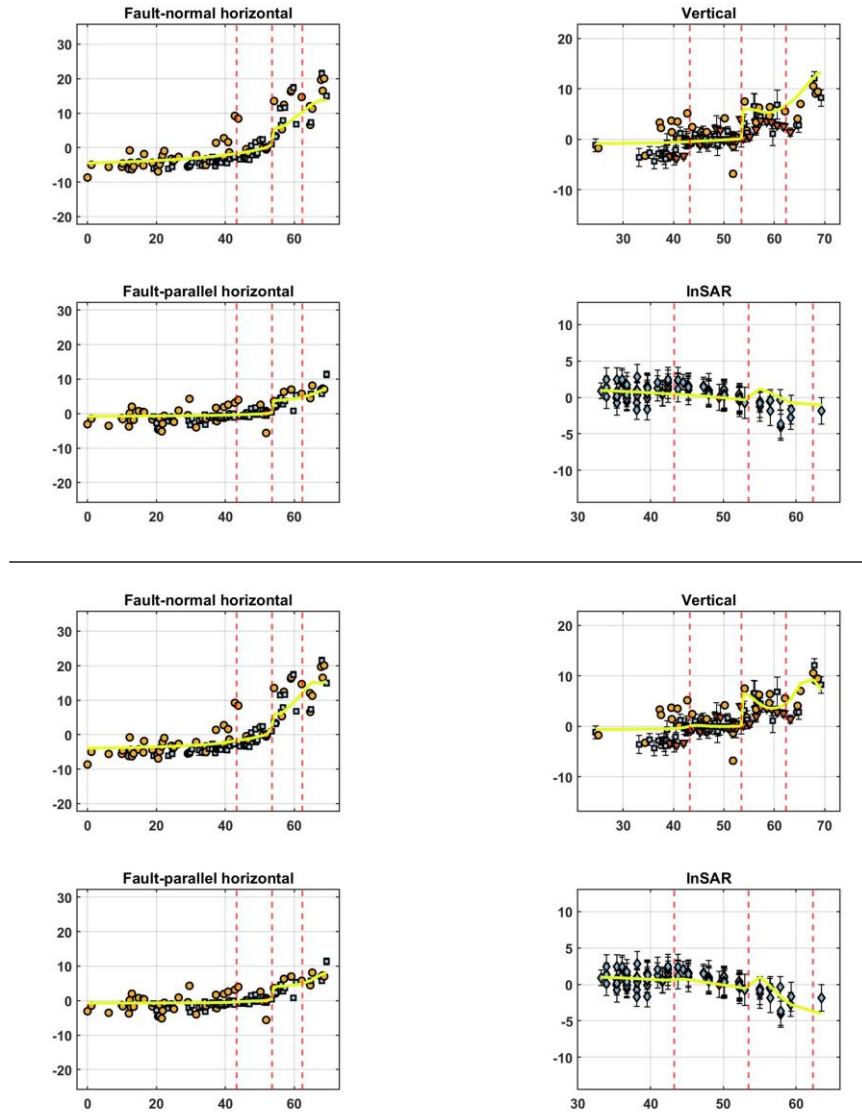


**Figure 20** The model result of optimal misfit for the lower and upper geometry of the 2-D model. Red dash indicates the position of three faults on the surface. Green line indicates the model solution. Yellow circle: the continuous-mode GPS velocity. Blue rectangle: the campaign-mode GPS velocity. Red triangle: leveling velocity. Blue rhombus: InSAR velocity. Y-axis represents the velocity relative to the reference station KZN1 (unit:  $\text{mm yr}^{-1}$ ). The X-axis represents the distance from station TASI projected at  $23.72^\circ \text{ N}$  (unit: km).

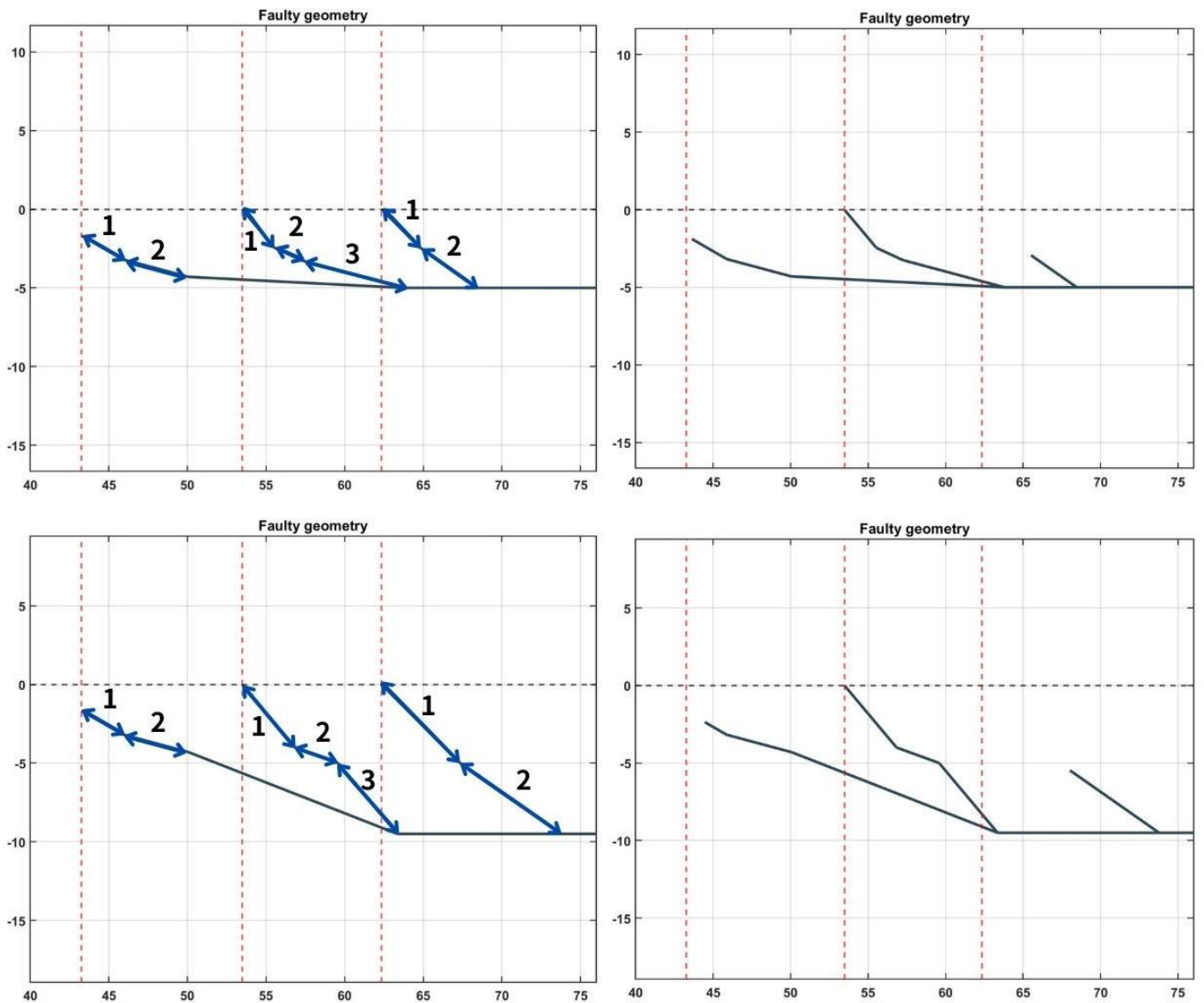


**Figure 21** The optimal geometry of the lower and upper detachment scenarios. The upper detachment scenario is on the top, while the lower detachment scenario is on the bottom. The differences between these two geometries indicate the locked parts. The left side shows the input, and the right side shows the 2-D model output. Red dashes indicate the positions of the three faults on the surface. Blue lines with arrows indicate the branches of each fault.



### 5.1.2 The southern profile of 2-D model

The optimal misfit geometry in the south profile, as detailed in chapter 5.1.1, includes most branches of the Changhua and the Chelungpu fault, while only incorporating the bottom branches of the Tamaopu-Shuangtung fault (Figure 21).

In the southern profile, the locked segment of the Tamaopu-Shuangtung fault is the largest, significantly larger than those of the Changhua and the Chelungpu fault. The Chelungpu fault has the smallest locked segment (Table 9, Figure 20). Regarding the slip rate, because the geometry of the model results shows that the branches closest to the surface are locked, the slip rate here represents the difference in velocity between the shallow and deep parts of the fault. The Tamaopu-Shuangtung fault has the highest rate, as well as the Changhua fault has the lowest, and the Chelungpu fault being intermediate. However, the slip rate of the Tamaopu-Shuangtung fault is unusually high, far exceeding the long-term geological rate, which is likely influenced by structures to the east outside the study area.



**Table 9** Slip rates and model misfit of 2-D model output from two profiles.

| Profile                          | North    |           |                    | South    |           |                    |
|----------------------------------|----------|-----------|--------------------|----------|-----------|--------------------|
| Total misfit                     | 872.2    |           |                    | 2169.7   |           |                    |
| Average misfit                   | 2.6      |           |                    | 5.0      |           |                    |
| Fault                            | Changhua | Chelungpu | Tamaopu-Shuangtung | Changhua | Chelungpu | Tamaopu-Shuangtung |
| Slip rate (mm yr <sup>-1</sup> ) | 0.6      | 5.8       | 0.8                | 1.2      | 9.5       | 14.4               |
| locking depth (km)               | 2.59     | 3.10      | 2.41               | 1.88     | 0.02      | 2.94               |
| locked part (%)                  | 62       | 96        | 65                 | 6        | 0.3       | 12                 |

### 5.1.3 The northern profile of 2-D model

After testing all possible geometry combination, the optimal model result in the northern profile retains only the bottom branches of the three faults (Figure 23). Details of the misfit for each combination are provided in Table 10.

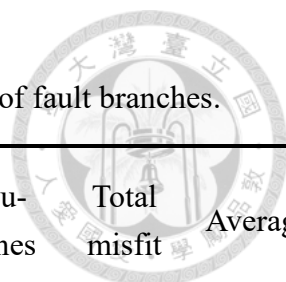


**Table 10** The misfit of the northern profile from all possible combinations of fault branches.

| Number of the<br>Changhua fault<br>branches | Number of the<br>Chelungpu fault<br>branches | Number of the Tamaopu-<br>Shuangtung fault branches | Total<br>misfit     | Average           |
|---------------------------------------------|----------------------------------------------|-----------------------------------------------------|---------------------|-------------------|
| 1                                           | 4                                            | 1                                                   | 921.7               | 2.8               |
| 1                                           | 3                                            | 1                                                   | 899.8               | 2.7               |
| 1                                           | 2                                            | 1                                                   | 878.8               | 2.7               |
| <b><u>1</u></b>                             | <b><u>1</u></b>                              | <b><u>1</u></b>                                     | <b><u>872.2</u></b> | <b><u>2.6</u></b> |
| 0                                           | 4                                            | 1                                                   | 902.5               | 2.7               |
| 0                                           | 3                                            | 1                                                   | 907.2               | 2.7               |
| 0                                           | 2                                            | 1                                                   | 896.9               | 2.7               |
| 0                                           | 1                                            | 1                                                   | 882.8               | 2.7               |
| 0                                           | 0                                            | 1                                                   | 943.6               | 2.9               |

Compared to the southern profile, the better model results for the northern profile may be due to the data here in northern of study area show more consistency than the southern and the absence of subsidence area. However, the vertical data still do not fit well, displaying a divergent pattern. The primary trend in both vertical and horizontal directions gradually rise from west to east (Figure 22). There is no significant velocity drop or raise across the fault in the data from the northern profile.

In the northern profile, the majority of the locking segment is contributed by the Chelungpu fault, followed by the Tamaopu-Shuangtung fault, and lastly, the Changhua fault (Table 10). The Chelungpu fault show highest velocity, followed by the Tamaopu-Shuangtung fault, and the Changhua fault. This also indicates that the order of slip deficit for the three faults.

Based on the results of the 2-D model from the northern and southern profiles, the Changhua fault shows the smallest velocity difference between the shallow and deep parts. The Chelungpu fault shows a significant velocity difference in both profiles, while the Tamaopu-Shuangtung fault shows a small velocity difference in the northern profile.

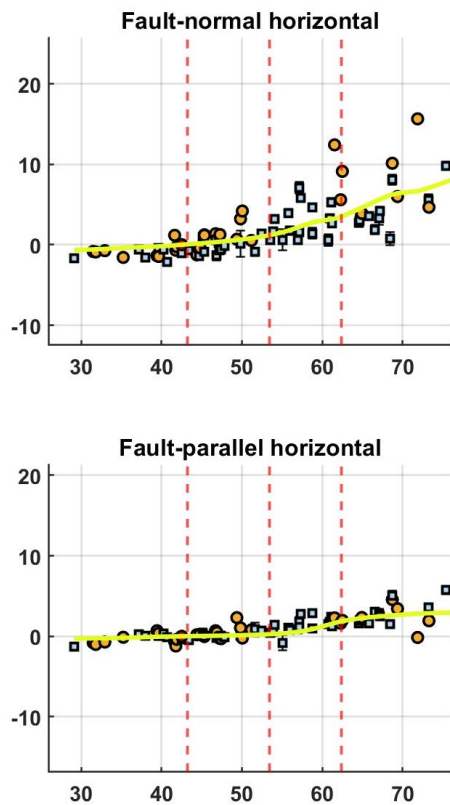


**Figure 22** The model results of optimal misfit for northern profile of the 2-D model. Red dash indicates the position of three faults on the surface. Green line indicates the model solution. Yellow circle: the continuous-mode GPS velocity. Blue rectangle: the campaign-mode GPS velocity. Red triangle: leveling velocity. Blue rhombus: InSAR velocity. Y-axis represents the velocity relative to the reference station GS22 (unit: mm yr<sup>-1</sup>). The X-axis represents the distance from station TASI projected at 23.72° N (unit: km).

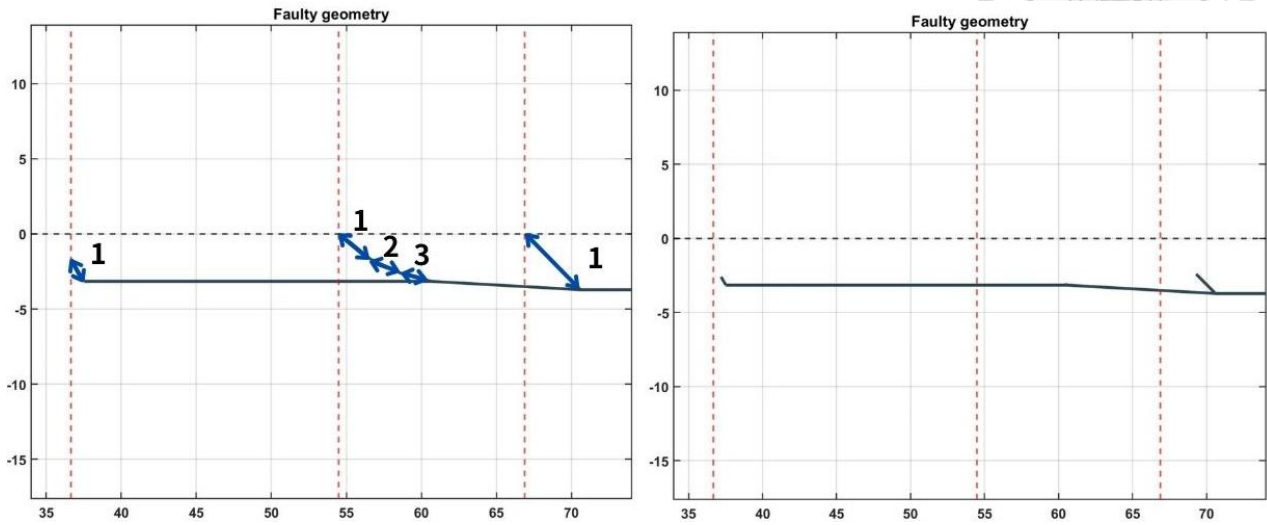


**Figure 23** The optimal geometry of the northern profile. The left side shows the input, and the right side shows the 2-D model output. The differences between these two geometries indicate the locked parts. Red dashes indicate the positions of the three faults on the surface. Blue lines with arrows indicate the branches of each fault.



## 5.2 Three-dimensional dislocation model

### 5.2.1 The results of 3-D model

The first scenario shows the biggest model misfit (Table 11). The highest slip deficit rate is on the Chelungpu fault and it is obvious at shallow depths and at the kinks of the fault. Additionally, the highest slip deficit rate is on the southern section. Next, the detachment shows the second highest slip deficit rate, with the deficit rate mainly in the southern parts. There are hotspots located in the central and southern regions beneath the Tamaopu-Shuangtung and the Changhua fault. Then, the Tamaopu-Shuangtung fault shows the third highest slip deficit rate, primarily concentrated in the central part of the fault and located at a shallow depth. Finally, the Changhua fault shows the lowest slip deficit rate among these faults and the detachment, with minimal slip deficit observed (Figure 24).

In the second scenario, the order of slip deficit rate is the same as in the previous scenario, but the values are slightly different (Table 11). The general pattern of the slip deficit rate on the Chelungpu fault in this scenario is similar to the first scenario. The highest slip deficit rate remains on the southern section. Then, the slip deficit rate of the detachment also follows a general pattern similar to the first scenario. However, the overall slip deficit rate values are higher than those in the first scenario. The slip deficit rate of the Tamaopu-Shuangtung fault is similar to that observed in the previous scenario. While the Changhua fault still showing the lowest slip deficit rate among the three faults, this rate is significantly higher than in the previous scenario. The slip deficit rate is higher on the flat of the fault



compared to the ramp. Notably, there is a hotspot of slip deficit in the southern part of the Changhua fault, indicating that the southern segment showing a higher slip deficit rate than the northern segment (Figure 24).

In the third scenario, the highest slip deficit rate is observed in the detachment (Table 11). Moreover, this scenario yields the optimal model misfit among all scenarios. The slip deficit rates of the Changhua fault and the Tamaopu-Shuangtung fault are the lowest in each of their respective three scenarios, while the slip deficit rate for the Chelungpu fault remains consistent. The highest slip deficit rate migrates to the southern detachment. The hotspots of the Chelungpu and the Tamaopu-Shuangtung fault remain at the same depths but show lower values. Additionally, there is barely slip deficit rate on the Changhua fault (Figure 24).

In conclusion, the Chelungpu fault, the Tamaopu-Shuangtung fault, and the detachment show a consistent pattern of slip deficit rate and the value of the slip deficit rates across all three scenarios, differing mainly in value of rates. The primary variation occurs with the Changhua fault. The scenario with the Changhua fault consisting flat and ramp make largest slip deficit rate. The other two barely show slip deficit rate.



**Table 11** The 3-D model output of slip deficit rate and misfit in the three scenarios. The values in parentheses represent one standard deviation. If the minimum value is less than 0, it is considered to be 0.

| No.        | Slip deficit rate (mm yr <sup>-1</sup> ) |                     |                    |                      | Misfit |         |
|------------|------------------------------------------|---------------------|--------------------|----------------------|--------|---------|
|            | Changhua                                 | Chelungpu           | Tamaopu-Shuangtung | Detachment           | Total  | Average |
| Scenario 1 | 1.0<br>(0.0 - 3.2)                       | 6.9<br>(1.8 - 12.0) | 3.6<br>(0.4 - 6.8) | 4.2<br>(0.0 - 20.8)  | 843.1  | 1.4     |
| Scenario 2 | 3.0<br>(0.0 - 6.6)                       | 6.8<br>(1.7 - 11.9) | 3.7<br>(0.5 - 7.0) | 4.8<br>(0.3 - 9.3)   | 825.4  | 1.4     |
| Scenario 3 | 0.4<br>(0.0 - 1.1)                       | 6.8<br>(2.1 - 11.6) | 3.2<br>(0.1 - 6.3) | 7.4<br>(0.0 - 111.2) | 758.8  | 1.3     |

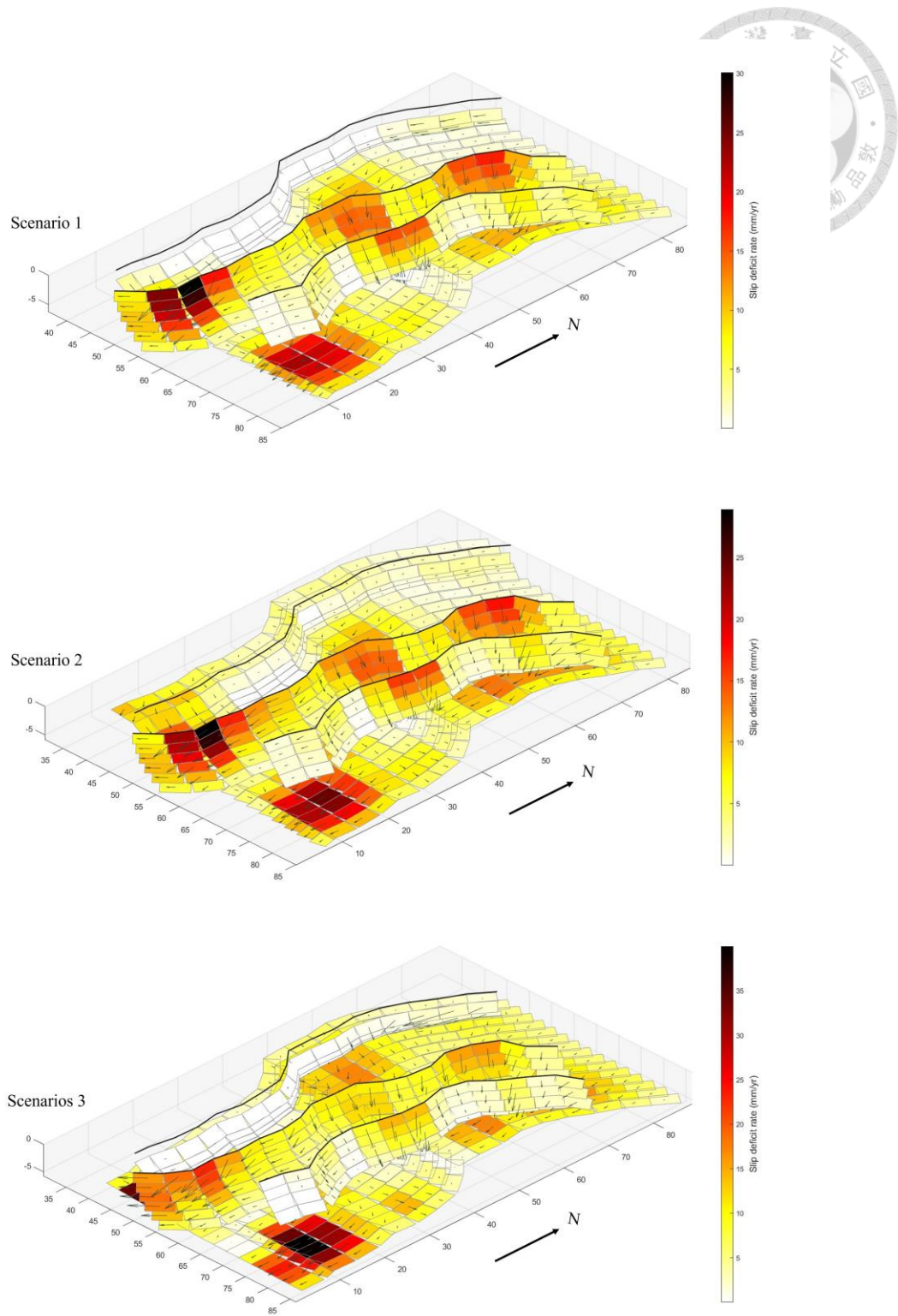


**Figure 24** The 3-dimensional model output of the three scenarios.

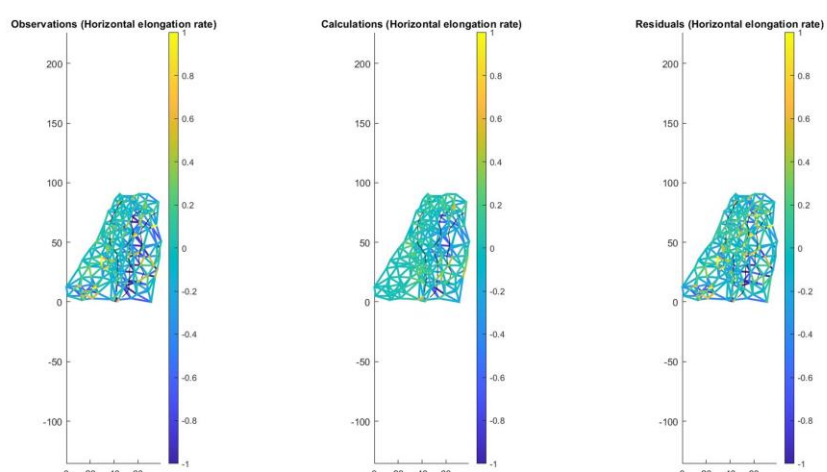
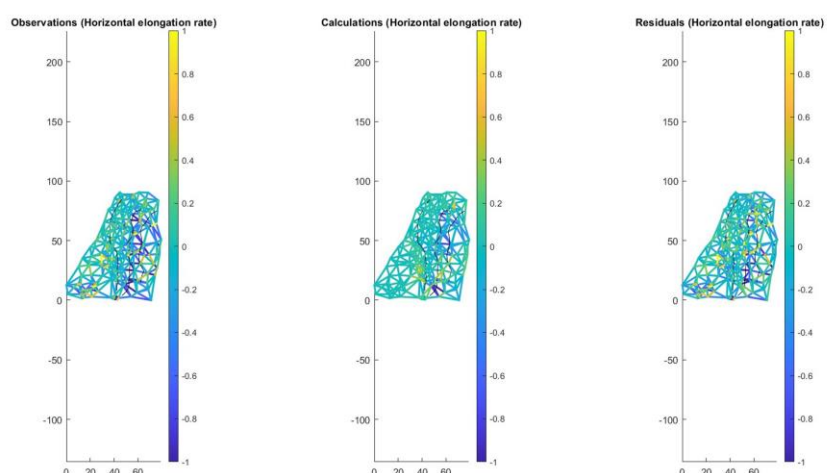
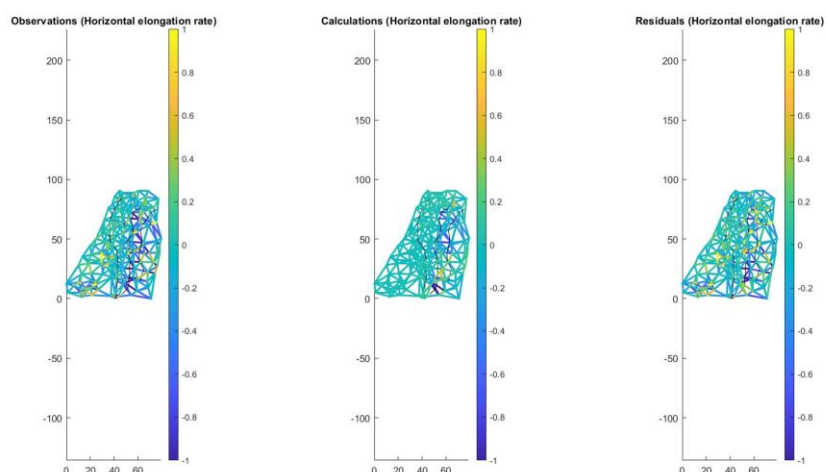


**Figure 25** The 3-dimensional model misfits in horizontal direction of the three scenarios.

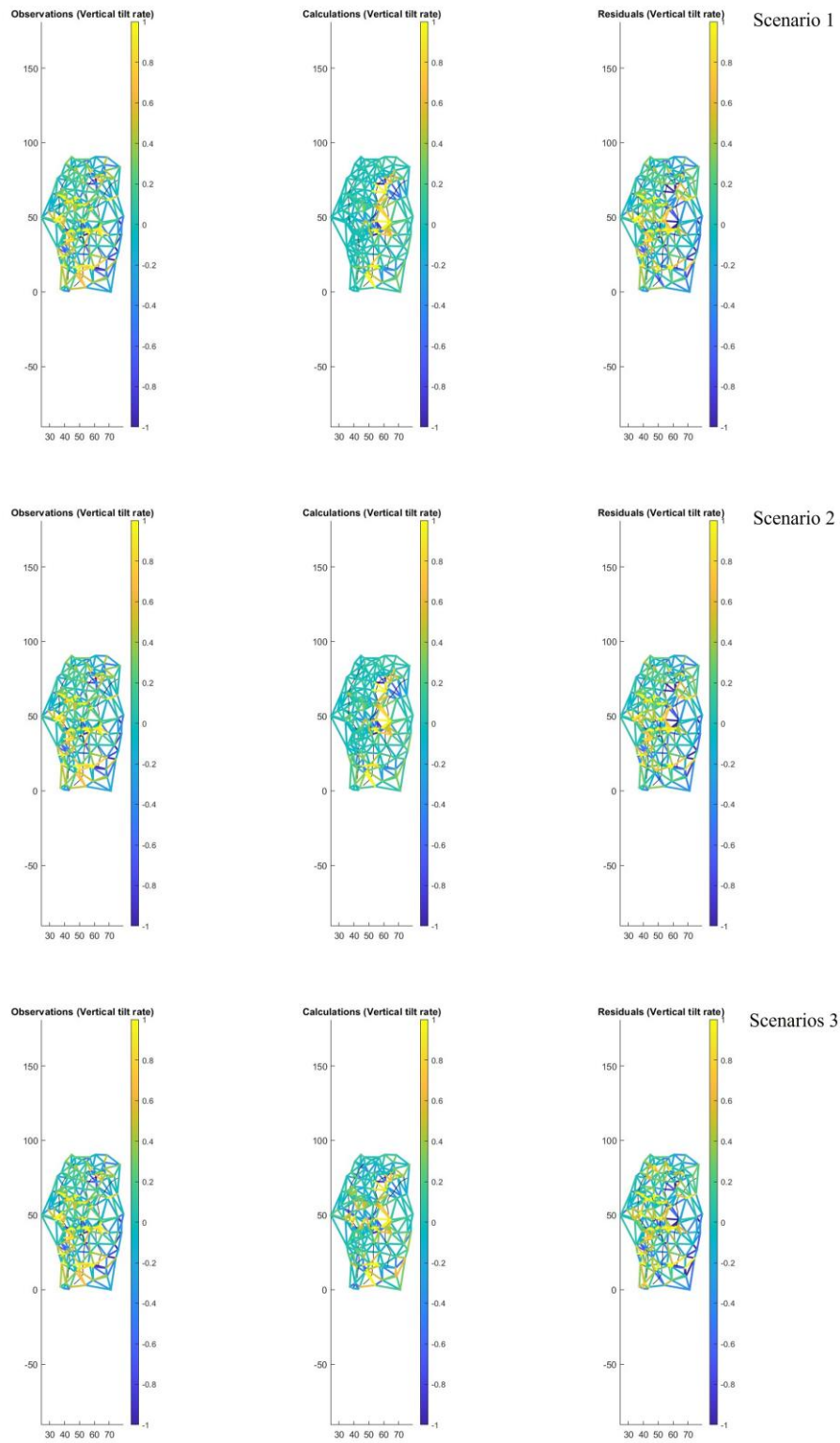


**Figure 26** The 3-dimensional model misfits in vertical direction of the three scenarios.

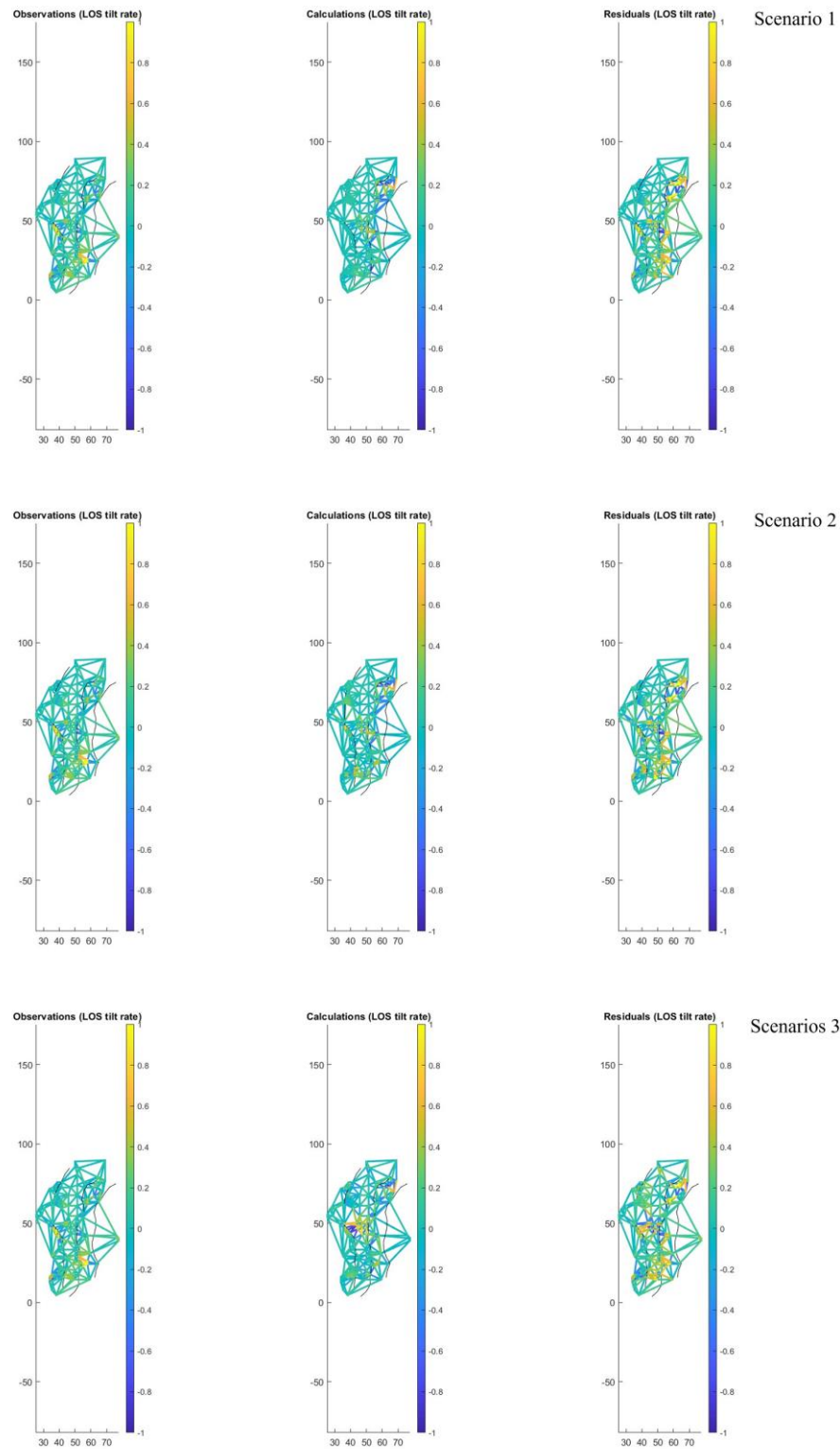


**Figure 27** The 3-dimensional model misfits in line-of-sight direction of the three scenarios.

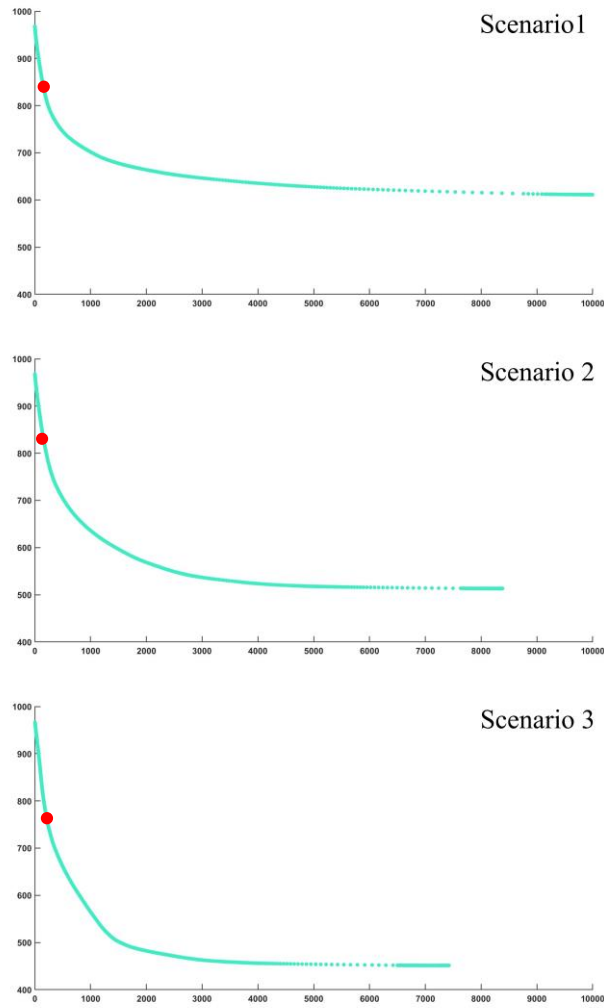


**Figure 28** The trade-off curves of three scenarios. Red point indicates the smooth parameter in each scenario. The trade-off curve plots the misfit function against the Euclidean norm of the model parameters. The X-axis represents the model misfit ( $\|(Gm - d)/\sigma\|_2$ ), calculated as the sum of the s Euclidean norm of differences between the observations and the model results, weighted by data error. The Y-axis represents the Euclidean norm of the model parameters ( $\|m\|_2$ ), which means the complexity of model. The misfit improves with increasing solution roughness. Here picks the smoothing parameter is 15.4882. Additional slip roughness will make the model result deviation from real world conditions significantly.



## 5.2.2 3-D model testing

### 5.2.2.1 The data testing of the 3-D model

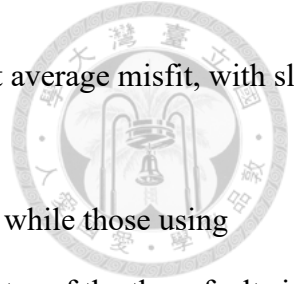
In this section, this study will individually input different datasets to test the model's performance under the three scenarios. Additionally, since the InSAR data spatial distribution is uneven after Quadtree processing, the data will not be used to test models alone. The testing 3-D model output is shown in Table 12.

First, using only horizontal data results in the largest average misfit, with an unusually high slip deficit rate for the Chelungpu fault. The slip deficit rate ranking for the three faults across all scenarios is the Chelungpu fault > the Tamaopu-Shuangtung fault > the Changhua fault.

Using both horizontal and vertical data yields results closest to those in Section 5.2.1, with the slip deficit rate ranking remaining the Chelungpu fault > the Tamaopu-Shuangtung fault > the Changhua fault in all scenarios. The inclusion of vertical data reduces the slip deficit rate for the Chelungpu fault, indicating that vertical data constrain its slip deficit rate effectively.

Using only horizontal and InSAR data results in the second-largest average misfit, with slip deficit rates similar to those obtained using only horizontal data. The ranking for the slip deficit rate remains the Chelungpu fault > the Tamaopu-Shuangtung fault > the Changhua fault across all scenarios. The Chelungpu fault shows the most significant variation, suggesting that InSAR data also constrain its slip deficit rate, albeit less effectively than vertical data.

Using only vertical data results in the second-smallest average misfit, with noticeably lower slip deficit rates for the Chelungpu and the Tamaopu-Shuangtung faults. The northern segment of the Chelungpu fault shows a significant reduction in slip deficit rate. In Scenario 2, the Changhua fault has the highest slip deficit rate among the three faults, but this rate is almost the same as when

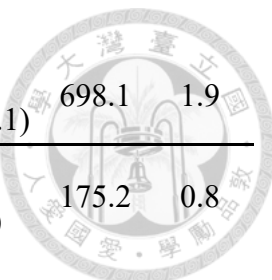


using other data. Using both vertical and InSAR data results in the smallest average misfit, with slip deficit rates similar to those obtained using only vertical data.

Overall, models using horizontal velocities produce the largest misfit, while those using vertical and InSAR velocities reduce the misfit. The order of detachment rates of the three faults is mainly the Chelungpu fault > the Tamaopu-Shuangdong fault > the Changhua fault. The Chelungpu fault shows the greatest variation across different datasets, followed by the Tamaopu-Shuangtung fault, while the Changhua fault's slip deficit rate remains stable.

**Table 12** The 3-D model output of slip deficit rate and misfit in the three scenarios for different data. The values in parentheses represent one standard deviation. If the minimum value is less than 0, it is considered to be 0.

| Data  | No.        | Slip deficit rate (mm yr <sup>-1</sup> ) |             |                    |             | Misfit |         |
|-------|------------|------------------------------------------|-------------|--------------------|-------------|--------|---------|
|       |            | Changhua                                 | Chelungpu   | Tamaopu-Shuangtung | Detachment  | Total  | Average |
| H     | Scenario 1 | 1.1                                      | 9.9         | 3.6                | 4.2         | 810.3  | 3.9     |
|       |            | (0 - 3.0)                                | (3.2- 16.5) | (0.6- 6.5)         | (0 - 19.2)  |        |         |
|       | Scenario 2 | 2.7                                      | 9.6         | 3.7                | 4.9         | 793.0  | 3.8     |
|       |            | (0 - 6.7)                                | (3.1- 16.1) | (0.8- 6.7)         | (0.4 - 9.4) |        |         |
|       | Scenario 3 | 0.3                                      | 9.3         | 3.7                | 7.4         | 696.3  | 3.4     |
|       |            | (0 - 0.8)                                | (3.2- 15.4) | (0.6- 6.8)         | (0 - 187.2) |        |         |
| H+V   | Scenario 1 | 1.0                                      | 7.4         | 3.5                | 4.2         | 842.0  | 2.0     |
|       |            | (0 - 3.3)                                | (2.0- 12.7) | (0.4- 6.6)         | (0 - 20.7)  |        |         |
|       | Scenario 2 | 3.0                                      | 7.2         | 3.7                | 4.8         | 824.1  | 1.9     |
|       |            | (0 - 6.7)                                | (1.9- 12.5) | (0.5- 6.9)         | (0 - 9.3)   |        |         |
|       | Scenario 3 | 0.4                                      | 7.2         | 3.1                | 7.5         | 757.5  | 1.8     |
|       |            | (0 - 1)                                  | (2.3- 12.1) | (0.1- 6.1)         | (0 - 117)   |        |         |
| H+LOS | Scenario 1 | 1.1                                      | 8.6         | 3.9                | 4.1         | 812.1  | 2.2     |
|       |            | (0 - 3.0)                                | (2.7- 14.6) | (0.6- 7.1)         | (0 - 19.7)  |        |         |
|       | Scenario 2 | 2.7                                      | 8.4         | 4.0                | 4.8         | 794.8  | 2.1     |
|       |            | (0 - 6.7)                                | (2.5- 14.3) | (0.8- 7.2)         | (0.1 - 9.4) |        |         |



|       |            |                  |                    |                   |                    |       |     |
|-------|------------|------------------|--------------------|-------------------|--------------------|-------|-----|
|       | Scenario 3 | 0.3<br>(0 - 0.9) | 8.3<br>(2.7- 13.9) | 3.8<br>(0.6- 7.1) | 7.4<br>(0 - 171.1) | 698.1 | 1.9 |
|       | Scenario 1 | 1.2<br>(0 - 2.9) | 2.2<br>(0.4- 4)    | 1.1<br>(0.1- 2)   | 2.8<br>(0 - 9)     | 175.2 | 0.8 |
| V     | Scenario 2 | 3.7<br>(0 - 6.9) | 2.5<br>(0.5- 4.5)  | 1.4<br>(0.2- 2.7) | 4.1<br>(0.6 - 7.5) | 153.8 | 0.7 |
|       | Scenario 3 | 0.8<br>(0 - 1.8) | 1.5<br>(0.1- 2.8)  | 1.1<br>(0.1- 2.1) | 8.6<br>(0 - 75.9)  | 132.3 | 0.6 |
|       | Scenario 1 | 1.1<br>(0 - 2.9) | 2.0<br>(0.5- 3.5)  | 1.1<br>(0.2- 2.0) | 2.6<br>(0 - 8.2)   | 177.6 | 0.4 |
| V+LOS | Scenario 2 | 2.7<br>(0 - 5.1) | 1.9<br>(0.5- 3.3)  | 1.1<br>(0.1- 2.2) | 2.9<br>(0.2 - 5.5) | 167.1 | 0.4 |
|       | Scenario 3 | 0.7<br>(0 - 1.7) | 1.4<br>(0.1- 2.7)  | 1.1<br>(0.1- 2.1) | 6.9<br>(0 - 55.8)  | 137.5 | 0.3 |

Note: "H": Horizontal velocity. "V": Vertical velocity. "LOS": Line-of-sight velocity.

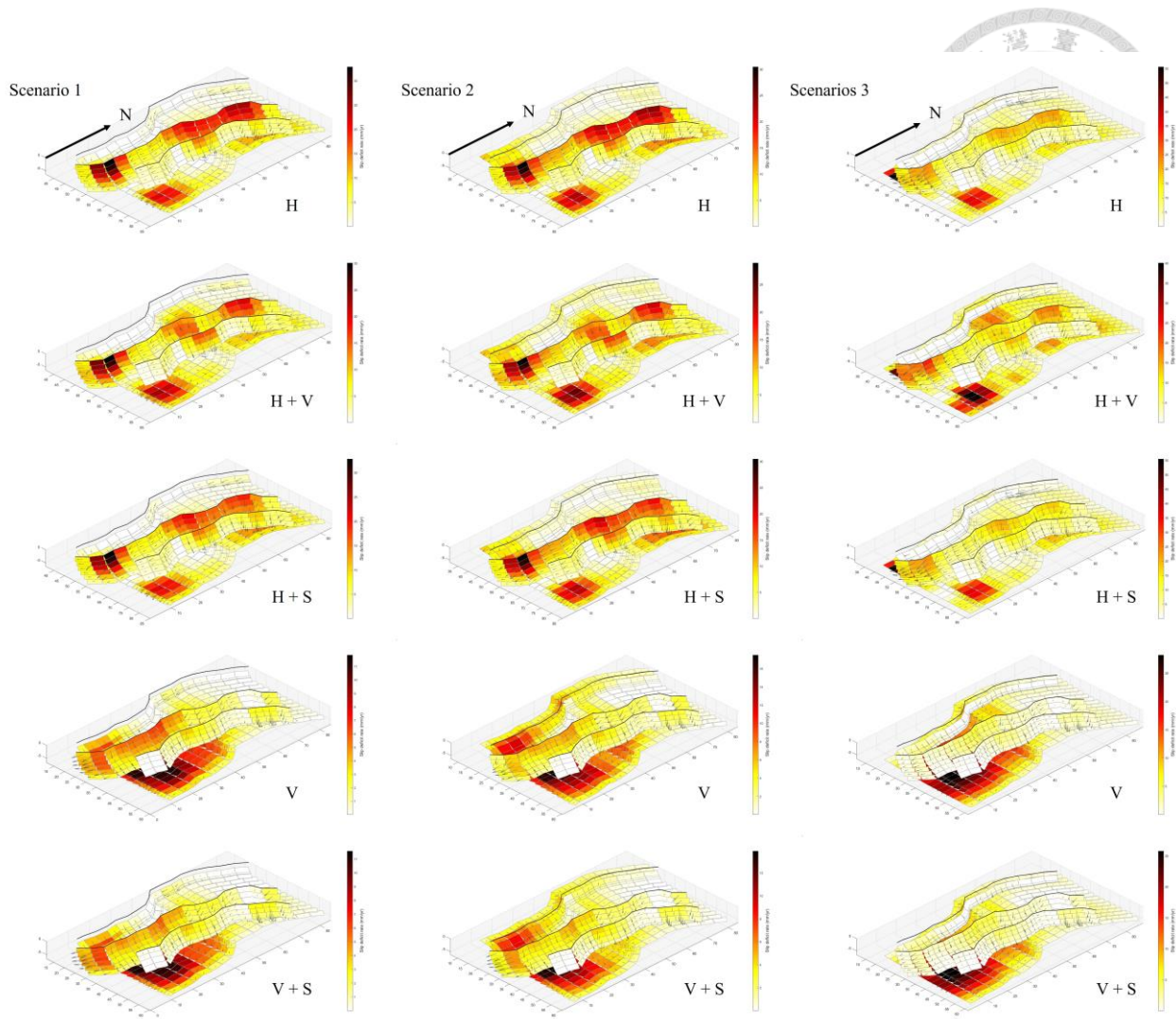


**Figure 29** The 3-dimensional model output of the three scenarios for different data. "H": Horizontal velocity is one of the input data. "V": Vertical velocity is one of the input data.. "S": Line-of-sight velocity is one of the input data. The left column is Scenario 1. The middle column is Scenario 2. The right column is Scenario 3.



### 5.2.2.2 The smoothing parameter of the 3-D model

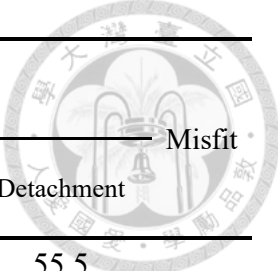
In this section, this study will test two smoothing parameters and analyze the model's performance under different smoothing conditions. The model results and data are shown in Figure 31 and Table 13. The two parameters are P1 and P2, where P1 is 0.0977 and P2 is 0.9772.

First, regarding P1, compared to the parameters in Section 5.2.1, the overall model misfit is the smallest. The misfit ranking for the three scenarios is Scenario 1 > Scenario 2 > Scenario 3. For the three faults in the three scenarios, the misfit ranking is the Tamaopu-Shuangtung fault > the Chelungpu fault > the Changhua fault.

For P2, compared to the parameters in Section 5.2.1 and P1, the overall model misfit is intermediate. The misfit ranking for the three scenarios remains Scenario 1 > Scenario 2 > Scenario 3. For the three faults in the three scenarios, the misfit ranking is again the Tamaopu-Shuangtung fault > the Chelungpu fault > the Changhua fault.

Overall, it is observed that as the smoothing parameter increases, the slip deficits of the Tamaopu-Shuangtung fault and the Chelungpu fault show a gradual decreasing trend, although they remain significantly higher than the geological slip rates. In comparison, the smoothing parameter used in Section 5.2.1 appears to be more reasonable. Additionally, in the results for both P1 and P2, the Changhua fault consistently shows the smallest slip deficit rate in all scenarios.

**Table 13** The 3-D model output of slip deficit rate and misfit in the three scenarios for different smoothing parameters. The values in parentheses represent one standard deviation. If the minimum value is less than 0, it is considered to be 0.



| No.        | Smoothing<br>parameter | Slip deficit rate (mm yr <sup>-1</sup> ) |                    |                      |                      | Misfit |
|------------|------------------------|------------------------------------------|--------------------|----------------------|----------------------|--------|
|            |                        | Changhua                                 | Chelungpu          | Tamaopu-Shuangtung   | Detachment           |        |
| Scenario 1 | P1                     | 3.8<br>(0 - 20.8)                        | 30.1<br>(0 - 89.2) | 39.9<br>(0 - 86.1)   | 55.5<br>(0 - 3246.4) | 639.9  |
|            | P2                     | 4<br>(0 - 23)                            | 14.6<br>(0 - 36.1) | 16.5<br>(1.4 - 31.6) | 23.4<br>(0 - 279.5)  | 711.5  |
| Scenario 2 | P1                     | 13.9<br>(0 - 77.3)                       | 28.2<br>(0 - 96.8) | 34.1<br>(0 - 73)     | 55.8<br>(0 - 243.7)  | 533.3  |
|            | P2                     | 8.9<br>(0 - 36.1)                        | 13.6<br>(0 - 33.3) | 18.8<br>(0 - 34.7)   | 29.5<br>(0 - 84.1)   | 630.1  |
| Scenario 3 | P1                     | 2.1<br>(0 - 6.8)                         | 25.0<br>(0 - 91.6) | 35.0<br>(0 - 77.6)   | 37.1<br>(0 - 2515.9) | 463.8  |
|            | P2                     | 2.1<br>(0 - 6.1)                         | 12.6<br>(0 - 42.5) | 19.5<br>(4.8 - 34.2) | 28<br>(0 - 785.5)    | 527.8  |

Note: P1 is 0.0977 , P2 is 0.9772 .

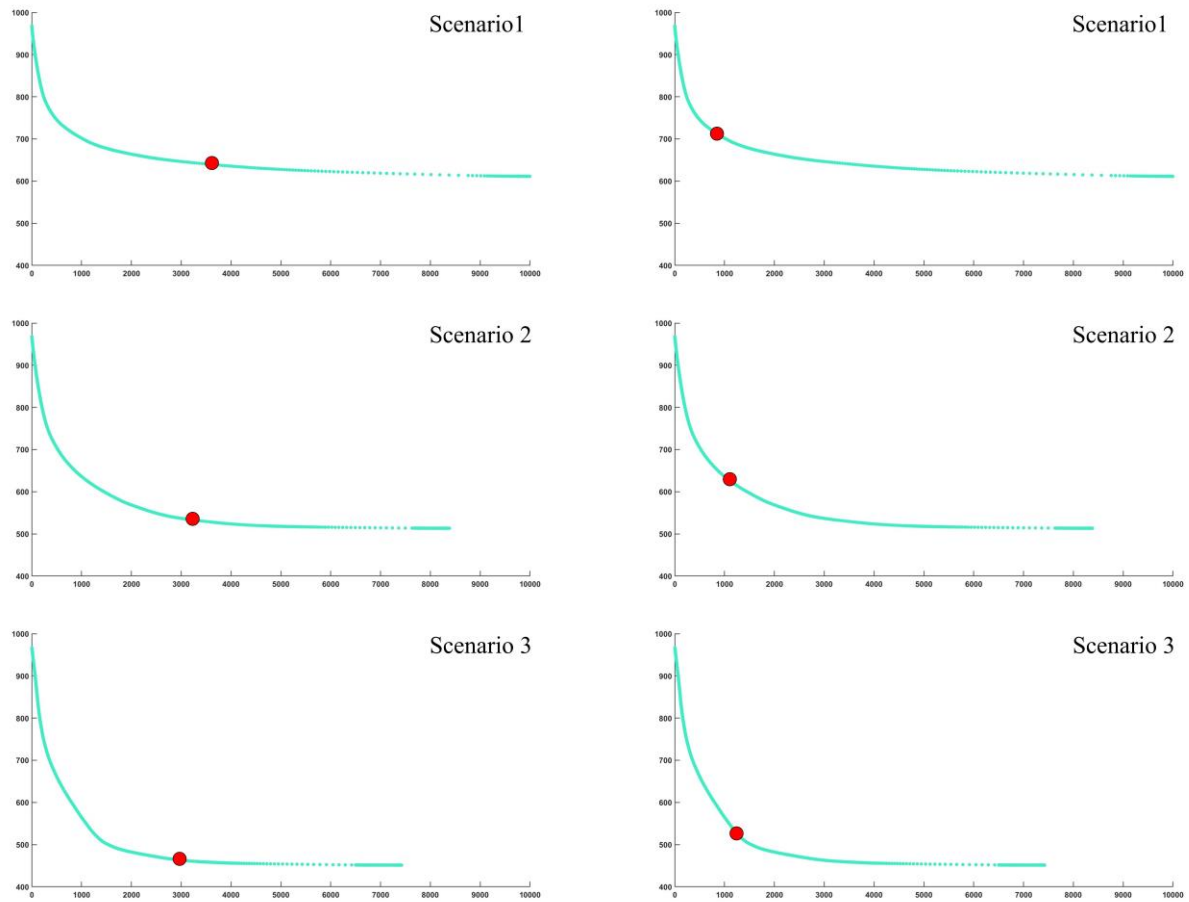


**Figure 30** The trade-off curves of different smoothing parameters in the three scenarios. Red point indicates the smooth parameter in each scenario. The left parameter is 0.0977. The right parameter is 0.9772.

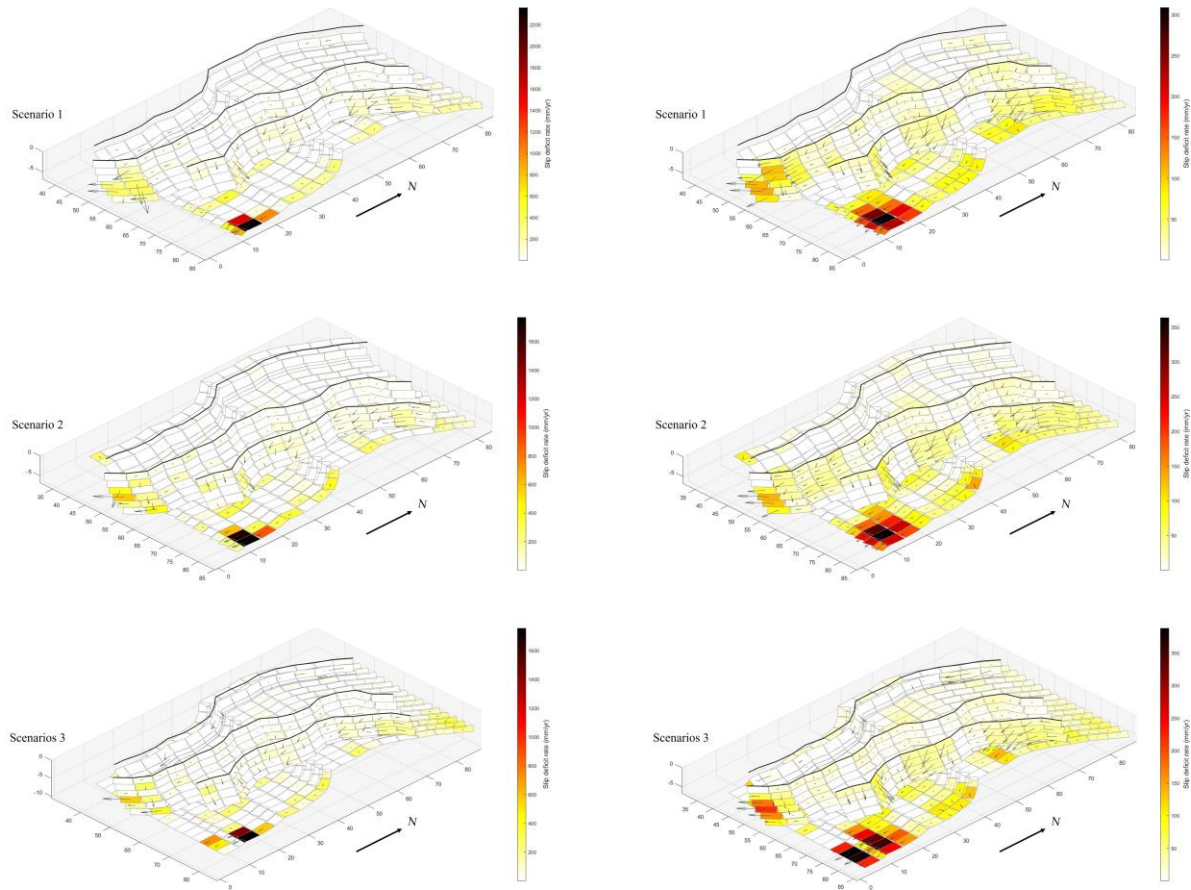


**Figure 31** The 3-dimensional model output in the three scenarios for different smoothing parameters. The left parameter is 0.0977. The right parameter is 0.9772.



### 5.3 The moment magnitude of the faults

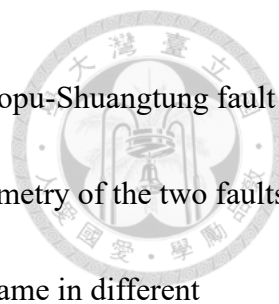
The Table 14 below shows the inferred moment magnitude of the Changhua fault for the three scenarios. The order of moments of the scenes is as follows: scene 2, scene 1, scene 3. Scenario 2, which assumes the Changhua fault consists of a ramp and a flat, has the highest moment magnitude. Although the fault rupture area of Scenario 1 and Scenario 3 are the same, the average slip deficit rate in Scenario 1 is higher, resulting in a slightly larger moment magnitude.

The magnitude of all three scenarios indicates that the Changhua fault has the potential to trigger earthquakes with a moment magnitude ranging from 6.0 to 7.9. This suggests that the Changhua fault remains dangerous, although the accumulated deficit is not as significant as that of the Chelungpu fault.

**Table 14** The moment magnitude and the rupture area of the Changhua fault in three scenarios.

| Scenarios  | Area (km <sup>2</sup> ) | Displacement (m) | Mw        |
|------------|-------------------------|------------------|-----------|
| Scenario 1 | 329                     | 0.3 - 12.0       | 6.2 - 7.3 |
| Scenario 2 | 766                     | 0.8 - 35.9       | 6.8 - 7.9 |
| Scenario 3 | 329                     | 0.1 - 4.8        | 6.0 - 7.1 |

The recurrence interval of the Changhua fault is 280 - 11960 years (Shyu et al., 2020).



The inferred moment magnitudes of the Changhua fault and the Tamaopu-Shuangtung fault in the three scenarios are shown in Table 15 and Table 16. Since the fault geometry of the two faults does not change across the scenarios, the moment magnitudes remain the same in different scenarios. However, the average displacement does change. For the Chelungpu fault, Scenario 1 shows the largest average displacement, while the remaining two scenarios show the same value. For the Tamaopu-Shuangtung fault, Scenario 2 shows the largest average displacement, followed by Scenario 1, with Scenario 3 showing a significantly smaller value than the others.

**Table 15** The moment magnitude and the rupture area of the Chelungpu fault in three scenarios.

| Scenarios  | Area (km <sup>2</sup> ) | Displacement (m) | Mw      |
|------------|-------------------------|------------------|---------|
| Scenario 1 | 861                     | 2.07-8.69        | 7.1-7.5 |
| Scenario 2 | 861                     | 2.04-8.57        | 7.1-7.5 |
| Scenario 3 | 861                     | 2.04-8.57        | 7.1-7.5 |

The recurrence interval of the Chelungpu fault is 300 - 1260 years (Shyu et al., 2020).



**Table 16** The moment magnitude and the rupture area of the Tamaopu-Shuangtung fault in three scenarios.

| Scenarios  | Area (km <sup>2</sup> ) | Displacement (m) | Mw      |
|------------|-------------------------|------------------|---------|
| Scenario 1 | 374.4522                | 0.72-14.3280     | 6.5-7.4 |
| Scenario 2 | 374.4522                | 0.74-14.7260     | 6.5-7.4 |
| Scenario 3 | 374.4522                | 0.64-12.7360     | 6.5-7.4 |

The recurrence interval of the Tamaopu-Shuangtung fault is 200 - 3980 years (Shyu et al., 2020).



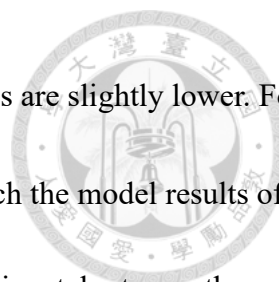
## Chapter 6 Discussions

### 6.1 Comparison with results of other studies

#### 6.1.1 The slip deficit rates from the 3-D model results

Here, this study will compare the results with those of 景國恩等 (2020), who used the same model, the Baseline Inversion model (Table 2). 景國恩等 (2020) used the Baseline Inversion model to calculate slip deficit rates but only used horizontal velocities for inversion. In their model, the fault geometry was set with the detachment extending from a depth of approximately 10 kilometers to shallower depths, branching from the Chelungpu and the Tamaopu-Shuangtung fault, and continuing to extend westward to connect with the Changhua fault. The data used included only GNSS data from the entire island.

In the three scenarios, the slip deficit rate of the Changhua fault varies significantly, ranging from 0.4 to 3.0 mm yr<sup>-1</sup> (Table 11). In contrast, the values for the Chelungpu and the Tamaopu-Shuangtung faults are more consistent, with the Chelungpu Fault ranging between 6.8 and 6.9 mm yr<sup>-1</sup>, and the Tamaopu-Shuangtung fault ranging from 3.2 to 3.7 mm yr<sup>-1</sup>. For the Changhua fault, 景國恩等 (2020) divided the fault into northern and southern segments, with the northern segment having a lower deficit rate than the southern segment. The smallest value in the three scenarios is slightly less than the northern segment's deficit rate, while the largest value is similar to the southern segment's deficit rate, indicating overall minimal differences. For the Chelungpu fault, the



values are close to those reported by 景國恩等 (2020), though their values are slightly lower. For the Tamaopu-Shuangtung fault, the results of this study do not closely match the model results of 景國恩等 (2020). The discrepancy is likely due to significantly higher horizontal rates on the eastern side of the study area, which may not be caused by elastic deformation, leading to an overestimation of the slip deficit rate in the model.

In conclusion, despite the differences in the data range, types, and the fault geometry, the slip deficit rates for the Changhua fault and the Chelungpu fault remain similar.

### 6.1.2 The moment magnitude of the faults

The moment magnitude of the Changhua fault, according to Shyu et al. (2020), is 7.57 or 7.77, which is higher than the moment magnitudes in Scenario 1 and Scenario 3 and close to Scenario 2 (Table 14). The moment magnitude of the Chelungpu fault, according to Shyu et al. (2020), is 7.60 or 7.81, which is higher than the moment magnitudes in all scenarios (Table 15). The moment magnitude of the Tamaopu-Shuangtung fault, according to Shyu et al. (2020), is 6.92 or 6.96, which is close to the value in Table 16.

Overall, the estimated magnitudes are similar, with slight numerical differences possibly arising from different calculation methods. The calculation formula is primarily influenced by the fault rupture area, and the precision in calculating the area will affect the final values.



## 6.2 Comprehensive assessment of slip deficit rates in three scenarios

To analyze the results of the 3-D model, the data was divided into northern and southern segments based on the north-south boundary used in the 2-D model. The averaged results for the northern and southern segments are shown in Figure 32, and the relationship between slip deficit and depth is shown in Figure 33.

For the Changhua fault, there is a divergence between the northern and southern segments (Figure 32). In Scenarios 1 and 2, the slip deficit rate in the southern segment is higher than in the northern segment. However, in Scenario 3, the slip deficit rate in the southern segment approaches zero, and shows a higher slip deficit rate in the northern segment than the southern segment. This might be due to the slip deficit rate of the southern segment transferring to the detachment in this scenario because the slip deficit rates in the northern segment across all three scenarios remain around  $1 \text{ mm yr}^{-1}$ . The trend of slip deficit rate with increasing depth is unclear (Figure 33), likely due to the relatively fewer layers of patches of the Changhua fault.

The results for the Chelungpu fault show consistent differences between the northern and southern segments across all three scenarios, with the slip deficit rate in the southern segment being higher than in the northern segment. This matches the slip rate pattern in Table 9, where the southern part of the Chelungpu fault shows a higher slip rate than the northern part. The values from



the 3-D model are close to those from the 2-D model, indicating good performance of the 2-D model for the Chelungpu fault.

For the Tamaopu-Shuangtung fault, it shows consistent differences between the northern and southern segments across all three scenarios, with the slip deficit rate in the southern segment being higher than in the northern segment. The trend of slip deficit rate with increasing depth is similar, showing a decrease in slip deficit rate with increasing depth.

Overall, in all three scenarios, the slip deficit rate values for the northern and southern segments are similar, except for the Changhua fault, where different scenarios result in noticeable variations.

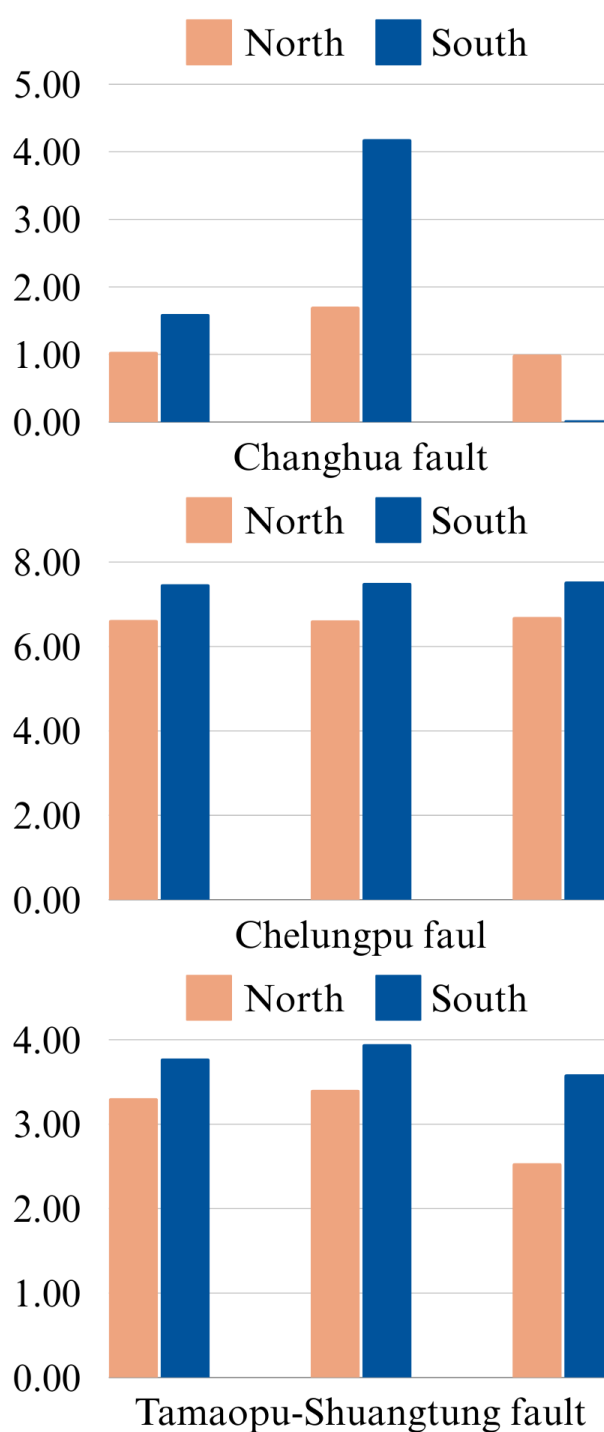


**Figure 32** The slip deficit rates across northern and southern segments. The left one is Scenarios 1. The middle one is Scenarios 2. The right one is Scenarios 3.

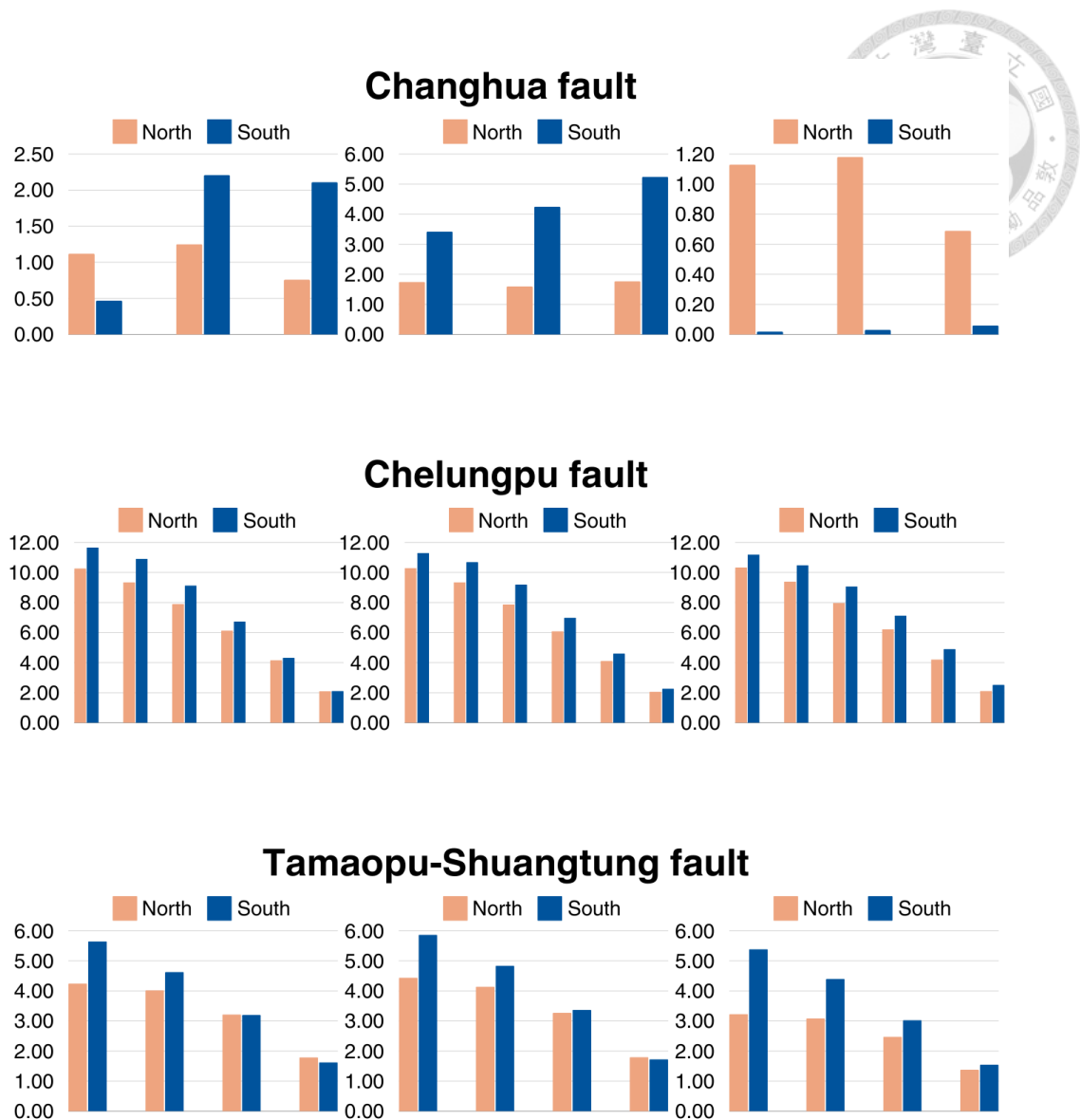


**Figure 33** The slip deficit rates in different depths across northern and southern segments. The left one is Scenarios 1. The middle one is Scenarios 2. The right one is Scenarios 3. In each respective scenario, the fault depth increases from shallow to deep from left to right. The unit is mm yr<sup>-1</sup>.



## 6.3 The impact of the Changhua fault's slip deficit rate

### 6.3.1 The impact to faults structures

The occurrence of the Chi-Chi earthquake demonstrates that orogenic activity can indeed cause significant hazards in the central Taiwan. However, results from the 3-D model reveal that the slip deficit inferred from strain is mostly concentrated on the Chelungpu fault. Regardless of the scenarios, the Changhua fault consistently shows the smallest slip deficit rate. This indicates that, compared to the other two faults, the Changhua fault currently has a minimal slip deficit rate. Additionally, the 2-D model results show that only a small portion of the slip transfers to the Changhua fault. Historical earthquake records indicate no significant earthquake events on the Changhua fault since 1848, and velocity fields within the timespan of this study show no significant change when crossing faults, suggesting that there are no creeping faults here. Therefore, it can be inferred that while the overall orogenic activity is moving westward, most of the stress in the central Taiwan is localized around the Chelungpu fault, resulting in the highest strain rate and slip deficit rate on this fault, irrespective of the geometric scenario.

In terms of structural, the faults in the central Taiwan form a series of imbricate structures, likely due to the specific direction of thrusting, which introduces many variables in the slip transfer path. Consequently, the area of greatest value of strain is not necessarily on the forefront fault. In



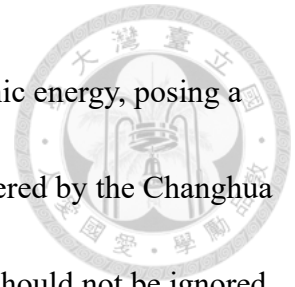
summary, despite the westward progression of orogenic activity and the Changhua fault being at the forefront, it does not exhibit the highest slip deficit rate.

### 6.3.2 The impact to earthquake hazards

The results of 3-D model implies that, in terms of earthquake hazards, the Chelungpu Fault remains one of the most critical faults in the central region that needs attention. Regardless of the different geometric scenario, the slip deficit of the Chelungpu fault surpasses that of the Changhua and the Tamaopu-Shuangtung fault. This indicates that, despite a major earthquake 25 years ago, the Chelungpu fault's slip deficit rate has likely continued to accumulate to the levels observed in this study. Although the Chi-Chi earthquake in 1999 reset the seismic cycle, it has been a quarter of a century since then, and the slip deficit rate on the fault may still be gradually building up.

From a public safety perspective, attention should remain focused on the Chelungpu fault, given its significant slip deficit rate and potential earthquake magnitude. However, it is still essential not to overlook the Changhua fault. While the Chelungpu fault has the highest slip deficit rate, the calculations are based on an average annual slip deficit rate. If this rate continues as observed in this study, the Changhua fault will still accumulate slip deficit for an additional 151 years compared to the Chelungpu fault. In other words, the Chelungpu fault has just started a new seismic cycle, whereas the Changhua fault has been in its current cycle for 176 years. The extra 151

years for the Changhua fault is sufficient to accumulate considerable seismic energy, posing a significant risk to over 3,000,000 people in the event of a earthquake triggered by the Changhua fault. Therefore, the potential hazards associated with the Changhua fault should not be ignored.

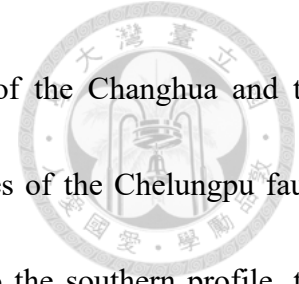




## Chapter 7 Conclusions

This study uses comprehensive geodetic data, including GNSS, precise leveling, and InSAR, to compile existing literature on fault geometry. A two-dimensional model was employed to test certain geometries, leading to the construction of a three-dimensional model of the deformation front in the central Taiwan. This model was then used to assess future seismic potential. The overall research can be summarized in the following points:

1. The upper detachment scenario provides a better fit for the model output, particularly in the vertical direction. Conversely, the model output of the lower detachment scenario overfits the velocity data.
2. The optimal misfit geometry in the southern profile includes most branches of the Changhua and Chelungpu fault, while only incorporating the bottom branches of the Tamaopu-Shuangtung fault. Because the model results show that the branches closest to the surface are locked, the slip rate here represents the difference in velocity between the shallow and deep parts of the fault. The Tamaopu-Shuangtung fault shows the highest slip rate, the Changhua fault the lowest, and the Chelungpu fault an intermediate rate. The slip rate of the Tamaopu-Shuangtung fault is significantly higher than in previous studies, possibly due to other structures in the eastern area outside the study area.



3. The optimal model result in the northern profile retains all most of the Changhua and the Tamaopu-Shuangtung fault, while including only the bottom branches of the Chelungpu fault. The slip rate in the northern profile is more reasonable compared to the southern profile. the Chelungpu fault shows the highest velocity, followed by the Tamaopu-Shuangtung and the Changhua fault.
4. For the 3-D model results, the Chelungpu fault, the Tamaopu-Shuangtung fault, and the detachment show a consistent pattern of slip deficit rate across all three scenarios, differing mainly in value of rates. The primary variation occurs with the Changhua fault. The scenario with the Changhua fault consisting flat and ramp make largest slip deficit rate. The other two barely show slip deficit rate. Scenario 3 of the 3-D model shows the optimal misfit.
5. The results of all three scenarios indicate that the Changhua fault has the potential to trigger earthquakes with a moment magnitude ranging from 6.0 to 7.9. The moment magnitude of the Chelungpu fault is ranging from 7.1 to 7.5. The moment magnitude of the Tamaopu-Shuangtung fault is ranging from 6.5 to 7.4.
6. Despite the westward propagation of orogenic activity and the Changhua fault being at the forefront, the Changhua Fault does not show the highest slip deficit rate. Instead, the Chelungpu Fault shows the highest slip deficit rate.



7. The Chelungpu fault has just started a new seismic cycle, whereas the Changhua fault has been in its current cycle for 176 years, posing a significant risk to over 3,000,000 people in the event of an earthquake triggered by the Changhua fault. Therefore, the potential hazards associated with the Changhua fault should not be ignored.



## Reference

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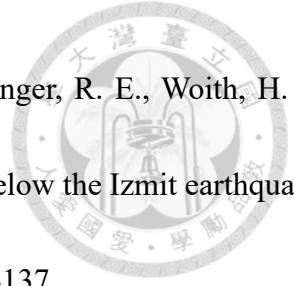
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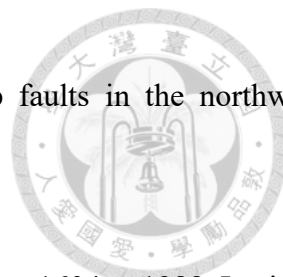
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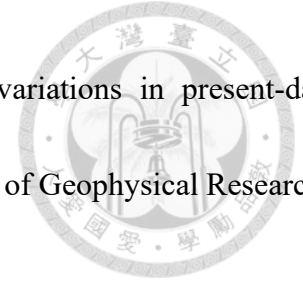
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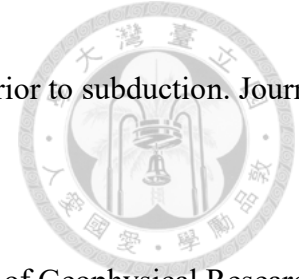
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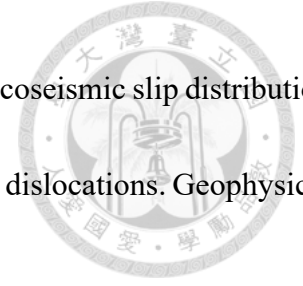
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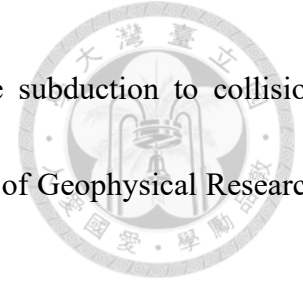
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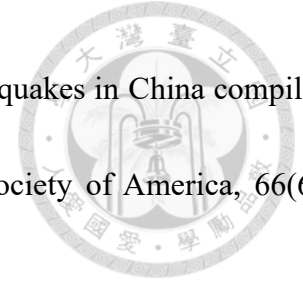
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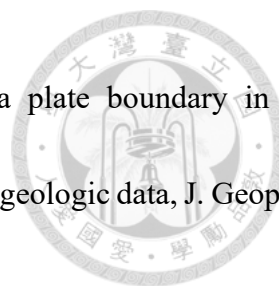
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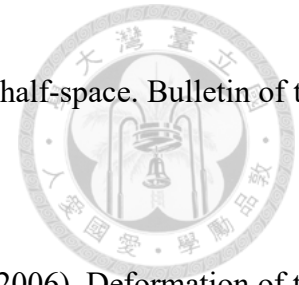
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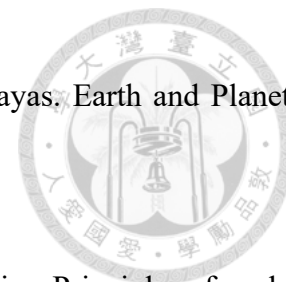
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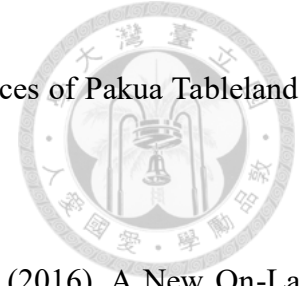
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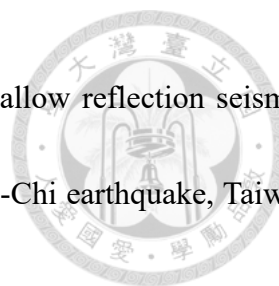
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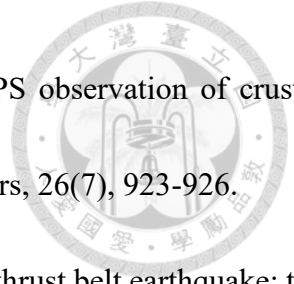
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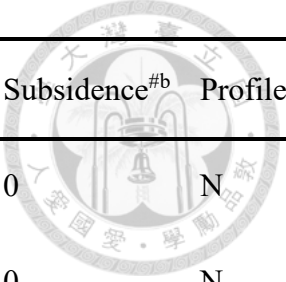
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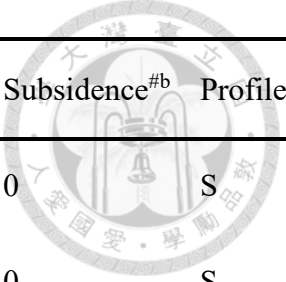
## Appendix

### Appendix A: Velocity of GNSS stations in horizontal direction

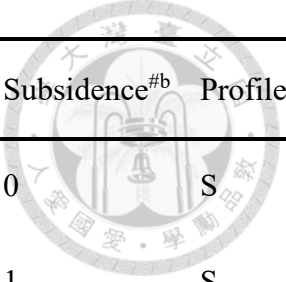
| Lon    | Lat    | VE     | VN    | SE    | SN    | Station | Type <sup>#a</sup> | Subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|--------|-------|-------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.63 | 24.421 | 2.375  | 1.503 | 0.080 | 0.072 | TC31    | C                  | 0                        | N                     |
| 120.63 | 24.362 | 1.503  | 1.457 | 0.010 | 0.008 | GS36    | C                  | 0                        | N                     |
| 120.66 | 24.356 | 2.401  | 0.976 | 0.034 | 0.023 | TEGS    | C                  | 0                        | N                     |
| 120.91 | 24.292 | 7.427  | 3.193 | 0.021 | 0.019 | SUC2    | C                  | 0                        | N                     |
| 120.54 | 24.291 | 1.189  | 1.148 | 0.046 | 0.027 | TACH    | C                  | 0                        | N                     |
| 120.87 | 24.282 | 8.751  | 4.697 | 0.075 | 0.077 | TC34    | C                  | 0                        | N                     |
| 120.60 | 24.280 | 2.504  | 0.891 | 0.026 | 0.026 | GS38    | C                  | 0                        | N                     |
| 120.69 | 24.272 | 3.290  | 2.067 | 0.007 | 0.006 | SGUN    | C                  | 0                        | N                     |
| 120.83 | 24.263 | 6.654  | 3.603 | 0.016 | 0.014 | DOSH    | C                  | 0                        | N                     |
| 120.80 | 24.226 | 8.353  | 2.886 | 0.063 | 0.040 | NSHE    | C                  | 0                        | N                     |
| 120.60 | 24.208 | 3.932  | 0.581 | 0.258 | 0.200 | TC12    | C                  | 0                        | N                     |
| 120.79 | 24.206 | 15.172 | 3.561 | 0.102 | 0.112 | TC13    | C                  | 0                        | N                     |
| 120.50 | 24.199 | 1.861  | 0.254 | 0.073 | 0.067 | TC32    | C                  | 0                        | N                     |
| 120.58 | 24.181 | 1.390  | 1.959 | 0.010 | 0.013 | GS40    | C                  | 0                        | N                     |



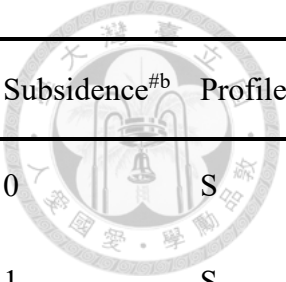
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|--------|--------|--------|-------|-------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.80 | 24.180 | 11.882 | 3.245 | 0.019 | 0.014 | S016    | C                  | 0                        | N                     |
| 120.65 | 24.178 | 3.403  | 1.747 | 0.075 | 0.072 | FCU1    | C                  | 0                        | N                     |
| 120.68 | 24.171 | 6.952  | 1.051 | 0.156 | 0.136 | TC22    | C                  | 0                        | N                     |
| 120.89 | 24.171 | 18.406 | 1.123 | 0.078 | 0.056 | HOPN    | C                  | 0                        | N                     |
| 120.86 | 24.160 | 12.888 | 5.826 | 0.081 | 0.082 | TC35    | C                  | 0                        | N                     |
| 120.65 | 24.154 | 4.024  | 0.988 | 0.171 | 0.179 | TC23    | C                  | 0                        | N                     |
| 120.63 | 24.153 | 3.942  | 1.313 | 0.012 | 0.009 | LSB0    | C                  | 0                        | N                     |
| 120.63 | 24.153 | 3.998  | 1.239 | 0.187 | 0.116 | LSBA    | C                  | 0                        | N                     |
| 120.60 | 24.153 | 2.077  | 0.062 | 0.146 | 0.180 | TC11    | C                  | 0                        | N                     |
| 120.58 | 24.145 | 1.303  | 1.643 | 0.062 | 0.048 | SHLU    | C                  | 0                        | N                     |
| 120.67 | 24.136 | 3.449  | 3.583 | 0.184 | 0.204 | TC21    | C                  | 0                        | N                     |
| 120.68 | 24.132 | 5.971  | 2.317 | 0.094 | 0.099 | TC01    | C                  | 0                        | N                     |
| 120.50 | 24.117 | 1.923  | 0.454 | 0.041 | 0.034 | VR01    | C                  | 0                        | N                     |
| 120.51 | 24.097 | 2.022  | 0.555 | 0.024 | 0.021 | GS21    | C                  | 0                        | N                     |
| 120.65 | 24.095 | 4.131  | 1.955 | 0.015 | 0.014 | GS23    | C                  | 0                        | N                     |
| 120.61 | 24.091 | 2.765  | 1.269 | 0.056 | 0.036 | GS22    | C                  | 0                        | N                     |
| 120.56 | 24.066 | 2.692  | 0.421 | 0.021 | 0.022 | CHUA    | C                  | 0                        | S                     |



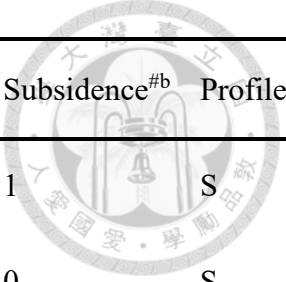
| Lon    | Lat    | VE      | VN     | SE    | SN    | Station | Type <sup>#a</sup> | Subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|---------|--------|-------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.44 | 24.060 | 3.180   | 0.187  | 0.013 | 0.010 | LUKN    | C                  | 0                        | S                     |
| 120.93 | 24.043 | -18.770 | 9.818  | 0.041 | 0.032 | DPIN    | C                  | 0                        | S                     |
| 120.70 | 24.043 | 6.567   | 3.199  | 0.010 | 0.025 | WUFN    | C                  | 0                        | S                     |
| 120.70 | 24.042 | 6.973   | 2.698  | 0.015 | 0.014 | WFEN    | C                  | 0                        | S                     |
| 120.72 | 24.035 | 10.173  | 4.707  | 0.014 | 0.012 | FNGU    | C                  | 0                        | S                     |
| 120.82 | 24.028 | 18.844  | 7.444  | 0.079 | 0.075 | GANK    | C                  | 0                        | S                     |
| 120.70 | 24.028 | 6.930   | 3.379  | 0.077 | 0.073 | TC33    | C                  | 0                        | S                     |
| 120.53 | 24.025 | 1.813   | 1.159  | 0.027 | 0.021 | GS24    | C                  | 0                        | S                     |
| 120.82 | 24.011 | 13.429  | 7.083  | 0.042 | 0.042 | FUQE    | C                  | 0                        | S                     |
| 120.64 | 23.987 | 4.043   | 2.337  | 0.021 | 0.020 | GS25    | C                  | 0                        | S                     |
| 120.74 | 23.983 | 12.159  | 5.702  | 0.022 | 0.019 | GS83    | C                  | 0                        | S                     |
| 120.69 | 23.979 | 6.837   | 2.390  | 0.048 | 0.034 | CAOT    | C                  | 0                        | S                     |
| 120.53 | 23.97  | 3.426   | 0.976  | 0.019 | 0.019 | PUS2    | C                  | 1                        | S                     |
| 120.47 | 23.961 | 1.351   | 2.158  | 0.099 | 0.072 | G811    | C                  | 1                        | S                     |
| 120.93 | 23.954 | -23.627 | 10.827 | 0.035 | 0.016 | S167    | C                  | 0                        | S                     |
| 120.48 | 23.948 | 1.667   | 6.912  | 0.063 | 0.047 | HNES    | C                  | 1                        | S                     |
| 120.70 | 23.946 | 6.829   | 2.620  | 0.007 | 0.006 | KZN1    | C                  | 0                        | S                     |



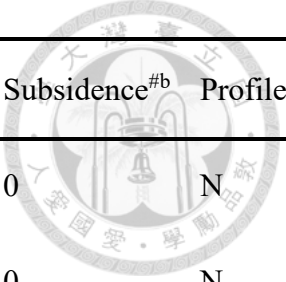
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|--------|--------|---------|--------|-------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.83 | 23.945 | 18.121  | 10.730 | 0.050 | 0.040 | CHIU    | C                  | 0                        | S                     |
| 120.39 | 23.938 | 1.977   | 1.365  | 0.021 | 0.016 | SSES    | C                  | 1                        | S                     |
| 120.32 | 23.922 | 1.356   | 0.840  | 0.031 | 0.022 | FUNY    | C                  | 1                        | S                     |
| 120.64 | 23.916 | 3.700   | 2.024  | 0.021 | 0.016 | PAKU    | C                  | 0                        | S                     |
| 120.37 | 23.90  | 2.462   | 0.914  | 0.017 | 0.016 | VR02    | C                  | 1                        | S                     |
| 120.80 | 23.884 | 21.494  | 8.381  | 0.042 | 0.029 | YUNL    | C                  | 0                        | S                     |
| 120.91 | 23.881 | -19.802 | 9.475  | 0.031 | 0.017 | SUN1    | C                  | 0                        | S                     |
| 120.65 | 23.87  | 5.399   | 2.035  | 0.021 | 0.014 | GS26    | C                  | 0                        | S                     |
| 120.29 | 23.86  | 2.240   | 0.977  | 0.015 | 0.013 | CHSG    | C                  | 1                        | S                     |
| 120.50 | 23.854 | 4.693   | -1.366 | 0.011 | 0.009 | SJES    | C                  | 1                        | S                     |
| 120.58 | 23.825 | 3.785   | 1.394  | 0.068 | 0.056 | GS27    | C                  | 0                        | S                     |
| 120.86 | 23.809 | 23.324  | 9.898  | 0.028 | 0.021 | GS84    | C                  | 0                        | S                     |
| 120.31 | 23.791 | 2.417   | 0.677  | 0.025 | 0.020 | FRES    | C                  | 1                        | S                     |
| 120.68 | 23.761 | 9.008   | 5.200  | 0.031 | 0.024 | JSAN    | C                  | 0                        | S                     |
| 120.59 | 23.757 | 5.440   | 2.461  | 0.014 | 0.010 | LNJS    | C                  | 0                        | S                     |
| 120.64 | 23.756 | 6.411   | 2.735  | 0.015 | 0.006 | PINT    | C                  | 0                        | S                     |
| 120.75 | 23.752 | 19.251  | 8.929  | 0.053 | 0.050 | LUGU    | C                  | 0                        | S                     |



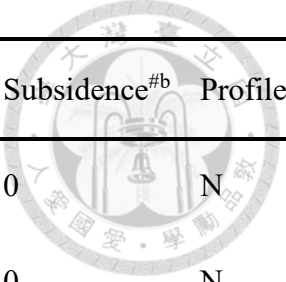
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|--------|--------|--------|--------|-------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.77 | 23.746 | 23.103 | 9.563  | 0.036 | 0.021 | S170    | C                  | 0                        | S                     |
| 120.40 | 23.741 | 4.633  | -0.300 | 0.031 | 0.025 | GFES    | C                  | 1                        | S                     |
| 120.43 | 23.733 | 3.602  | 1.517  | 0.013 | 0.012 | NTUH    | C                  | 1                        | S                     |
| 120.29 | 23.729 | 1.252  | 1.299  | 0.029 | 0.025 | HUWE    | C                  | 1                        | S                     |
| 120.31 | 23.723 | 0.618  | -1.096 | 0.052 | 0.043 | LYES    | C                  | 1                        | S                     |
| 120.19 | 23.720 | -1.826 | -0.455 | 0.119 | 0.055 | TASI    | C                  | 1                        | S                     |
| 120.41 | 23.709 | 5.884  | 2.009  | 0.061 | 0.062 | JMES    | C                  | 1                        | S                     |
| 120.25 | 23.704 | 1.243  | -0.906 | 0.053 | 0.042 | ANES    | C                  | 1                        | S                     |
| 120.85 | 23.697 | 26.496 | 9.536  | 0.017 | 0.014 | SINY    | C                  | 0                        | S                     |
| 120.86 | 23.688 | 26.884 | 9.645  | 0.029 | 0.021 | FKD2    | C                  | 0                        | S                     |
| 120.39 | 23.688 | -0.089 | -1.939 | 0.033 | 0.023 | TKJS    | C                  | 1                        | S                     |
| 120.35 | 23.687 | 1.661  | 3.110  | 0.012 | 0.010 | HLES    | C                  | 1                        | S                     |
| 120.31 | 23.678 | 2.440  | 1.270  | 0.064 | 0.059 | SNES    | C                  | 1                        | S                     |
| 120.45 | 23.674 | 4.163  | 3.513  | 0.017 | 0.013 | DNAN    | C                  | 1                        | S                     |
| 120.77 | 23.665 | 23.462 | 9.608  | 0.012 | 0.015 | SANL    | C                  | 0                        | S                     |
| 120.35 | 23.659 | 4.975  | 3.001  | 0.058 | 0.051 | STES    | C                  | 1                        | S                     |
| 120.31 | 23.653 | 6.042  | 2.722  | 0.080 | 0.068 | YCES    | C                  | 1                        | S                     |



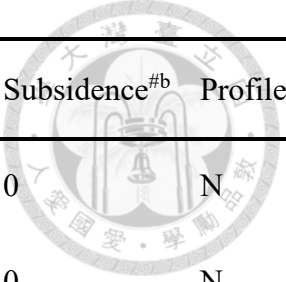
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|--------|--------|--------|--------|-------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.20 | 23.653 | 1.856  | 1.146  | 0.018 | 0.016 | MDES    | C                  | 1                        | S                     |
| 120.59 | 23.646 | 8.445  | 5.202  | 0.010 | 0.006 | GUKN    | C                  | 0                        | S                     |
| 120.72 | 23.634 | 20.346 | 6.252  | 0.023 | 0.024 | TSLN    | C                  | 0                        | S                     |
| 120.40 | 23.634 | 3.436  | -2.514 | 0.087 | 0.059 | JJES    | C                  | 1                        | S                     |
| 120.33 | 23.627 | 2.547  | 3.375  | 0.041 | 0.036 | KTES    | C                  | 1                        | S                     |
| 120.55 | 23.626 | 8.226  | 4.293  | 0.015 | 0.014 | YOKN    | C                  | 0                        | S                     |
| 120.62 | 23.624 | 15.237 | 6.580  | 0.016 | 0.012 | GKFM    | C                  | 0                        | S                     |
| 120.32 | 23.622 | 0.562  | 4.620  | 0.255 | 0.205 | JSES    | C                  | 1                        | S                     |
| 120.58 | 23.615 | 9.588  | 4.538  | 0.011 | 0.007 | JHSN    | C                  | 0                        | S                     |
| 120.61 | 23.612 | 16.044 | 5.766  | 0.009 | 0.029 | GLS     | C                  | 0                        | S                     |
| 120.70 | 23.946 | 6.297  | -2.993 | 0.098 | 0.126 | KZON    | C                  | 0                        | S                     |
| 120.89 | 23.608 | -31.46 | 11.404 | 0.042 | 0.029 | WANS    | C                  | 0                        | S                     |
| 120.63 | 24.421 | 1.378  | 1.319  | 0.244 | 0.242 | G092    | R                  | 0                        | N                     |
| 120.79 | 24.421 | 3.344  | 2.780  | 0.355 | 0.217 | M357    | R                  | 0                        | N                     |
| 120.86 | 24.419 | 3.538  | 2.776  | 0.394 | 0.183 | GF32    | R                  | 0                        | N                     |
| 120.65 | 24.406 | 1.409  | 1.044  | 0.288 | 0.202 | GE21    | R                  | 0                        | N                     |
| 120.75 | 24.405 | 3.322  | 2.157  | 0.213 | 0.127 | G101    | R                  | 0                        | N                     |



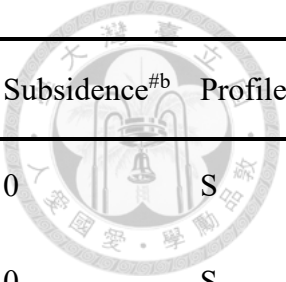
| Lon    | Lat    | VE     | VN    | SE    | SN    | Station | Type <sup>#a</sup> | Subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|--------|-------|-------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.70 | 24.389 | 1.862  | 2.124 | 0.256 | 0.417 | GE22    | R                  | 0                        | N                     |
| 120.59 | 24.379 | 0.638  | 1.138 | 0.205 | 0.229 | G091    | R                  | 0                        | N                     |
| 120.73 | 24.377 | 3.355  | 0.461 | 0.659 | 0.487 | M359    | R                  | 0                        | N                     |
| 120.84 | 24.374 | 4.624  | 4.299 | 0.303 | 0.232 | GF34    | R                  | 0                        | N                     |
| 120.95 | 24.359 | -7.385 | 4.929 | 0.501 | 0.370 | GF39    | R                  | 0                        | N                     |
| 120.66 | 24.356 | 2.206  | 1.368 | 0.150 | 0.214 | M045    | R                  | 0                        | N                     |
| 120.62 | 24.351 | 2.046  | 0.756 | 0.187 | 0.189 | G896    | R                  | 0                        | N                     |
| 120.77 | 24.344 | 4.186  | 2.285 | 0.335 | 0.185 | G165    | R                  | 0                        | N                     |
| 120.85 | 24.338 | 6.087  | 4.092 | 0.407 | 0.307 | GF42    | R                  | 0                        | N                     |
| 120.65 | 24.334 | 2.087  | 1.292 | 0.214 | 0.116 | G903    | R                  | 0                        | N                     |
| 120.75 | 24.326 | 4.322  | 2.401 | 0.247 | 0.184 | G173    | R                  | 0                        | N                     |
| 120.82 | 24.325 | 5.492  | 2.887 | 0.279 | 0.239 | GF47    | R                  | 0                        | N                     |
| 120.84 | 24.314 | 6.322  | 2.908 | 0.204 | 0.203 | GF45    | R                  | 0                        | N                     |
| 120.56 | 24.312 | 1.163  | 1.363 | 0.153 | 0.124 | G090    | R                  | 0                        | N                     |
| 120.82 | 24.312 | 5.784  | 3.231 | 0.343 | 0.283 | GF44    | R                  | 0                        | N                     |
| 120.68 | 24.311 | 2.914  | 1.323 | 0.819 | 0.258 | GF48    | R                  | 0                        | N                     |
| 120.79 | 24.310 | 5.412  | 2.540 | 0.241 | 0.161 | G920    | R                  | 0                        | N                     |



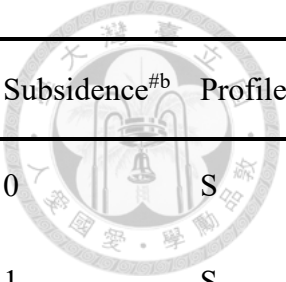
| Lon    | Lat    | VE      | VN    | SE    | SN    | Station | Type <sup>#a</sup> | Subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|---------|-------|-------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.71 | 24.308 | 3.314   | 1.693 | 0.215 | 0.191 | G174    | R                  | 0                        | N                     |
| 120.74 | 24.308 | 4.509   | 2.036 | 0.263 | 0.211 | G172    | R                  | 0                        | N                     |
| 120.85 | 24.299 | 6.995   | 3.739 | 0.232 | 0.251 | GF46    | R                  | 0                        | N                     |
| 120.79 | 24.299 | 6.053   | 3.031 | 0.161 | 0.216 | G102    | R                  | 0                        | N                     |
| 120.61 | 24.299 | 1.688   | 0.881 | 0.161 | 0.151 | M904    | R                  | 0                        | N                     |
| 120.91 | 24.291 | 8.349   | 4.892 | 0.349 | 0.198 | G098    | R                  | 0                        | N                     |
| 120.63 | 24.276 | 1.926   | 1.216 | 0.229 | 0.225 | G176    | R                  | 0                        | N                     |
| 120.66 | 24.273 | 2.602   | 1.184 | 0.159 | 0.150 | G175    | R                  | 0                        | N                     |
| 120.72 | 24.261 | 4.382   | 1.881 | 0.165 | 0.153 | G103    | R                  | 0                        | N                     |
| 120.79 | 24.257 | 8.024   | 3.670 | 0.277 | 0.237 | GF50    | R                  | 0                        | N                     |
| 120.58 | 24.228 | 2.312   | 1.300 | 0.260 | 0.236 | GF49    | R                  | 0                        | N                     |
| 120.65 | 24.222 | 3.012   | 1.179 | 0.214 | 0.186 | AF26    | R                  | 0                        | N                     |
| 120.70 | 24.214 | 4.195   | 2.014 | 0.212 | 0.136 | 3091    | R                  | 0                        | N                     |
| 120.55 | 24.188 | 2.166   | 1.560 | 0.165 | 0.081 | G926    | R                  | 0                        | N                     |
| 120.93 | 24.183 | -12.603 | 7.020 | 0.234 | 0.254 | GF52    | R                  | 0                        | N                     |
| 120.86 | 24.160 | 10.816  | 6.274 | 0.323 | 0.334 | GF51    | R                  | 0                        | N                     |
| 120.63 | 24.157 | 3.706   | 1.602 | 0.246 | 0.313 | AF17    | R                  | 0                        | N                     |



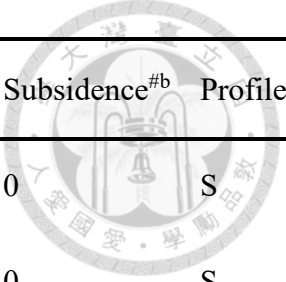
| Lon    | Lat    | VE      | VN     | SE    | SN    | Station | Type <sup>#a</sup> | Subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|---------|--------|-------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.74 | 24.145 | 6.723   | 2.348  | 0.260 | 0.198 | GE25    | R                  | 0                        | N                     |
| 120.58 | 24.138 | 2.160   | 1.654  | 0.165 | 0.123 | M044    | R                  | 0                        | N                     |
| 120.72 | 24.132 | 5.934   | 2.668  | 0.177 | 0.134 | G947    | R                  | 0                        | N                     |
| 120.75 | 24.123 | 8.576   | 4.030  | 0.198 | 0.140 | AF25    | R                  | 0                        | N                     |
| 120.77 | 24.110 | 7.368   | 4.173  | 0.209 | 0.151 | G958    | R                  | 0                        | N                     |
| 120.75 | 24.103 | 9.859   | 3.020  | 0.352 | 0.329 | M314    | R                  | 0                        | N                     |
| 120.65 | 24.094 | 3.379   | 1.796  | 0.137 | 0.132 | AF15    | R                  | 0                        | N                     |
| 120.47 | 24.090 | 1.086   | -0.053 | 0.122 | 0.182 | M486    | R                  | 0                        | N                     |
| 120.57 | 24.073 | 2.459   | 1.330  | 0.206 | 0.150 | AF19    | R                  | 0                        | S                     |
| 120.97 | 24.064 | -20.700 | 11.800 | 0.248 | 0.353 | G961    | R                  | 0                        | S                     |
| 120.43 | 24.056 | 1.235   | 0.740  | 0.180 | 0.129 | G055    | R                  | 0                        | S                     |
| 120.59 | 24.049 | 2.307   | 1.648  | 0.246 | 0.251 | GE10    | R                  | 0                        | S                     |
| 120.51 | 24.037 | 1.708   | 1.131  | 0.338 | 0.160 | AF09    | R                  | 0                        | S                     |
| 120.67 | 24.036 | 4.630   | 2.320  | 0.141 | 0.094 | AF16    | R                  | 0                        | S                     |
| 120.73 | 24.035 | 10.004  | 4.915  | 0.227 | 0.190 | AF24    | R                  | 0                        | S                     |
| 120.65 | 24.031 | 3.296   | 1.592  | 0.197 | 0.214 | M387    | R                  | 0                        | S                     |
| 120.83 | 24.028 | 14.107  | 8.417  | 0.180 | 0.218 | G960    | R                  | 0                        | S                     |



| Lon    | Lat    | VE      | VN     | SE    | SN    | Station | Type <sup>#a</sup> | Subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|---------|--------|-------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.55 | 24.016 | 1.593   | 0.575  | 0.460 | 0.136 | GE14    | R                  | 0                        | S                     |
| 120.64 | 24.015 | 3.863   | 2.238  | 0.354 | 0.239 | AF14    | R                  | 0                        | S                     |
| 120.96 | 24.012 | -22.953 | 12.191 | 0.307 | 0.388 | G963    | R                  | 0                        | S                     |
| 120.42 | 24.008 | 0.745   | 0.410  | 0.191 | 0.126 | G057    | R                  | 1                        | S                     |
| 120.38 | 24.006 | 0.961   | -0.097 | 0.189 | 0.148 | G056    | R                  | 1                        | S                     |
| 120.57 | 23.988 | 3.010   | 1.222  | 0.205 | 0.189 | GF54    | R                  | 0                        | S                     |
| 120.72 | 23.985 | 10.495  | 5.641  | 0.242 | 0.239 | G259    | R                  | 0                        | S                     |
| 120.52 | 23.985 | 1.588   | -0.541 | 0.157 | 0.145 | AF07    | R                  | 1                        | S                     |
| 120.78 | 23.982 | 13.677  | 8.007  | 0.319 | 0.382 | C013    | R                  | 0                        | S                     |
| 120.62 | 23.971 | 3.472   | 1.754  | 0.282 | 0.181 | AF29    | R                  | 0                        | S                     |
| 120.75 | 23.96  | 14.647  | 5.273  | 0.333 | 0.222 | AF22    | R                  | 0                        | S                     |
| 120.51 | 23.953 | 2.324   | 0.690  | 0.766 | 0.465 | M918    | R                  | 1                        | S                     |
| 120.87 | 23.95  | 21.789  | 14.039 | 0.355 | 0.491 | G962    | R                  | 0                        | S                     |
| 120.96 | 23.949 | -25.683 | 13.688 | 0.403 | 0.638 | GE32    | R                  | 0                        | S                     |
| 120.70 | 23.947 | 6.710   | 2.083  | 0.276 | 0.244 | AF13    | R                  | 0                        | S                     |
| 120.67 | 23.929 | 5.301   | 2.486  | 0.205 | 0.208 | G304    | R                  | 0                        | S                     |
| 120.63 | 23.928 | 4.035   | 1.771  | 0.224 | 0.193 | M085    | R                  | 0                        | S                     |



| Lon    | Lat    | VE      | VN     | SE    | SN    | Station | Type <sup>#a</sup> | Subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|---------|--------|-------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.64 | 23.925 | 4.317   | 1.965  | 0.201 | 0.177 | G305    | R                  | 0                        | S                     |
| 120.54 | 23.925 | 4.195   | 2.014  | 0.212 | 0.136 | AF03    | R                  | 1                        | S                     |
| 120.52 | 23.92  | 1.587   | 2.265  | 0.192 | 0.129 | G276    | R                  | 1                        | S                     |
| 120.58 | 23.919 | 2.588   | 1.625  | 0.194 | 0.152 | G316    | R                  | 0                        | S                     |
| 120.59 | 23.899 | 2.833   | 1.486  | 0.222 | 0.170 | AF05    | R                  | 0                        | S                     |
| 120.48 | 23.893 | 1.261   | 0.520  | 0.159 | 0.167 | G063    | R                  | 1                        | S                     |
| 120.71 | 23.891 | 7.864   | 3.019  | 0.191 | 0.217 | G303    | R                  | 0                        | S                     |
| 120.56 | 23.886 | 2.928   | 1.487  | 0.226 | 0.147 | G301    | R                  | 0                        | S                     |
| 120.74 | 23.886 | 13.284  | 7.238  | 0.322 | 0.281 | G302    | R                  | 0                        | S                     |
| 120.38 | 23.875 | 0.764   | 1.797  | 0.208 | 0.251 | G046    | R                  | 1                        | S                     |
| 120.53 | 23.871 | 2.695   | 1.773  | 0.260 | 0.174 | AF04    | R                  | 0                        | S                     |
| 120.48 | 23.87  | 1.617   | -0.713 | 0.171 | 0.158 | G314    | R                  | 1                        | S                     |
| 120.61 | 23.852 | 4.073   | 1.479  | 0.279 | 0.252 | G293    | R                  | 0                        | S                     |
| 120.93 | 23.848 | -31.437 | 13.342 | 0.556 | 0.260 | G967    | R                  | 0                        | S                     |
| 120.63 | 23.842 | 4.755   | 2.238  | 0.172 | 0.132 | G288    | R                  | 0                        | S                     |
| 120.59 | 23.841 | 3.615   | 2.037  | 0.239 | 0.154 | G319    | R                  | 0                        | S                     |
| 120.66 | 23.837 | 5.600   | 2.525  | 0.198 | 0.196 | G045    | R                  | 0                        | S                     |



| Lon    | Lat    | VE      | VN     | SE    | SN    | Station | Type <sup>#a</sup> | Subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|---------|--------|-------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.75 | 23.833 | 18.449  | 6.331  | 0.311 | 0.154 | G044    | R                  | 0                        | S                     |
| 120.61 | 23.83  | 4.051   | 2.539  | 0.299 | 0.193 | G262    | R                  | 0                        | S                     |
| 120.54 | 23.824 | 2.654   | 1.300  | 0.172 | 0.154 | AF02    | R                  | 0                        | S                     |
| 120.57 | 23.816 | 2.785   | 1.903  | 0.217 | 0.121 | G321    | R                  | 0                        | S                     |
| 120.64 | 23.801 | 4.977   | 2.971  | 0.146 | 0.233 | G038    | R                  | 0                        | S                     |
| 120.92 | 23.798 | -31.056 | 10.619 | 0.756 | 0.327 | GE31    | R                  | 0                        | S                     |
| 120.39 | 23.796 | 2.118   | -1.635 | 0.136 | 0.154 | G065    | R                  | 1                        | S                     |
| 120.49 | 23.791 | 2.597   | 1.236  | 0.208 | 0.271 | G312    | R                  | 1                        | S                     |
| 120.56 | 23.769 | 3.394   | 2.245  | 0.170 | 0.194 | AF01    | R                  | 0                        | S                     |
| 120.74 | 23.767 | 18.343  | 7.007  | 0.358 | 0.237 | G307    | R                  | 0                        | S                     |
| 120.69 | 23.763 | 9.151   | 3.677  | 0.235 | 0.172 | G041    | R                  | 0                        | S                     |
| 120.77 | 23.756 | 24.259  | 3.472  | 0.477 | 0.213 | M007    | R                  | 0                        | S                     |
| 120.60 | 23.744 | 4.504   | 2.388  | 0.339 | 0.179 | GE68    | R                  | 0                        | S                     |
| 120.86 | 23.738 | 28.375  | 8.428  | 0.457 | 0.280 | G969    | R                  | 0                        | S                     |
| 120.67 | 23.728 | 8.436   | 4.361  | 0.366 | 0.213 | G308    | R                  | 0                        | S                     |
| 120.65 | 23.714 | 7.451   | 4.148  | 0.204 | 0.265 | G040    | R                  | 0                        | S                     |
| 120.43 | 23.714 | 2.785   | 0.492  | 0.211 | 0.165 | G069    | R                  | 1                        | S                     |



Note:

#a: "C": continuous-mode GPS; "R": campaign-mode GPS.

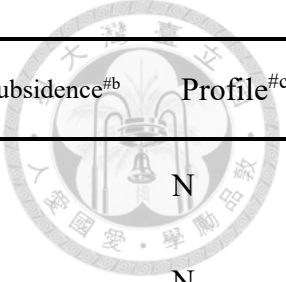
#b: "0": the station is not in the subsidence area; "1": the station is in the subsidence area.

#c: "N" the station belongs to the north profile in the 2-D model; "S" the station belongs to the south profile in the 2-D model.

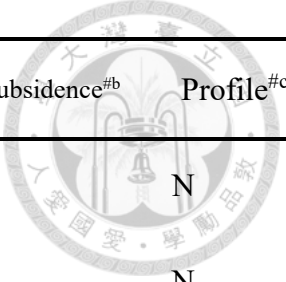


Appendix B: Velocity of GNSS and leveling in vertical direction

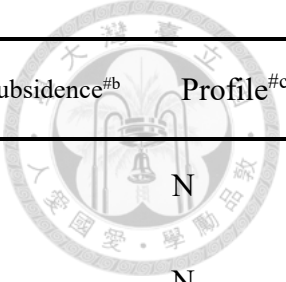
| Lon    | Lat    | VU     | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|--------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.63 | 24.421 | -2.347 | 0.233 | TC31    | C                  | 0                        | N                     |
| 120.63 | 24.362 | -1.648 | 0.021 | GS36    | C                  | 0                        | N                     |
| 120.66 | 24.356 | -1.019 | 0.069 | TEGS    | C                  | 0                        | N                     |
| 120.91 | 24.292 | 1.507  | 0.058 | SUC2    | C                  | 0                        | N                     |
| 120.54 | 24.291 | -4.042 | 0.105 | TACH    | C                  | 0                        | N                     |
| 120.87 | 24.282 | 0.309  | 0.238 | TC34    | C                  | 0                        | N                     |
| 120.60 | 24.280 | -2.697 | 0.079 | GS38    | C                  | 0                        | N                     |
| 120.69 | 24.272 | -1.973 | 0.019 | SGUN    | C                  | 0                        | N                     |
| 120.83 | 24.263 | 1.530  | 0.039 | DOSH    | C                  | 0                        | N                     |
| 120.80 | 24.226 | -0.599 | 0.119 | NSHE    | C                  | 0                        | N                     |
| 120.60 | 24.208 | -2.375 | 0.717 | TC12    | C                  | 0                        | N                     |
| 120.79 | 24.206 | -1.106 | 0.277 | TC13    | C                  | 0                        | N                     |
| 120.50 | 24.199 | -5.849 | 0.239 | TC32    | C                  | 0                        | N                     |
| 120.58 | 24.181 | -2.563 | 0.027 | GS40    | C                  | 0                        | N                     |
| 120.8  | 24.180 | -0.843 | 0.031 | S016    | C                  | 0                        | N                     |



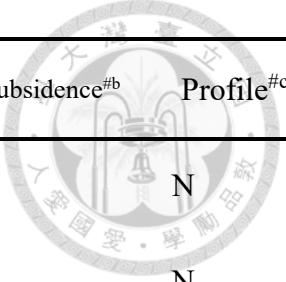
| Lon    | Lat    | VU     | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|--------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.65 | 24.178 | -2.351 | 0.274 | FCU1    | C                  | 0                        | N                     |
| 120.68 | 24.171 | -5.322 | 0.472 | TC22    | C                  | 0                        | N                     |
| 120.89 | 24.171 | 3.413  | 0.255 | HOPN    | C                  | 0                        | N                     |
| 120.86 | 24.160 | -3.012 | 0.279 | TC35    | C                  | 0                        | N                     |
| 120.65 | 24.154 | -5.859 | 0.583 | TC23    | C                  | 0                        | N                     |
| 120.63 | 24.153 | -3.233 | 0.032 | LSB0    | C                  | 0                        | N                     |
| 120.63 | 24.153 | -0.613 | 0.367 | LSBA    | C                  | 0                        | N                     |
| 120.60 | 24.153 | -3.891 | 0.534 | TC11    | C                  | 0                        | N                     |
| 120.58 | 24.145 | -5.189 | 0.217 | SHLU    | C                  | 0                        | N                     |
| 120.67 | 24.136 | -5.668 | 0.614 | TC21    | C                  | 0                        | N                     |
| 120.68 | 24.132 | -2.263 | 0.327 | TC01    | C                  | 0                        | N                     |
| 120.50 | 24.117 | -5.143 | 0.100 | VR01    | C                  | 0                        | N                     |
| 120.51 | 24.097 | -4.236 | 0.063 | GS21    | C                  | 0                        | N                     |
| 120.65 | 24.095 | -2.976 | 0.045 | GS23    | C                  | 0                        | N                     |
| 120.61 | 24.091 | -3.034 | 0.202 | GS22    | C                  | 0                        | N                     |
| 120.53 | 24.196 | -4.003 | 0.030 | G921    | L11                | 0                        | N                     |
| 120.55 | 24.196 | -3.542 | 0.084 | G924    | L11                | 0                        | N                     |



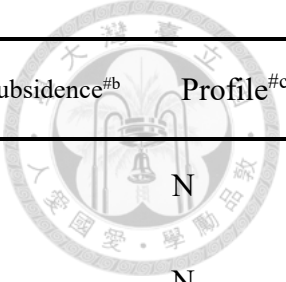
| Lon    | Lat    | VU     | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|--------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.54 | 24.194 | -3.927 | 0.042 | G922    | L11                | 0                        | N                     |
| 120.54 | 24.189 | -4.479 | 0.114 | 1088    | L11                | 0                        | N                     |
| 120.55 | 24.188 | -5.903 | 0.187 | G926    | L11                | 0                        | N                     |
| 120.56 | 24.186 | -4.199 | 0.123 | G927    | L11                | 0                        | N                     |
| 120.56 | 24.181 | -4.824 | 0.224 | G928    | L11                | 0                        | N                     |
| 120.57 | 24.176 | -4.602 | 0.219 | G929    | L11                | 0                        | N                     |
| 120.58 | 24.169 | -4.524 | 0.206 | G930    | L11                | 0                        | N                     |
| 120.58 | 24.169 | -4.721 | 0.210 | G931    | L11                | 0                        | N                     |
| 120.59 | 24.164 | -3.640 | 0.393 | GG13    | L11                | 0                        | N                     |
| 120.62 | 24.152 | -5.801 | 0.301 | G936    | L11                | 0                        | N                     |
| 120.61 | 24.147 | -5.286 | 0.286 | G935    | L11                | 0                        | N                     |
| 120.63 | 24.146 | -4.669 | 0.224 | G937    | L11                | 0                        | N                     |
| 120.64 | 24.143 | -5.298 | 0.216 | G938    | L11                | 0                        | N                     |
| 120.65 | 24.135 | -5.444 | 0.186 | G940    | L11                | 0                        | N                     |
| 120.73 | 24.134 | -4.541 | 0.241 | G948    | L11                | 0                        | N                     |
| 120.69 | 24.133 | -4.432 | 0.216 | G944    | L11                | 0                        | N                     |
| 120.66 | 24.133 | -5.152 | 0.280 | G941    | L11                | 0                        | N                     |



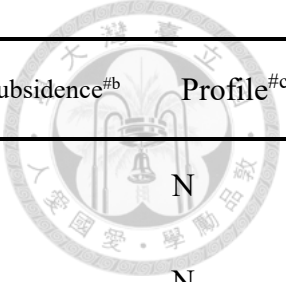
| Lon    | Lat    | VU     | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|--------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.7  | 24.132 | -5.005 | 0.508 | GG15    | L11                | 0                        | N                     |
| 120.72 | 24.132 | -4.527 | 0.241 | G947    | L11                | 0                        | N                     |
| 120.67 | 24.132 | -4.414 | 0.209 | G942    | L11                | 0                        | N                     |
| 120.74 | 24.130 | -3.942 | 0.295 | GE87    | L11                | 0                        | N                     |
| 120.68 | 24.129 | -4.162 | 0.471 | GG14    | L11                | 0                        | N                     |
| 120.71 | 24.127 | -4.502 | 0.218 | G946    | L11                | 0                        | N                     |
| 120.75 | 24.123 | -2.016 | 0.223 | G952    | L11                | 0                        | N                     |
| 120.75 | 24.123 | -2.007 | 0.193 | AF25    | L11                | 0                        | N                     |
| 120.63 | 24.421 | -0.914 | 0.998 | G092    | R                  | 0                        | N                     |
| 120.79 | 24.421 | -4.153 | 1.188 | M357    | R                  | 0                        | N                     |
| 120.86 | 24.419 | -1.466 | 1.143 | GF32    | R                  | 0                        | N                     |
| 120.65 | 24.406 | -1.331 | 0.551 | GE21    | R                  | 0                        | N                     |
| 120.75 | 24.405 | -4.049 | 1.010 | G101    | R                  | 0                        | N                     |
| 120.70 | 24.389 | -1.347 | 0.631 | GE22    | R                  | 0                        | N                     |
| 120.59 | 24.379 | -2.984 | 0.901 | G091    | R                  | 0                        | N                     |
| 120.73 | 24.377 | -2.105 | 1.041 | M359    | R                  | 0                        | N                     |
| 120.84 | 24.374 | -3.945 | 0.924 | GF34    | R                  | 0                        | N                     |



| Lon    | Lat    | VU     | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|--------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.95 | 24.359 | 1.108  | 1.324 | GF39    | R                  | 0                        | N                     |
| 120.66 | 24.356 | -1.188 | 0.882 | M045    | R                  | 0                        | N                     |
| 120.62 | 24.351 | -1.751 | 0.706 | G896    | R                  | 0                        | N                     |
| 120.77 | 24.344 | -2.626 | 1.073 | G165    | R                  | 0                        | N                     |
| 120.85 | 24.338 | -1.960 | 1.265 | GF42    | R                  | 0                        | N                     |
| 120.65 | 24.334 | -2.260 | 0.686 | G903    | R                  | 0                        | N                     |
| 120.75 | 24.326 | -4.665 | 1.396 | G173    | R                  | 0                        | N                     |
| 120.82 | 24.325 | -1.886 | 1.105 | GF47    | R                  | 0                        | N                     |
| 120.84 | 24.314 | 0.274  | 0.670 | GF45    | R                  | 0                        | N                     |
| 120.56 | 24.312 | -3.011 | 0.652 | G090    | R                  | 0                        | N                     |
| 120.82 | 24.312 | -0.869 | 0.772 | GF44    | R                  | 0                        | N                     |
| 120.68 | 24.311 | -2.586 | 0.937 | GF48    | R                  | 0                        | N                     |
| 120.79 | 24.31  | -2.048 | 1.002 | G920    | R                  | 0                        | N                     |
| 120.71 | 24.308 | -3.496 | 0.931 | G174    | R                  | 0                        | N                     |
| 120.74 | 24.308 | -1.972 | 0.768 | G172    | R                  | 0                        | N                     |
| 120.85 | 24.299 | -0.488 | 0.892 | GF46    | R                  | 0                        | N                     |
| 120.79 | 24.299 | -2.314 | 0.339 | G102    | R                  | 0                        | N                     |

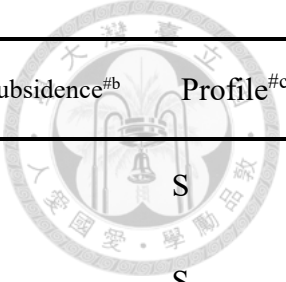


| Lon    | Lat    | VU     | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|--------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.61 | 24.299 | -3.221 | 0.456 | M904    | R                  | 0                        | N                     |
| 120.91 | 24.291 | 1.255  | 1.144 | G098    | R                  | 0                        | N                     |
| 120.63 | 24.276 | -3.489 | 0.757 | G176    | R                  | 0                        | N                     |
| 120.66 | 24.273 | -2.907 | 0.486 | G175    | R                  | 0                        | N                     |
| 120.72 | 24.261 | -3.226 | 0.964 | G103    | R                  | 0                        | N                     |
| 120.79 | 24.257 | 2.238  | 1.137 | GF50    | R                  | 0                        | N                     |
| 120.58 | 24.228 | -2.522 | 0.971 | GF49    | R                  | 0                        | N                     |
| 120.65 | 24.222 | -3.268 | 0.558 | AF26    | R                  | 0                        | N                     |
| 120.70 | 24.214 | -2.572 | 0.671 | 3091    | R                  | 0                        | N                     |
| 120.55 | 24.188 | -5.903 | 0.623 | G926    | R                  | 0                        | N                     |
| 120.93 | 24.183 | 1.014  | 0.881 | GF52    | R                  | 0                        | N                     |
| 120.86 | 24.160 | -0.887 | 0.686 | GF51    | R                  | 0                        | N                     |
| 120.63 | 24.157 | -3.230 | 1.482 | AF17    | R                  | 0                        | N                     |
| 120.74 | 24.145 | -3.531 | 0.835 | GE25    | R                  | 0                        | N                     |
| 120.58 | 24.138 | -3.649 | 0.642 | M044    | R                  | 0                        | N                     |
| 120.72 | 24.132 | -3.352 | 0.848 | G947    | R                  | 0                        | N                     |
| 120.75 | 24.123 | -1.249 | 0.729 | AF25    | R                  | 0                        | N                     |



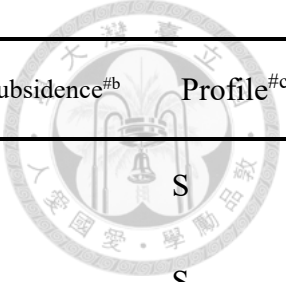
| Lon    | Lat    | VU     | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|--------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.77 | 24.110 | -1.066 | 0.908 | G958    | R                  | 0                        | N                     |
| 120.75 | 24.103 | -3.994 | 0.929 | M314    | R                  | 0                        | N                     |
| 120.65 | 24.094 | -3.166 | 0.598 | AF15    | R                  | 0                        | N                     |
| 120.47 | 24.090 | -3.609 | 0.994 | M486    | R                  | 0                        | N                     |
| 120.56 | 24.066 | -1.421 | 0.070 | CHUA    | C                  | 0                        | S                     |
| 120.44 | 24.060 | -5.438 | 0.040 | LUKN    | C                  | 0                        | S                     |
| 120.93 | 24.043 | 1.199  | 0.100 | DPIN    | C                  | 0                        | S                     |
| 120.70 | 24.043 | -3.030 | 0.020 | WUFN    | C                  | 0                        | S                     |
| 120.70 | 24.042 | -3.083 | 0.043 | WFEN    | C                  | 0                        | S                     |
| 120.72 | 24.035 | -1.919 | 0.034 | FNGU    | C                  | 0                        | S                     |
| 120.82 | 24.028 | -0.851 | 0.211 | GANK    | C                  | 0                        | S                     |
| 120.70 | 24.028 | -5.018 | 0.251 | TC33    | C                  | 0                        | S                     |
| 120.53 | 24.025 | -6.934 | 0.102 | GS24    | C                  | 0                        | S                     |
| 120.82 | 24.011 | 0.396  | 0.114 | FUQE    | C                  | 0                        | S                     |
| 120.64 | 23.987 | -3.324 | 0.061 | GS25    | C                  | 0                        | S                     |
| 120.74 | 23.983 | -0.298 | 0.056 | GS83    | C                  | 0                        | S                     |
| 120.69 | 23.979 | -4.003 | 0.103 | CAOT    | C                  | 0                        | S                     |

| Lon    | Lat     | VU      | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|---------|---------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.53 | 23.970  | -16.733 | 0.065 | PUS2    | C                  | 1                        | S                     |
| 120.47 | 23.961  | -32.892 | 0.296 | G811    | C                  | 1                        | S                     |
| 120.93 | 23.954  | 4.109   | 0.034 | S167    | C                  | 0                        | S                     |
| 120.48 | 23.948  | -28.688 | 0.224 | HNES    | C                  | 1                        | S                     |
| 120.70 | 23.946  | -3.669  | 0.015 | KZN1    | C                  | 0                        | S                     |
| 120.70 | 23.946  | -10.511 | 0.307 | KZON    | C                  | 0                        | S                     |
| 120.83 | 23.945  | 3.338   | 0.083 | CHIU    | C                  | 0                        | S                     |
| 120.39 | 23.938  | -25.445 | 0.074 | SSES    | C                  | 1                        | S                     |
| 120.32 | 23.922  | -6.917  | 0.080 | FUNY    | C                  | 1                        | S                     |
| 120.64 | 23.916  | -2.270  | 0.045 | PAKU    | C                  | 0                        | S                     |
| 120.37 | 23.900  | -23.630 | 0.073 | VR02    | C                  | 1                        | S                     |
| 120.80 | 23.884  | 1.894   | 0.099 | YUNL    | C                  | 0                        | S                     |
| 120.91 | 23.8812 | 1.835   | 0.053 | SUN1    | C                  | 0                        | S                     |
| 120.65 | 23.870  | -2.223  | 0.047 | GS26    | C                  | 0                        | S                     |
| 120.29 | 23.860  | -0.540  | 0.127 | CHSG    | C                  | 1                        | S                     |
| 120.50 | 23.854  | -27.472 | 0.027 | SJES    | C                  | 1                        | S                     |
| 120.58 | 23.825  | -2.257  | 0.200 | GS27    | C                  | 0                        | S                     |



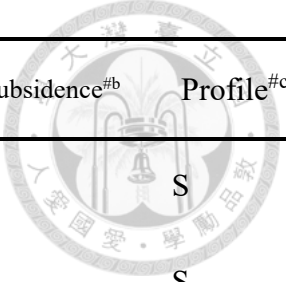
| Lon    | Lat    | VU      | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|---------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.86 | 23.809 | 5.383   | 0.078 | GS84    | C                  | 0                        | S                     |
| 120.31 | 23.791 | -18.391 | 0.091 | FRES    | C                  | 1                        | S                     |
| 120.68 | 23.761 | 0.497   | 0.085 | JSAN    | C                  | 0                        | S                     |
| 120.59 | 23.757 | -3.532  | 0.034 | LNJS    | C                  | 0                        | S                     |
| 120.64 | 23.756 | -4.073  | 0.030 | PINT    | C                  | 0                        | S                     |
| 120.75 | 23.752 | 2.598   | 0.180 | LUGU    | C                  | 0                        | S                     |
| 120.77 | 23.746 | 0.955   | 0.052 | S170    | C                  | 0                        | S                     |
| 120.40 | 23.741 | -32.765 | 0.121 | GFES    | C                  | 1                        | S                     |
| 120.43 | 23.733 | -30.102 | 0.048 | NTUH    | C                  | 1                        | S                     |
| 120.29 | 23.729 | -22.726 | 0.129 | HUWE    | C                  | 1                        | S                     |
| 120.31 | 23.723 | -35.625 | 0.224 | LYES    | C                  | 1                        | S                     |
| 120.19 | 23.720 | -21.626 | 0.351 | TASI    | C                  | 1                        | S                     |
| 120.41 | 23.709 | -37.281 | 0.258 | JMES    | C                  | 1                        | S                     |
| 120.25 | 23.704 | -24.823 | 0.216 | ANES    | C                  | 1                        | S                     |
| 120.85 | 23.697 | 6.893   | 0.041 | SINY    | C                  | 0                        | S                     |
| 120.86 | 23.688 | 5.767   | 0.078 | FKD2    | C                  | 0                        | S                     |
| 120.39 | 23.688 | -40.209 | 0.105 | TKJS    | C                  | 1                        | S                     |

| Lon    | Lat    | VU      | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|---------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.35 | 23.687 | -46.511 | 0.060 | HLES    | C                  | 1                        | S                     |
| 120.31 | 23.678 | -55.725 | 0.366 | SNES    | C                  | 1                        | S                     |
| 120.45 | 23.674 | -14.332 | 0.068 | DNAN    | C                  | 1                        | S                     |
| 120.77 | 23.665 | 2.719   | 0.030 | SANL    | C                  | 0                        | S                     |
| 120.35 | 23.659 | -54.914 | 0.467 | STES    | C                  | 1                        | S                     |
| 120.31 | 23.653 | -45.494 | 0.424 | YCES    | C                  | 1                        | S                     |
| 120.20 | 23.653 | -35.524 | 0.105 | MDES    | C                  | 1                        | S                     |
| 120.59 | 23.646 | -0.175  | 0.020 | GUKN    | C                  | 0                        | S                     |
| 120.72 | 23.634 | 3.822   | 0.071 | TSLN    | C                  | 0                        | S                     |
| 120.40 | 23.634 | -55.116 | 0.526 | JJES    | C                  | 1                        | S                     |
| 120.33 | 23.627 | -42.008 | 0.100 | KTES    | C                  | 1                        | S                     |
| 120.55 | 23.626 | -0.349  | 0.042 | YOKN    | C                  | 0                        | S                     |
| 120.62 | 23.624 | -1.251  | 0.042 | GKFM    | C                  | 0                        | S                     |
| 120.32 | 23.622 | -50.116 | 1.707 | JSES    | C                  | 1                        | S                     |
| 120.58 | 23.615 | 0.018   | 0.017 | JHSN    | C                  | 0                        | S                     |
| 120.61 | 23.612 | 1.485   | 0.021 | GLS     | C                  | 0                        | S                     |
| 120.89 | 23.608 | 7.534   | 0.077 | WANS    | C                  | 0                        | S                     |



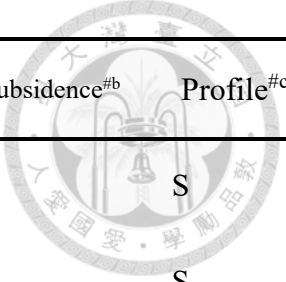
| Lon    | Lat    | VU     | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|--------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.81 | 23.992 | -2.234 | 0.397 | C015    | L1718              | 0                        | S                     |
| 120.68 | 23.987 | -3.862 | 0.295 | X115    | L1718              | 0                        | S                     |
| 120.76 | 23.986 | -0.112 | 0.314 | C012    | L1718              | 0                        | S                     |
| 120.74 | 23.985 | -1.722 | 0.353 | C011    | L1718              | 0                        | S                     |
| 120.80 | 23.985 | -1.108 | 0.348 | C014    | L1718              | 0                        | S                     |
| 120.77 | 23.984 | -0.263 | 0.704 | 9404    | L1718              | 0                        | S                     |
| 120.74 | 23.983 | -0.298 | 1.282 | B280    | L1718              | 0                        | S                     |
| 120.75 | 23.982 | 0.052  | 0.473 | GF68    | L1718              | 0                        | S                     |
| 120.78 | 23.982 | -0.887 | 0.338 | C013    | L1718              | 0                        | S                     |
| 120.73 | 23.982 | -3.120 | 0.394 | T045    | L1718              | 0                        | S                     |
| 120.69 | 23.980 | -4.124 | 0.398 | T075    | L1718              | 0                        | S                     |
| 120.69 | 23.979 | -3.641 | 0.753 | C009    | L1718              | 0                        | S                     |
| 120.70 | 23.979 | -3.540 | 0.442 | T055    | L1718              | 0                        | S                     |
| 120.68 | 23.979 | -3.764 | 0.293 | C090    | L1718              | 0                        | S                     |
| 120.72 | 23.979 | -3.417 | 0.437 | C010    | L1718              | 0                        | S                     |
| 120.62 | 23.978 | -3.976 | 0.279 | C086    | L1718              | 0                        | S                     |
| 120.70 | 23.978 | -4.108 | 0.944 | B241    | L1718              | 0                        | S                     |

| Lon    | Lat    | VU      | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|---------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.70 | 23.978 | -3.173  | 0.319 | T009    | L1718              | 0                        | S                     |
| 120.63 | 23.978 | -3.492  | 0.290 | G268    | L1718              | 0                        | S                     |
| 120.63 | 23.978 | -4.691  | 0.314 | C087    | L1718              | 0                        | S                     |
| 120.67 | 23.978 | -1.894  | 1.217 | GH17    | L1718              | 0                        | S                     |
| 120.71 | 23.977 | 0.317   | 0.291 | B240    | L1718              | 0                        | S                     |
| 120.67 | 23.976 | -1.541  | 1.282 | GH16    | L1718              | 0                        | S                     |
| 120.62 | 23.975 | -4.347  | 0.360 | G270    | L1718              | 0                        | S                     |
| 120.63 | 23.974 | -3.487  | 0.288 | G269    | L1718              | 0                        | S                     |
| 120.61 | 23.974 | -4.516  | 0.237 | C085    | L1718              | 0                        | S                     |
| 120.64 | 23.973 | -4.180  | 0.374 | G267    | L1718              | 0                        | S                     |
| 120.65 | 23.972 | -4.119  | 0.294 | G266    | L1718              | 0                        | S                     |
| 120.61 | 23.971 | -3.950  | 0.744 | GG18    | L1718              | 0                        | S                     |
| 120.65 | 23.971 | -4.704  | 0.325 | C088    | L1718              | 0                        | S                     |
| 120.67 | 23.968 | -3.639  | 0.676 | C089    | L1718              | 0                        | S                     |
| 120.60 | 23.968 | -6.973  | 0.280 | C084    | L1718              | 0                        | S                     |
| 120.59 | 23.962 | -7.467  | 0.194 | C083    | L1718              | 0                        | S                     |
| 120.47 | 23.960 | -30.552 | 0.377 | C078    | L1718              | 1                        | S                     |

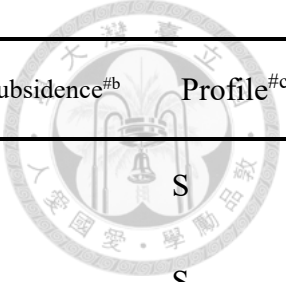


| Lon    | Lat    | VU      | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|---------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.40 | 23.959 | -16.835 | 0.798 | GG19    | L1718              | 1                        | S                     |
| 120.57 | 23.958 | -7.046  | 0.349 | GE91    | L1718              | 0                        | S                     |
| 120.57 | 23.956 | -8.831  | 1.031 | X112    | L1718              | 1                        | S                     |
| 120.49 | 23.955 | -28.068 | 0.862 | G274    | L1718              | 1                        | S                     |
| 120.43 | 23.955 | -9.972  | 0.673 | G324    | L1718              | 1                        | S                     |
| 120.54 | 23.954 | -12.974 | 0.669 | C081    | L1718              | 1                        | S                     |
| 120.51 | 23.953 | -31.993 | 0.595 | C079    | L1718              | 1                        | S                     |
| 120.55 | 23.952 | -13.891 | 0.412 | G882    | L1718              | 1                        | S                     |
| 120.56 | 23.952 | -12.044 | 1.272 | C082    | L1718              | 1                        | S                     |
| 120.52 | 23.950 | -21.055 | 0.219 | G323    | L1718              | 1                        | S                     |
| 120.44 | 23.947 | -22.207 | 0.426 | C077    | L1718              | 1                        | S                     |
| 120.57 | 24.073 | -4.387  | 0.918 | AF19    | R                  | 0                        | S                     |
| 120.97 | 24.064 | 3.403   | 0.773 | G961    | R                  | 0                        | S                     |
| 120.43 | 24.056 | -4.866  | 0.640 | G055    | R                  | 0                        | S                     |
| 120.59 | 24.049 | -3.615  | 0.636 | GE10    | R                  | 0                        | S                     |
| 120.51 | 24.037 | -7.288  | 0.896 | AF09    | R                  | 0                        | S                     |
| 120.67 | 24.036 | -4.661  | 0.437 | AF16    | R                  | 0                        | S                     |

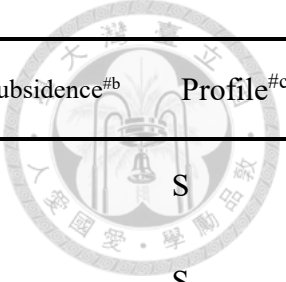
| Lon    | Lat    | VU      | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|---------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.73 | 24.035 | -2.402  | 0.903 | AF24    | R                  | 0                        | S                     |
| 120.65 | 24.031 | -4.355  | 0.832 | M387    | R                  | 0                        | S                     |
| 120.83 | 24.028 | -0.859  | 0.718 | G960    | R                  | 0                        | S                     |
| 120.55 | 24.016 | -6.547  | 0.678 | GE14    | R                  | 0                        | S                     |
| 120.64 | 24.015 | -3.138  | 0.591 | AF14    | R                  | 0                        | S                     |
| 120.96 | 24.012 | 6.559   | 0.576 | G963    | R                  | 0                        | S                     |
| 120.42 | 24.008 | -13.323 | 0.577 | G057    | R                  | 1                        | S                     |
| 120.38 | 24.006 | -12.437 | 0.638 | G056    | R                  | 1                        | S                     |
| 120.57 | 23.988 | -7.532  | 0.934 | GF54    | R                  | 0                        | S                     |
| 120.72 | 23.985 | -0.478  | 0.892 | G259    | R                  | 0                        | S                     |
| 120.52 | 23.985 | -10.010 | 0.519 | AF07    | R                  | 1                        | S                     |
| 120.78 | 23.982 | 3.192   | 1.436 | C013    | R                  | 0                        | S                     |
| 120.62 | 23.971 | -2.628  | 0.676 | AF29    | R                  | 0                        | S                     |
| 120.75 | 23.960 | 1.206   | 0.665 | AF22    | R                  | 0                        | S                     |
| 120.51 | 23.953 | -31.264 | 1.012 | M918    | R                  | 1                        | S                     |
| 120.87 | 23.950 | 4.564   | 0.819 | G962    | R                  | 0                        | S                     |
| 120.96 | 23.949 | 9.106   | 0.839 | GE32    | R                  | 0                        | S                     |



| Lon    | Lat    | VU      | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|---------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.70 | 23.947 | -4.217  | 0.870 | AF13    | R                  | 0                        | S                     |
| 120.67 | 23.929 | -3.764  | 0.822 | G304    | R                  | 0                        | S                     |
| 120.63 | 23.928 | -2.748  | 0.687 | M085    | R                  | 0                        | S                     |
| 120.64 | 23.925 | -2.657  | 0.798 | G305    | R                  | 0                        | S                     |
| 120.54 | 23.925 | -2.572  | 0.671 | AF03    | R                  | 1                        | S                     |
| 120.52 | 23.920 | -24.877 | 0.655 | G276    | R                  | 1                        | S                     |
| 120.58 | 23.919 | -7.272  | 0.763 | G316    | R                  | 0                        | S                     |
| 120.59 | 23.899 | -5.720  | 0.803 | AF05    | R                  | 0                        | S                     |
| 120.48 | 23.893 | -22.331 | 0.475 | G063    | R                  | 1                        | S                     |
| 120.71 | 23.891 | -3.637  | 0.797 | G303    | R                  | 0                        | S                     |
| 120.56 | 23.886 | -6.935  | 0.571 | G301    | R                  | 0                        | S                     |
| 120.74 | 23.886 | 2.870   | 1.219 | G302    | R                  | 0                        | S                     |
| 120.38 | 23.875 | -16.986 | 0.915 | G046    | R                  | 1                        | S                     |
| 120.53 | 23.871 | -6.289  | 0.586 | AF04    | R                  | 0                        | S                     |
| 120.48 | 23.870 | -22.083 | 0.402 | G314    | R                  | 1                        | S                     |
| 120.61 | 23.852 | -3.600  | 0.968 | G293    | R                  | 0                        | S                     |
| 120.93 | 23.848 | 12.050  | 1.304 | G967    | R                  | 0                        | S                     |



| Lon    | Lat    | VU      | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|---------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.63 | 23.842 | -4.560  | 0.827 | G288    | R                  | 0                        | S                     |
| 120.59 | 23.841 | -2.492  | 0.636 | G319    | R                  | 0                        | S                     |
| 120.66 | 23.837 | -3.034  | 1.120 | G045    | R                  | 0                        | S                     |
| 120.75 | 23.833 | 0.799   | 0.579 | G044    | R                  | 0                        | S                     |
| 120.61 | 23.830 | -3.727  | 0.814 | G262    | R                  | 0                        | S                     |
| 120.54 | 23.824 | -8.024  | 0.741 | AF02    | R                  | 0                        | S                     |
| 120.57 | 23.816 | -6.523  | 0.614 | G321    | R                  | 0                        | S                     |
| 120.64 | 23.801 | -3.586  | 0.676 | G038    | R                  | 0                        | S                     |
| 120.92 | 23.798 | 12.732  | 1.450 | GE31    | R                  | 0                        | S                     |
| 120.39 | 23.796 | -19.249 | 1.042 | G065    | R                  | 1                        | S                     |
| 120.49 | 23.791 | -10.048 | 0.990 | G312    | R                  | 1                        | S                     |
| 120.56 | 23.769 | -6.851  | 0.908 | AF01    | R                  | 0                        | S                     |
| 120.74 | 23.767 | 2.799   | 1.312 | G307    | R                  | 0                        | S                     |
| 120.69 | 23.763 | -1.973  | 0.401 | G041    | R                  | 0                        | S                     |
| 120.77 | 23.756 | -2.614  | 1.163 | M007    | R                  | 0                        | S                     |
| 120.60 | 23.744 | -4.079  | 0.597 | GE68    | R                  | 0                        | S                     |
| 120.86 | 23.738 | 8.389   | 0.680 | G969    | R                  | 0                        | S                     |



| Lon    | Lat    | VU      | SU    | Station | Type <sup>#a</sup> | subsidence <sup>#b</sup> | Profile <sup>#c</sup> |
|--------|--------|---------|-------|---------|--------------------|--------------------------|-----------------------|
| 120.67 | 23.728 | -4.184  | 1.353 | G308    | R                  | 0                        | S                     |
| 120.65 | 23.714 | -3.655  | 0.774 | G040    | R                  | 0                        | S                     |
| 120.43 | 23.714 | -39.110 | 1.635 | G069    | R                  | 1                        | S                     |

Note:

#a: "C": continuous-mode GPS; "R": campaign-mode GPS; "L11" / "L1718": leveling route 11 / 1718

#b: "0": the station is not in the subsidence area; "1": the station is in the subsidence area.

#c: "N" the station belongs to north profile in the 2-D model; "S" the station belongs to south profile in the 2-D model.



## Appendix C: Velocity of InSAR in line-of-sight direction

| Lon    | Lat    | V     | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|-------|------|--------------------------|-----------------------|
| 120.87 | 24.413 | 1.17  | 0.55 | 0                        | N                     |
| 120.68 | 24.406 | 1.01  | 0.48 | 0                        | N                     |
| 120.68 | 24.377 | 1.11  | 0.41 | 0                        | N                     |
| 120.70 | 24.369 | 0.86  | 0.35 | 0                        | N                     |
| 120.69 | 24.332 | 0.72  | 0.28 | 0                        | N                     |
| 120.82 | 24.318 | 0.35  | 0.36 | 0                        | N                     |
| 120.84 | 24.310 | 0.60  | 0.42 | 0                        | N                     |
| 120.84 | 24.296 | 1.09  | 0.41 | 0                        | N                     |
| 120.85 | 24.296 | 0.59  | 0.45 | 0                        | N                     |
| 120.87 | 24.296 | 0.61  | 0.50 | 0                        | N                     |
| 120.57 | 24.288 | 0.42  | 0.50 | 0                        | N                     |
| 120.60 | 24.288 | 0.53  | 0.42 | 0                        | N                     |
| 120.74 | 24.288 | -0.40 | 0.17 | 0                        | N                     |
| 120.76 | 24.281 | -0.21 | 0.20 | 0                        | N                     |
| 120.81 | 24.281 | 1.06  | 0.38 | 0                        | N                     |
| 120.69 | 24.274 | -0.04 | 0.17 | 0                        | N                     |
| 120.56 | 24.266 | -0.35 | 0.49 | 0                        | N                     |
| 120.58 | 24.266 | 0.09  | 0.46 | 0                        | N                     |
| 120.54 | 24.259 | -0.10 | 0.53 | 0                        | N                     |
| 120.60 | 24.259 | 0.53  | 0.39 | 0                        | N                     |
| 120.65 | 24.259 | 0.24  | 0.27 | 0                        | N                     |
| 120.74 | 24.259 | -0.10 | 0.14 | 0                        | N                     |
| 120.79 | 24.259 | 0.06  | 0.34 | 0                        | N                     |
| 120.82 | 24.259 | 0.78  | 0.44 | 0                        | N                     |
| 120.52 | 24.252 | 0.24  | 0.55 | 0                        | N                     |
| 120.56 | 24.252 | -0.57 | 0.48 | 0                        | N                     |
| 120.58 | 24.252 | 0.23  | 0.46 | 0                        | N                     |
| 120.84 | 24.237 | 0.56  | 0.51 | 0                        | N                     |
| 120.85 | 24.237 | 0.50  | 0.53 | 0                        | N                     |
| 120.57 | 24.230 | 0.35  | 0.42 | 0                        | N                     |
| 120.64 | 24.215 | -0.01 | 0.27 | 0                        | N                     |
| 120.69 | 24.215 | -0.46 | 0.19 | 0                        | N                     |
| 120.56 | 24.207 | -0.07 | 0.41 | 0                        | N                     |

| Lon    | Lat    | V     | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|-------|------|--------------------------|-----------------------|
| 120.58 | 24.207 | 0.03  | 0.38 | 0                        | N                     |
| 120.80 | 24.207 | -1.77 | 0.41 | 0                        | N                     |
| 120.84 | 24.207 | -0.27 | 0.56 | 0                        | N                     |
| 120.82 | 24.200 | -0.53 | 0.50 | 0                        | N                     |
| 120.56 | 24.193 | 0.07  | 0.40 | 0                        | N                     |
| 120.58 | 24.193 | 0.23  | 0.38 | 0                        | N                     |
| 120.59 | 24.193 | 0.52  | 0.35 | 0                        | N                     |
| 120.74 | 24.193 | -1.34 | 0.26 | 0                        | N                     |
| 120.76 | 24.193 | -0.46 | 0.31 | 0                        | N                     |
| 120.84 | 24.193 | -0.94 | 0.56 | 0                        | N                     |
| 120.54 | 24.178 | 0.17  | 0.47 | 0                        | N                     |
| 120.55 | 24.178 | 0.29  | 0.44 | 0                        | N                     |
| 120.58 | 24.178 | 0.80  | 0.36 | 0                        | N                     |
| 120.59 | 24.178 | 0.87  | 0.34 | 0                        | N                     |
| 120.60 | 24.178 | 0.76  | 0.32 | 0                        | N                     |
| 120.76 | 24.178 | -1.31 | 0.32 | 0                        | N                     |
| 120.83 | 24.178 | -0.65 | 0.56 | 0                        | N                     |
| 120.74 | 24.171 | -1.85 | 0.29 | 0                        | N                     |
| 120.54 | 24.163 | 0.00  | 0.46 | 0                        | N                     |
| 120.55 | 24.163 | 0.22  | 0.44 | 0                        | N                     |
| 120.58 | 24.163 | 0.89  | 0.39 | 0                        | N                     |
| 120.59 | 24.163 | 0.72  | 0.39 | 0                        | N                     |
| 120.60 | 24.163 | 0.70  | 0.35 | 0                        | N                     |
| 120.76 | 24.163 | -2.00 | 0.37 | 0                        | N                     |
| 120.64 | 24.156 | -0.34 | 0.34 | 0                        | N                     |
| 120.69 | 24.156 | -1.26 | 0.29 | 0                        | N                     |
| 120.47 | 24.149 | 0.01  | 0.57 | 0                        | N                     |
| 120.49 | 24.141 | 0.05  | 0.54 | 0                        | N                     |
| 120.60 | 24.141 | 0.52  | 0.41 | 0                        | N                     |
| 120.45 | 24.134 | -0.39 | 0.59 | 0                        | N                     |
| 120.47 | 24.134 | -0.08 | 0.58 | 0                        | N                     |
| 120.73 | 24.119 | -2.40 | 0.42 | 0                        | N                     |
| 120.44 | 24.105 | -0.22 | 0.65 | 0                        | N                     |
| 120.73 | 24.105 | -2.50 | 0.44 | 0                        | N                     |
| 120.47 | 24.097 | -0.18 | 0.57 | 0                        | N                     |



| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.64 | 24.097 | -0.65  | 0.45 | 0                        | N                     |
| 120.69 | 24.097 | -1.68  | 0.43 | 0                        | N                     |
| 120.44 | 24.090 | -0.42  | 0.66 | 0                        | N                     |
| 120.73 | 24.090 | -2.49  | 0.47 | 0                        | N                     |
| 120.40 | 24.075 | -10.88 | 0.68 | 1                        | S                     |
| 120.44 | 24.075 | -0.46  | 0.66 | 1                        | S                     |
| 120.62 | 24.060 | -0.06  | 0.50 | 0                        | S                     |
| 120.63 | 24.060 | -0.73  | 0.51 | 0                        | S                     |
| 120.70 | 24.060 | -1.99  | 0.52 | 0                        | S                     |
| 120.43 | 24.053 | -0.58  | 0.66 | 1                        | S                     |
| 120.46 | 24.053 | -0.99  | 0.61 | 1                        | S                     |
| 120.49 | 24.053 | -1.44  | 0.56 | 1                        | S                     |
| 120.51 | 24.053 | -1.38  | 0.53 | 0                        | S                     |
| 120.54 | 24.053 | -1.00  | 0.52 | 0                        | S                     |
| 120.65 | 24.053 | -0.81  | 0.51 | 0                        | S                     |
| 120.68 | 24.053 | -1.46  | 0.50 | 0                        | S                     |
| 120.41 | 24.046 | -0.39  | 0.69 | 1                        | S                     |
| 120.62 | 24.046 | 0.02   | 0.52 | 0                        | S                     |
| 120.63 | 24.046 | -0.55  | 0.53 | 0                        | S                     |
| 120.70 | 24.046 | -1.88  | 0.54 | 0                        | S                     |
| 120.38 | 24.031 | -3.38  | 0.70 | 1                        | S                     |
| 120.40 | 24.031 | -2.15  | 0.69 | 1                        | S                     |
| 120.41 | 24.031 | -1.69  | 0.67 | 1                        | S                     |
| 120.43 | 24.031 | -2.03  | 0.66 | 1                        | S                     |
| 120.44 | 24.031 | -3.11  | 0.64 | 1                        | S                     |
| 120.45 | 24.031 | -2.64  | 0.61 | 1                        | S                     |
| 120.47 | 24.031 | -2.48  | 0.57 | 1                        | S                     |
| 120.48 | 24.031 | -2.91  | 0.55 | 1                        | S                     |
| 120.49 | 24.031 | -4.00  | 0.54 | 1                        | S                     |
| 120.51 | 24.031 | -3.29  | 0.53 | 1                        | S                     |
| 120.52 | 24.031 | -2.56  | 0.53 | 1                        | S                     |
| 120.54 | 24.031 | -2.37  | 0.55 | 0                        | S                     |
| 120.55 | 24.031 | -1.56  | 0.55 | 0                        | S                     |
| 120.63 | 24.024 | -0.21  | 0.55 | 0                        | S                     |
| 120.65 | 24.024 | -0.68  | 0.57 | 0                        | S                     |





| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.68 | 24.024 | -1.17  | 0.57 | 0                        | S                     |
| 120.38 | 24.016 | -3.09  | 0.71 | 1                        | S                     |
| 120.40 | 24.016 | -3.15  | 0.69 | 1                        | S                     |
| 120.41 | 24.016 | -3.26  | 0.67 | 1                        | S                     |
| 120.43 | 24.016 | -3.99  | 0.65 | 1                        | S                     |
| 120.44 | 24.016 | -4.08  | 0.62 | 1                        | S                     |
| 120.45 | 24.016 | -4.59  | 0.61 | 1                        | S                     |
| 120.47 | 24.016 | -4.50  | 0.60 | 1                        | S                     |
| 120.48 | 24.016 | -6.53  | 0.59 | 1                        | S                     |
| 120.49 | 24.016 | -10.96 | 0.57 | 1                        | S                     |
| 120.51 | 24.016 | -6.96  | 0.56 | 1                        | S                     |
| 120.52 | 24.016 | -4.63  | 0.56 | 1                        | S                     |
| 120.54 | 24.016 | -3.99  | 0.58 | 1                        | S                     |
| 120.55 | 24.016 | -2.91  | 0.58 | 0                        | S                     |
| 120.56 | 24.016 | -1.29  | 0.58 | 0                        | S                     |
| 120.37 | 24.002 | -3.34  | 0.72 | 1                        | S                     |
| 120.38 | 24.002 | -4.31  | 0.71 | 1                        | S                     |
| 120.40 | 24.002 | -4.98  | 0.70 | 1                        | S                     |
| 120.41 | 24.002 | -4.74  | 0.68 | 1                        | S                     |
| 120.43 | 24.002 | -6.21  | 0.65 | 1                        | S                     |
| 120.44 | 24.002 | -6.37  | 0.62 | 1                        | S                     |
| 120.45 | 24.002 | -6.99  | 0.62 | 1                        | S                     |
| 120.47 | 24.002 | -6.79  | 0.60 | 1                        | S                     |
| 120.48 | 24.002 | -12.04 | 0.60 | 1                        | S                     |
| 120.49 | 24.002 | -11.19 | 0.58 | 1                        | S                     |
| 120.51 | 24.002 | -9.39  | 0.58 | 1                        | S                     |
| 120.52 | 24.002 | -4.96  | 0.59 | 1                        | S                     |
| 120.54 | 24.002 | -3.66  | 0.61 | 1                        | S                     |
| 120.55 | 24.002 | -3.80  | 0.63 | 1                        | S                     |
| 120.56 | 24.002 | -3.02  | 0.63 | 0                        | S                     |
| 120.58 | 24.002 | -1.70  | 0.62 | 0                        | S                     |
| 120.73 | 24.002 | -2.82  | 0.67 | 0                        | S                     |
| 120.65 | 23.994 | -0.80  | 0.65 | 0                        | S                     |
| 120.68 | 23.994 | -1.19  | 0.63 | 0                        | S                     |
| 120.36 | 23.987 | -2.39  | 0.76 | 1                        | S                     |



| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.37 | 23.987 | -3.13  | 0.73 | 1                        | S                     |
| 120.38 | 23.987 | -6.03  | 0.72 | 1                        | S                     |
| 120.40 | 23.987 | -5.45  | 0.71 | 1                        | S                     |
| 120.41 | 23.987 | -6.87  | 0.69 | 1                        | S                     |
| 120.43 | 23.987 | -10.04 | 0.67 | 1                        | S                     |
| 120.44 | 23.987 | -9.22  | 0.64 | 1                        | S                     |
| 120.45 | 23.987 | -9.80  | 0.62 | 1                        | S                     |
| 120.47 | 23.987 | -13.11 | 0.60 | 1                        | S                     |
| 120.48 | 23.987 | -20.44 | 0.59 | 1                        | S                     |
| 120.49 | 23.987 | -18.19 | 0.59 | 1                        | S                     |
| 120.51 | 23.987 | -8.22  | 0.60 | 1                        | S                     |
| 120.52 | 23.987 | -7.21  | 0.61 | 1                        | S                     |
| 120.54 | 23.987 | -5.61  | 0.64 | 1                        | S                     |
| 120.55 | 23.987 | -4.93  | 0.66 | 1                        | S                     |
| 120.56 | 23.987 | -4.01  | 0.67 | 0                        | S                     |
| 120.58 | 23.987 | -2.41  | 0.65 | 0                        | S                     |
| 120.73 | 23.987 | -2.97  | 0.70 | 0                        | S                     |
| 120.74 | 23.987 | -2.86  | 0.69 | 0                        | S                     |
| 120.76 | 23.987 | -2.62  | 0.70 | 0                        | S                     |
| 120.94 | 23.987 | -5.34  | 0.94 | 0                        | S                     |
| 120.34 | 23.972 | -1.69  | 0.77 | 1                        | S                     |
| 120.36 | 23.972 | -3.02  | 0.75 | 1                        | S                     |
| 120.37 | 23.972 | -5.96  | 0.75 | 1                        | S                     |
| 120.38 | 23.972 | -9.40  | 0.73 | 1                        | S                     |
| 120.40 | 23.972 | -6.85  | 0.70 | 1                        | S                     |
| 120.41 | 23.972 | -6.84  | 0.72 | 1                        | S                     |
| 120.43 | 23.972 | -9.56  | 0.72 | 1                        | S                     |
| 120.44 | 23.972 | -11.13 | 0.70 | 1                        | S                     |
| 120.45 | 23.972 | -11.39 | 0.66 | 1                        | S                     |
| 120.47 | 23.972 | -16.47 | 0.63 | 1                        | S                     |
| 120.48 | 23.972 | -21.21 | 0.61 | 1                        | S                     |
| 120.49 | 23.972 | -20.57 | 0.62 | 1                        | S                     |
| 120.51 | 23.972 | -15.22 | 0.64 | 1                        | S                     |
| 120.52 | 23.972 | -11.54 | 0.66 | 1                        | S                     |
| 120.54 | 23.972 | -10.55 | 0.69 | 1                        | S                     |

| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.55 | 23.972 | -8.74  | 0.68 | 1                        | S                     |
| 120.56 | 23.972 | -6.34  | 0.69 | 1                        | S                     |
| 120.58 | 23.972 | -3.94  | 0.71 | 0                        | S                     |
| 120.74 | 23.972 | -2.71  | 0.74 | 0                        | S                     |
| 120.94 | 23.972 | -5.17  | 0.93 | 0                        | S                     |
| 120.95 | 23.972 | -5.71  | 0.95 | 0                        | S                     |
| 120.60 | 23.965 | -1.95  | 0.73 | 0                        | S                     |
| 120.34 | 23.958 | -2.33  | 0.76 | 1                        | S                     |
| 120.36 | 23.958 | -4.45  | 0.75 | 1                        | S                     |
| 120.37 | 23.958 | -8.16  | 0.74 | 1                        | S                     |
| 120.38 | 23.958 | -10.61 | 0.72 | 1                        | S                     |
| 120.40 | 23.958 | -9.59  | 0.71 | 1                        | S                     |
| 120.43 | 23.958 | -6.60  | 0.69 | 1                        | S                     |
| 120.44 | 23.958 | -9.32  | 0.68 | 1                        | S                     |
| 120.45 | 23.958 | -11.73 | 0.69 | 1                        | S                     |
| 120.47 | 23.958 | -18.67 | 0.67 | 1                        | S                     |
| 120.48 | 23.958 | -21.05 | 0.64 | 1                        | S                     |
| 120.49 | 23.958 | -20.56 | 0.66 | 1                        | S                     |
| 120.51 | 23.958 | -20.61 | 0.67 | 1                        | S                     |
| 120.52 | 23.958 | -14.34 | 0.68 | 1                        | S                     |
| 120.54 | 23.958 | -9.66  | 0.70 | 1                        | S                     |
| 120.55 | 23.958 | -8.59  | 0.71 | 1                        | S                     |
| 120.56 | 23.958 | -7.26  | 0.72 | 1                        | S                     |
| 120.58 | 23.958 | -3.78  | 0.74 | 1                        | S                     |
| 120.63 | 23.958 | -0.83  | 0.94 | 0                        | S                     |
| 120.95 | 23.958 | -5.78  | 0.94 | 0                        | S                     |
| 120.33 | 23.943 | -2.25  | 0.78 | 1                        | S                     |
| 120.34 | 23.943 | -3.91  | 0.76 | 1                        | S                     |
| 120.36 | 23.943 | -6.95  | 0.75 | 1                        | S                     |
| 120.37 | 23.943 | -9.17  | 0.74 | 1                        | S                     |
| 120.40 | 23.943 | -14.12 | 0.72 | 1                        | S                     |
| 120.41 | 23.943 | -11.13 | 0.71 | 1                        | S                     |
| 120.43 | 23.943 | -9.70  | 0.70 | 1                        | S                     |
| 120.44 | 23.943 | -13.06 | 0.69 | 1                        | S                     |
| 120.45 | 23.943 | -13.45 | 0.69 | 1                        | S                     |



| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.47 | 23.943 | -9.96  | 0.69 | 1                        | S                     |
| 120.48 | 23.943 | -10.94 | 0.69 | 1                        | S                     |
| 120.49 | 23.943 | -14.92 | 0.70 | 1                        | S                     |
| 120.51 | 23.943 | -16.72 | 0.71 | 1                        | S                     |
| 120.52 | 23.943 | -11.09 | 0.71 | 1                        | S                     |
| 120.54 | 23.943 | -8.79  | 0.71 | 1                        | S                     |
| 120.55 | 23.943 | -7.66  | 0.73 | 1                        | S                     |
| 120.57 | 23.936 | -4.04  | 0.76 | 1                        | S                     |
| 120.60 | 23.936 | -1.81  | 0.84 | 0                        | S                     |
| 120.68 | 23.936 | -1.94  | 0.97 | 0                        | S                     |
| 120.33 | 23.928 | -2.01  | 0.78 | 1                        | S                     |
| 120.34 | 23.928 | -5.08  | 0.77 | 1                        | S                     |
| 120.36 | 23.928 | -7.71  | 0.75 | 1                        | S                     |
| 120.37 | 23.928 | -8.39  | 0.76 | 1                        | S                     |
| 120.41 | 23.928 | -16.96 | 0.72 | 1                        | S                     |
| 120.47 | 23.928 | -4.54  | 0.71 | 1                        | S                     |
| 120.48 | 23.928 | -5.02  | 0.71 | 1                        | S                     |
| 120.49 | 23.928 | -12.69 | 0.72 | 1                        | S                     |
| 120.51 | 23.928 | -16.36 | 0.73 | 1                        | S                     |
| 120.52 | 23.928 | -11.50 | 0.75 | 1                        | S                     |
| 120.54 | 23.928 | -11.38 | 0.74 | 1                        | S                     |
| 120.55 | 23.928 | -6.44  | 0.76 | 1                        | S                     |
| 120.70 | 23.928 | -2.50  | 1.03 | 0                        | S                     |
| 120.33 | 23.913 | -2.67  | 0.79 | 1                        | S                     |
| 120.36 | 23.913 | -8.38  | 0.78 | 1                        | S                     |
| 120.40 | 23.913 | -14.56 | 0.75 | 1                        | S                     |
| 120.41 | 23.913 | -19.34 | 0.74 | 1                        | S                     |
| 120.43 | 23.913 | -18.16 | 0.72 | 1                        | S                     |
| 120.44 | 23.913 | -15.09 | 0.72 | 1                        | S                     |
| 120.45 | 23.913 | -10.98 | 0.72 | 1                        | S                     |
| 120.47 | 23.913 | -6.90  | 0.72 | 1                        | S                     |
| 120.48 | 23.913 | -3.07  | 0.72 | 1                        | S                     |
| 120.49 | 23.913 | -7.07  | 0.73 | 1                        | S                     |
| 120.51 | 23.913 | -11.98 | 0.75 | 1                        | S                     |
| 120.52 | 23.913 | -11.47 | 0.76 | 1                        | S                     |



| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.54 | 23.913 | -11.16 | 0.77 | 1                        | S                     |
| 120.55 | 23.913 | -6.71  | 0.78 | 1                        | S                     |
| 120.56 | 23.913 | -2.97  | 0.80 | 1                        | S                     |
| 120.58 | 23.913 | -1.77  | 0.81 | 0                        | S                     |
| 120.60 | 23.906 | -1.72  | 0.90 | 0                        | S                     |
| 120.68 | 23.906 | -1.85  | 1.04 | 0                        | S                     |
| 120.31 | 23.899 | -1.90  | 0.81 | 1                        | S                     |
| 120.33 | 23.899 | -2.22  | 0.80 | 1                        | S                     |
| 120.34 | 23.899 | -4.43  | 0.80 | 1                        | S                     |
| 120.36 | 23.899 | -9.01  | 0.80 | 1                        | S                     |
| 120.37 | 23.899 | -11.95 | 0.79 | 1                        | S                     |
| 120.38 | 23.899 | -12.90 | 0.77 | 1                        | S                     |
| 120.40 | 23.899 | -13.77 | 0.77 | 1                        | S                     |
| 120.41 | 23.899 | -15.70 | 0.76 | 1                        | S                     |
| 120.43 | 23.899 | -17.50 | 0.74 | 1                        | S                     |
| 120.44 | 23.899 | -11.70 | 0.73 | 1                        | S                     |
| 120.45 | 23.899 | -7.70  | 0.71 | 1                        | S                     |
| 120.47 | 23.899 | -10.36 | 0.71 | 1                        | S                     |
| 120.48 | 23.899 | -8.96  | 0.72 | 1                        | S                     |
| 120.49 | 23.899 | -3.66  | 0.74 | 1                        | S                     |
| 120.51 | 23.899 | -4.97  | 0.76 | 1                        | S                     |
| 120.52 | 23.899 | -6.75  | 0.78 | 1                        | S                     |
| 120.54 | 23.899 | -10.42 | 0.79 | 1                        | S                     |
| 120.55 | 23.899 | -3.36  | 0.79 | 1                        | S                     |
| 120.56 | 23.899 | -1.88  | 0.82 | 0                        | S                     |
| 120.58 | 23.899 | -1.66  | 0.86 | 0                        | S                     |
| 120.70 | 23.899 | -2.79  | 1.08 | 0                        | S                     |
| 120.34 | 23.884 | -5.02  | 0.81 | 1                        | S                     |
| 120.36 | 23.884 | -8.41  | 0.82 | 1                        | S                     |
| 120.37 | 23.884 | -9.43  | 0.81 | 1                        | S                     |
| 120.38 | 23.884 | -10.07 | 0.80 | 1                        | S                     |
| 120.40 | 23.884 | -12.06 | 0.79 | 1                        | S                     |
| 120.41 | 23.884 | -10.83 | 0.78 | 1                        | S                     |
| 120.43 | 23.884 | -9.26  | 0.76 | 1                        | S                     |
| 120.44 | 23.884 | -8.03  | 0.75 | 1                        | S                     |



| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.45 | 23.884 | -11.27 | 0.73 | 1                        | S                     |
| 120.47 | 23.884 | -14.01 | 0.73 | 1                        | S                     |
| 120.48 | 23.884 | -12.09 | 0.74 | 1                        | S                     |
| 120.49 | 23.884 | -5.36  | 0.75 | 1                        | S                     |
| 120.51 | 23.884 | -3.46  | 0.78 | 1                        | S                     |
| 120.52 | 23.884 | -2.21  | 0.79 | 1                        | S                     |
| 120.54 | 23.884 | -2.78  | 0.81 | 1                        | S                     |
| 120.55 | 23.884 | -2.32  | 0.82 | 0                        | S                     |
| 120.70 | 23.884 | -2.45  | 1.03 | 0                        | S                     |
| 120.77 | 23.884 | -5.04  | 0.82 | 0                        | S                     |
| 120.32 | 23.877 | -2.22  | 0.82 | 1                        | S                     |
| 120.68 | 23.877 | -2.08  | 1.08 | 0                        | S                     |
| 120.34 | 23.869 | -5.56  | 0.82 | 1                        | S                     |
| 120.36 | 23.869 | -5.92  | 0.82 | 1                        | S                     |
| 120.37 | 23.869 | -6.66  | 0.82 | 1                        | S                     |
| 120.38 | 23.869 | -7.49  | 0.81 | 1                        | S                     |
| 120.40 | 23.869 | -8.49  | 0.80 | 1                        | S                     |
| 120.41 | 23.869 | -8.59  | 0.79 | 1                        | S                     |
| 120.43 | 23.869 | -9.18  | 0.77 | 1                        | S                     |
| 120.44 | 23.869 | -9.03  | 0.77 | 1                        | S                     |
| 120.47 | 23.869 | -15.73 | 0.77 | 1                        | S                     |
| 120.48 | 23.869 | -15.65 | 0.76 | 1                        | S                     |
| 120.49 | 23.869 | -11.80 | 0.79 | 1                        | S                     |
| 120.51 | 23.869 | -2.05  | 0.80 | 1                        | S                     |
| 120.52 | 23.869 | -1.66  | 0.80 | 1                        | S                     |
| 120.54 | 23.869 | -1.57  | 0.83 | 0                        | S                     |
| 120.55 | 23.869 | -1.05  | 0.83 | 0                        | S                     |
| 120.63 | 23.869 | -1.31  | 0.99 | 0                        | S                     |
| 120.70 | 23.869 | -2.29  | 0.93 | 0                        | S                     |
| 120.27 | 23.855 | -1.77  | 0.89 | 1                        | S                     |
| 120.29 | 23.855 | -1.53  | 0.86 | 1                        | S                     |
| 120.30 | 23.855 | -1.94  | 0.85 | 1                        | S                     |
| 120.31 | 23.855 | -2.75  | 0.83 | 1                        | S                     |
| 120.33 | 23.855 | -3.20  | 0.82 | 1                        | S                     |
| 120.34 | 23.855 | -4.09  | 0.82 | 1                        | S                     |



| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.36 | 23.855 | -4.89  | 0.81 | 1                        | S                     |
| 120.37 | 23.855 | -5.99  | 0.82 | 1                        | S                     |
| 120.40 | 23.855 | -7.41  | 0.81 | 1                        | S                     |
| 120.41 | 23.855 | -6.91  | 0.79 | 1                        | S                     |
| 120.43 | 23.855 | -9.34  | 0.77 | 1                        | S                     |
| 120.44 | 23.855 | -11.27 | 0.78 | 1                        | S                     |
| 120.45 | 23.855 | -11.87 | 0.78 | 1                        | S                     |
| 120.47 | 23.855 | -17.16 | 0.77 | 1                        | S                     |
| 120.48 | 23.855 | -21.82 | 0.76 | 1                        | S                     |
| 120.49 | 23.855 | -20.48 | 0.78 | 1                        | S                     |
| 120.51 | 23.855 | -11.23 | 0.80 | 1                        | S                     |
| 120.52 | 23.855 | -2.87  | 0.81 | 1                        | S                     |
| 120.54 | 23.855 | -0.81  | 0.84 | 1                        | S                     |
| 120.55 | 23.855 | -0.54  | 0.83 | 0                        | S                     |
| 120.63 | 23.855 | -0.72  | 0.90 | 0                        | S                     |
| 120.70 | 23.855 | -2.38  | 0.97 | 0                        | S                     |
| 120.68 | 23.847 | -1.95  | 1.07 | 0                        | S                     |
| 120.30 | 23.840 | -3.26  | 0.86 | 1                        | S                     |
| 120.31 | 23.840 | -3.55  | 0.85 | 1                        | S                     |
| 120.33 | 23.840 | -5.01  | 0.84 | 1                        | S                     |
| 120.34 | 23.840 | -7.37  | 0.83 | 1                        | S                     |
| 120.41 | 23.840 | -9.01  | 0.82 | 1                        | S                     |
| 120.44 | 23.840 | -10.05 | 0.80 | 1                        | S                     |
| 120.45 | 23.840 | -12.50 | 0.79 | 1                        | S                     |
| 120.47 | 23.840 | -15.74 | 0.78 | 1                        | S                     |
| 120.48 | 23.840 | -20.35 | 0.77 | 1                        | S                     |
| 120.49 | 23.840 | -20.68 | 0.75 | 1                        | S                     |
| 120.51 | 23.840 | -15.17 | 0.80 | 1                        | S                     |
| 120.52 | 23.840 | -7.15  | 0.81 | 1                        | S                     |
| 120.54 | 23.840 | -2.39  | 0.81 | 1                        | S                     |
| 120.55 | 23.840 | -0.90  | 0.81 | 1                        | S                     |
| 120.70 | 23.840 | -2.36  | 1.01 | 0                        | S                     |
| 120.76 | 23.840 | -6.39  | 0.89 | 0                        | S                     |
| 120.51 | 23.825 | -8.97  | 0.80 | 1                        | S                     |
| 120.52 | 23.825 | -6.30  | 0.79 | 1                        | S                     |





| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.54 | 23.825 | -4.06  | 0.79 | 1                        | S                     |
| 120.55 | 23.825 | -2.89  | 0.80 | 1                        | S                     |
| 120.56 | 23.825 | -1.70  | 0.80 | 1                        | S                     |
| 120.58 | 23.825 | -0.85  | 0.82 | 0                        | S                     |
| 120.66 | 23.825 | -1.27  | 1.13 | 0                        | S                     |
| 120.73 | 23.825 | -3.56  | 1.00 | 0                        | S                     |
| 120.74 | 23.825 | -4.16  | 1.00 | 0                        | S                     |
| 120.76 | 23.825 | -5.99  | 0.96 | 0                        | S                     |
| 120.81 | 23.825 | -4.13  | 0.91 | 0                        | S                     |
| 120.71 | 23.818 | -3.01  | 1.08 | 0                        | S                     |
| 120.37 | 23.811 | -7.65  | 0.91 | 1                        | S                     |
| 120.38 | 23.811 | -4.53  | 0.90 | 1                        | S                     |
| 120.40 | 23.811 | -6.48  | 0.88 | 1                        | S                     |
| 120.41 | 23.811 | -4.42  | 0.86 | 1                        | S                     |
| 120.43 | 23.811 | -3.12  | 0.85 | 1                        | S                     |
| 120.52 | 23.811 | -2.30  | 0.78 | 1                        | S                     |
| 120.54 | 23.811 | -2.48  | 0.79 | 1                        | S                     |
| 120.55 | 23.811 | -2.74  | 0.81 | 1                        | S                     |
| 120.58 | 23.811 | -0.77  | 0.86 | 0                        | S                     |
| 120.73 | 23.811 | -3.12  | 0.95 | 0                        | S                     |
| 120.20 | 23.796 | -10.22 | 1.02 | 1                        | S                     |
| 120.23 | 23.796 | -2.04  | 0.98 | 1                        | S                     |
| 120.25 | 23.796 | -2.74  | 0.97 | 1                        | S                     |
| 120.26 | 23.796 | -3.85  | 0.96 | 1                        | S                     |
| 120.27 | 23.796 | -5.92  | 0.94 | 1                        | S                     |
| 120.29 | 23.796 | -7.28  | 0.92 | 1                        | S                     |
| 120.30 | 23.796 | -8.02  | 0.91 | 1                        | S                     |
| 120.31 | 23.796 | -8.91  | 0.91 | 1                        | S                     |
| 120.33 | 23.796 | -8.83  | 0.91 | 1                        | S                     |
| 120.34 | 23.796 | -10.38 | 0.92 | 1                        | S                     |
| 120.36 | 23.796 | -9.07  | 0.94 | 1                        | S                     |
| 120.37 | 23.796 | -9.16  | 0.92 | 1                        | S                     |
| 120.38 | 23.796 | -8.09  | 0.89 | 1                        | S                     |
| 120.40 | 23.796 | -7.98  | 0.89 | 1                        | S                     |
| 120.41 | 23.796 | -6.40  | 0.87 | 1                        | S                     |

| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.43 | 23.796 | -6.57  | 0.87 | 1                        | S                     |
| 120.44 | 23.796 | -5.97  | 0.86 | 1                        | S                     |
| 120.45 | 23.796 | -4.96  | 0.83 | 1                        | S                     |
| 120.47 | 23.796 | -4.11  | 0.83 | 1                        | S                     |
| 120.54 | 23.796 | -0.78  | 0.81 | 1                        | S                     |
| 120.55 | 23.796 | -1.23  | 0.84 | 1                        | S                     |
| 120.56 | 23.796 | -1.16  | 0.85 | 1                        | S                     |
| 120.58 | 23.796 | -0.10  | 0.86 | 1                        | S                     |
| 120.59 | 23.796 | -1.05  | 0.87 | 0                        | S                     |
| 120.60 | 23.796 | -1.24  | 0.88 | 0                        | S                     |
| 120.62 | 23.796 | -1.15  | 0.86 | 0                        | S                     |
| 120.63 | 23.796 | -0.86  | 0.91 | 0                        | S                     |
| 120.68 | 23.789 | -2.02  | 0.98 | 0                        | S                     |
| 120.23 | 23.781 | -1.53  | 0.99 | 1                        | S                     |
| 120.25 | 23.781 | -2.79  | 0.97 | 1                        | S                     |
| 120.26 | 23.781 | -4.63  | 0.95 | 1                        | S                     |
| 120.27 | 23.781 | -9.30  | 0.96 | 1                        | S                     |
| 120.29 | 23.781 | -10.13 | 0.96 | 1                        | S                     |
| 120.30 | 23.781 | -9.07  | 0.93 | 1                        | S                     |
| 120.34 | 23.781 | -15.51 | 0.93 | 1                        | S                     |
| 120.36 | 23.781 | -15.74 | 0.92 | 1                        | S                     |
| 120.37 | 23.781 | -13.33 | 0.92 | 1                        | S                     |
| 120.38 | 23.781 | -10.83 | 0.90 | 1                        | S                     |
| 120.40 | 23.781 | -11.52 | 0.89 | 1                        | S                     |
| 120.41 | 23.781 | -6.93  | 0.88 | 1                        | S                     |
| 120.43 | 23.781 | -4.43  | 0.86 | 1                        | S                     |
| 120.44 | 23.781 | -3.56  | 0.84 | 1                        | S                     |
| 120.45 | 23.781 | -3.00  | 0.83 | 1                        | S                     |
| 120.47 | 23.781 | -2.99  | 0.83 | 1                        | S                     |
| 120.48 | 23.781 | -3.84  | 0.83 | 1                        | S                     |
| 120.49 | 23.781 | -2.90  | 0.82 | 1                        | S                     |
| 120.51 | 23.781 | -3.71  | 0.82 | 1                        | S                     |
| 120.52 | 23.781 | -3.20  | 0.82 | 1                        | S                     |
| 120.54 | 23.781 | -2.56  | 0.83 | 1                        | S                     |
| 120.56 | 23.781 | -4.34  | 0.86 | 1                        | S                     |



| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.58 | 23.781 | -0.73  | 0.90 | 0                        | S                     |
| 120.60 | 23.781 | -0.76  | 0.86 | 0                        | S                     |
| 120.22 | 23.766 | -1.82  | 1.00 | 1                        | S                     |
| 120.23 | 23.766 | -4.14  | 0.99 | 1                        | S                     |
| 120.26 | 23.766 | -6.64  | 0.96 | 1                        | S                     |
| 120.27 | 23.766 | -13.24 | 0.98 | 1                        | S                     |
| 120.29 | 23.766 | -11.64 | 0.95 | 1                        | S                     |
| 120.33 | 23.766 | -16.91 | 0.92 | 1                        | S                     |
| 120.34 | 23.766 | -20.09 | 0.93 | 1                        | S                     |
| 120.36 | 23.766 | -19.64 | 0.91 | 1                        | S                     |
| 120.37 | 23.766 | -20.68 | 0.91 | 1                        | S                     |
| 120.38 | 23.766 | -19.02 | 0.90 | 1                        | S                     |
| 120.40 | 23.766 | -16.09 | 0.89 | 1                        | S                     |
| 120.41 | 23.766 | -12.07 | 0.89 | 1                        | S                     |
| 120.43 | 23.766 | -6.09  | 0.85 | 1                        | S                     |
| 120.44 | 23.766 | -4.37  | 0.83 | 1                        | S                     |
| 120.45 | 23.766 | -4.07  | 0.83 | 1                        | S                     |
| 120.47 | 23.766 | -4.94  | 0.83 | 1                        | S                     |
| 120.48 | 23.766 | -4.14  | 0.83 | 1                        | S                     |
| 120.49 | 23.766 | -3.72  | 0.82 | 1                        | S                     |
| 120.51 | 23.766 | -5.34  | 0.82 | 1                        | S                     |
| 120.52 | 23.766 | -3.55  | 0.82 | 1                        | S                     |
| 120.54 | 23.766 | -3.05  | 0.83 | 0                        | S                     |
| 120.55 | 23.766 | -2.50  | 0.83 | 0                        | S                     |
| 120.56 | 23.766 | -2.00  | 0.84 | 0                        | S                     |
| 120.58 | 23.766 | -0.99  | 0.85 | 0                        | S                     |
| 120.59 | 23.766 | -0.25  | 0.85 | 0                        | S                     |
| 120.60 | 23.766 | -0.22  | 0.84 | 0                        | S                     |
| 120.62 | 23.766 | 0.12   | 0.86 | 0                        | S                     |
| 120.66 | 23.766 | -1.50  | 0.88 | 0                        | S                     |
| 120.70 | 23.766 | -2.48  | 0.85 | 0                        | S                     |
| 120.68 | 23.759 | -2.00  | 0.87 | 0                        | S                     |
| 120.22 | 23.752 | -3.43  | 1.00 | 1                        | S                     |
| 120.23 | 23.752 | -6.64  | 0.99 | 1                        | S                     |
| 120.25 | 23.752 | -6.31  | 0.98 | 1                        | S                     |



| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.26 | 23.752 | -11.63 | 0.96 | 1                        | S                     |
| 120.27 | 23.752 | -17.40 | 0.98 | 1                        | S                     |
| 120.29 | 23.752 | -14.58 | 0.96 | 1                        | S                     |
| 120.36 | 23.752 | -20.81 | 0.92 | 1                        | S                     |
| 120.37 | 23.752 | -23.23 | 0.89 | 1                        | S                     |
| 120.38 | 23.752 | -23.65 | 0.90 | 1                        | S                     |
| 120.40 | 23.752 | -20.31 | 0.88 | 1                        | S                     |
| 120.41 | 23.752 | -16.87 | 0.86 | 1                        | S                     |
| 120.43 | 23.752 | -13.61 | 0.84 | 1                        | S                     |
| 120.44 | 23.752 | -10.18 | 0.84 | 1                        | S                     |
| 120.47 | 23.752 | -7.21  | 0.84 | 1                        | S                     |
| 120.48 | 23.752 | -4.13  | 0.82 | 1                        | S                     |
| 120.49 | 23.752 | -4.68  | 0.82 | 1                        | S                     |
| 120.51 | 23.752 | -4.23  | 0.83 | 1                        | S                     |
| 120.52 | 23.752 | -2.20  | 0.81 | 0                        | S                     |
| 120.54 | 23.752 | -2.09  | 0.82 | 0                        | S                     |
| 120.55 | 23.752 | -1.90  | 0.83 | 0                        | S                     |
| 120.56 | 23.752 | -1.37  | 0.83 | 0                        | S                     |
| 120.60 | 23.752 | 0.13   | 0.86 | 0                        | S                     |
| 120.66 | 23.752 | -1.65  | 0.88 | 0                        | S                     |
| 120.22 | 23.737 | -7.96  | 1.01 | 1                        | S                     |
| 120.23 | 23.737 | -9.24  | 1.01 | 1                        | S                     |
| 120.37 | 23.737 | -23.52 | 0.89 | 1                        | S                     |
| 120.38 | 23.737 | -25.96 | 0.90 | 1                        | S                     |
| 120.40 | 23.737 | -28.19 | 0.89 | 1                        | S                     |
| 120.41 | 23.737 | -24.99 | 0.86 | 1                        | S                     |
| 120.43 | 23.737 | -18.19 | 0.83 | 1                        | S                     |
| 120.44 | 23.737 | -13.80 | 0.83 | 1                        | S                     |
| 120.45 | 23.737 | -10.22 | 0.83 | 1                        | S                     |
| 120.47 | 23.737 | -7.53  | 0.81 | 1                        | S                     |
| 120.48 | 23.737 | -5.19  | 0.80 | 1                        | S                     |
| 120.49 | 23.737 | -3.17  | 0.82 | 1                        | S                     |
| 120.51 | 23.737 | -1.91  | 0.81 | 1                        | S                     |
| 120.52 | 23.737 | -0.97  | 0.80 | 0                        | S                     |
| 120.66 | 23.737 | -1.83  | 0.89 | 0                        | S                     |



| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.67 | 23.737 | -2.29  | 0.90 | 0                        | S                     |
| 120.77 | 23.737 | -3.98  | 0.99 | 0                        | S                     |
| 120.54 | 23.730 | -0.18  | 0.82 | 0                        | S                     |
| 120.20 | 23.722 | -10.42 | 1.02 | 1                        | S                     |
| 120.22 | 23.722 | -11.36 | 1.03 | 1                        | S                     |
| 120.23 | 23.722 | -10.00 | 1.02 | 1                        | S                     |
| 120.25 | 23.722 | -10.96 | 1.01 | 1                        | S                     |
| 120.41 | 23.722 | -24.05 | 0.87 | 1                        | S                     |
| 120.43 | 23.722 | -20.06 | 0.86 | 1                        | S                     |
| 120.44 | 23.722 | -14.13 | 0.85 | 1                        | S                     |
| 120.45 | 23.722 | -10.26 | 0.84 | 1                        | S                     |
| 120.47 | 23.722 | -9.34  | 0.78 | 1                        | S                     |
| 120.48 | 23.722 | -6.19  | 0.79 | 1                        | S                     |
| 120.49 | 23.722 | -2.60  | 0.81 | 1                        | S                     |
| 120.51 | 23.722 | 0.10   | 0.82 | 1                        | S                     |
| 120.52 | 23.722 | 0.17   | 0.81 | 0                        | S                     |
| 120.20 | 23.708 | -10.88 | 1.04 | 1                        | S                     |
| 120.22 | 23.708 | -11.29 | 1.05 | 1                        | S                     |
| 120.25 | 23.708 | -10.48 | 1.04 | 1                        | S                     |
| 120.26 | 23.708 | -14.78 | 1.05 | 1                        | S                     |
| 120.27 | 23.708 | -18.52 | 1.03 | 1                        | S                     |
| 120.29 | 23.708 | -21.24 | 0.99 | 1                        | S                     |
| 120.31 | 23.708 | -25.70 | 0.96 | 1                        | S                     |
| 120.33 | 23.708 | -27.56 | 0.94 | 1                        | S                     |
| 120.34 | 23.708 | -28.86 | 0.93 | 1                        | S                     |
| 120.36 | 23.708 | -27.66 | 0.92 | 1                        | S                     |
| 120.37 | 23.708 | -27.11 | 0.92 | 1                        | S                     |
| 120.38 | 23.708 | -25.42 | 0.92 | 1                        | S                     |
| 120.40 | 23.708 | -24.75 | 0.92 | 1                        | S                     |
| 120.41 | 23.708 | -24.09 | 0.90 | 1                        | S                     |
| 120.43 | 23.708 | -22.58 | 0.89 | 1                        | S                     |
| 120.44 | 23.708 | -16.87 | 0.88 | 1                        | S                     |
| 120.45 | 23.708 | -11.99 | 0.87 | 1                        | S                     |
| 120.47 | 23.708 | -6.93  | 0.84 | 1                        | S                     |
| 120.48 | 23.708 | -3.68  | 0.84 | 1                        | S                     |



| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.51 | 23.700 | 0.02   | 0.83 | 1                        | S                     |
| 120.54 | 23.700 | 0.13   | 0.80 | 0                        | S                     |
| 120.20 | 23.693 | -10.62 | 1.06 | 1                        | S                     |
| 120.23 | 23.693 | -10.68 | 1.03 | 1                        | S                     |
| 120.25 | 23.693 | -13.92 | 1.04 | 1                        | S                     |
| 120.26 | 23.693 | -23.68 | 1.07 | 1                        | S                     |
| 120.27 | 23.693 | -26.18 | 1.04 | 1                        | S                     |
| 120.29 | 23.693 | -26.86 | 1.00 | 1                        | S                     |
| 120.30 | 23.693 | -24.43 | 0.95 | 1                        | S                     |
| 120.31 | 23.693 | -26.37 | 0.94 | 1                        | S                     |
| 120.36 | 23.693 | -29.39 | 0.95 | 1                        | S                     |
| 120.37 | 23.693 | -28.08 | 0.93 | 1                        | S                     |
| 120.38 | 23.693 | -26.93 | 0.91 | 1                        | S                     |
| 120.40 | 23.693 | -27.25 | 0.92 | 1                        | S                     |
| 120.41 | 23.693 | -26.04 | 0.91 | 1                        | S                     |
| 120.43 | 23.693 | -21.51 | 0.90 | 1                        | S                     |
| 120.44 | 23.693 | -13.16 | 0.89 | 1                        | S                     |
| 120.45 | 23.693 | -6.74  | 0.87 | 1                        | S                     |
| 120.47 | 23.693 | -3.21  | 0.84 | 1                        | S                     |
| 120.48 | 23.693 | -2.53  | 0.84 | 1                        | S                     |
| 120.49 | 23.693 | -1.64  | 0.84 | 1                        | S                     |
| 120.19 | 23.678 | -11.78 | 1.05 | 1                        | S                     |
| 120.20 | 23.678 | -14.79 | 1.06 | 1                        | S                     |
| 120.22 | 23.678 | -14.05 | 1.05 | 1                        | S                     |
| 120.23 | 23.678 | -16.23 | 1.03 | 1                        | S                     |
| 120.25 | 23.678 | -17.15 | 1.02 | 1                        | S                     |
| 120.26 | 23.678 | -22.72 | 1.05 | 1                        | S                     |
| 120.27 | 23.678 | -23.26 | 1.02 | 1                        | S                     |
| 120.29 | 23.678 | -23.40 | 1.00 | 1                        | S                     |
| 120.31 | 23.678 | -30.75 | 0.98 | 1                        | S                     |
| 120.36 | 23.678 | -32.93 | 0.95 | 1                        | S                     |
| 120.37 | 23.678 | -30.97 | 0.94 | 1                        | S                     |
| 120.38 | 23.678 | -31.11 | 0.94 | 1                        | S                     |
| 120.40 | 23.678 | -31.66 | 0.93 | 1                        | S                     |
| 120.41 | 23.678 | -25.52 | 0.94 | 1                        | S                     |



| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.44 | 23.678 | -10.46 | 0.92 | 1                        | S                     |
| 120.45 | 23.678 | -6.74  | 0.89 | 1                        | S                     |
| 120.47 | 23.678 | -4.79  | 0.86 | 1                        | S                     |
| 120.48 | 23.678 | -5.16  | 0.85 | 1                        | S                     |
| 120.49 | 23.678 | -3.04  | 0.85 | 1                        | S                     |
| 120.51 | 23.678 | -0.96  | 0.84 | 1                        | S                     |
| 120.54 | 23.678 | 0.18   | 0.81 | 0                        | S                     |
| 120.2  | 23.664 | -19.24 | 1.10 | 1                        | S                     |
| 120.22 | 23.664 | -18.37 | 1.07 | 1                        | S                     |
| 120.26 | 23.664 | -18.12 | 1.03 | 1                        | S                     |
| 120.27 | 23.664 | -18.67 | 1.00 | 1                        | S                     |
| 120.29 | 23.664 | -21.10 | 0.99 | 1                        | S                     |
| 120.31 | 23.664 | -31.53 | 1.02 | 1                        | S                     |
| 120.33 | 23.664 | -33.07 | 0.98 | 1                        | S                     |
| 120.36 | 23.664 | -37.28 | 1.01 | 1                        | S                     |
| 120.38 | 23.664 | -32.15 | 0.98 | 1                        | S                     |
| 120.41 | 23.664 | -16.03 | 0.97 | 1                        | S                     |
| 120.43 | 23.664 | -8.70  | 0.94 | 1                        | S                     |
| 120.44 | 23.664 | -7.03  | 0.94 | 1                        | S                     |
| 120.45 | 23.664 | -5.80  | 0.92 | 1                        | S                     |
| 120.47 | 23.664 | -4.16  | 0.89 | 1                        | S                     |
| 120.48 | 23.664 | -4.46  | 0.88 | 1                        | S                     |
| 120.49 | 23.664 | -3.13  | 0.88 | 1                        | S                     |
| 120.54 | 23.664 | 0.78   | 0.83 | 1                        | S                     |
| 120.16 | 23.649 | -7.16  | 1.06 | 1                        | S                     |
| 120.18 | 23.649 | -11.13 | 1.06 | 1                        | S                     |
| 120.19 | 23.649 | -14.76 | 1.07 | 1                        | S                     |
| 120.20 | 23.649 | -20.11 | 1.10 | 1                        | S                     |
| 120.22 | 23.649 | -19.62 | 1.09 | 1                        | S                     |
| 120.26 | 23.649 | -18.06 | 1.03 | 1                        | S                     |
| 120.27 | 23.649 | -20.86 | 1.00 | 1                        | S                     |
| 120.29 | 23.649 | -24.25 | 0.99 | 1                        | S                     |
| 120.30 | 23.649 | -28.32 | 1.01 | 1                        | S                     |
| 120.31 | 23.649 | -31.37 | 1.03 | 1                        | S                     |
| 120.36 | 23.649 | -37.36 | 1.02 | 1                        | S                     |



| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.43 | 23.649 | -11.42 | 0.95 | 1                        | S                     |
| 120.44 | 23.649 | -8.30  | 0.94 | 1                        | S                     |
| 120.45 | 23.649 | -5.87  | 0.92 | 1                        | S                     |
| 120.47 | 23.649 | -3.51  | 0.92 | 1                        | S                     |
| 120.49 | 23.649 | -1.45  | 0.88 | 1                        | S                     |
| 120.54 | 23.649 | 0.79   | 0.84 | 1                        | S                     |
| 120.55 | 23.649 | 0.50   | 0.85 | 1                        | S                     |
| 120.56 | 23.649 | 0.53   | 0.85 | 0                        | S                     |
| 120.16 | 23.634 | -6.07  | 1.06 | 1                        | S                     |
| 120.18 | 23.634 | -8.51  | 1.06 | 1                        | S                     |
| 120.19 | 23.634 | -16.61 | 1.07 | 1                        | S                     |
| 120.20 | 23.634 | -20.98 | 1.08 | 1                        | S                     |
| 120.30 | 23.634 | -27.17 | 1.01 | 1                        | S                     |
| 120.31 | 23.634 | -30.93 | 1.04 | 1                        | S                     |
| 120.33 | 23.634 | -29.50 | 1.06 | 1                        | S                     |
| 120.34 | 23.634 | -31.42 | 1.02 | 1                        | S                     |
| 120.36 | 23.634 | -36.18 | 1.04 | 1                        | S                     |
| 120.40 | 23.634 | -30.20 | 1.00 | 1                        | S                     |
| 120.41 | 23.634 | -26.96 | 1.00 | 1                        | S                     |
| 120.43 | 23.634 | -20.42 | 1.00 | 1                        | S                     |
| 120.48 | 23.634 | -1.41  | 0.89 | 1                        | S                     |
| 120.55 | 23.634 | 0.71   | 0.87 | 1                        | S                     |
| 120.15 | 23.619 | -6.06  | 1.05 | 1                        | S                     |
| 120.16 | 23.619 | -5.02  | 1.04 | 1                        | S                     |
| 120.18 | 23.619 | -6.84  | 1.06 | 1                        | S                     |
| 120.19 | 23.619 | -12.75 | 1.06 | 1                        | S                     |
| 120.20 | 23.619 | -15.68 | 1.08 | 1                        | S                     |
| 120.23 | 23.619 | -20.97 | 1.08 | 1                        | S                     |
| 120.25 | 23.619 | -15.68 | 1.05 | 1                        | S                     |
| 120.26 | 23.619 | -15.09 | 1.04 | 1                        | S                     |
| 120.30 | 23.619 | -30.52 | 1.02 | 1                        | S                     |
| 120.31 | 23.619 | -34.16 | 1.05 | 1                        | S                     |
| 120.34 | 23.619 | -28.68 | 1.00 | 1                        | S                     |
| 120.36 | 23.619 | -32.66 | 1.01 | 1                        | S                     |
| 120.40 | 23.619 | -31.61 | 1.01 | 1                        | S                     |



| Lon    | Lat    | V      | Sd   | Subsidence <sup>#a</sup> | Profile <sup>#b</sup> |
|--------|--------|--------|------|--------------------------|-----------------------|
| 120.41 | 23.619 | -27.57 | 1.01 | 1                        | S                     |
| 120.43 | 23.619 | -20.59 | 0.99 | 1                        | S                     |
| 120.44 | 23.619 | -10.40 | 0.96 | 1                        | S                     |
| 120.47 | 23.619 | -2.36  | 0.93 | 1                        | S                     |
| 120.55 | 23.619 | 0.71   | 0.89 | 1                        | S                     |
| 120.56 | 23.619 | 0.43   | 0.90 | 1                        | S                     |



Note:

#a: "0" means the station is not in the subsidence area; "1" means the station is in the subsidence area.

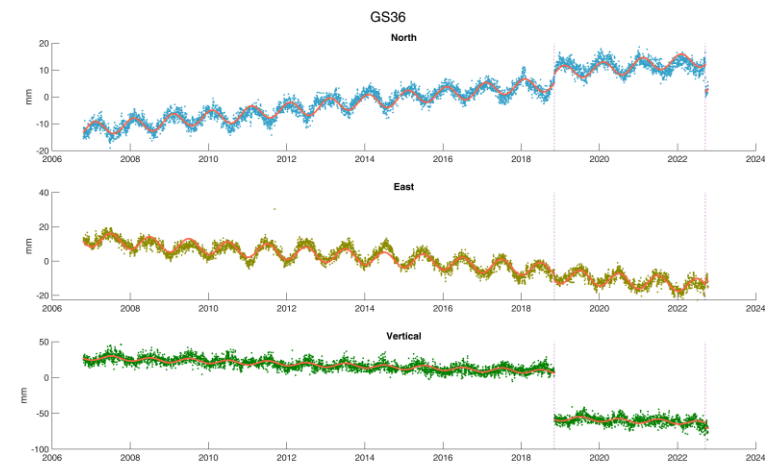
#b: "N" the station belongs to north profile in the 2-D model; "S" the station belongs to south profile in the 2-D model.

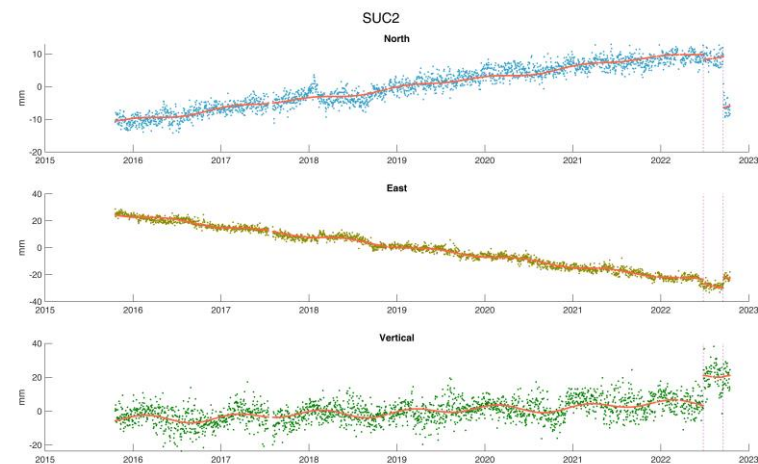
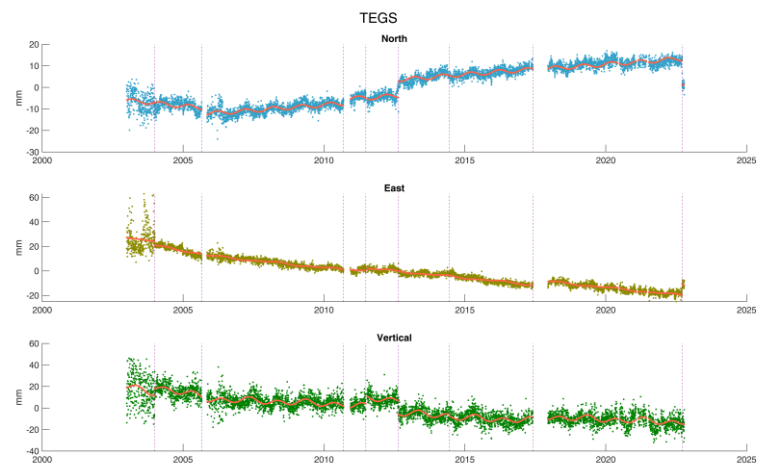
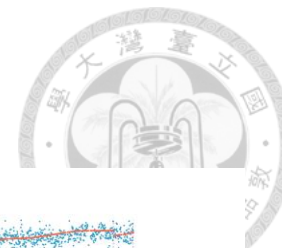


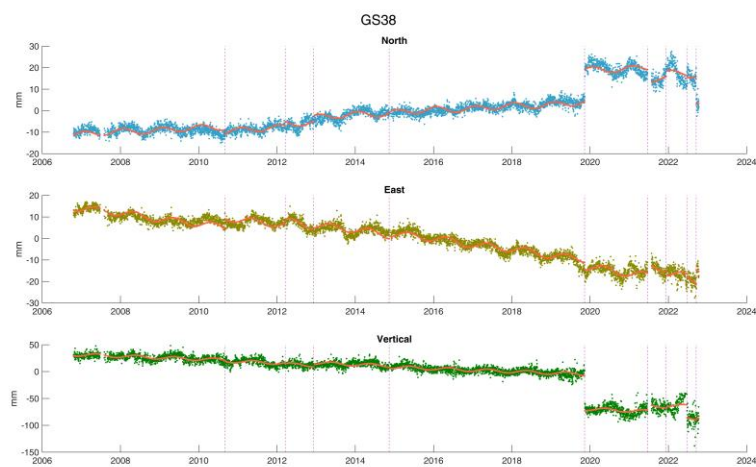
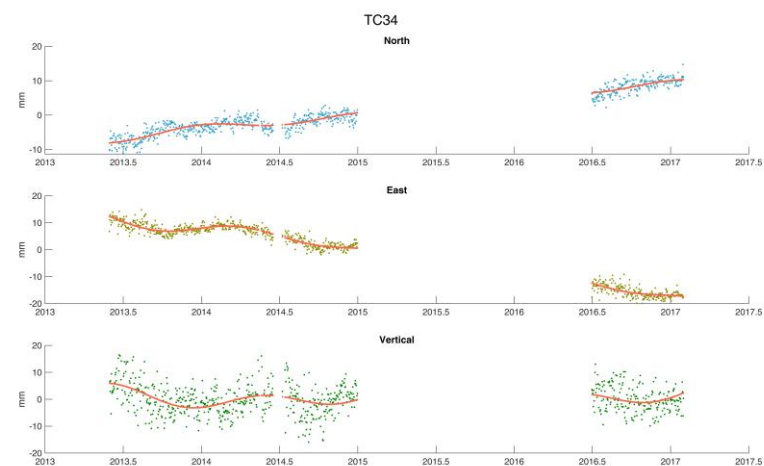
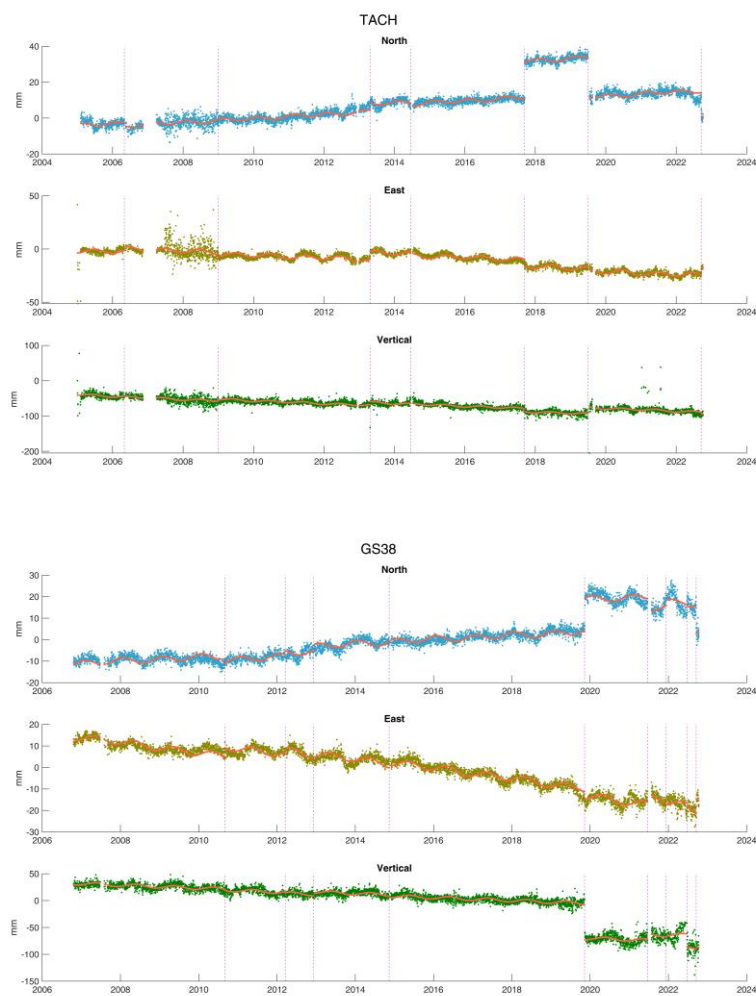
## Appendix D: Fitting result of GNSS and leveling data

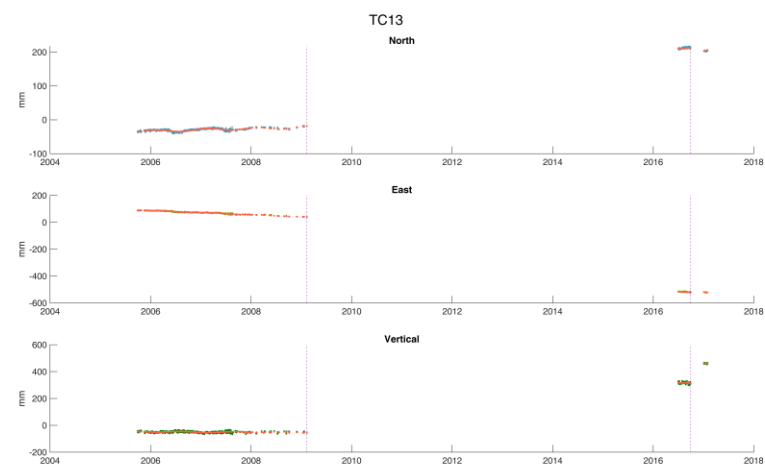
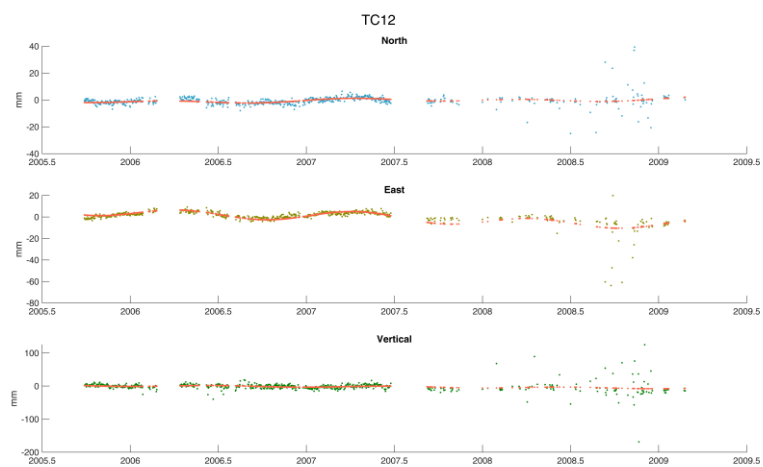
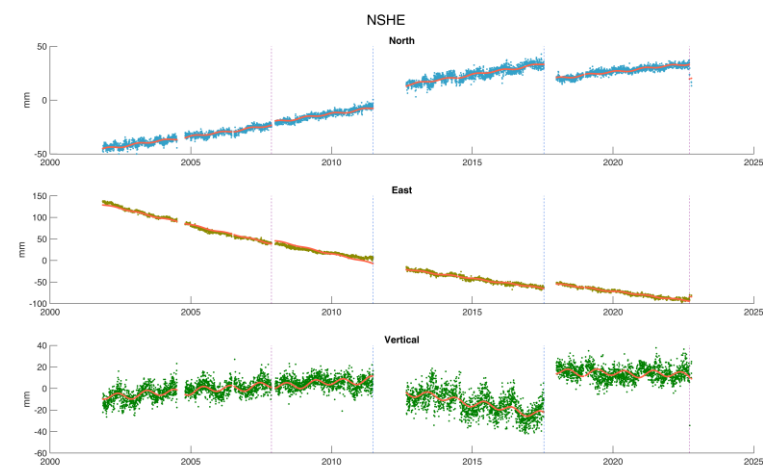
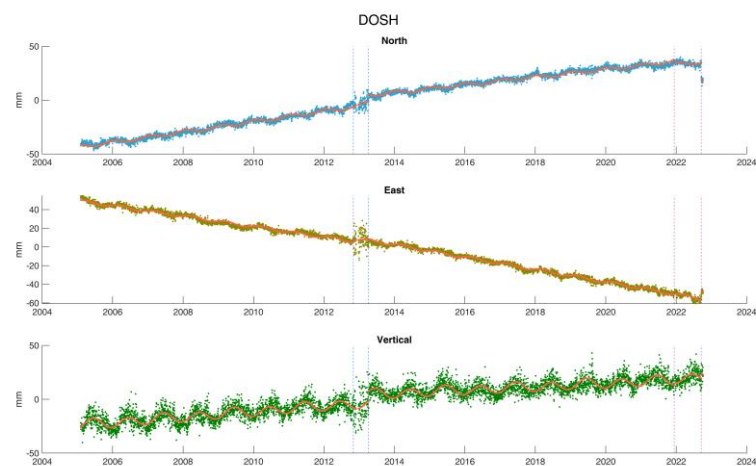
### Appendix D1: Continuous-mode GNSS

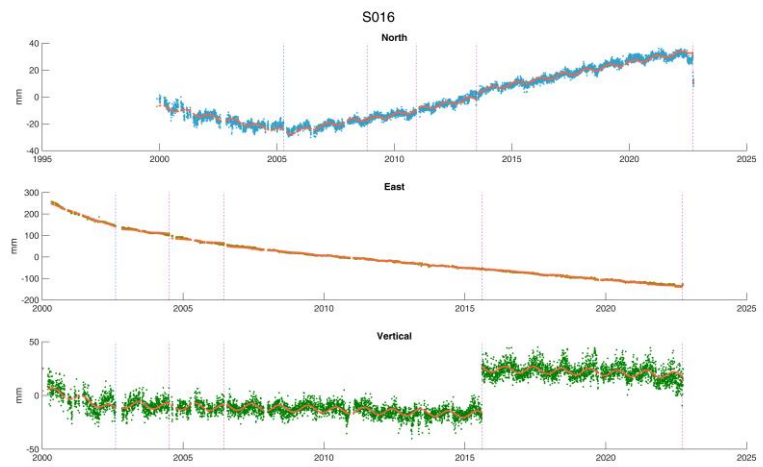
Here are the fitting results of GNSS stations. Red lines are the fitting results. Purple dashes indicate the Heaviside step function. Blue dashes indicate the change of velocity. Black dashes indicate the logarithmic postseismic deformation.

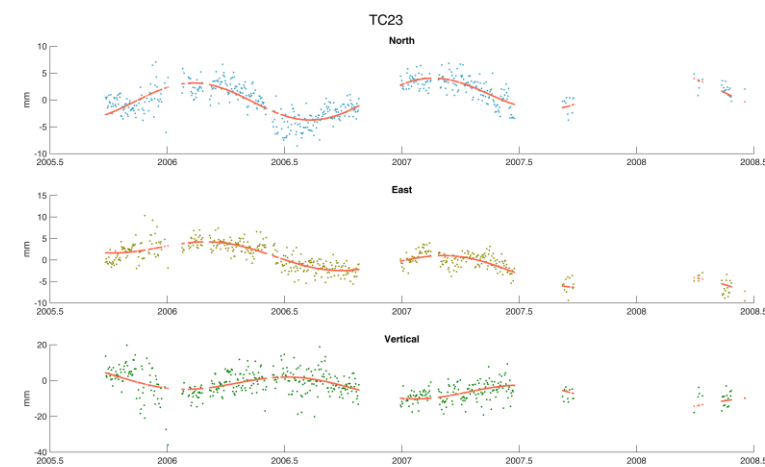
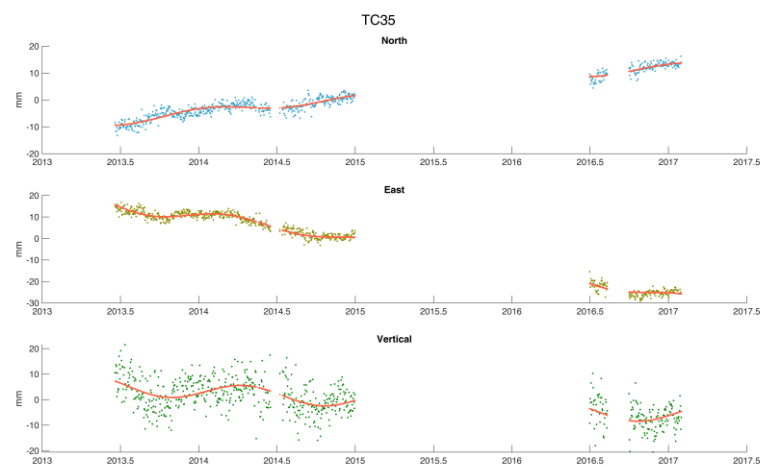
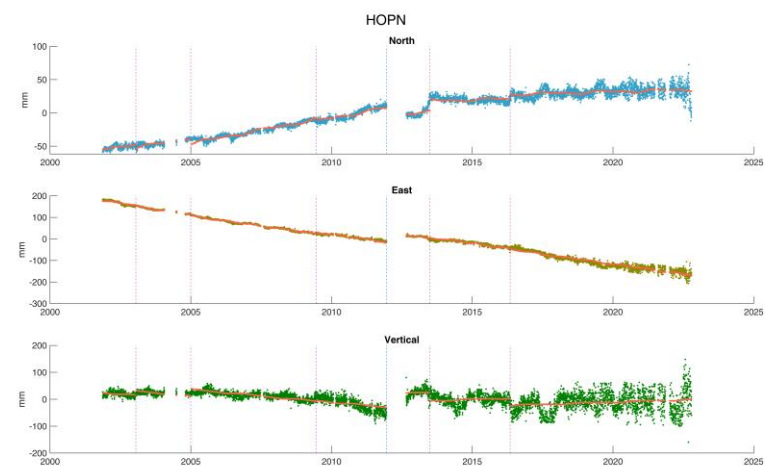


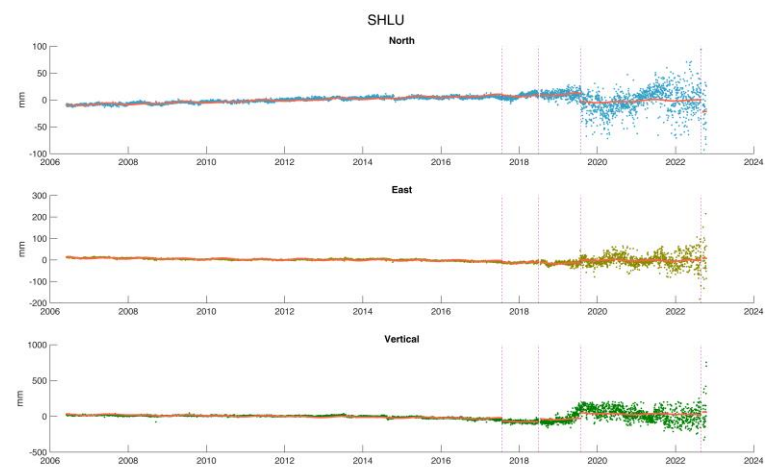
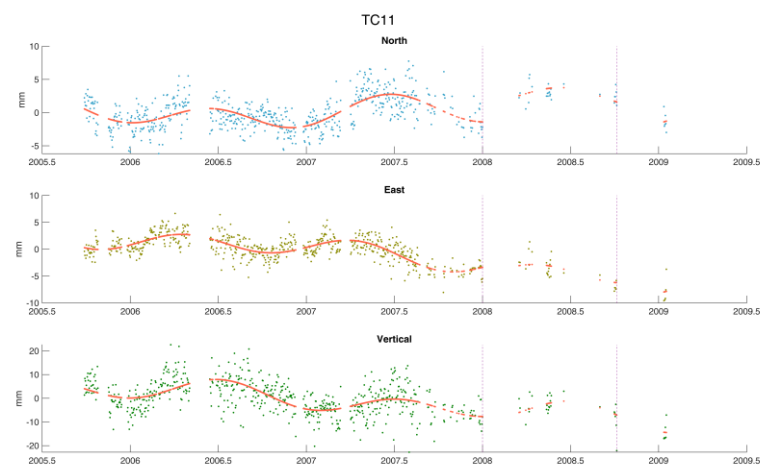
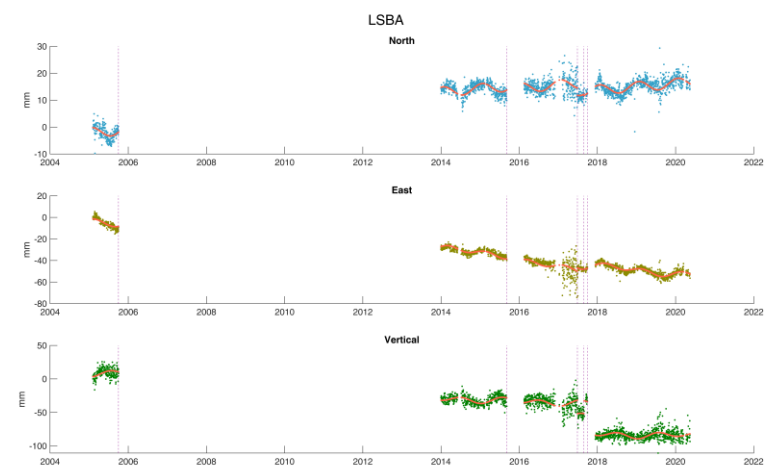
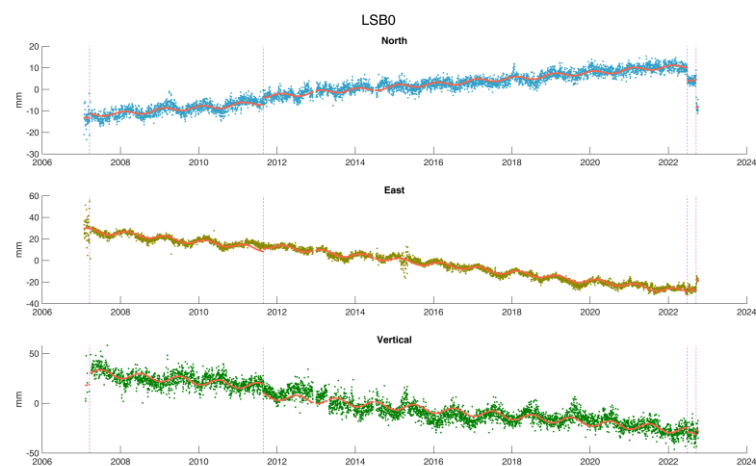


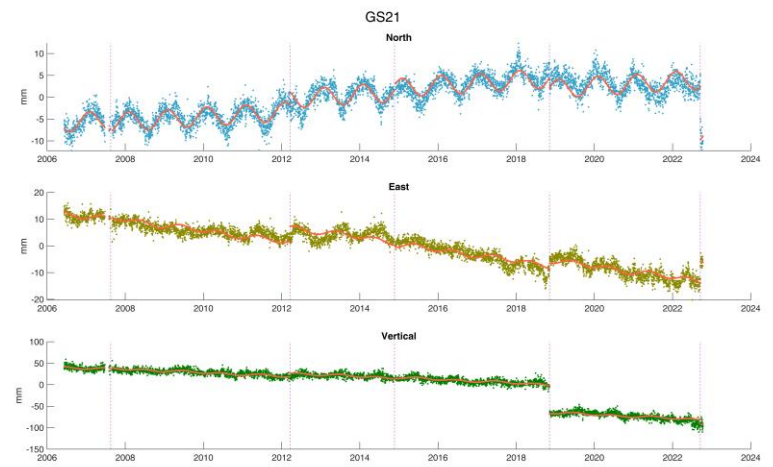
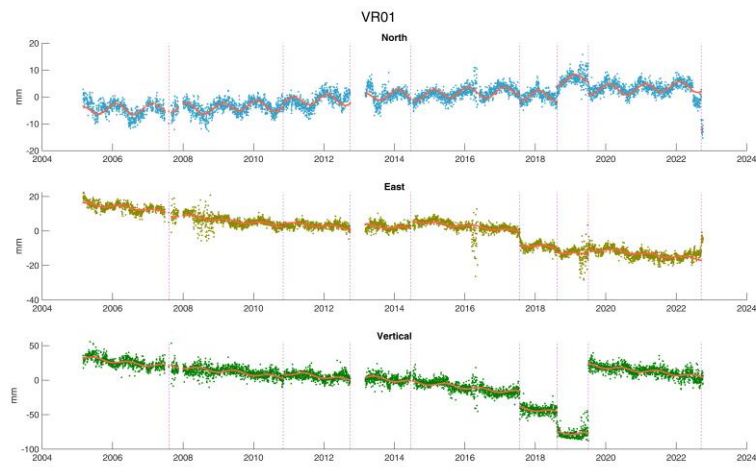
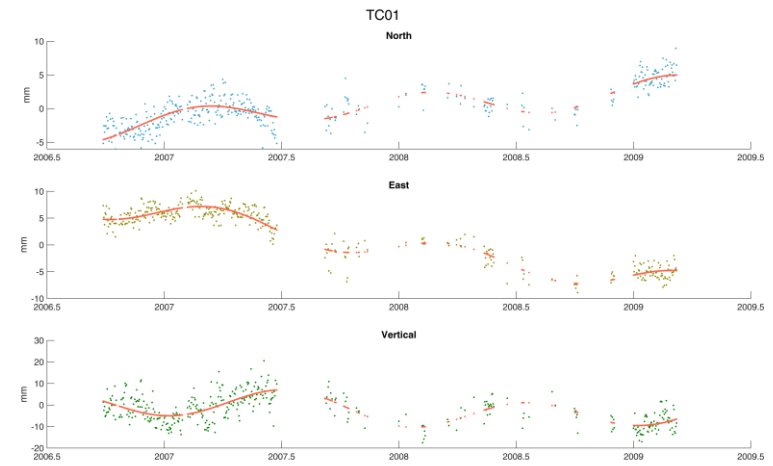
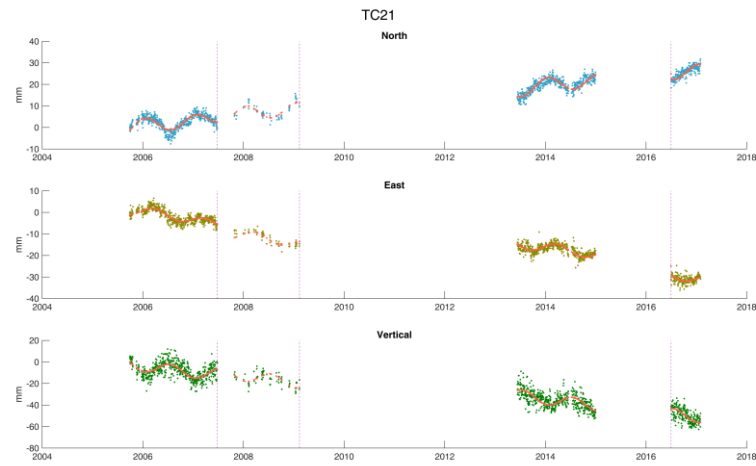


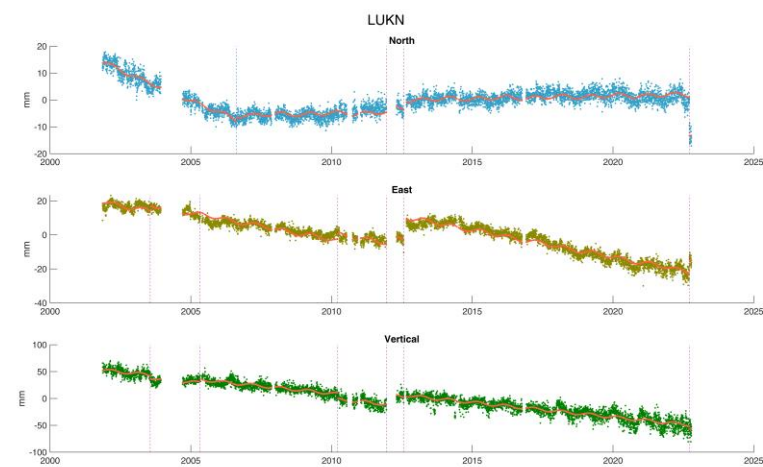
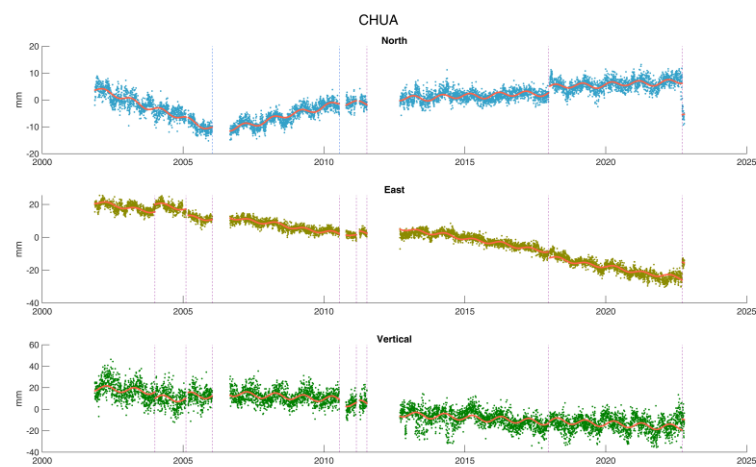
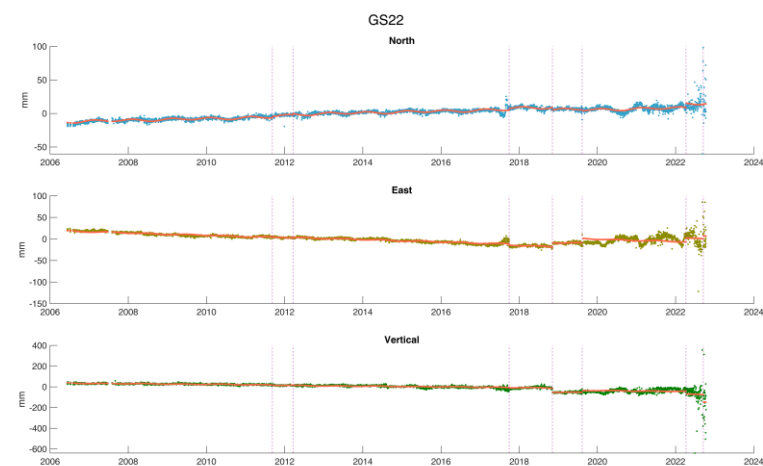
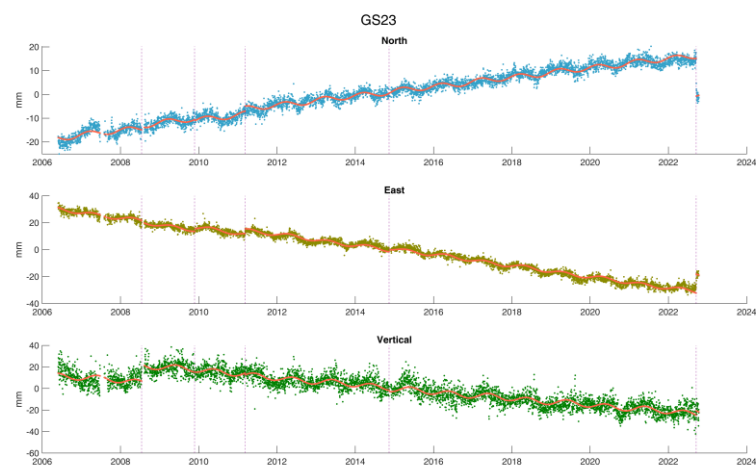


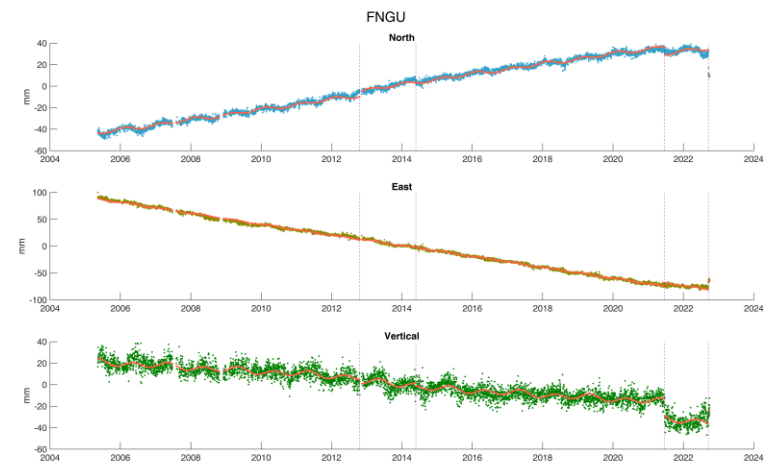
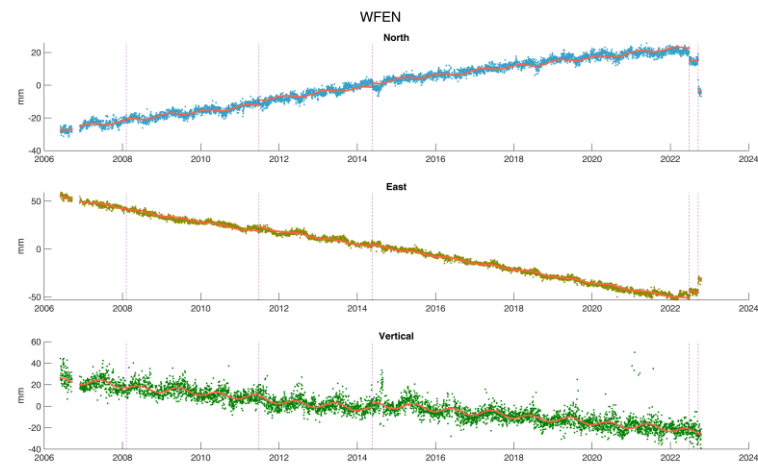
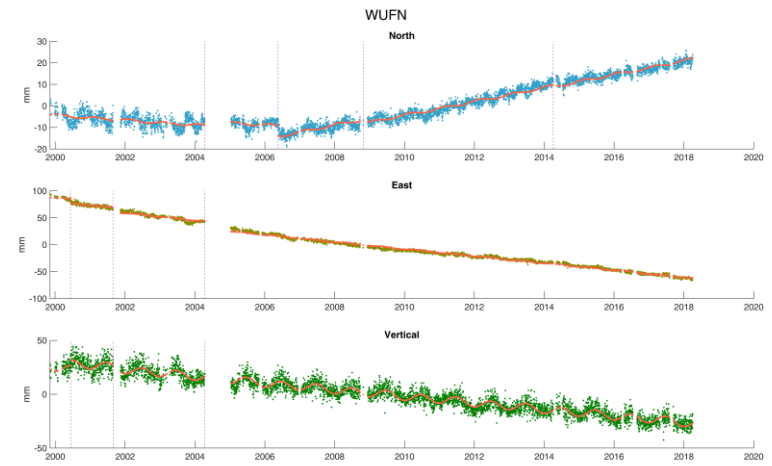
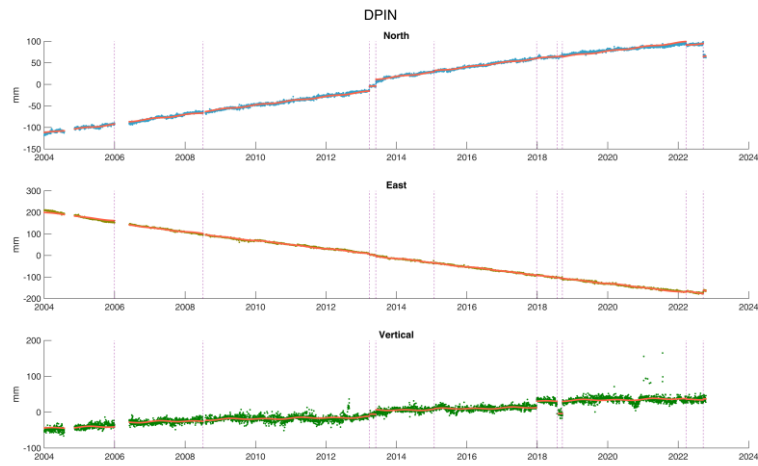


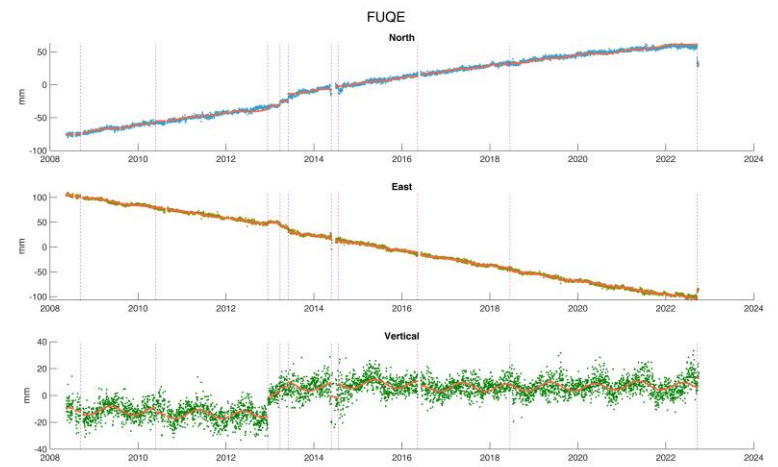
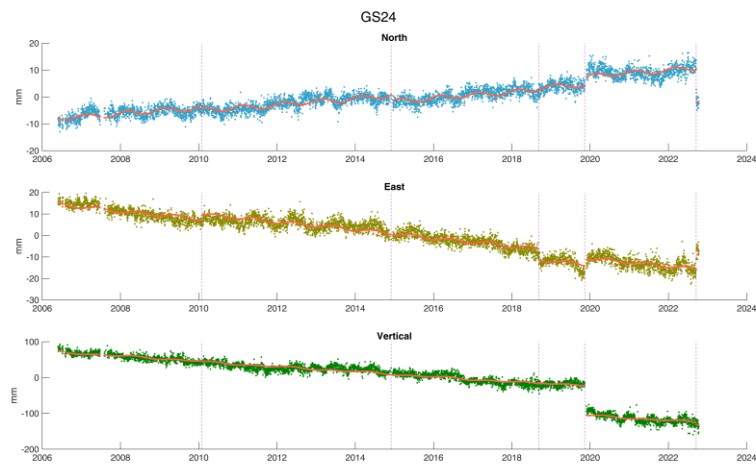
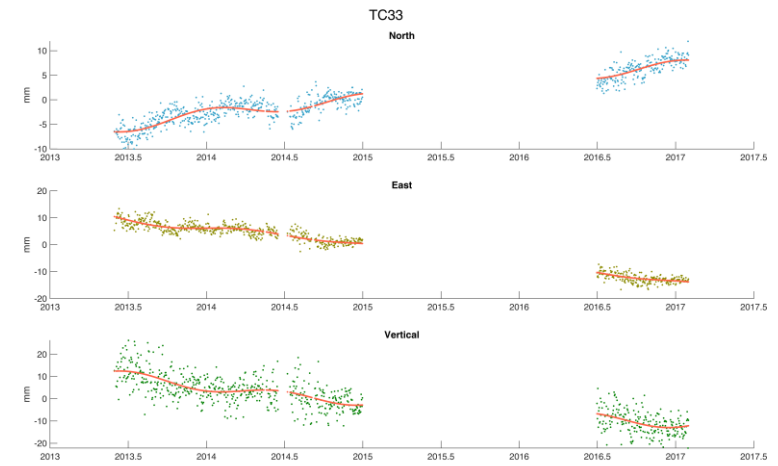
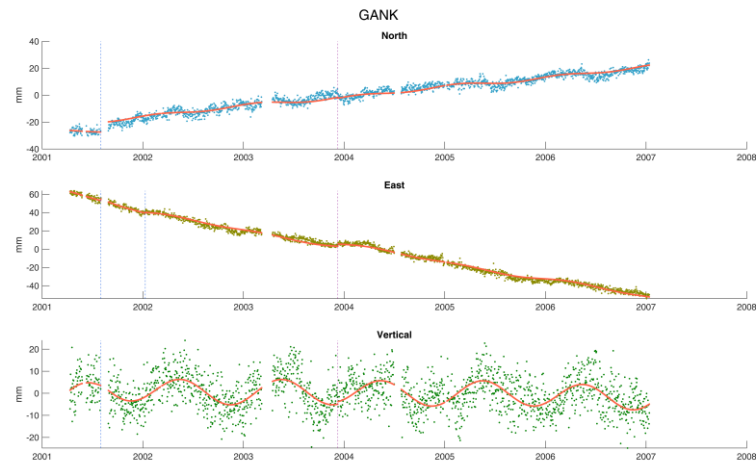


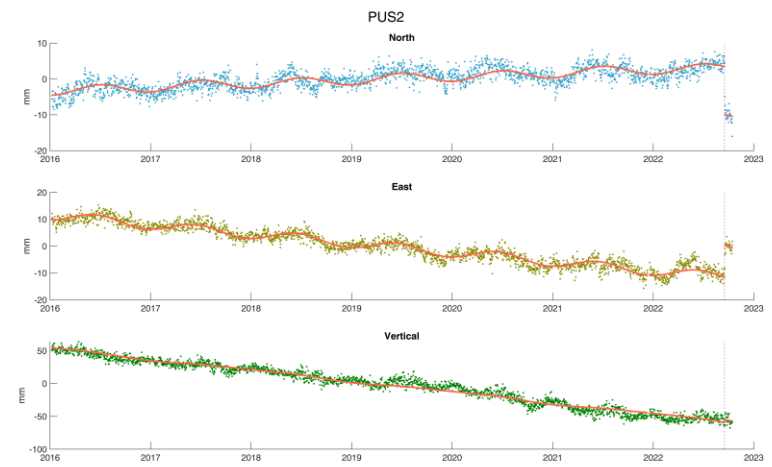
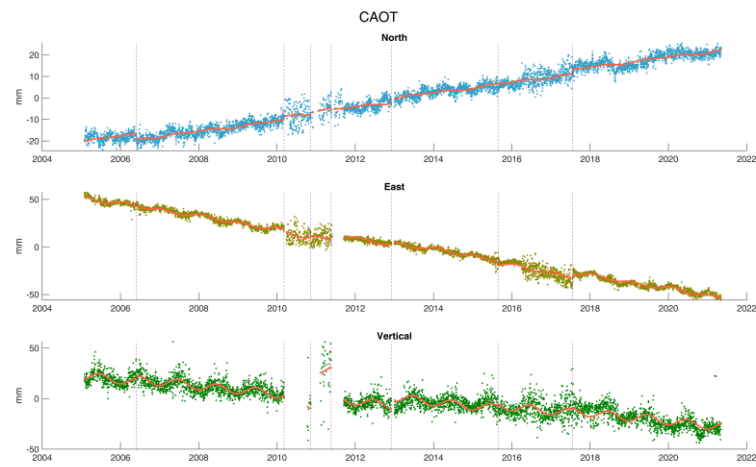
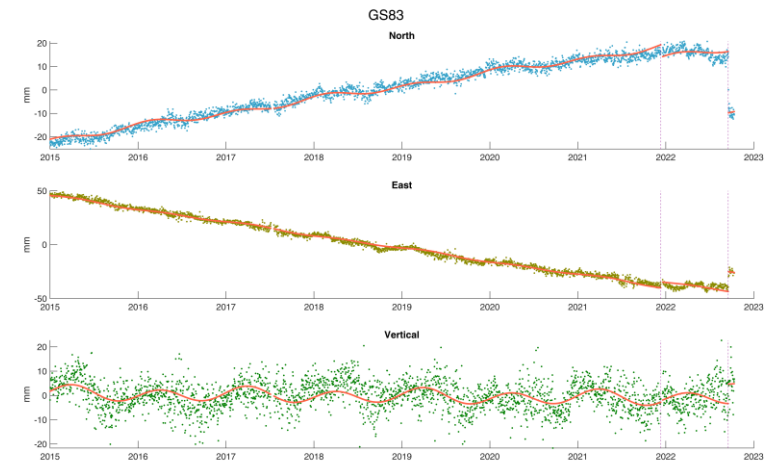


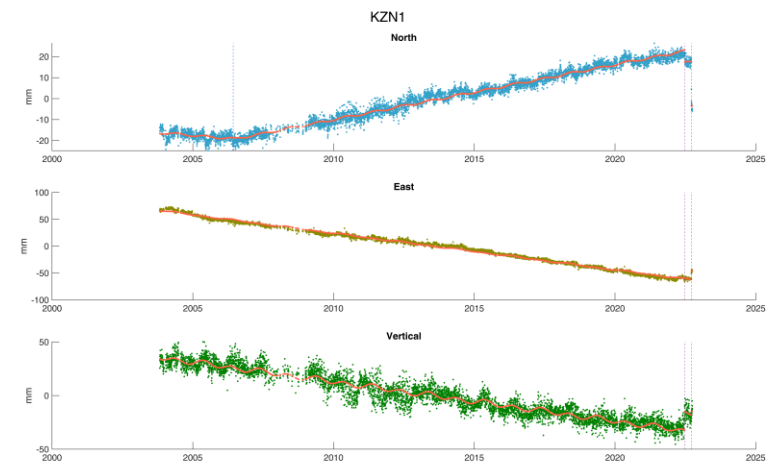
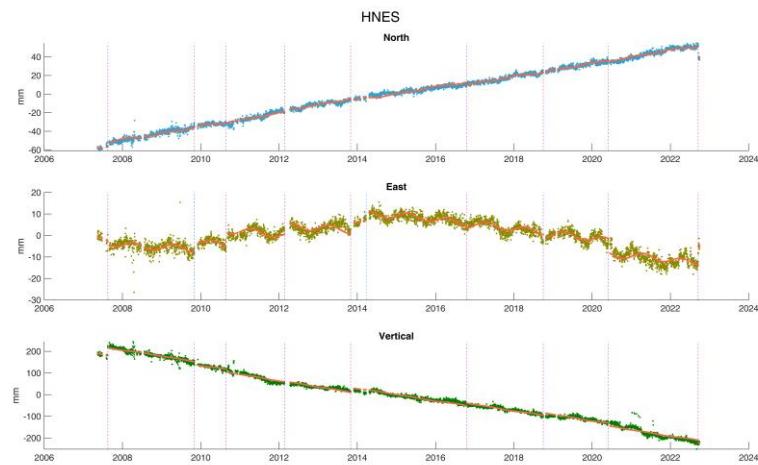
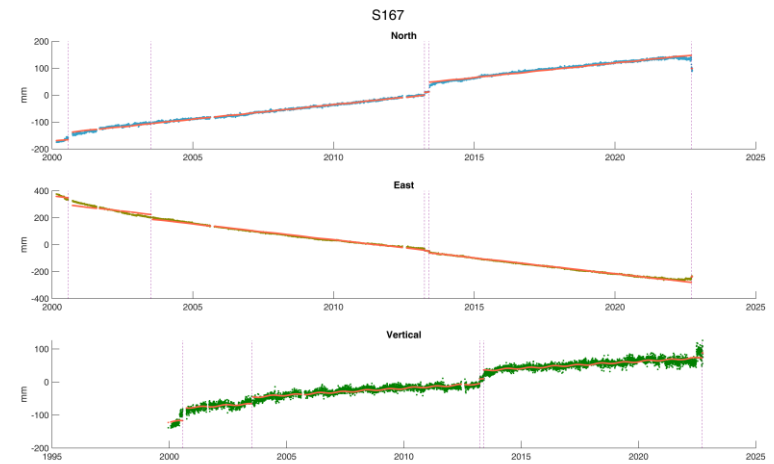
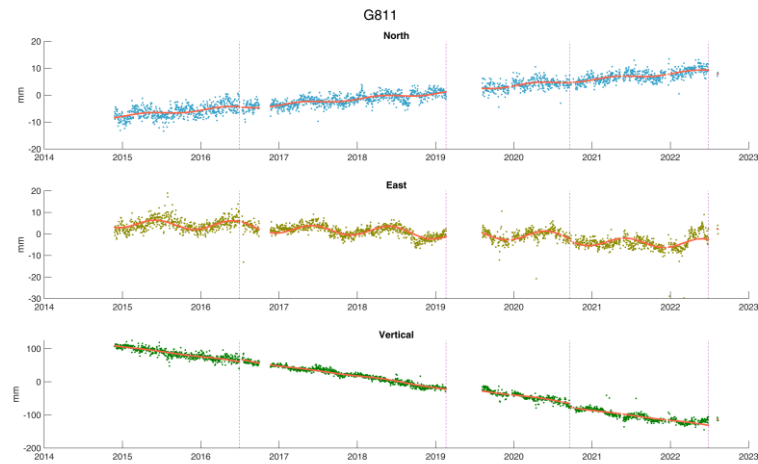


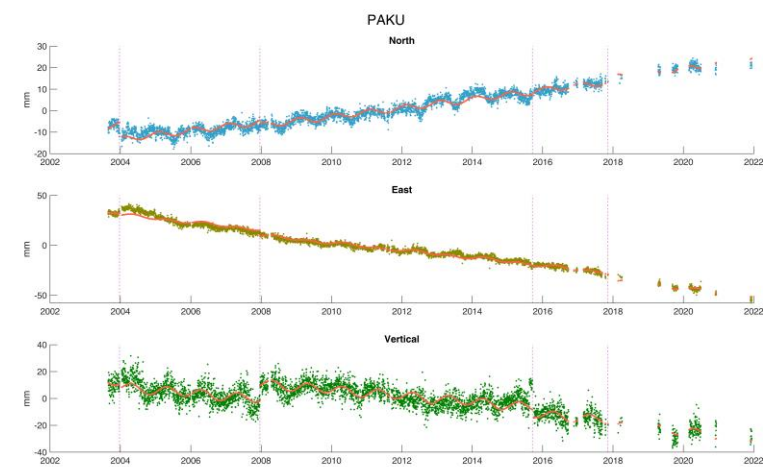
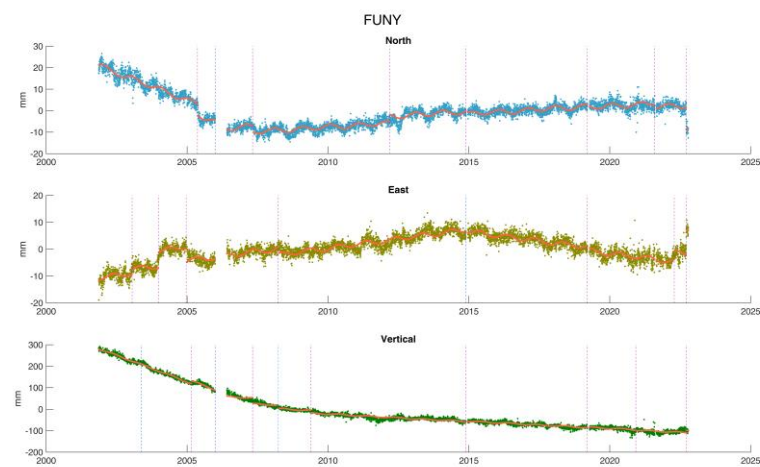
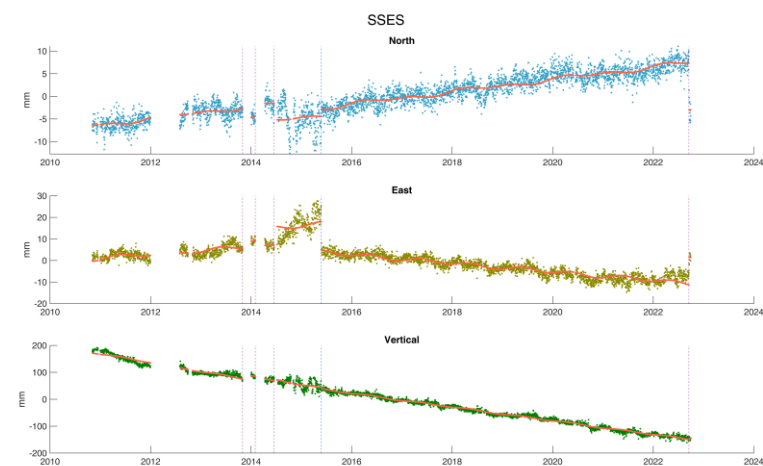
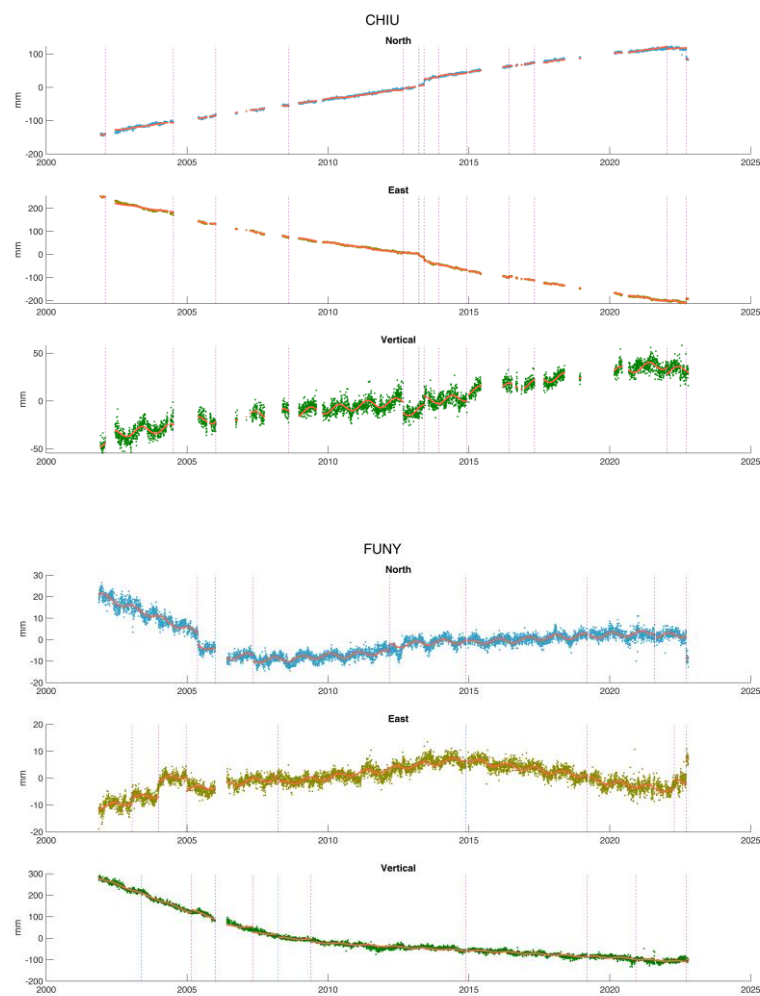


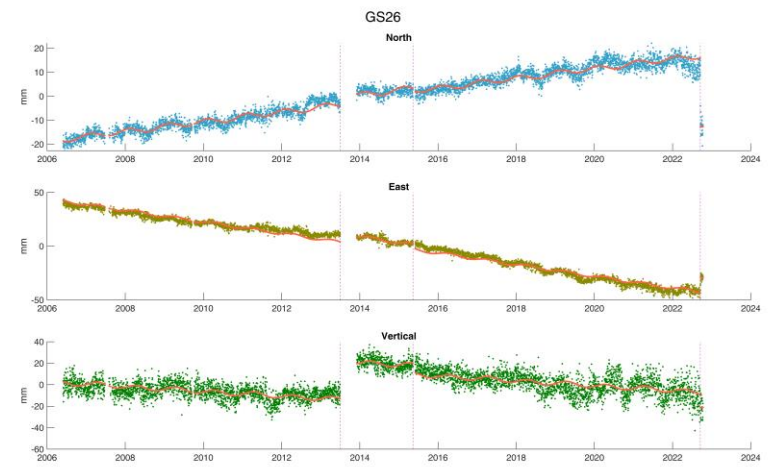
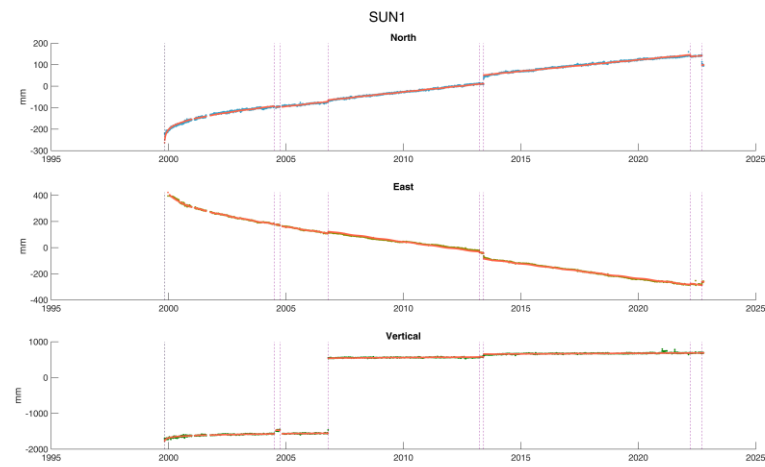
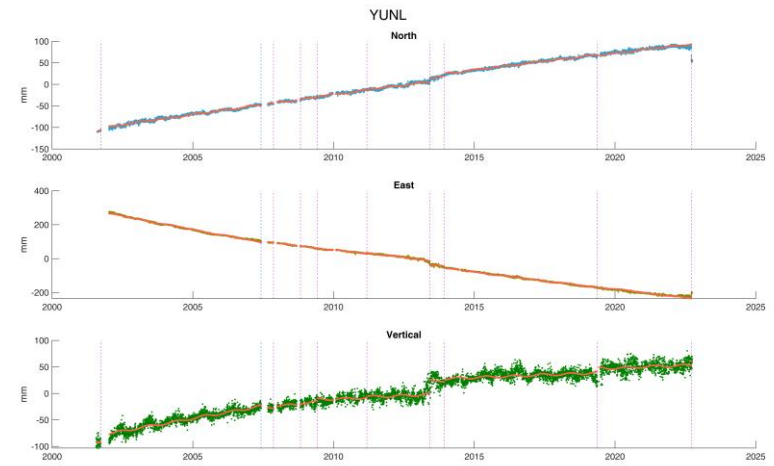
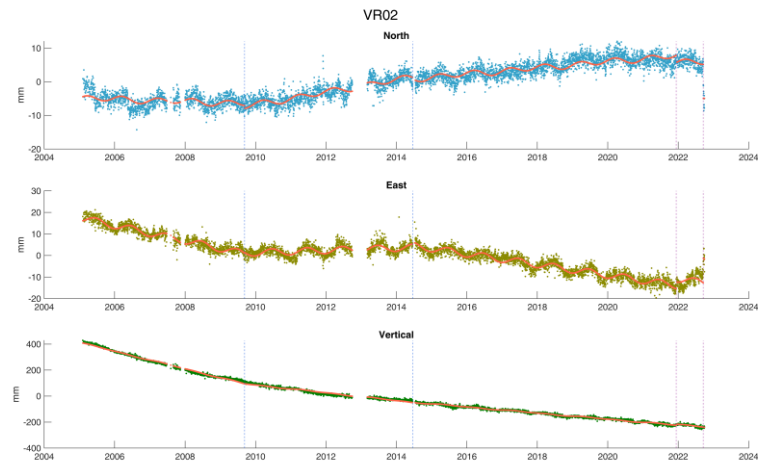


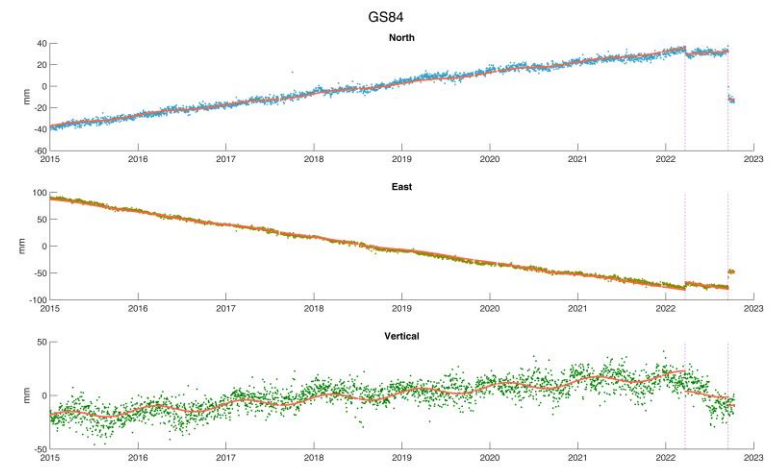
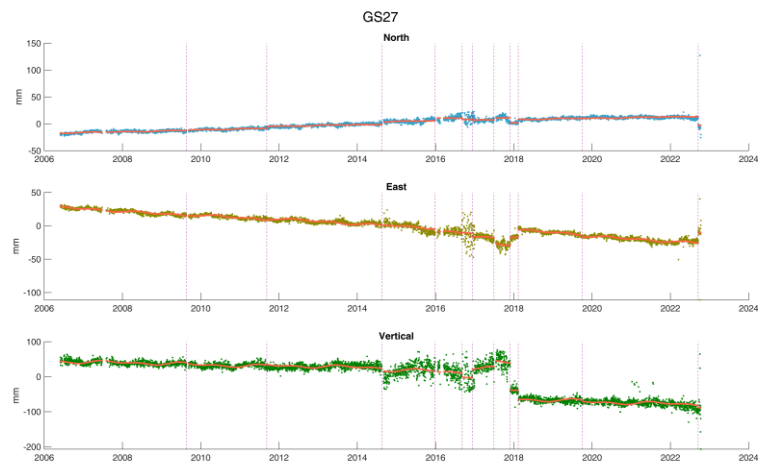
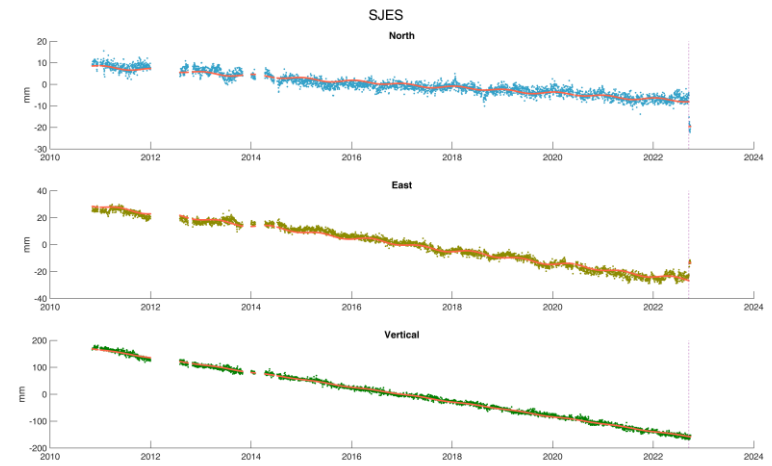
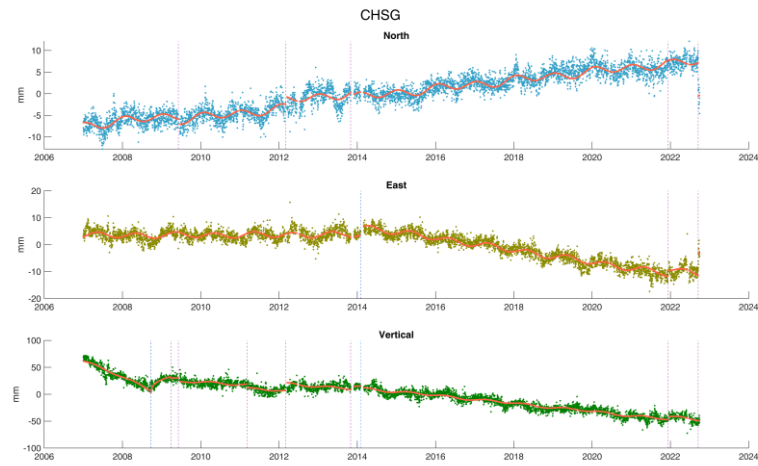


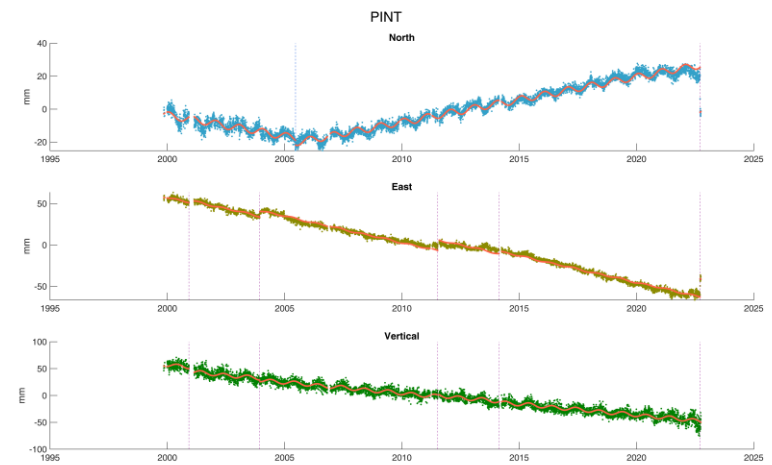
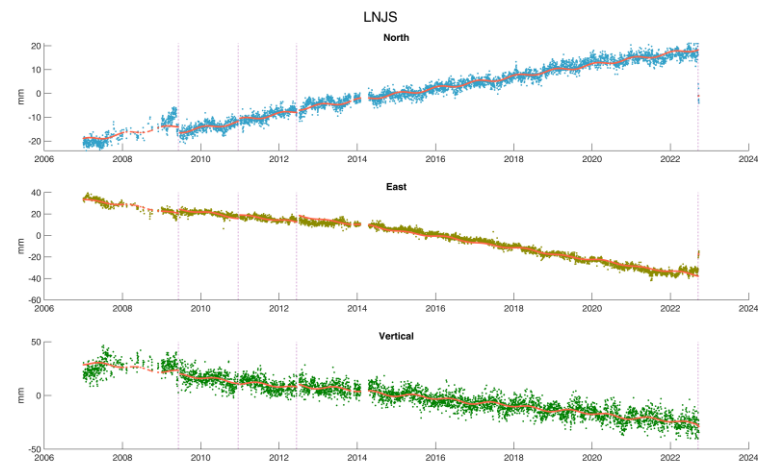
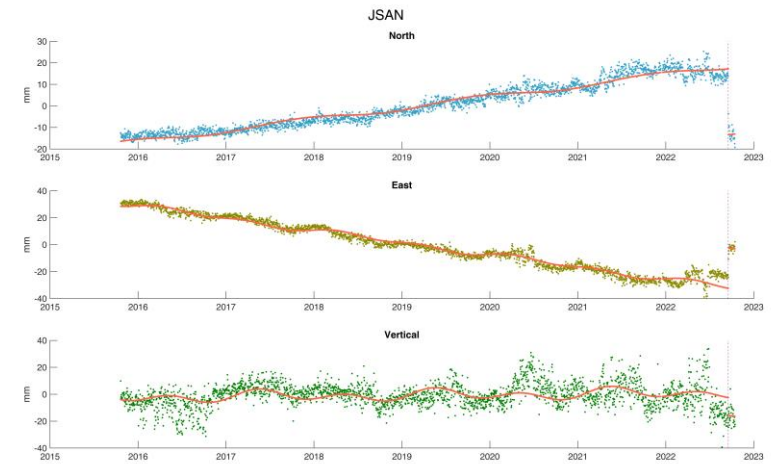
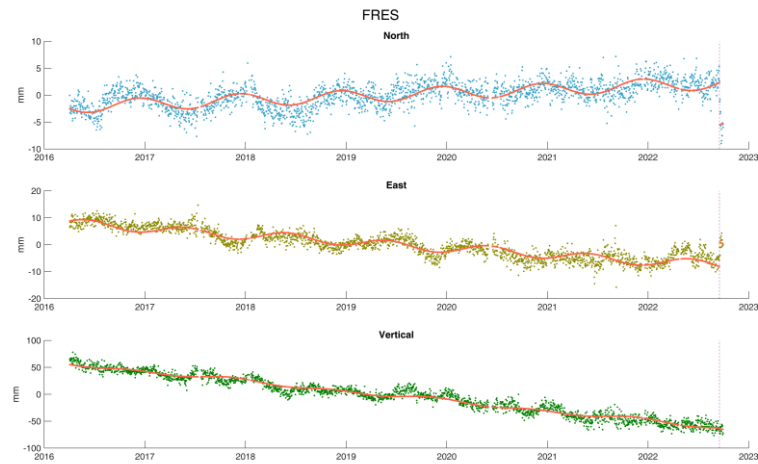


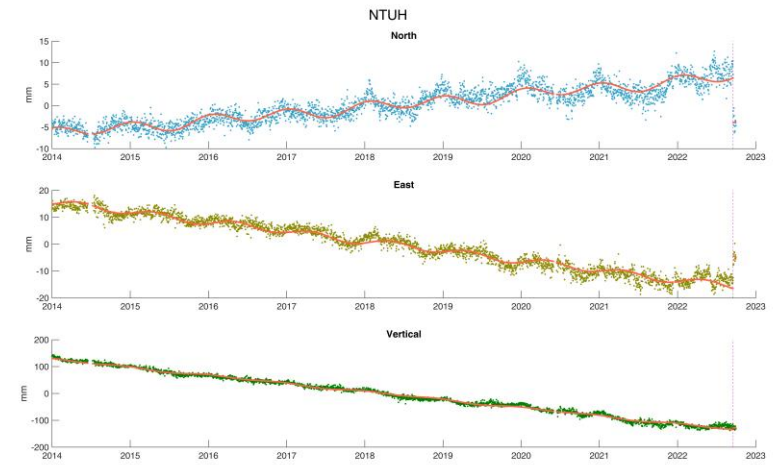
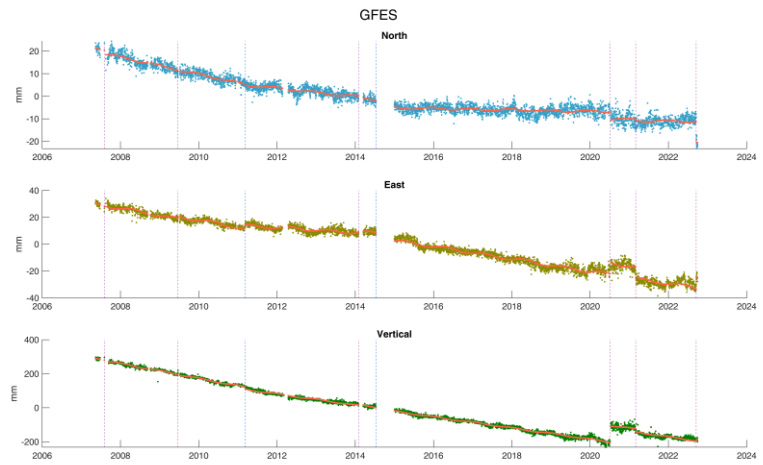
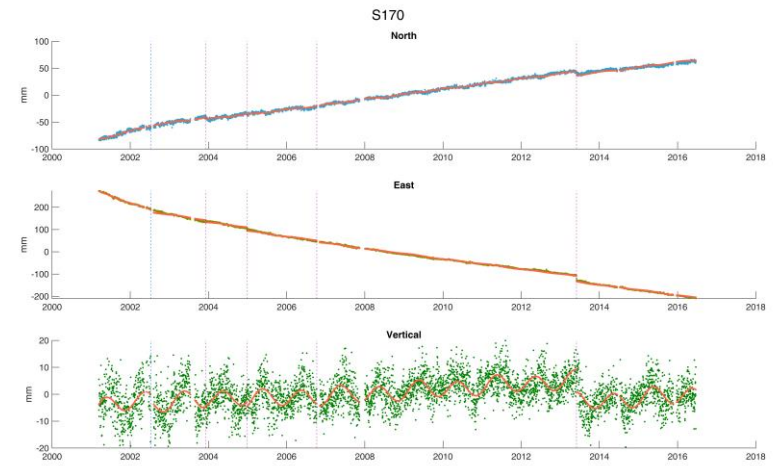
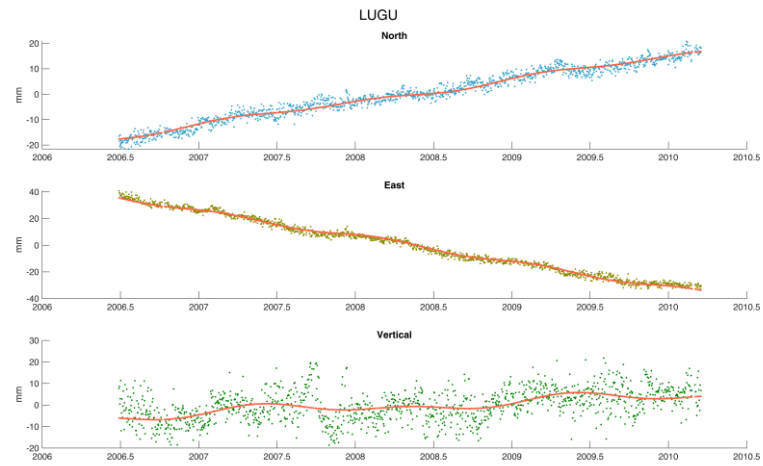


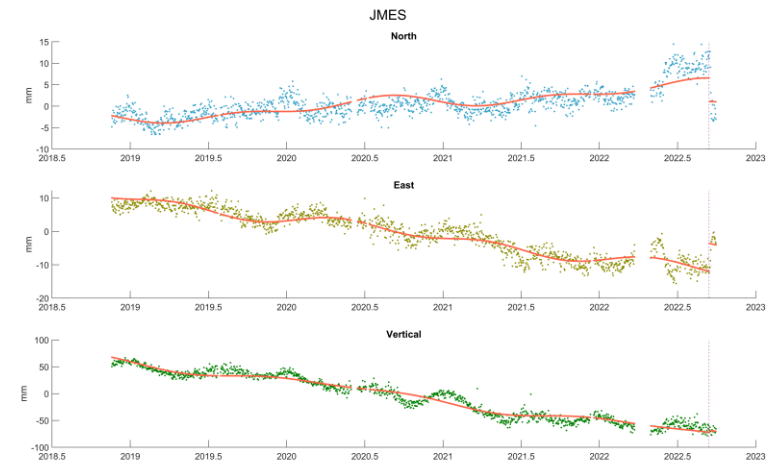
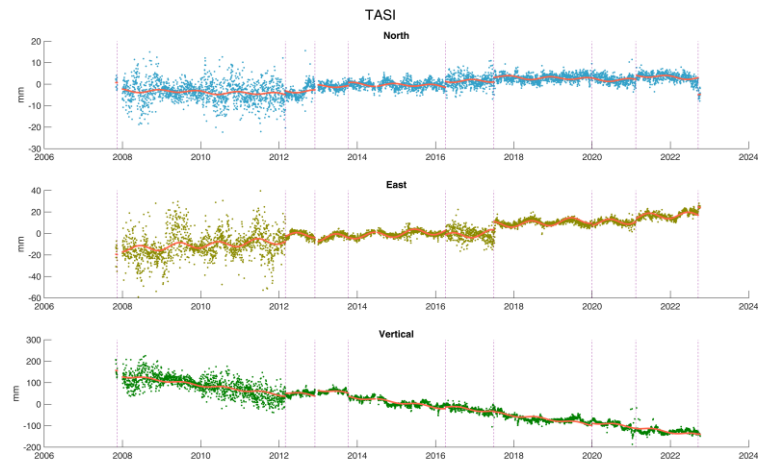
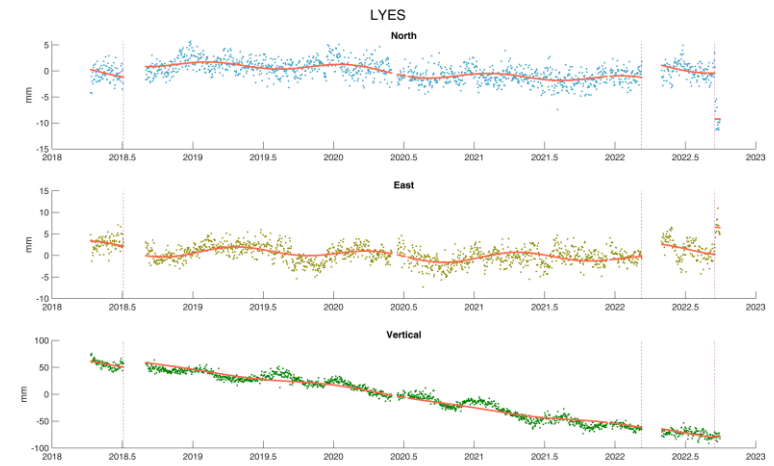
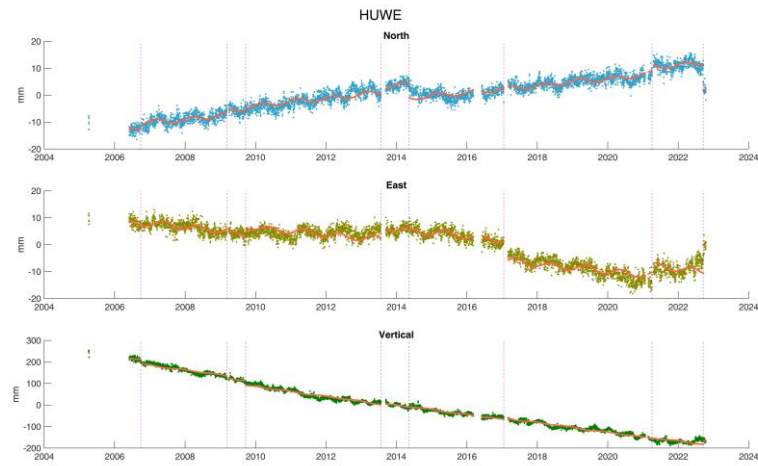


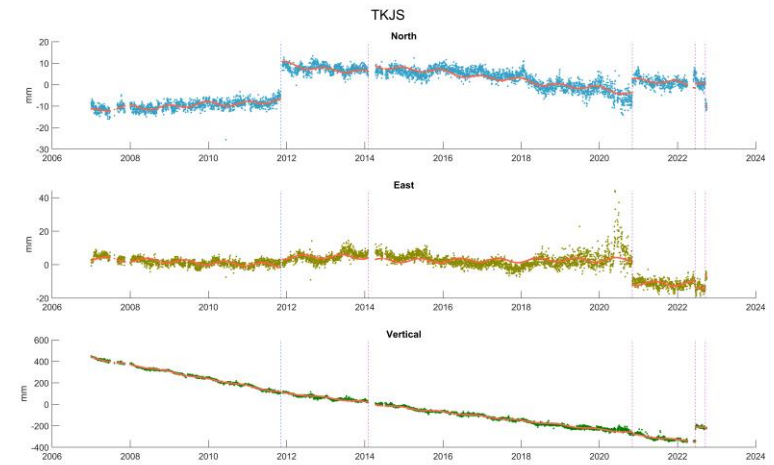
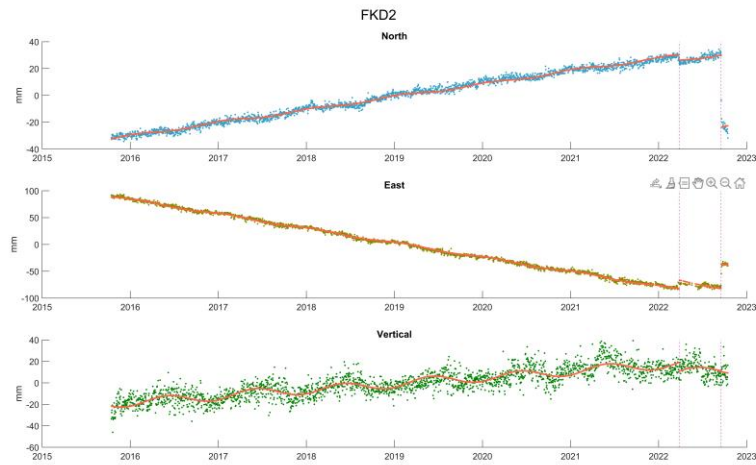
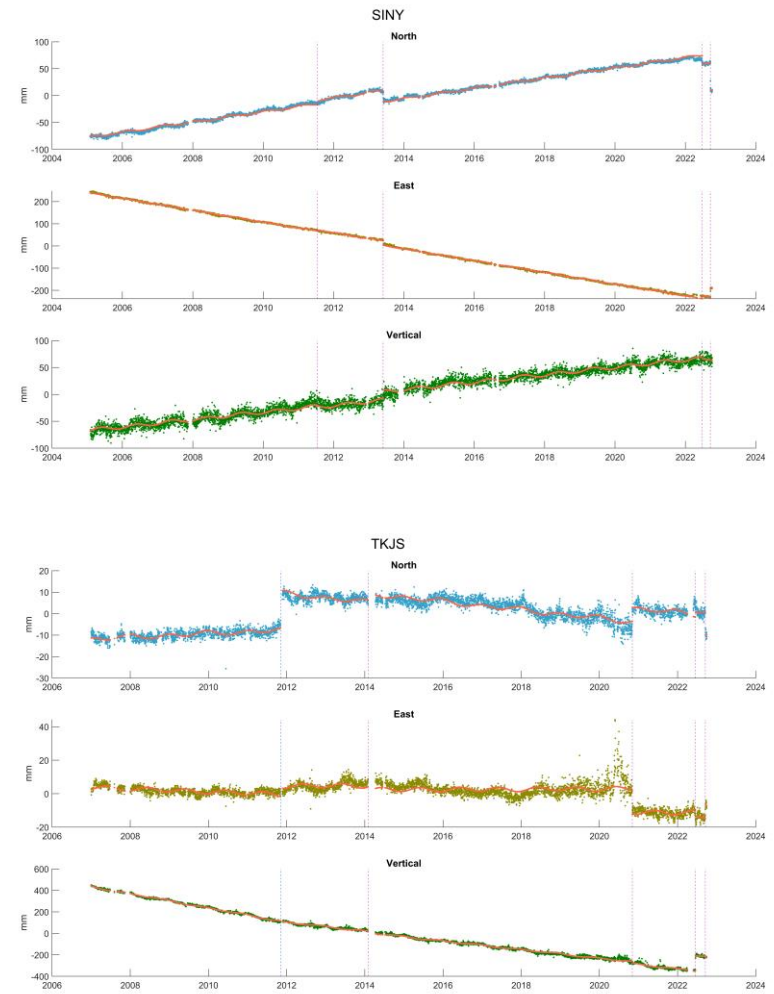
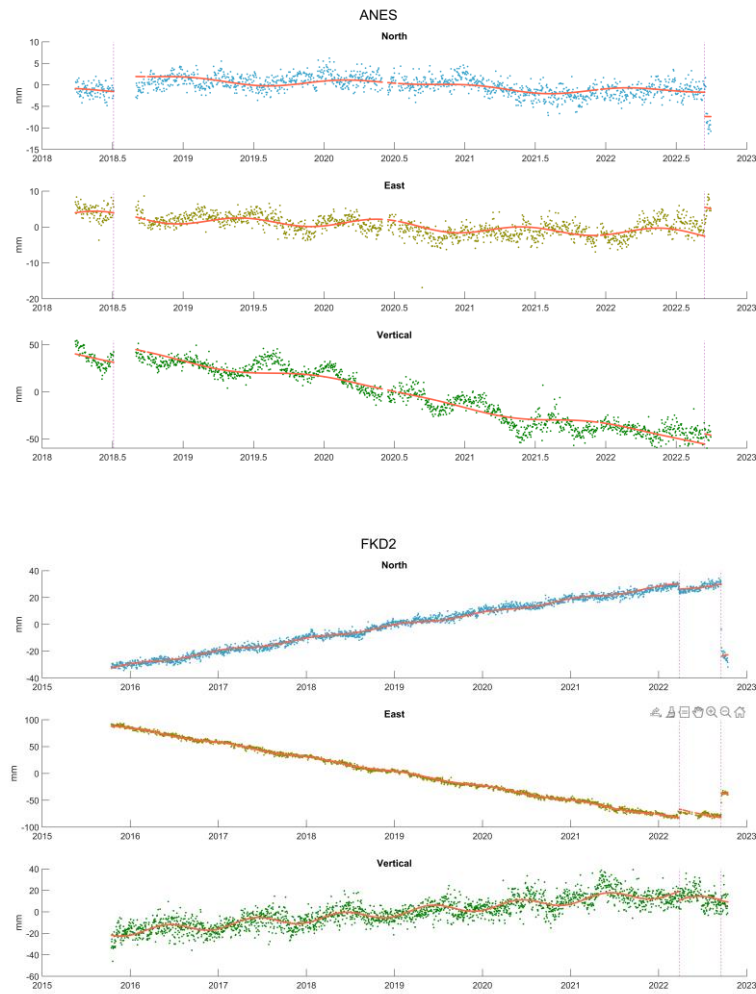


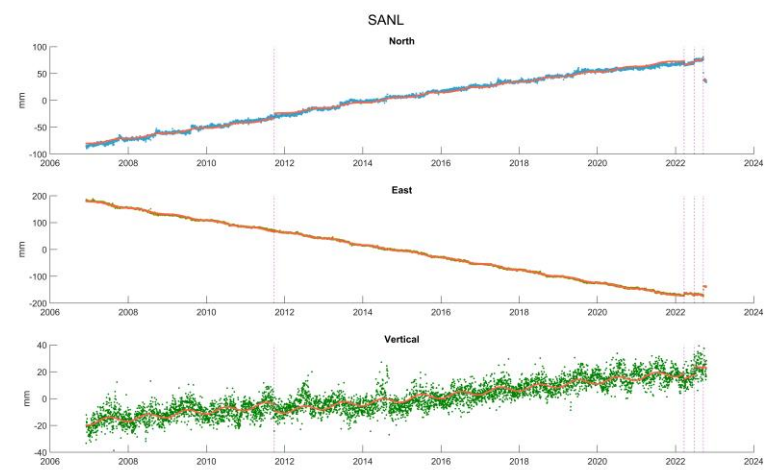
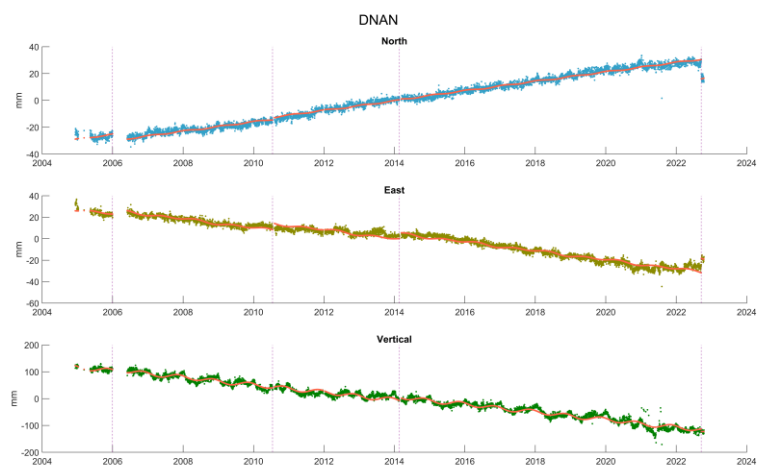
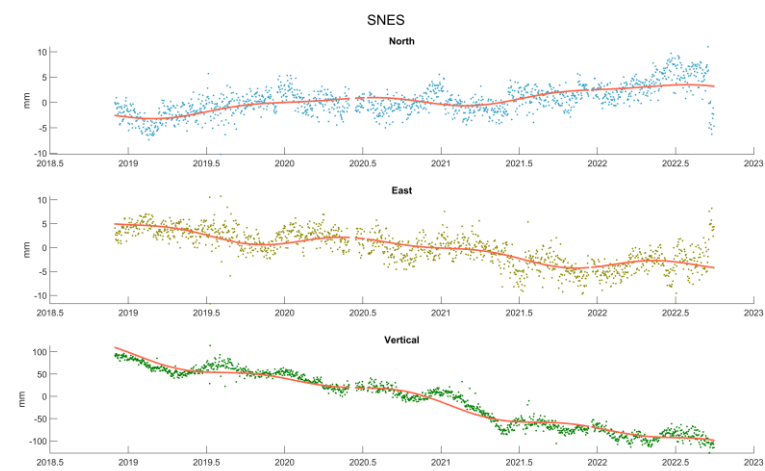
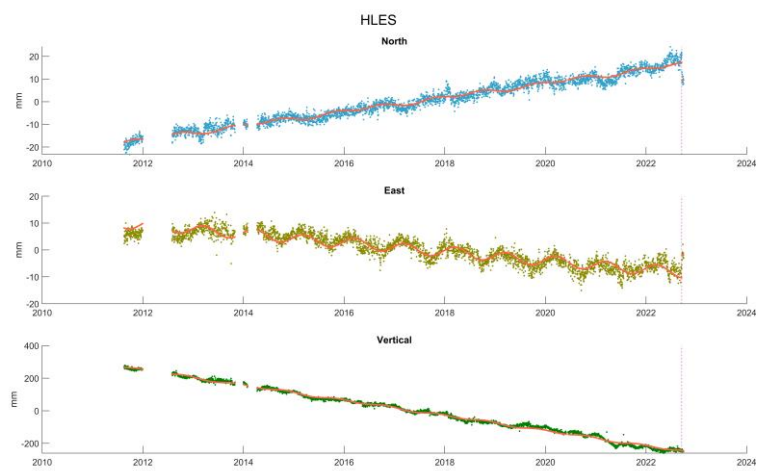


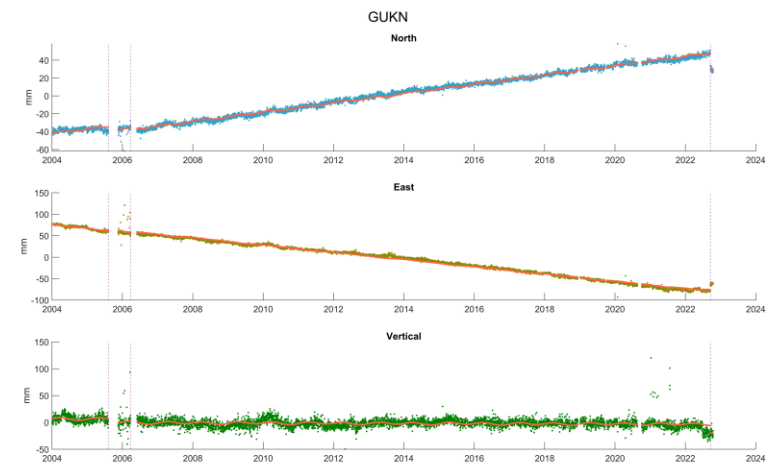
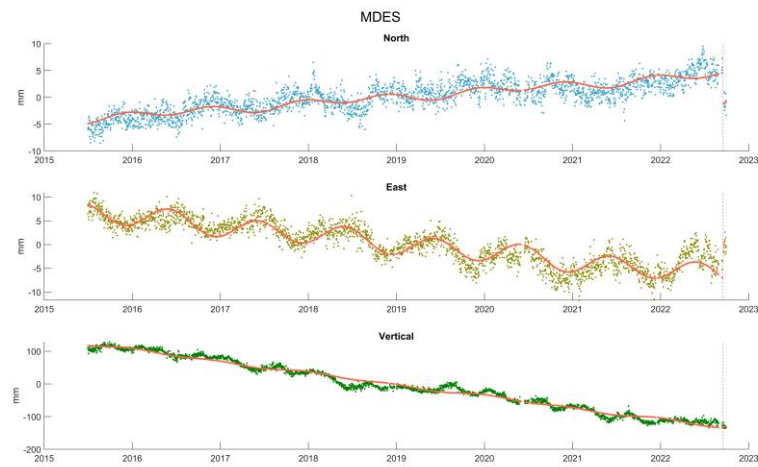
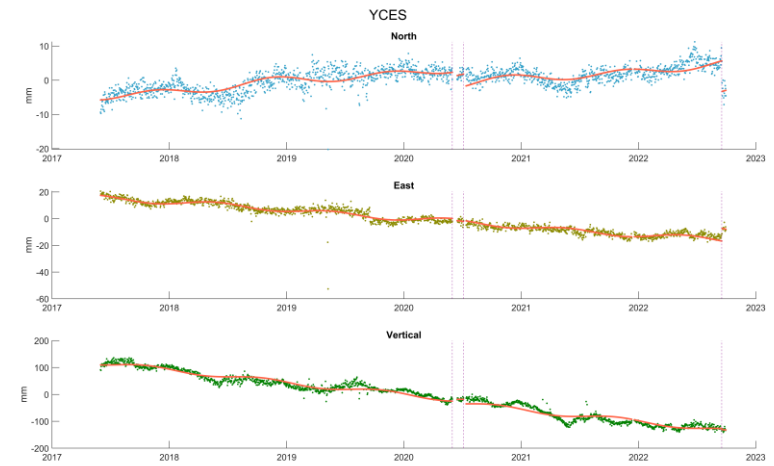
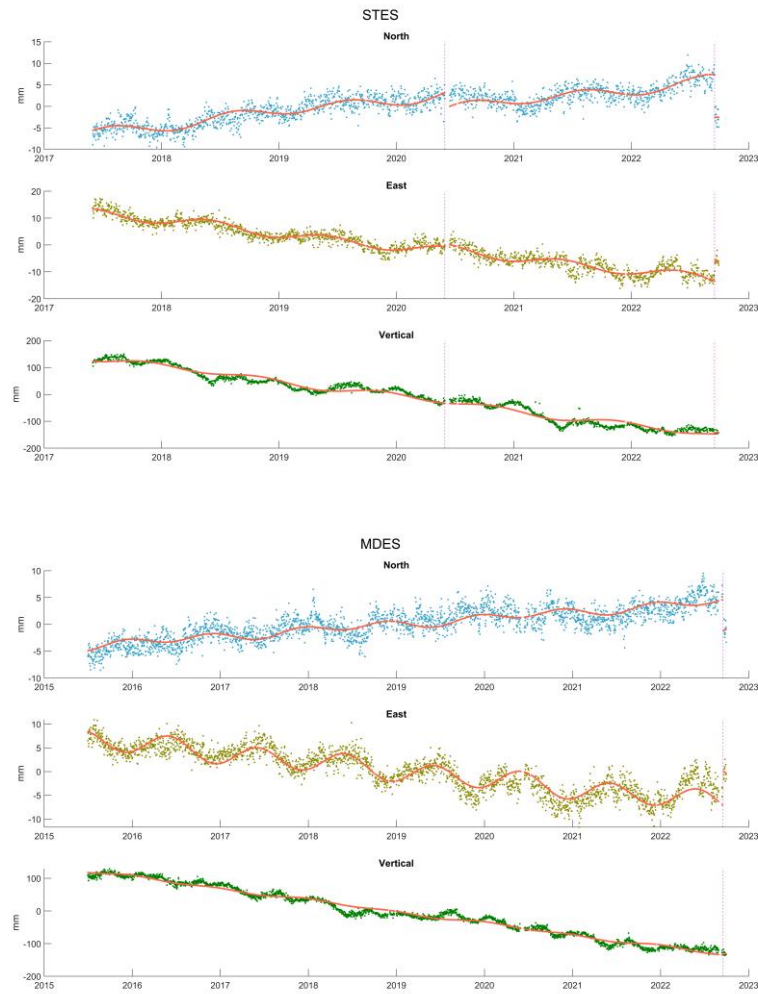


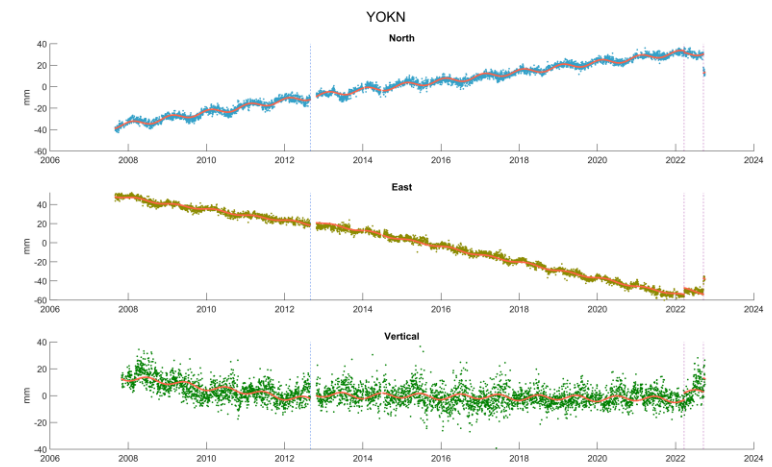
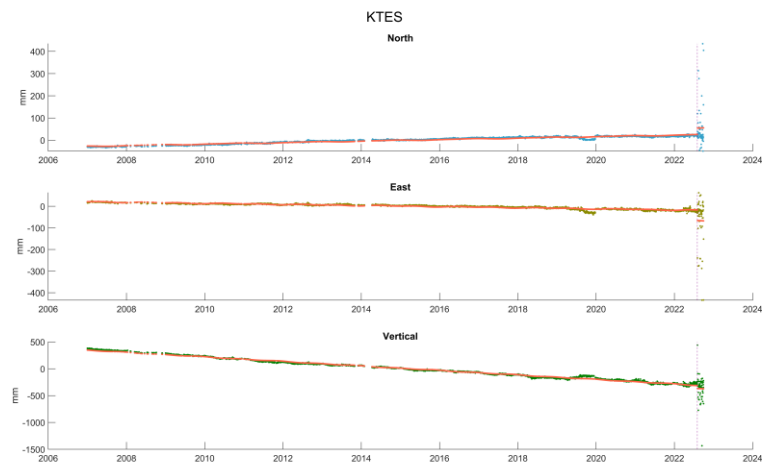
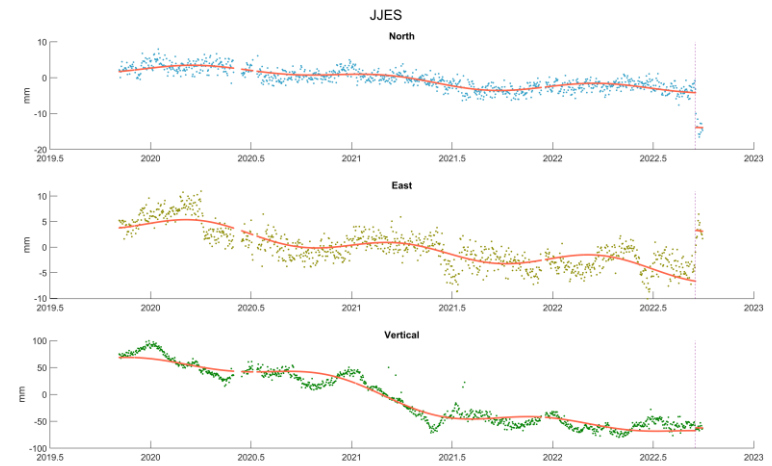
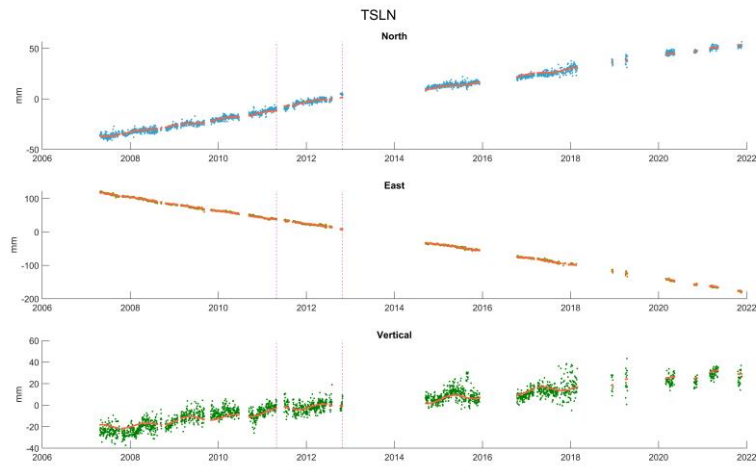


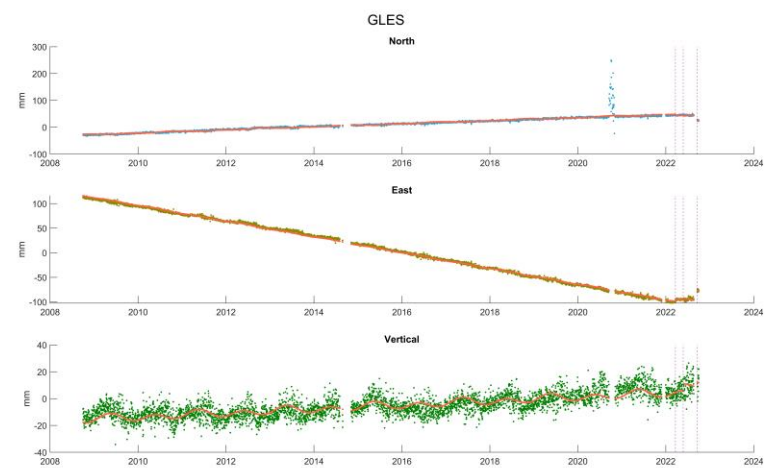
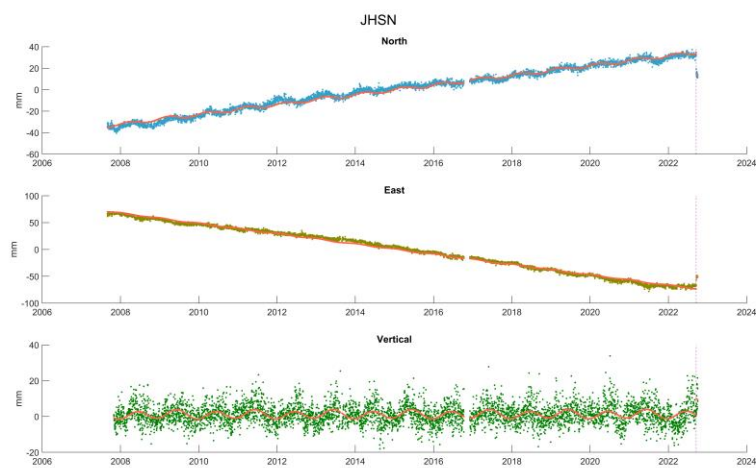
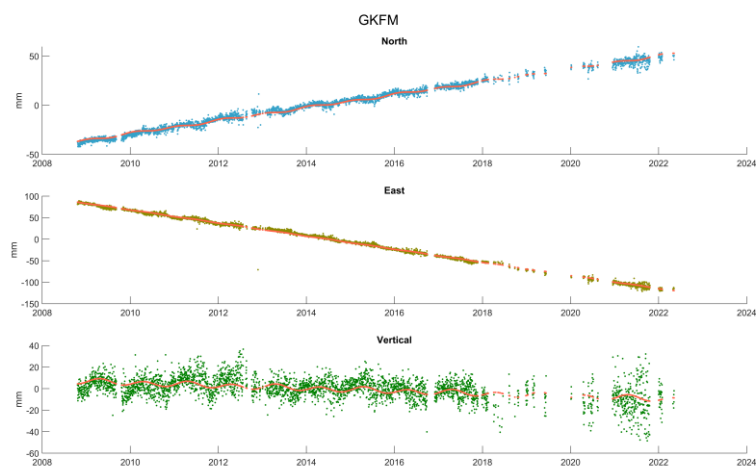


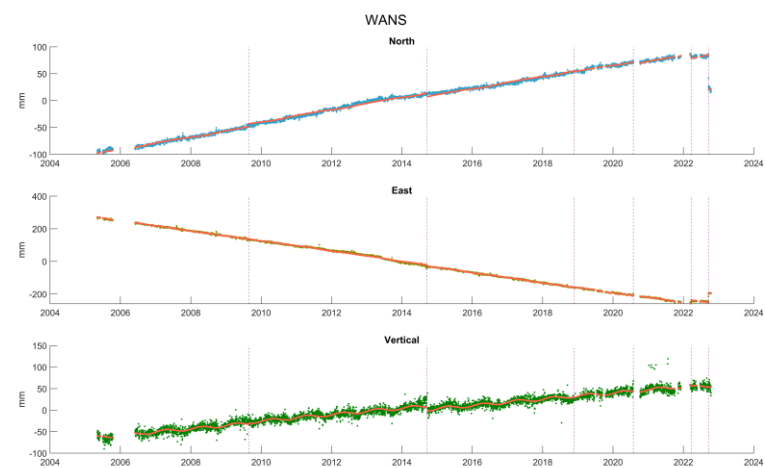
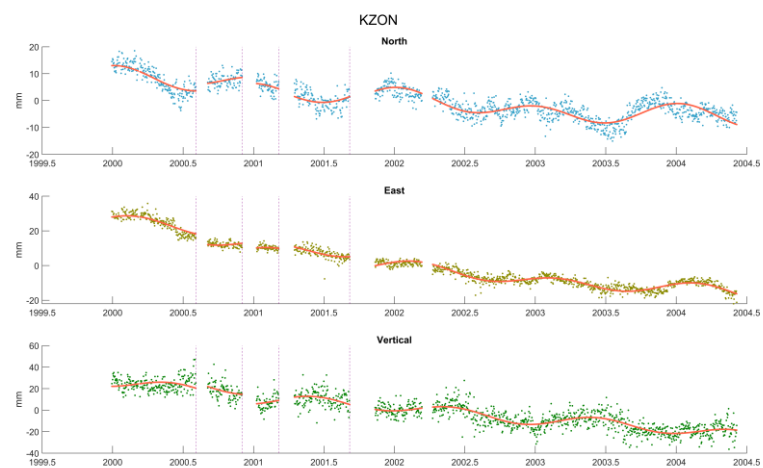








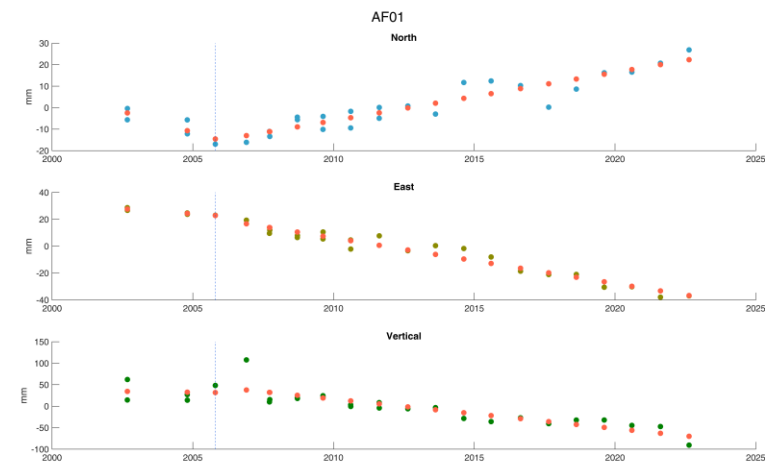
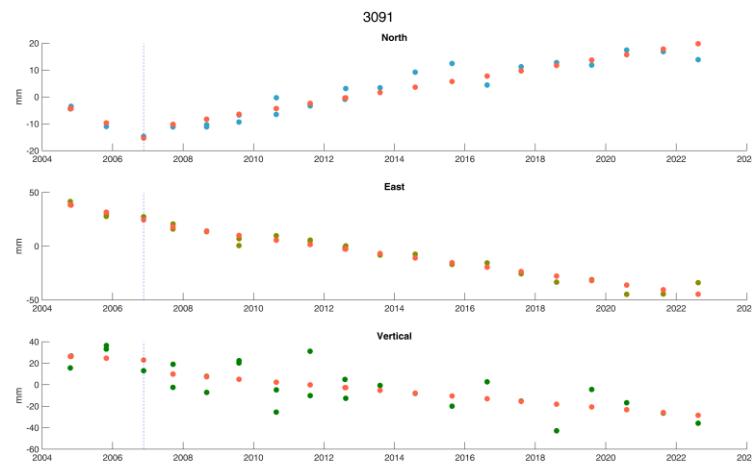


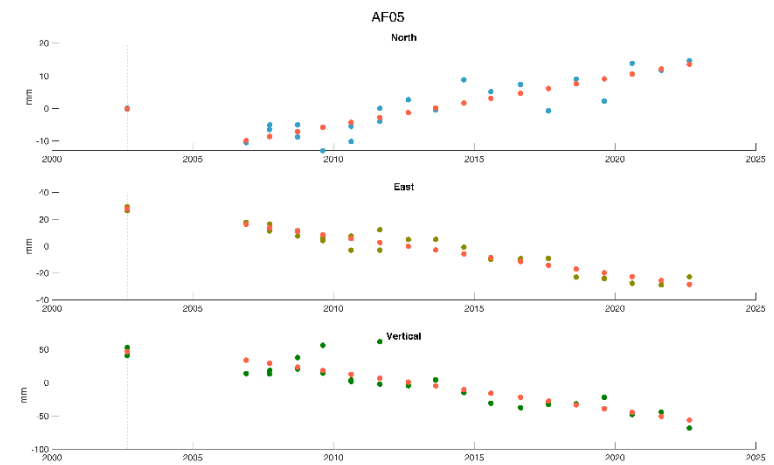
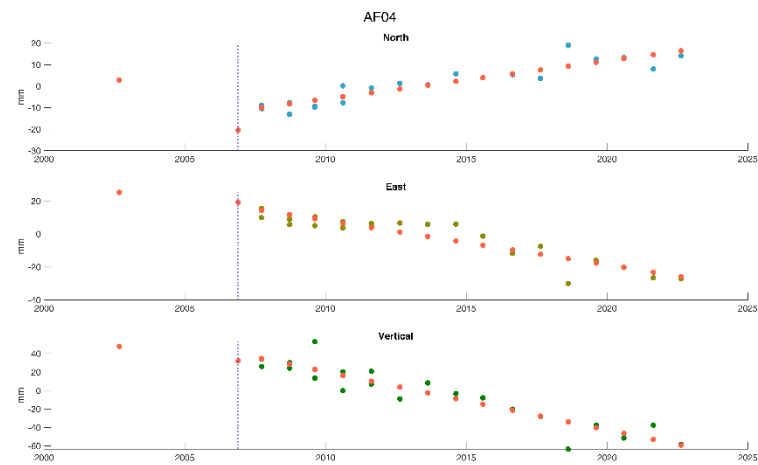
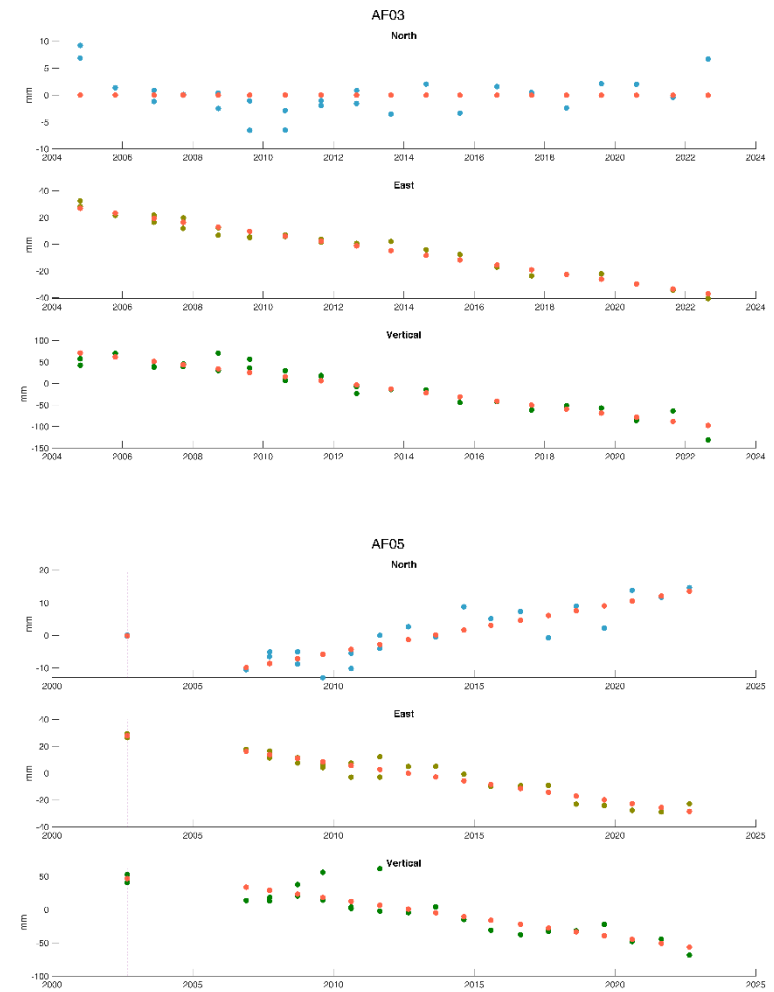
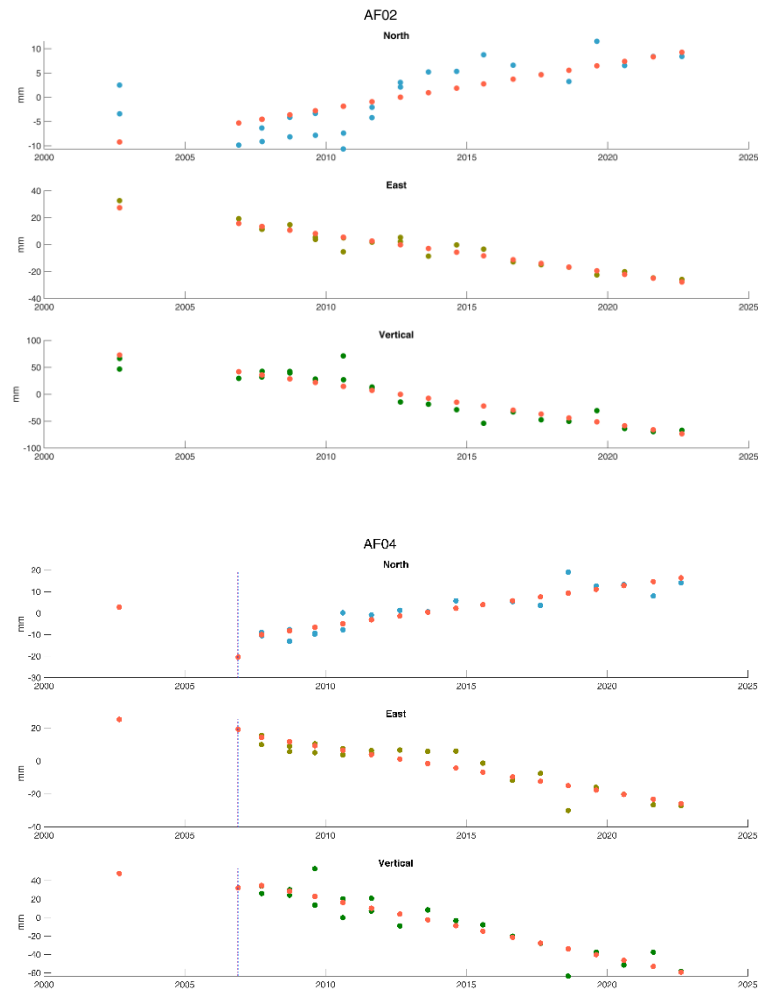


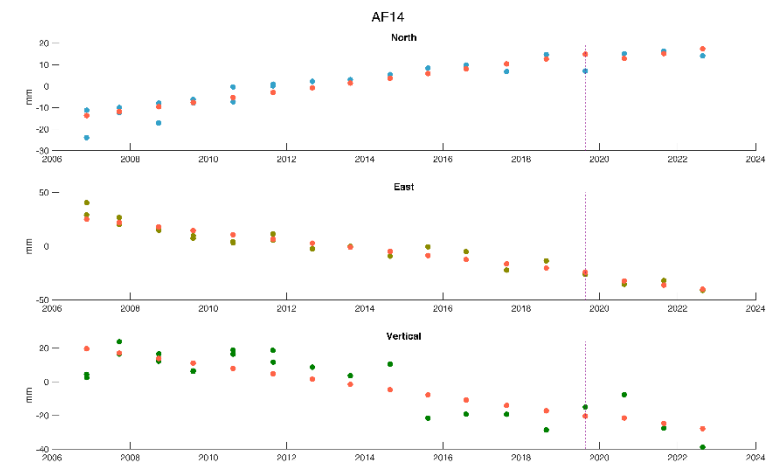
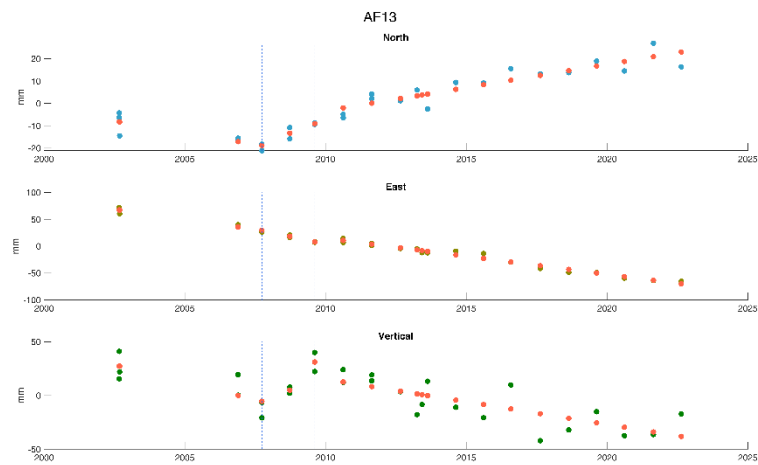
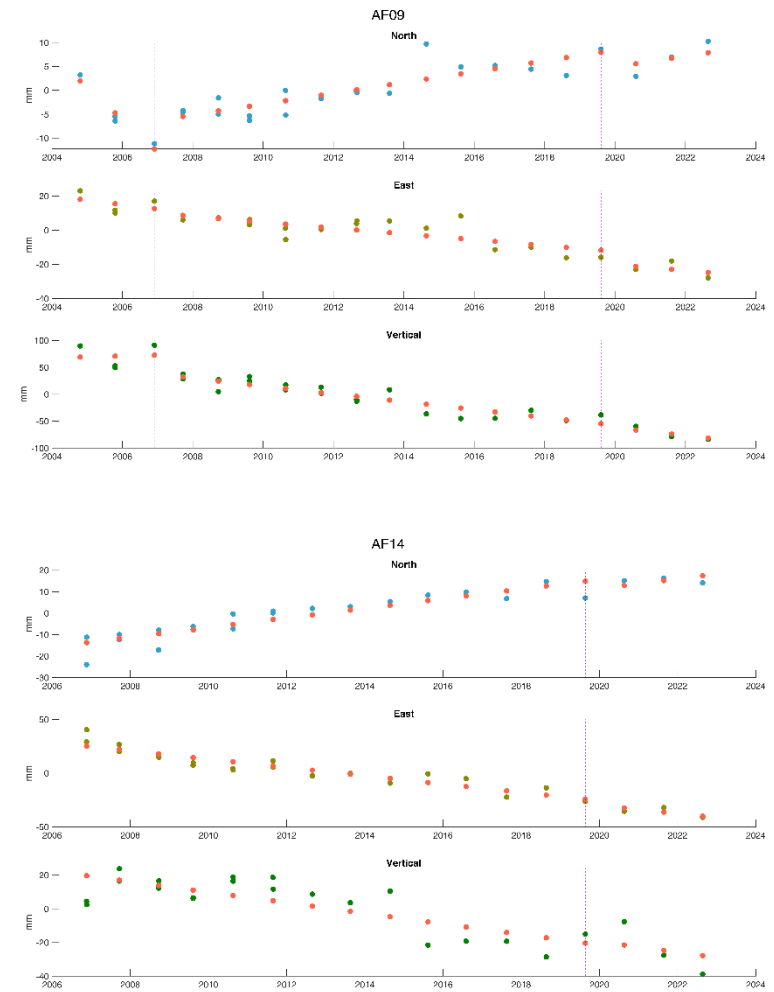
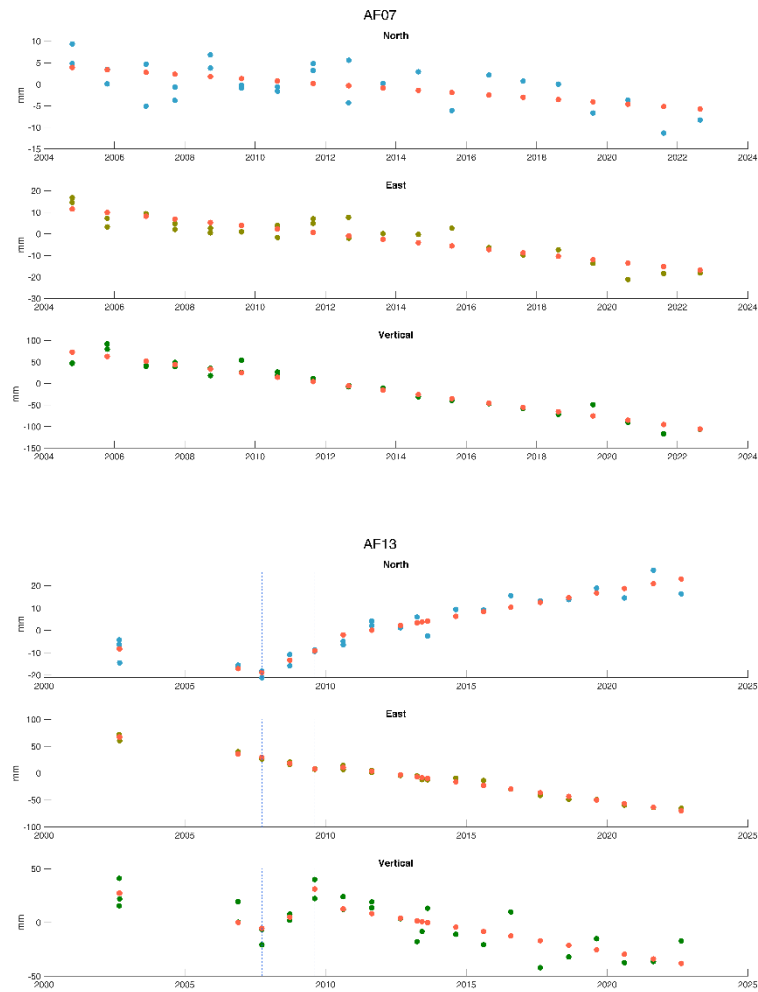


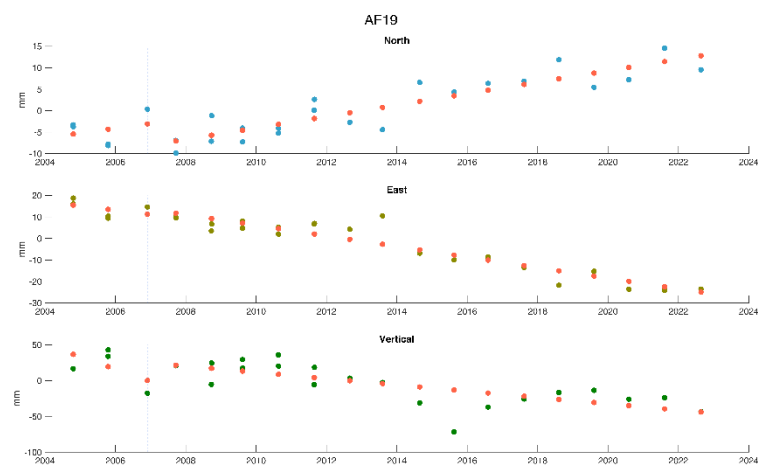
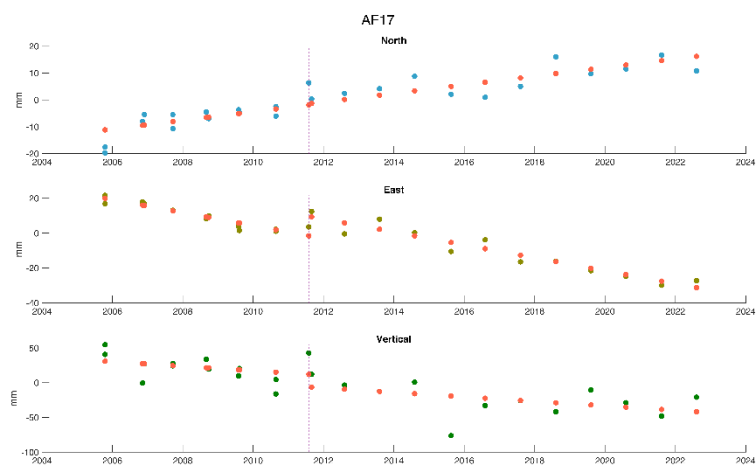
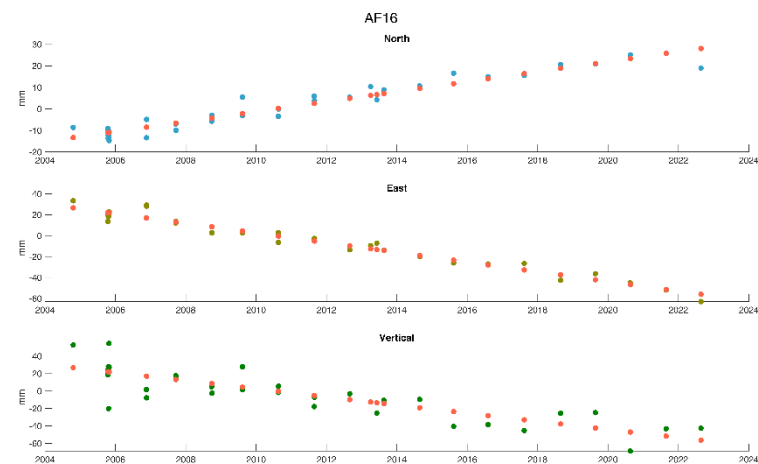
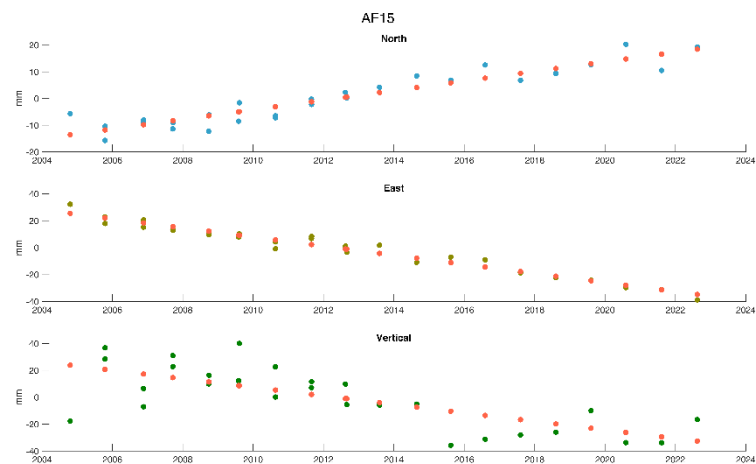
## Appendix D2: Campaign-mode GNSS

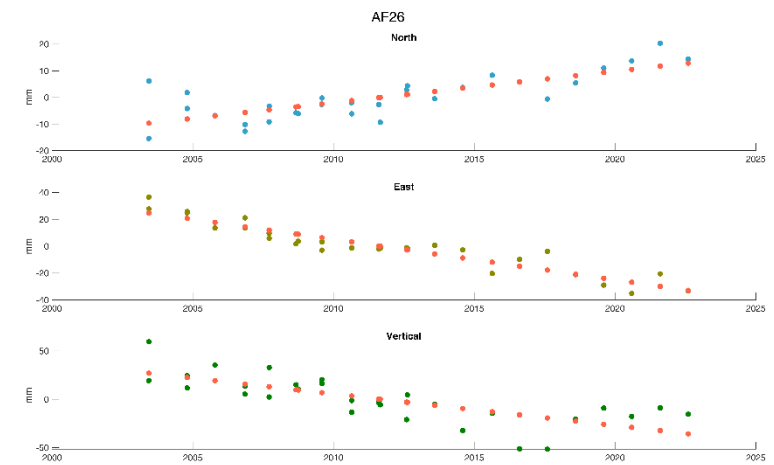
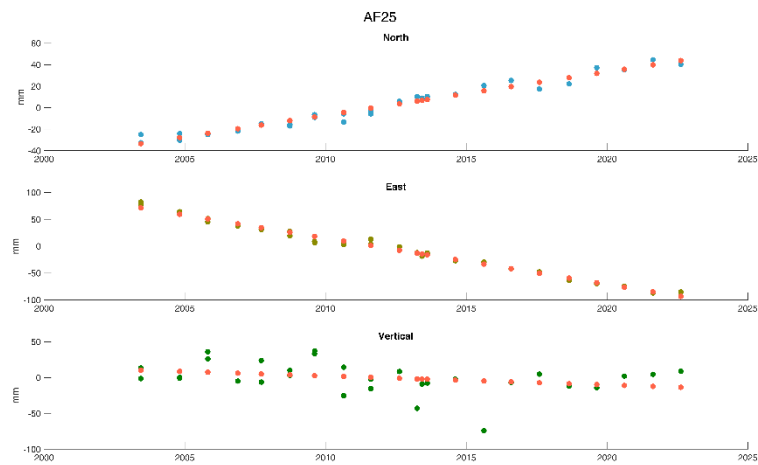
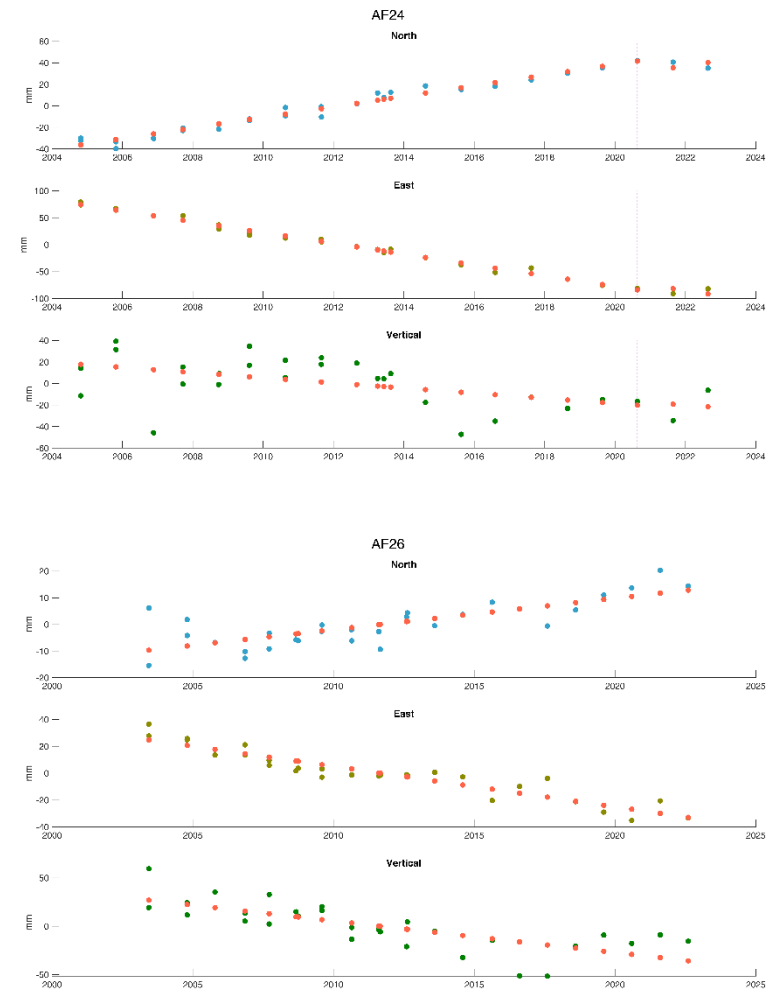
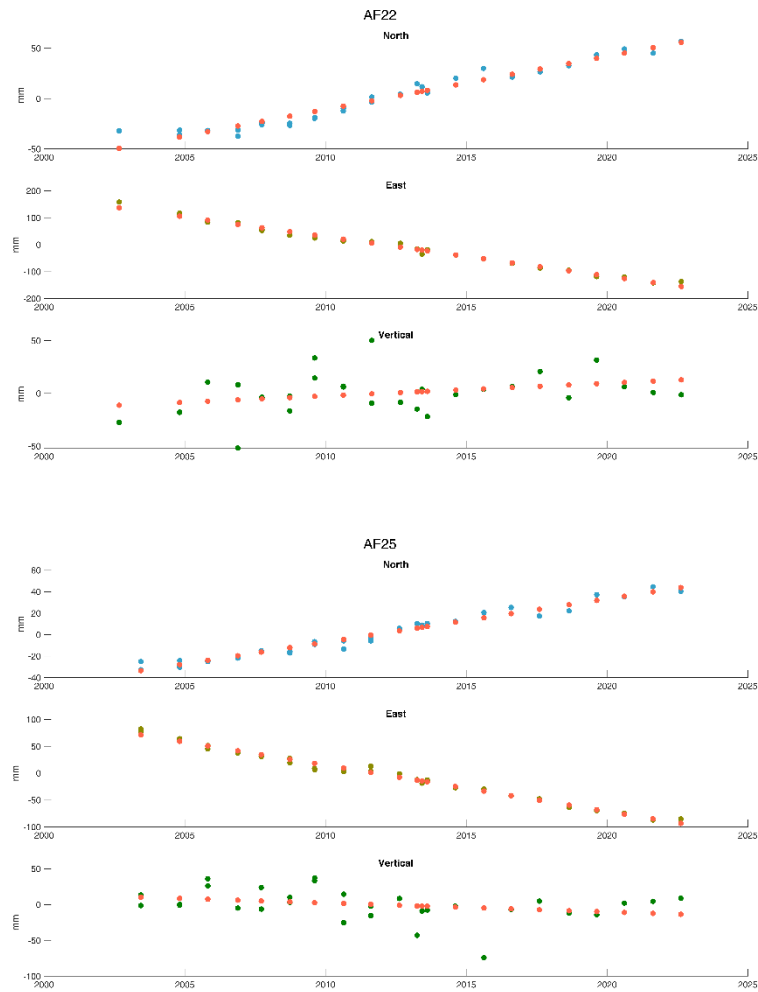
Here are the fitting results of campaign-mode GNSS stations. Red lines are the fitting results. Purple dashes indicate the Heaviside step function. Blue dashes indicate the change of velocity. Black dashes indicate the logarithmic postseismic deformation.

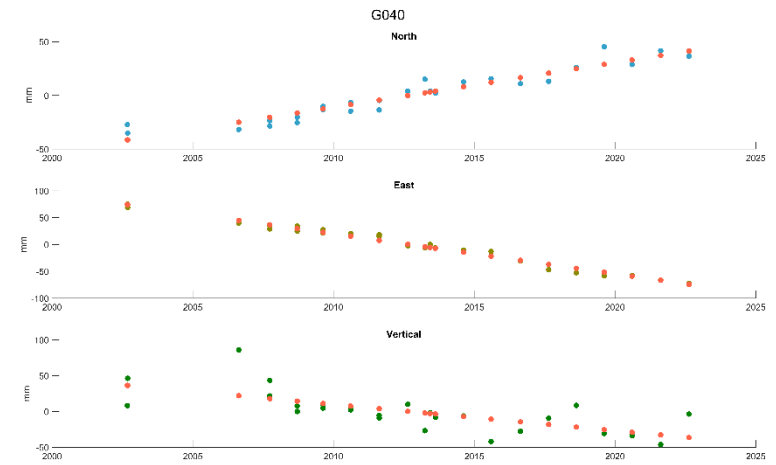
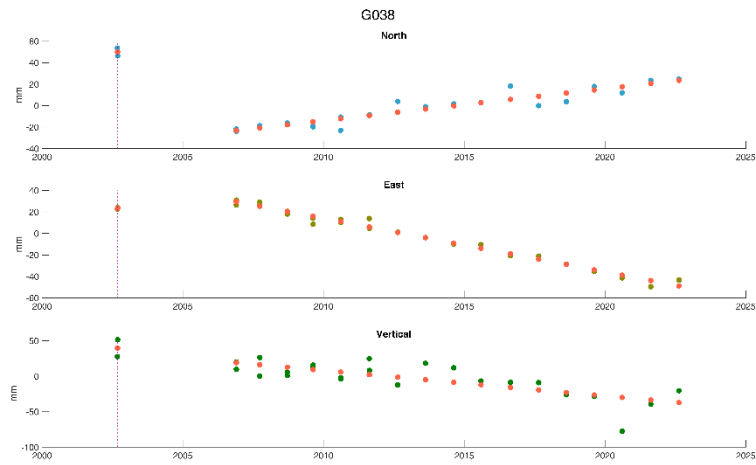
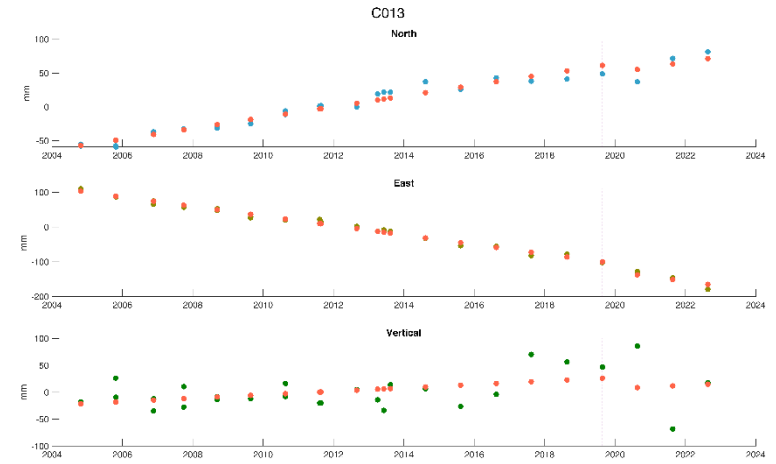
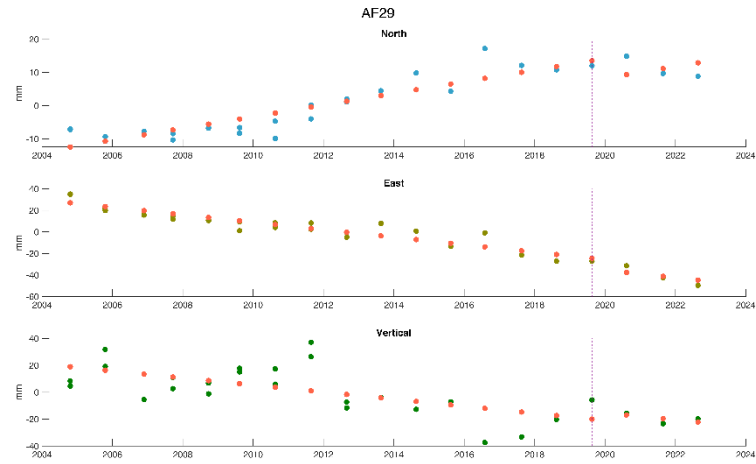


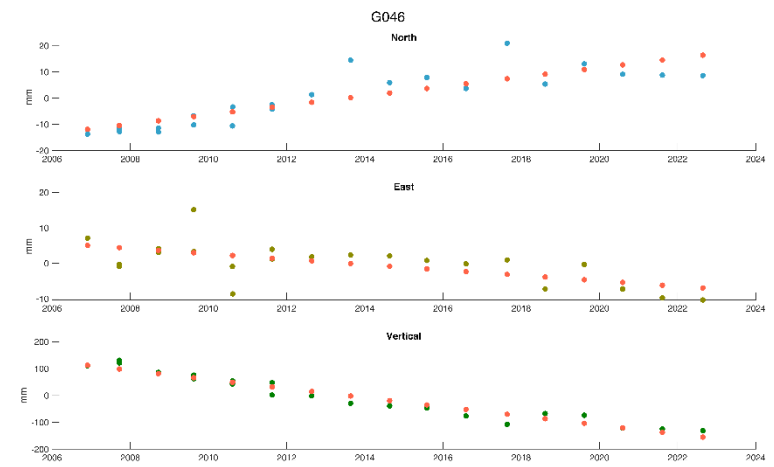
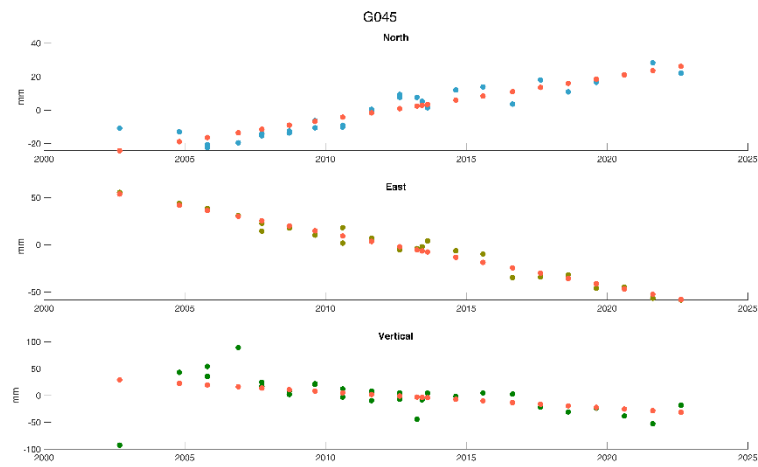
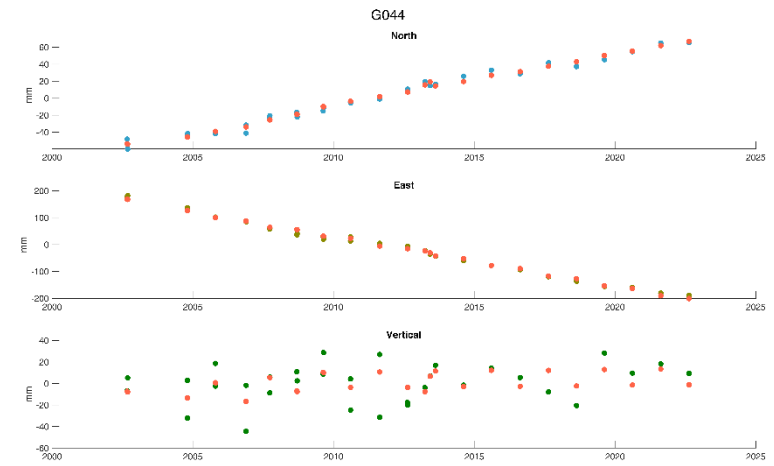
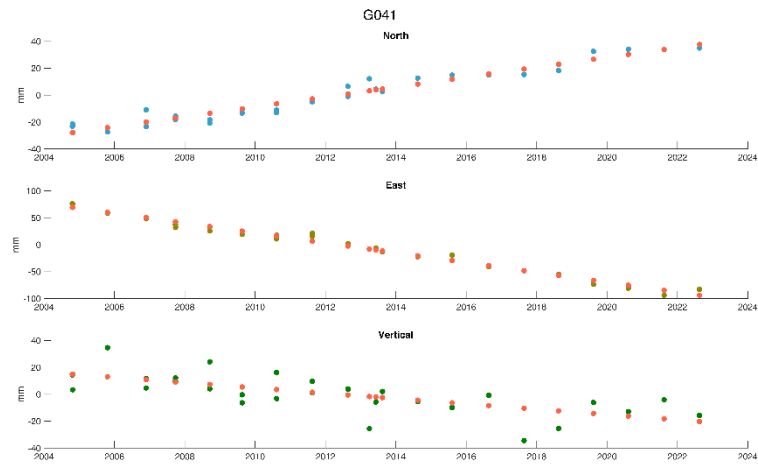


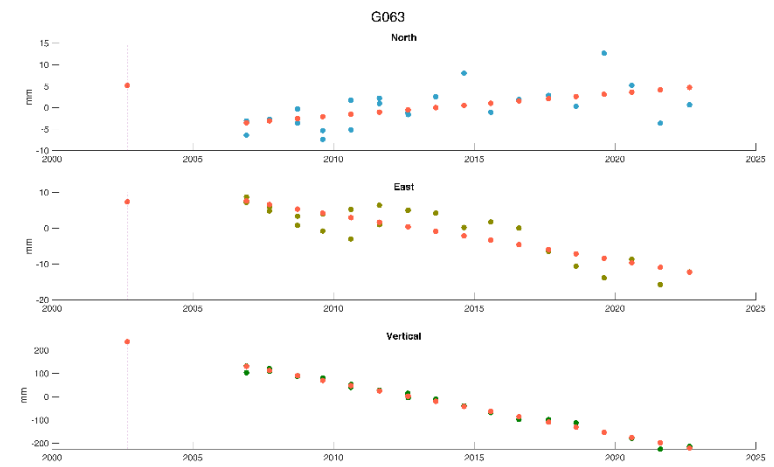
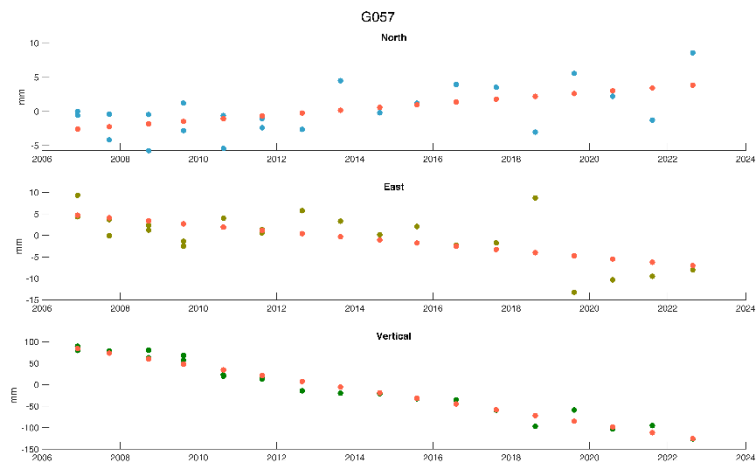
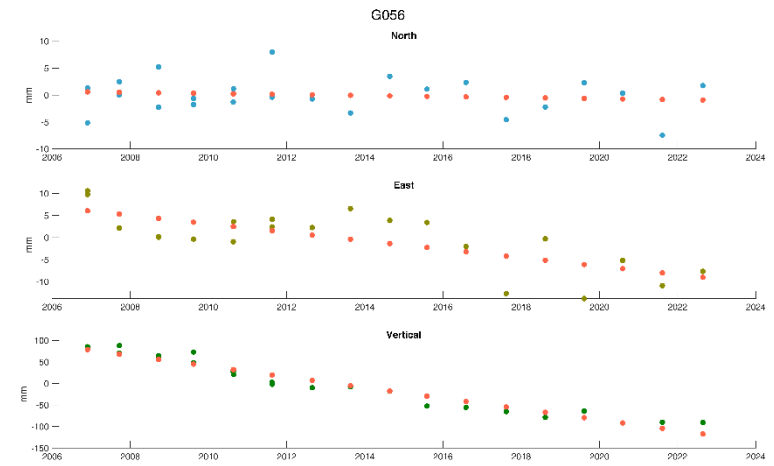
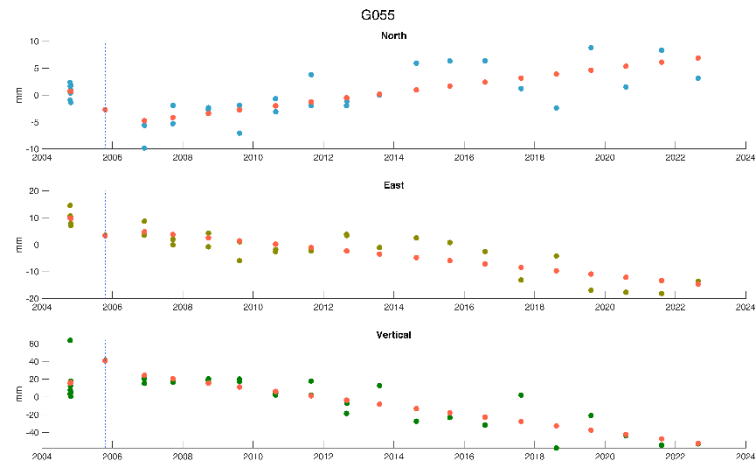


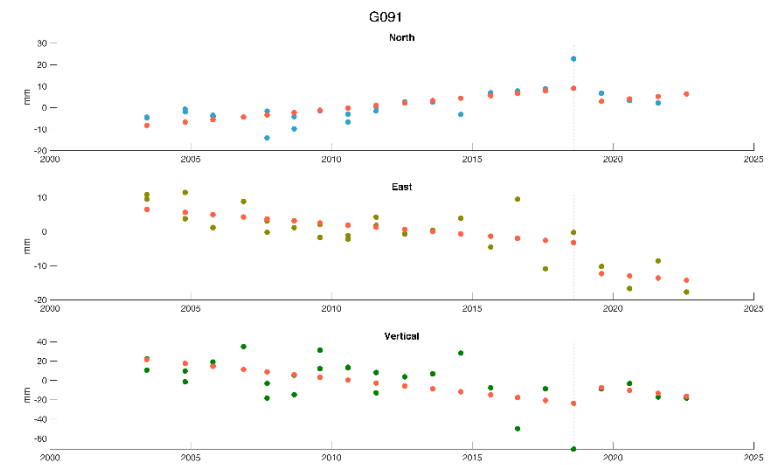
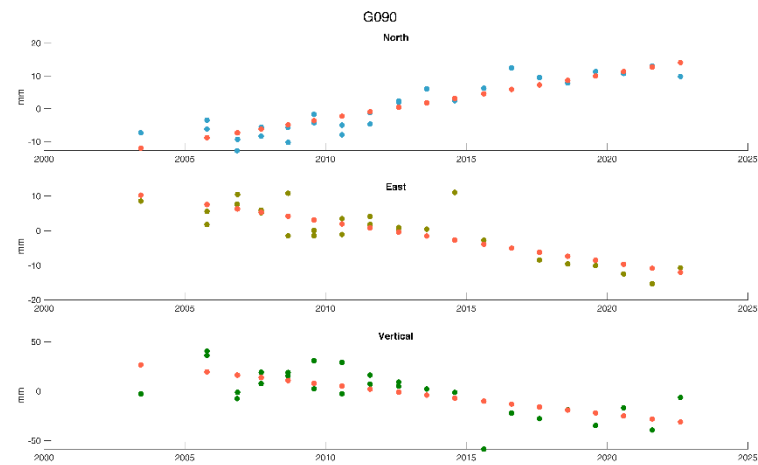
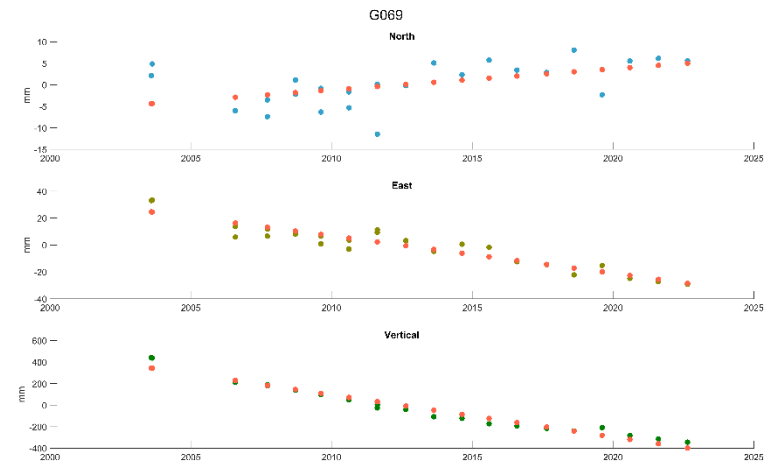
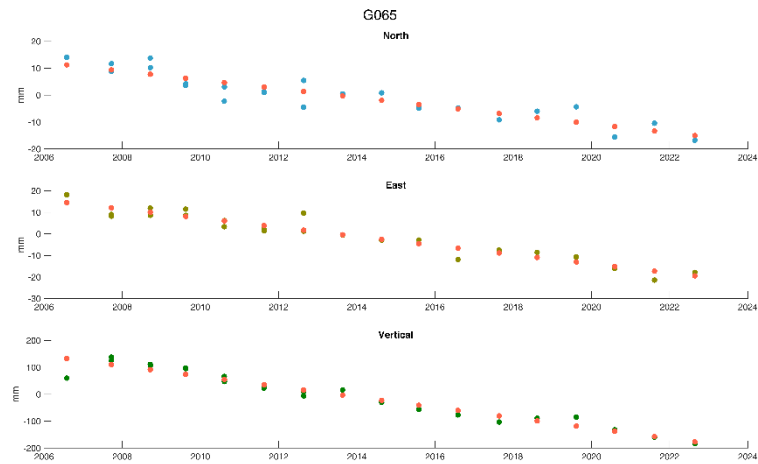


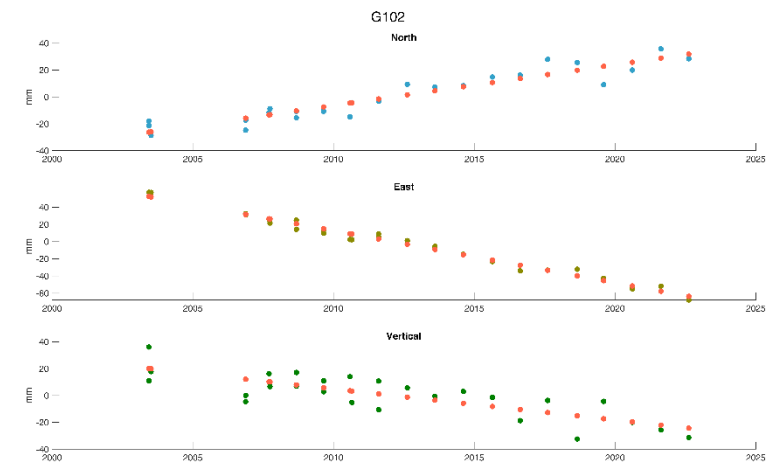
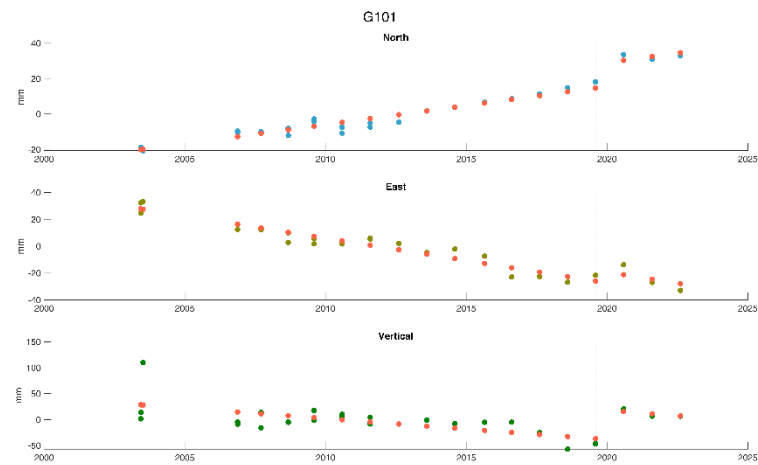
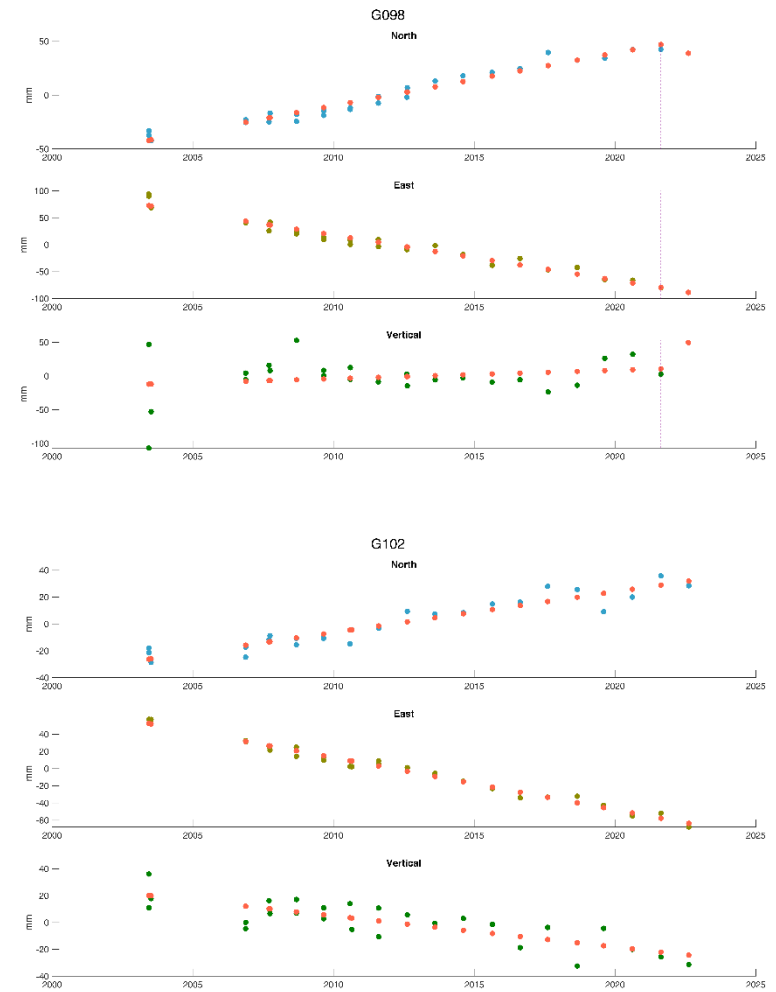
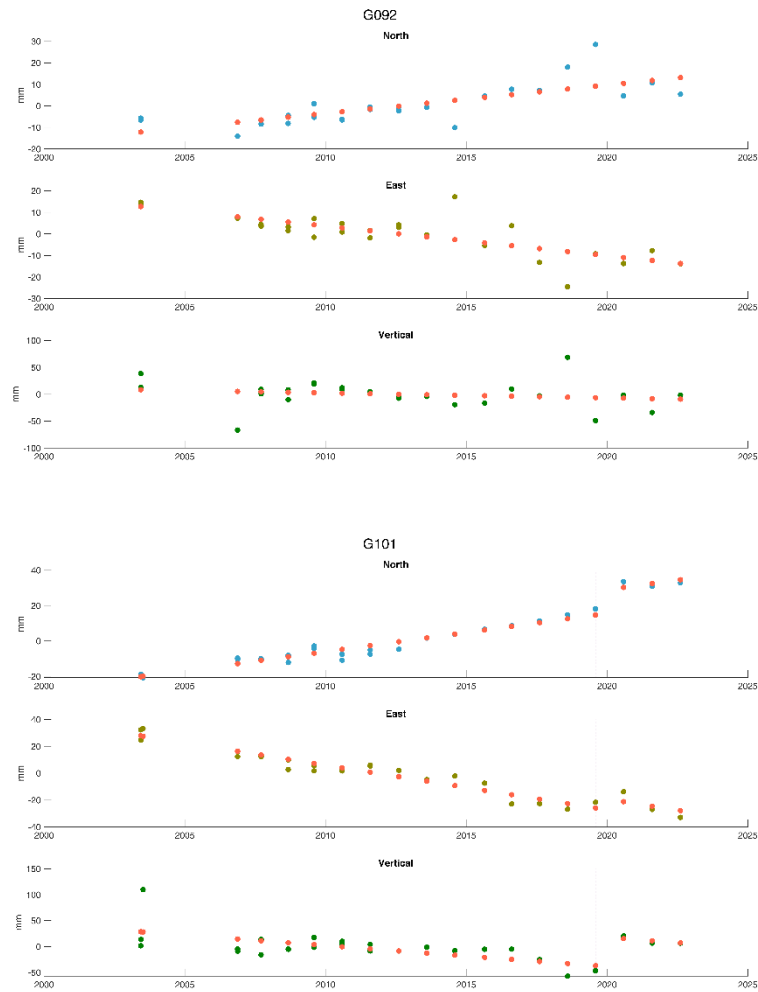


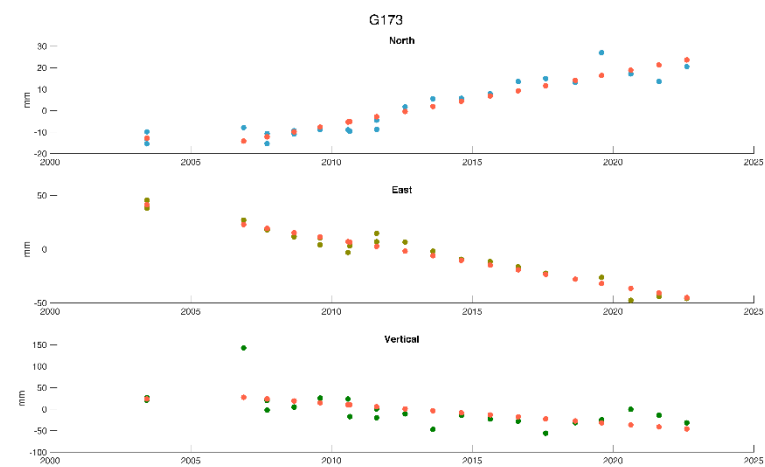
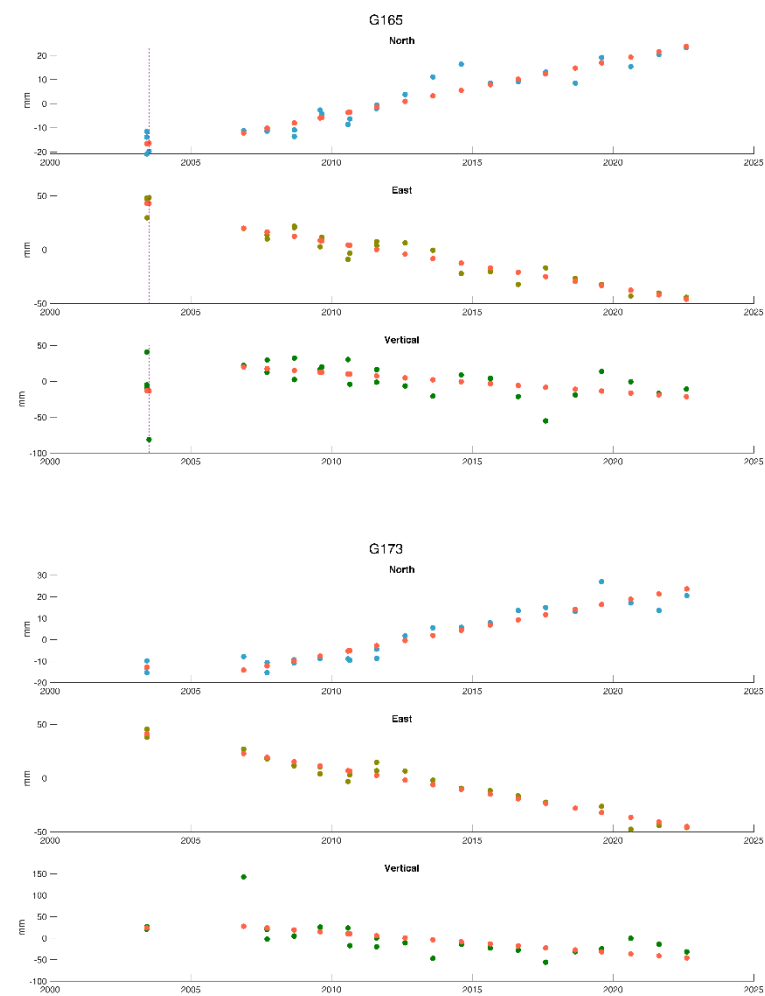
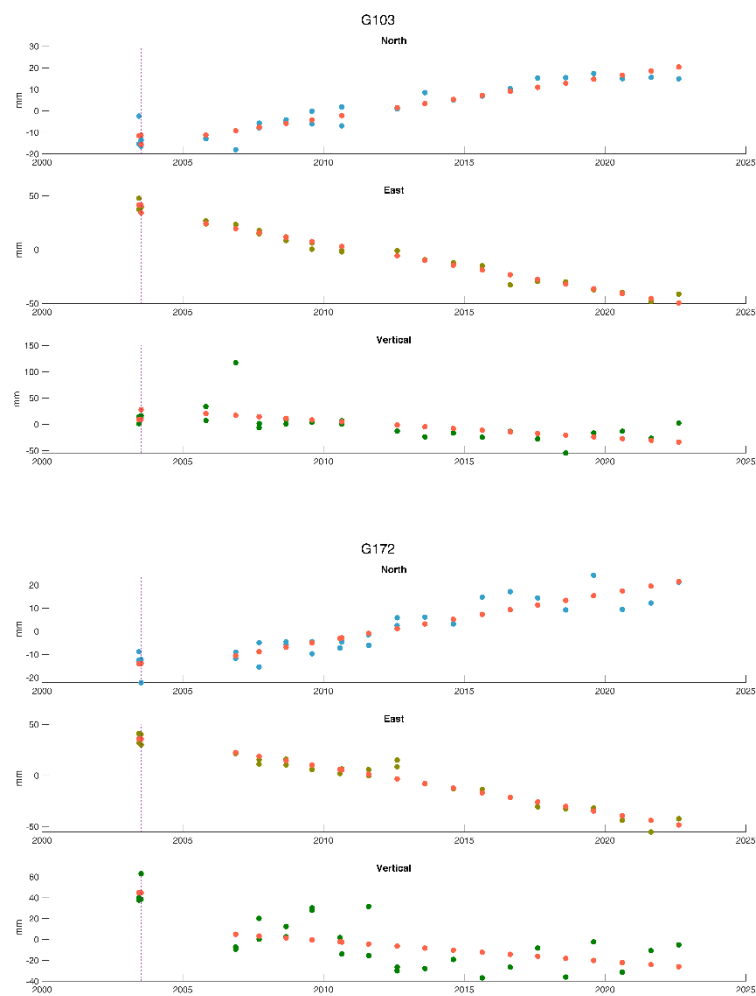


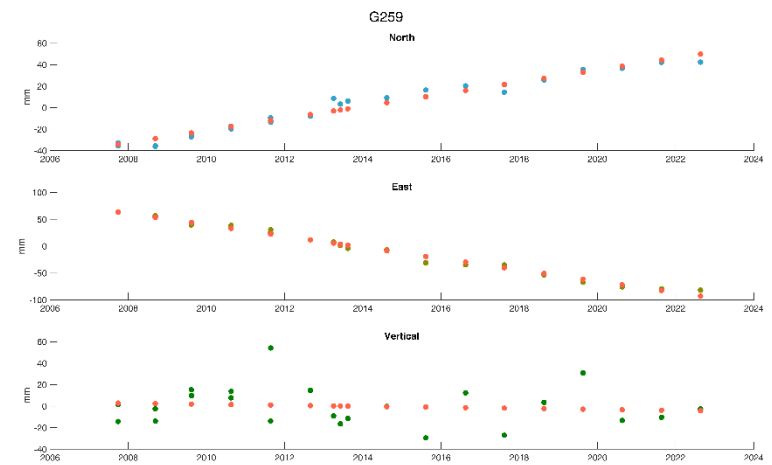
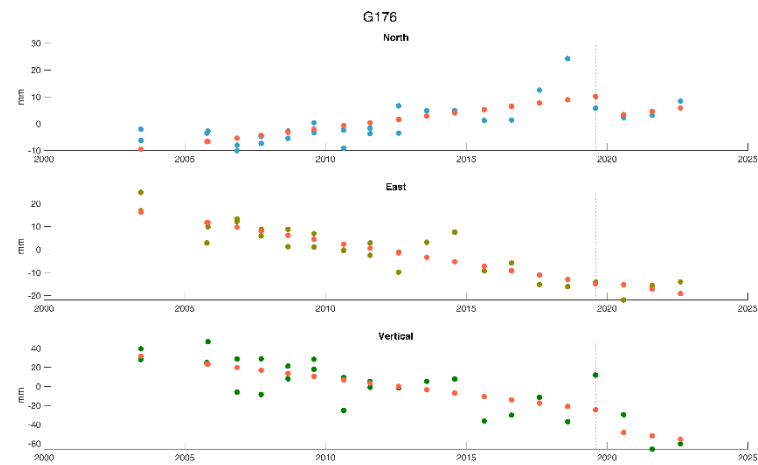
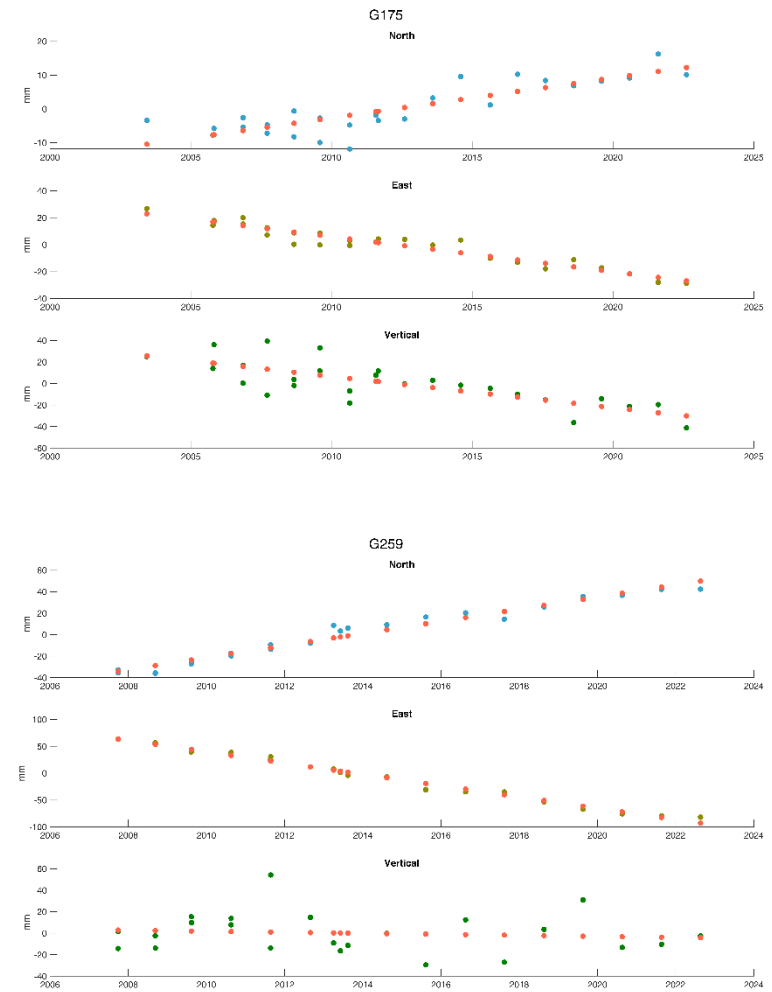
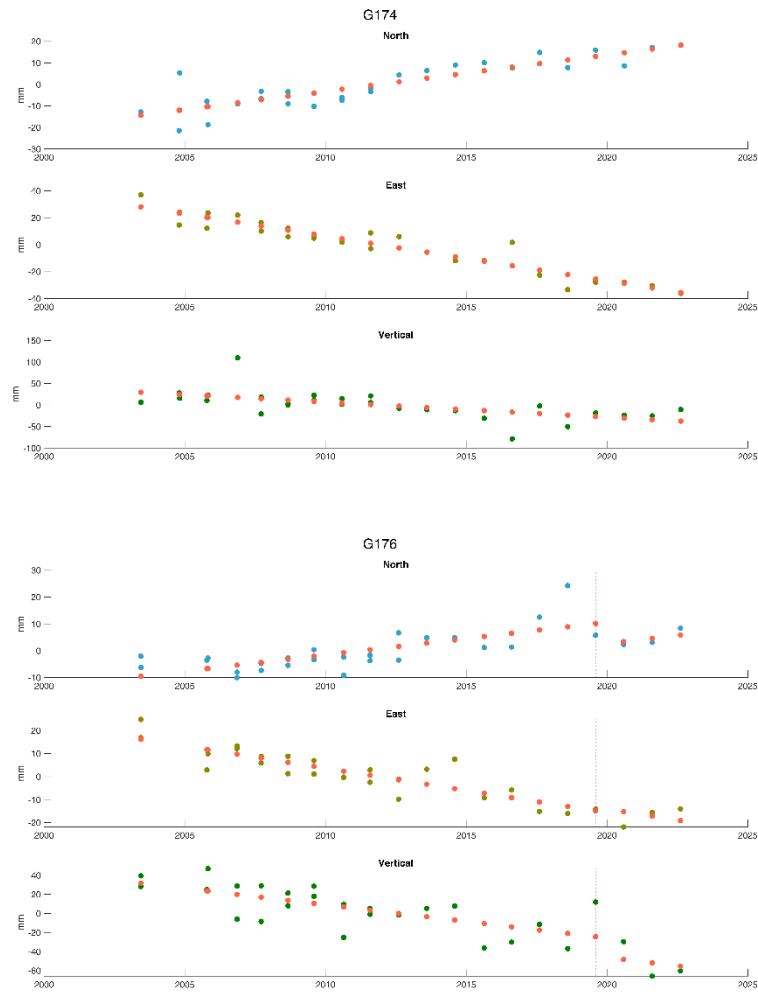


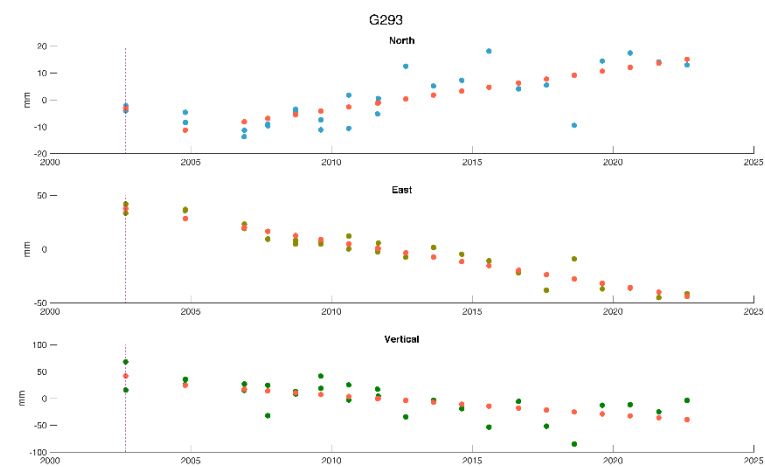
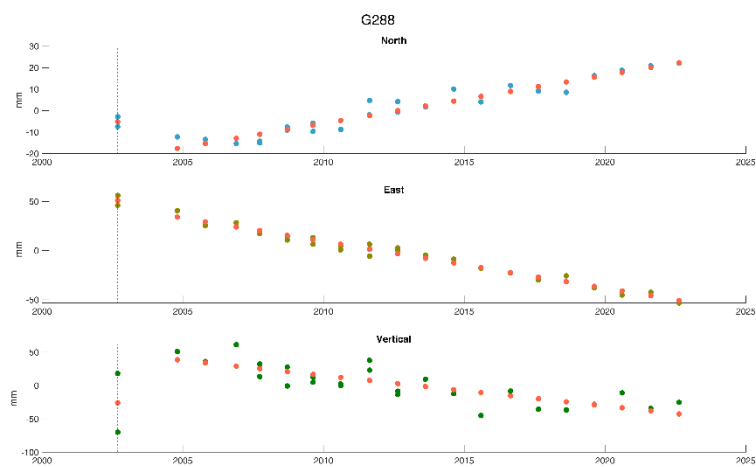
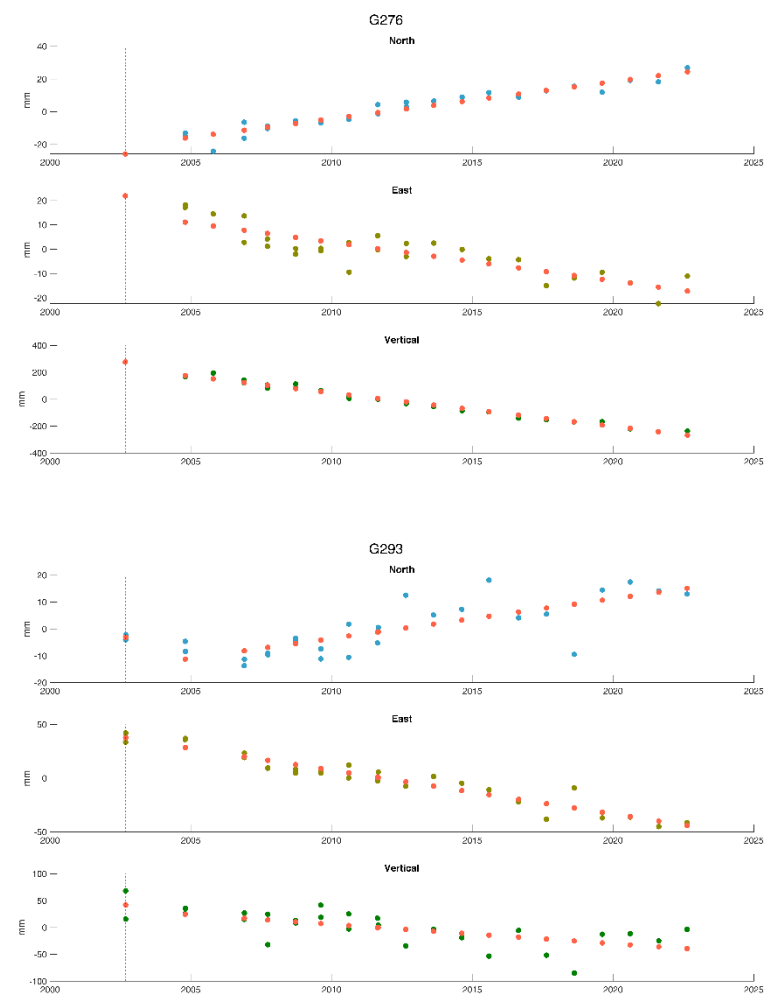
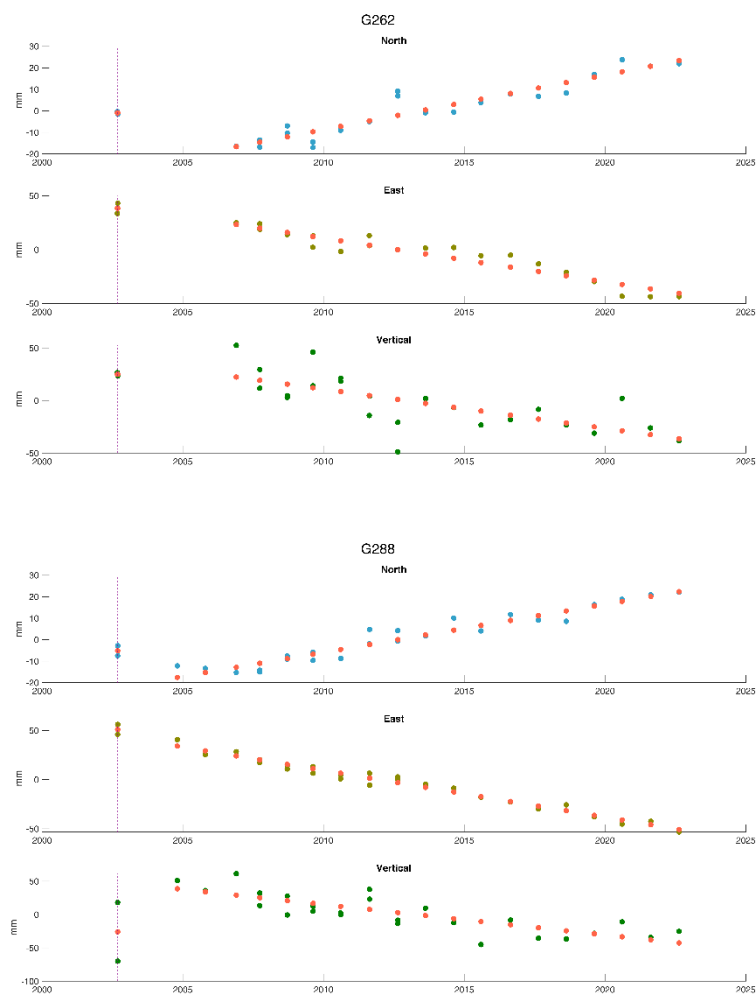


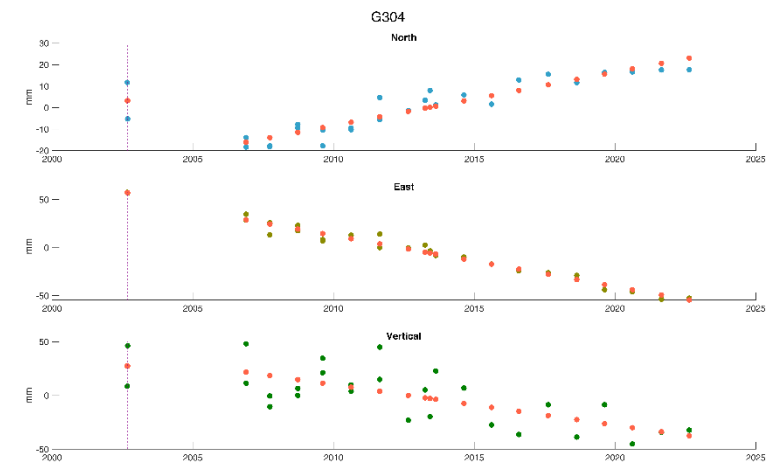
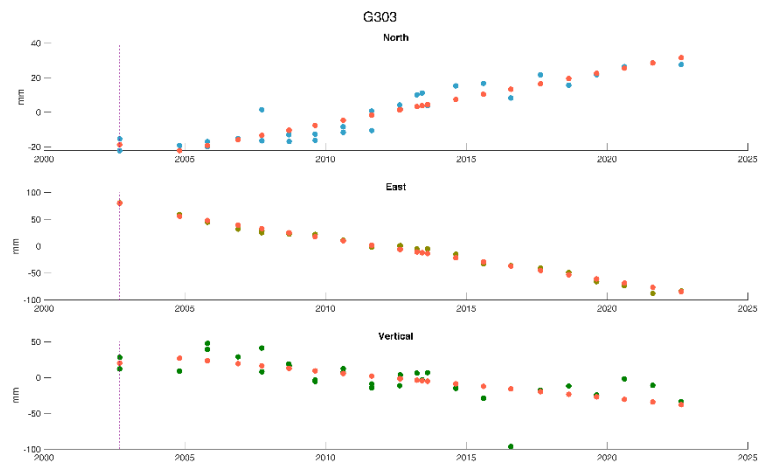
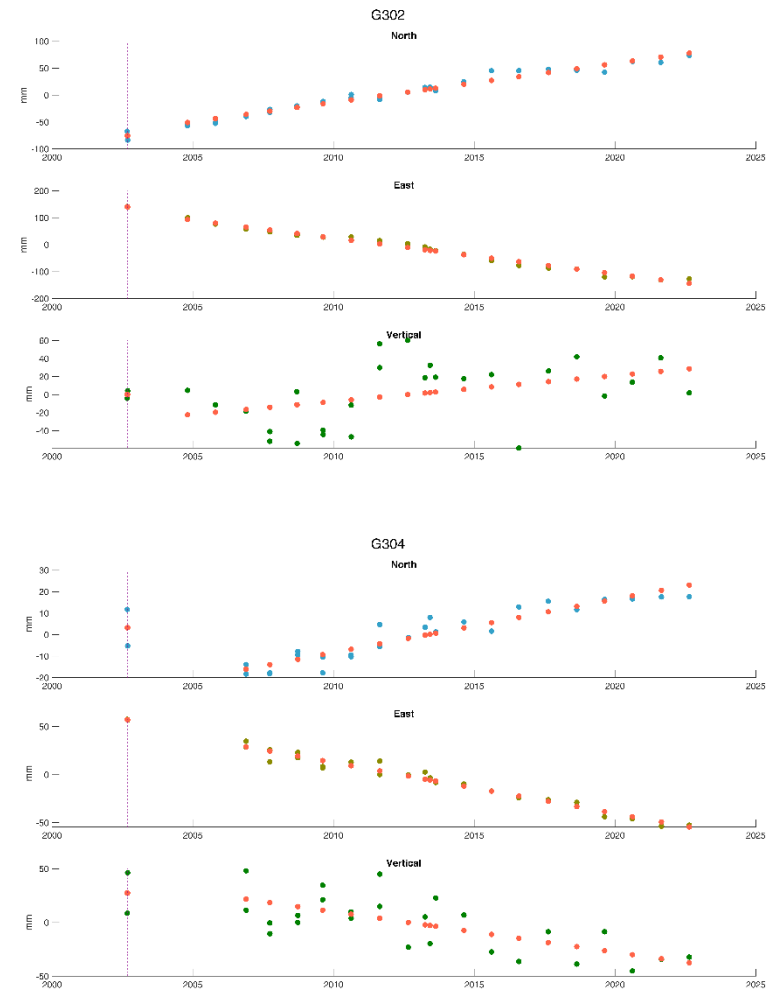
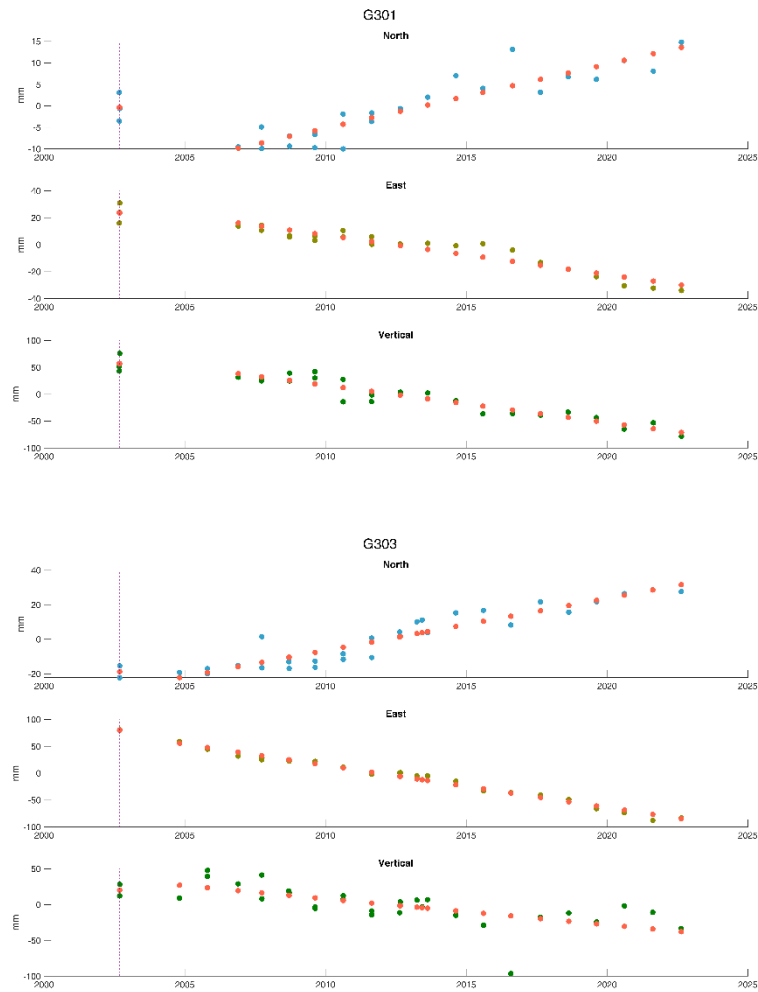


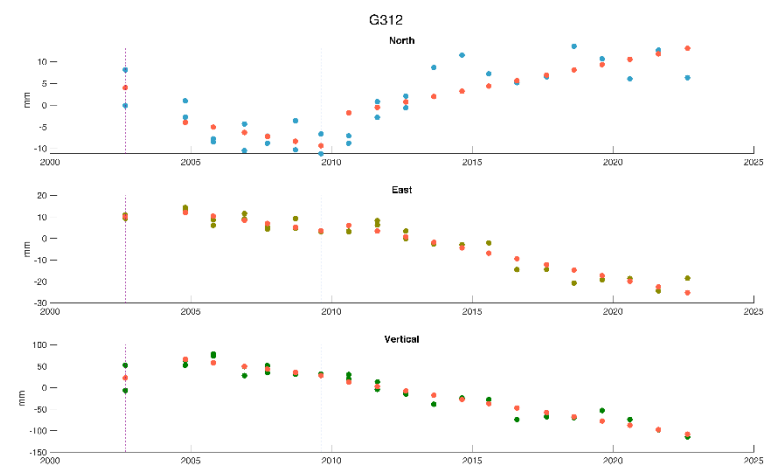
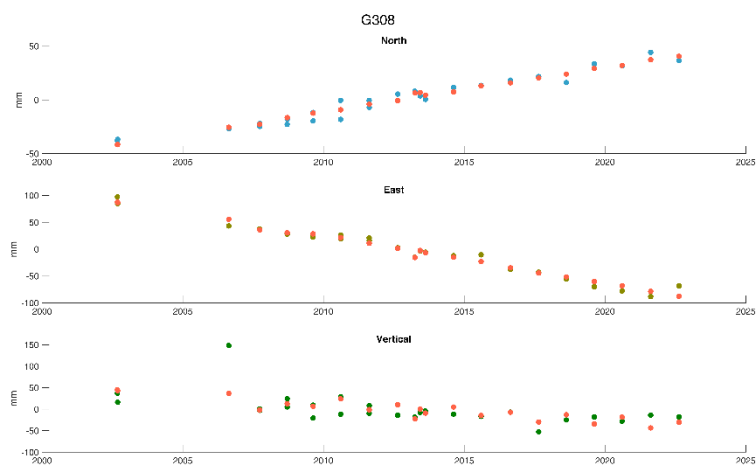
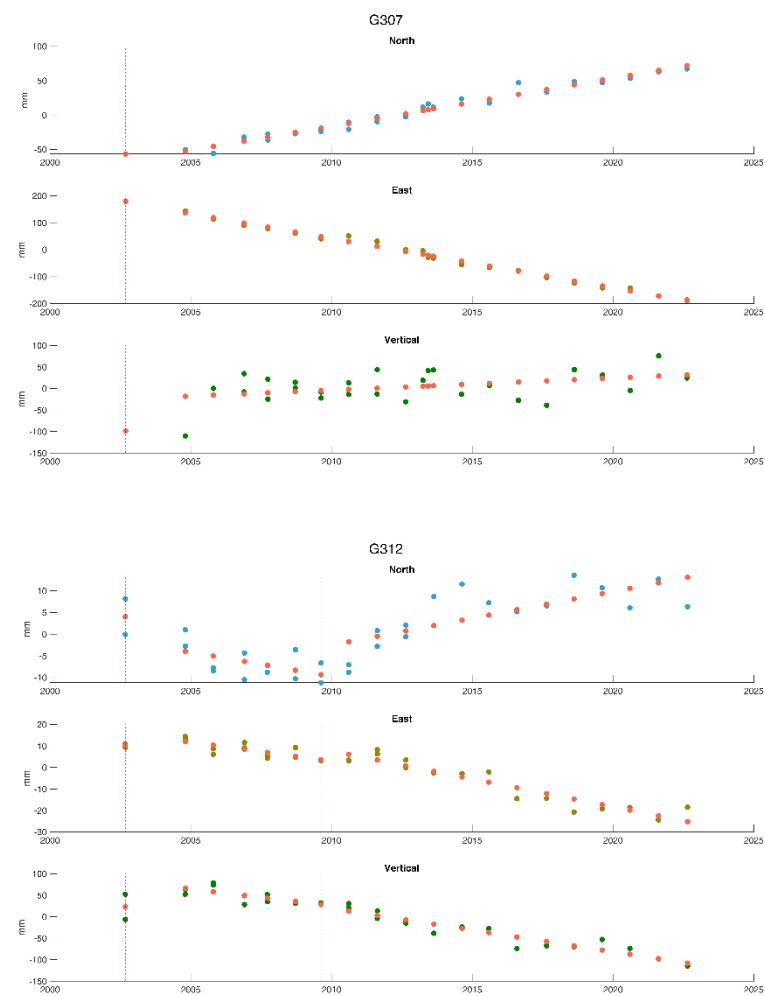
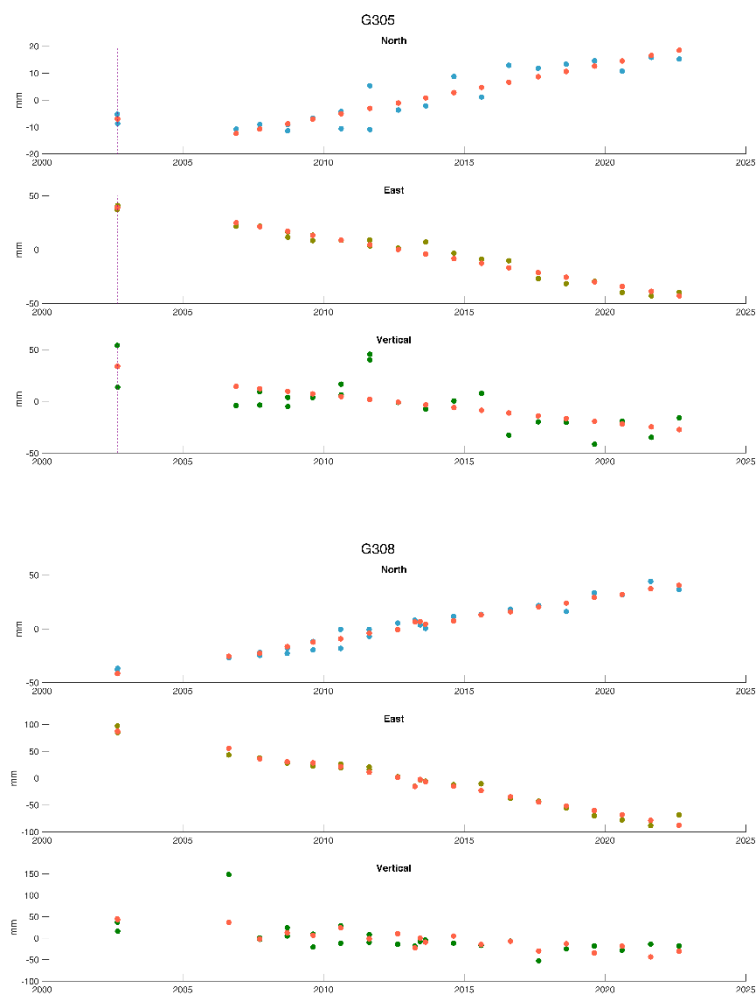


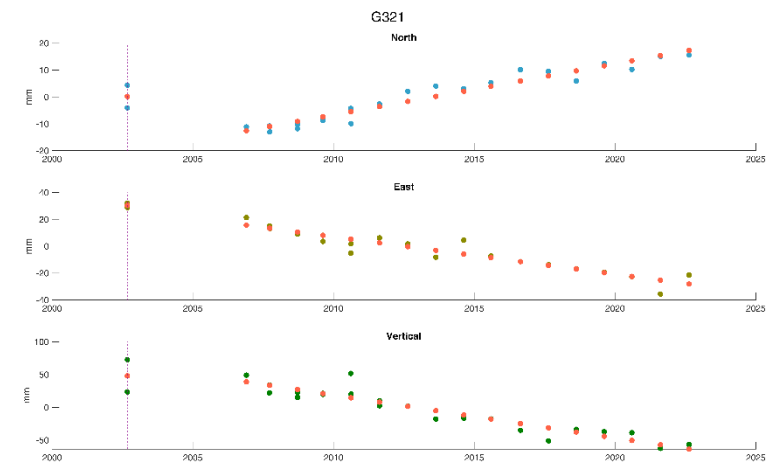
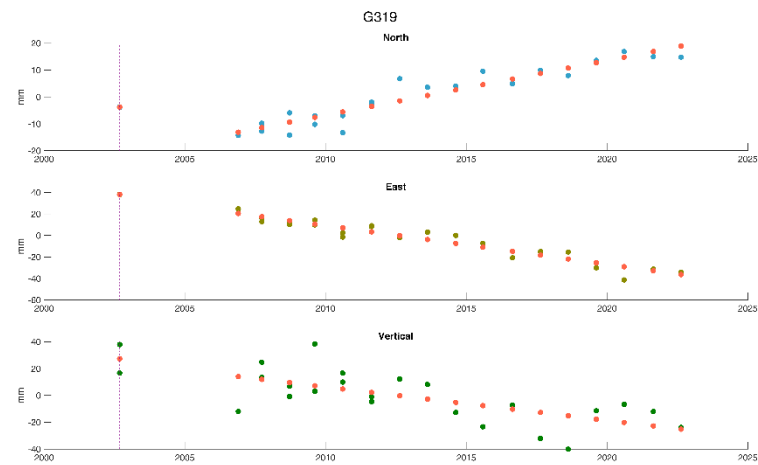
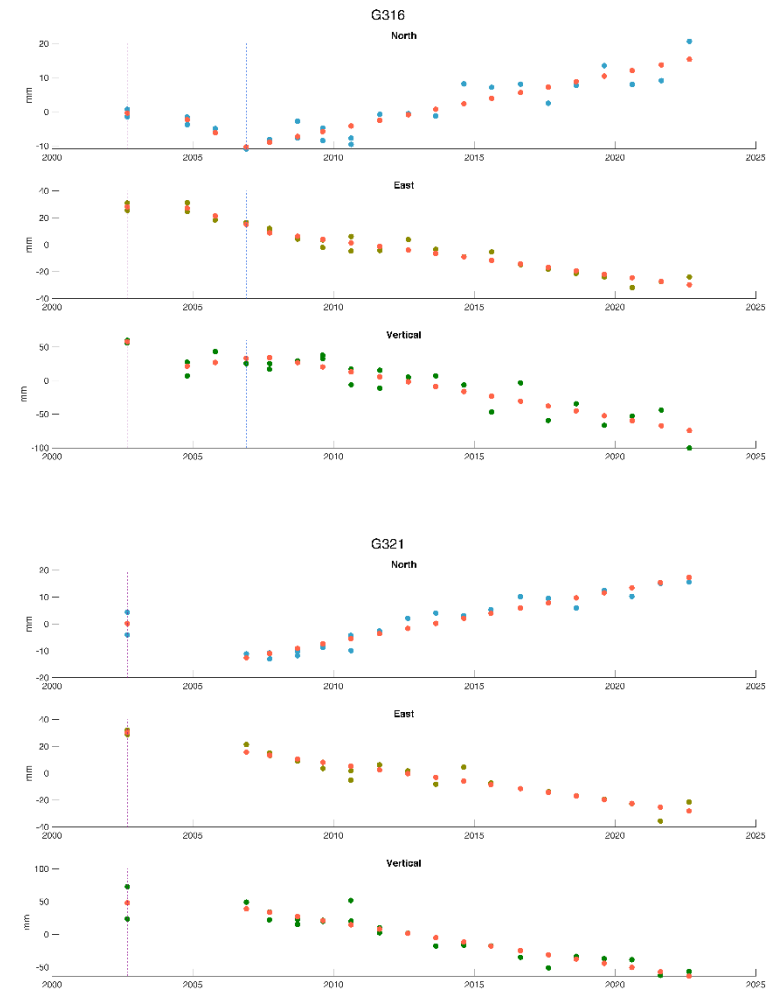
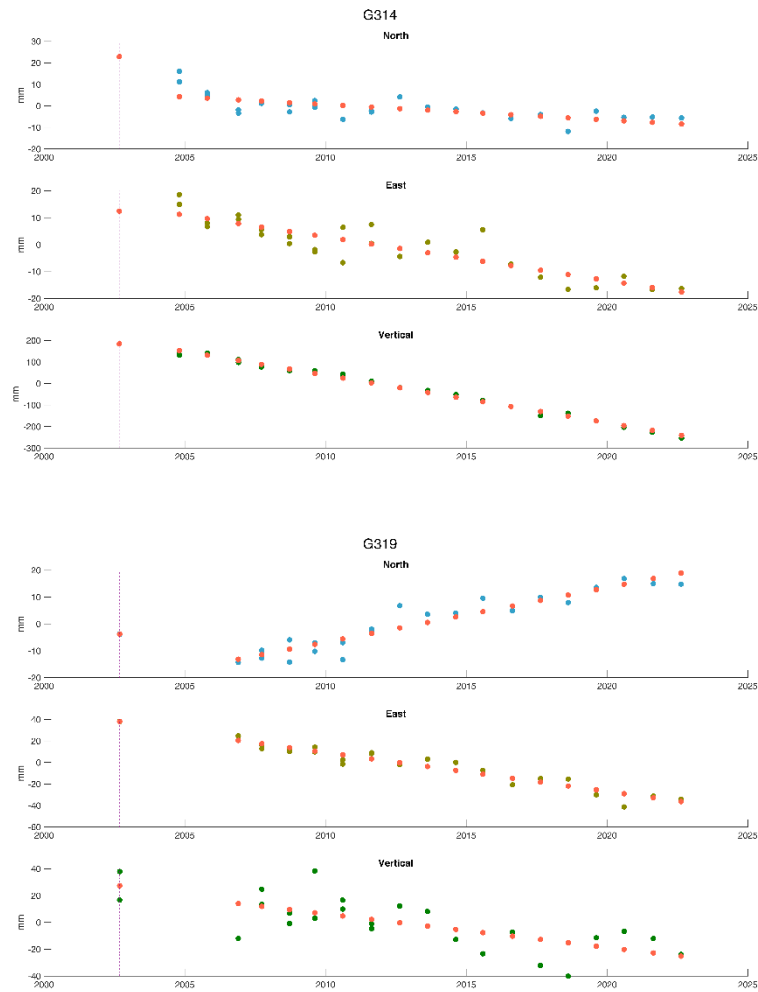


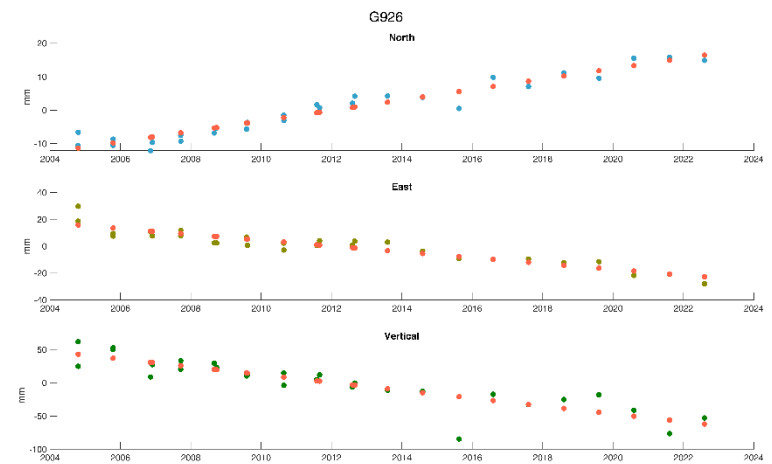
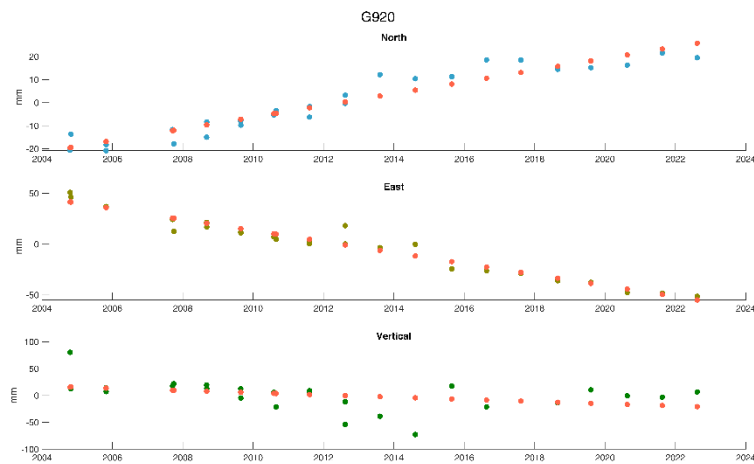
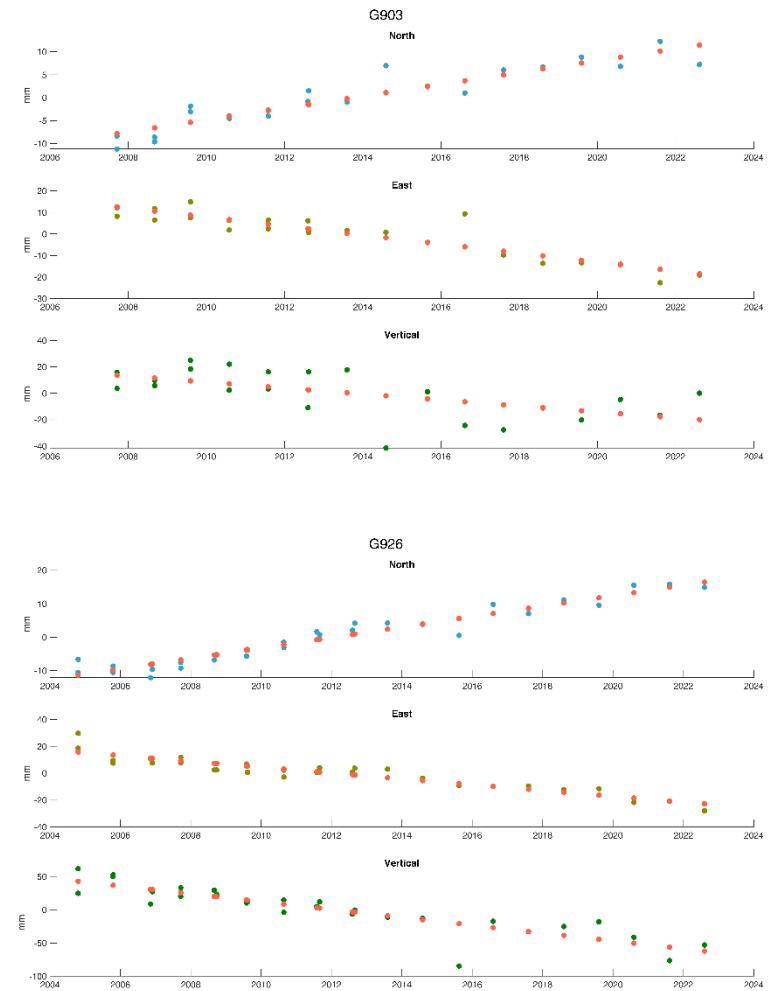
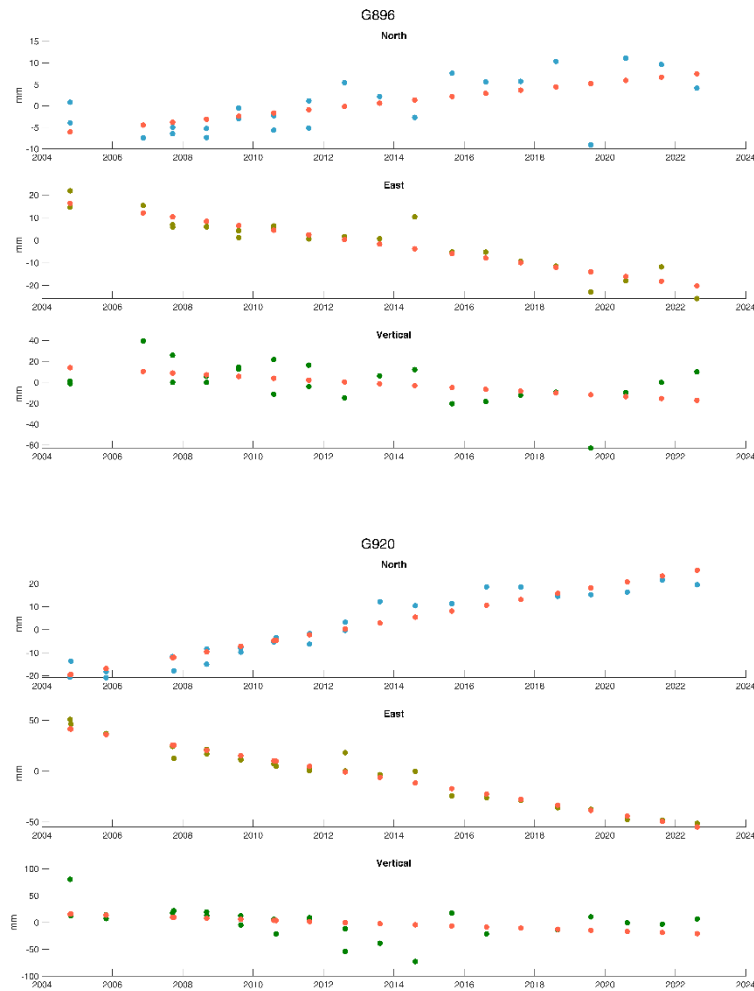


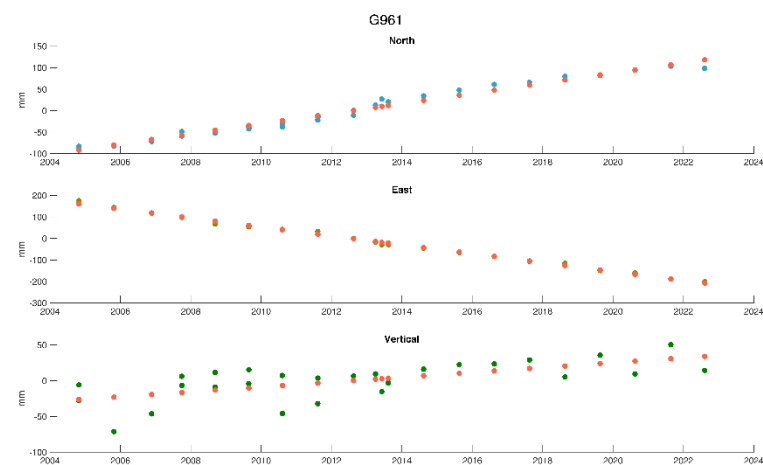
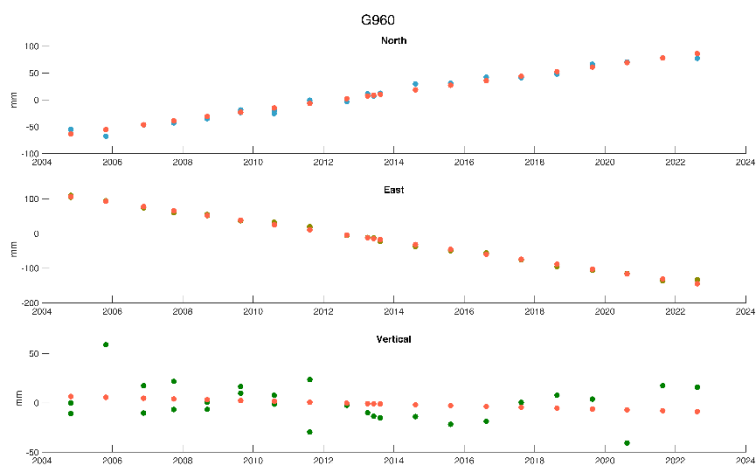
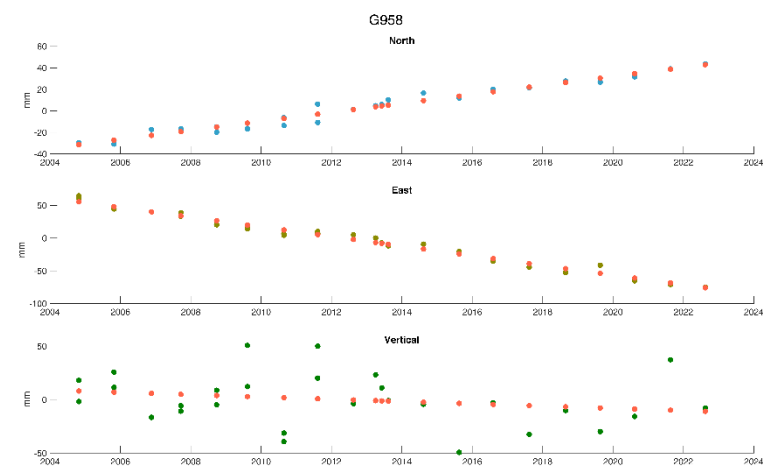
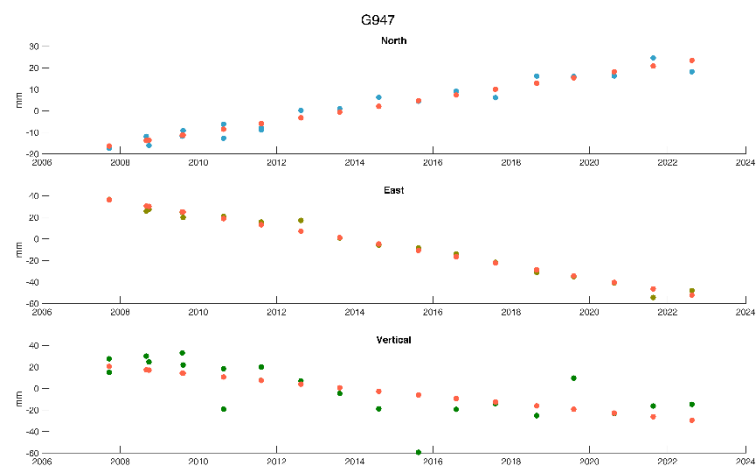


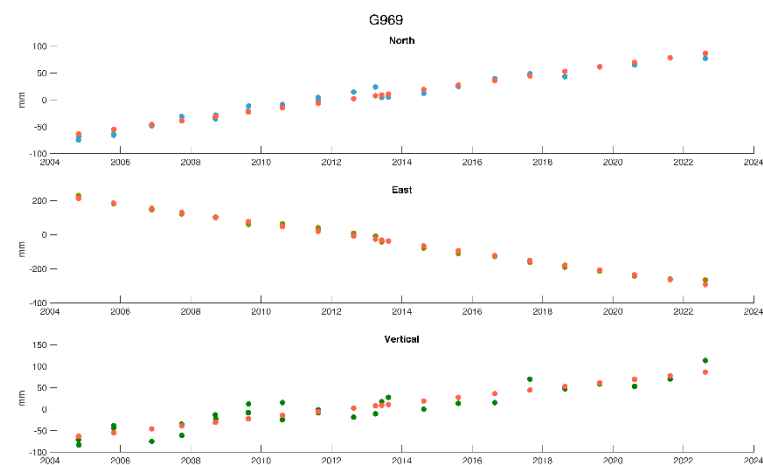
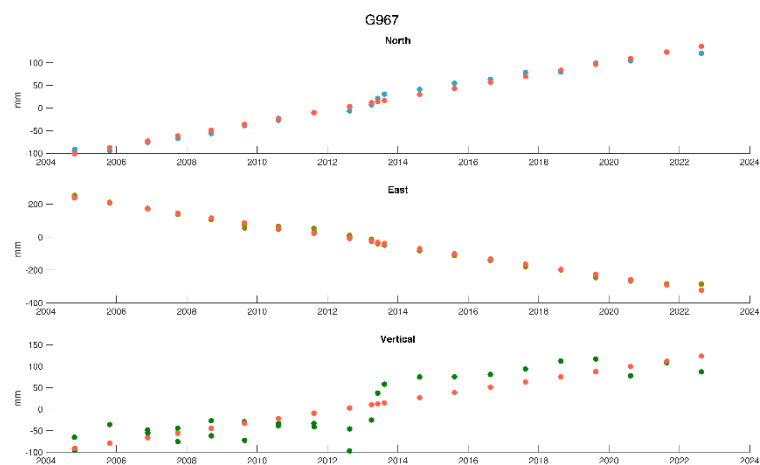
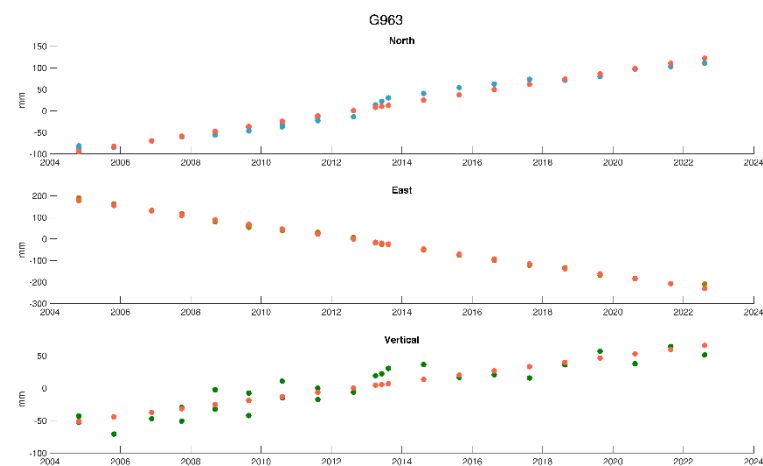
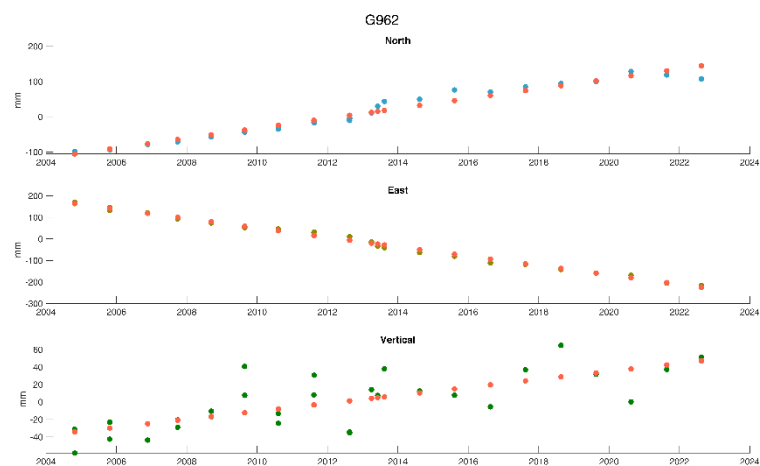


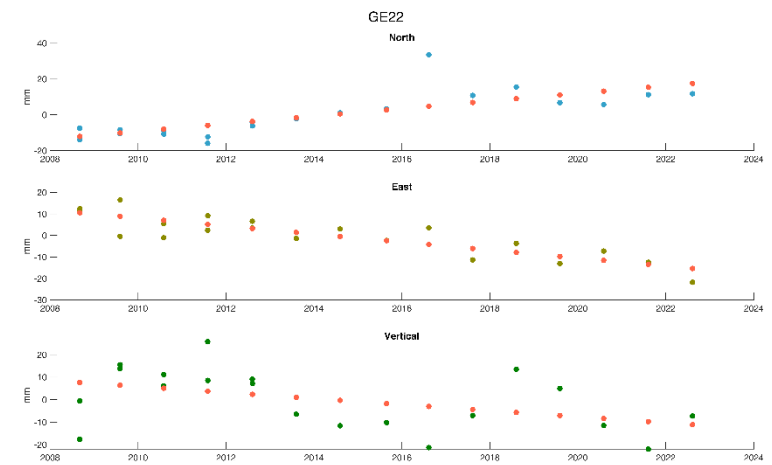
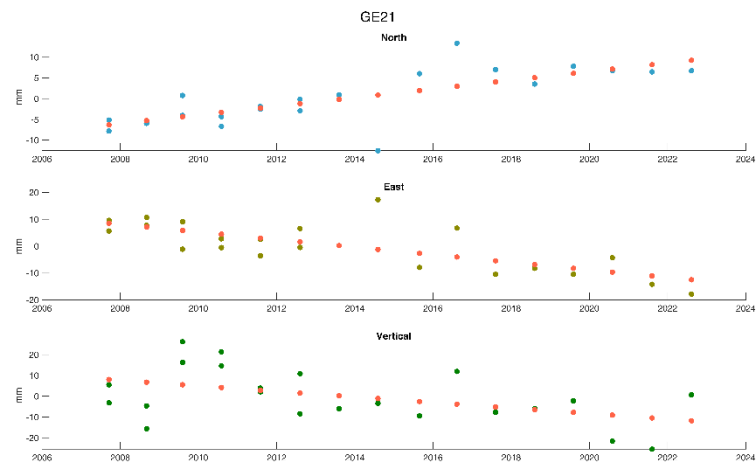
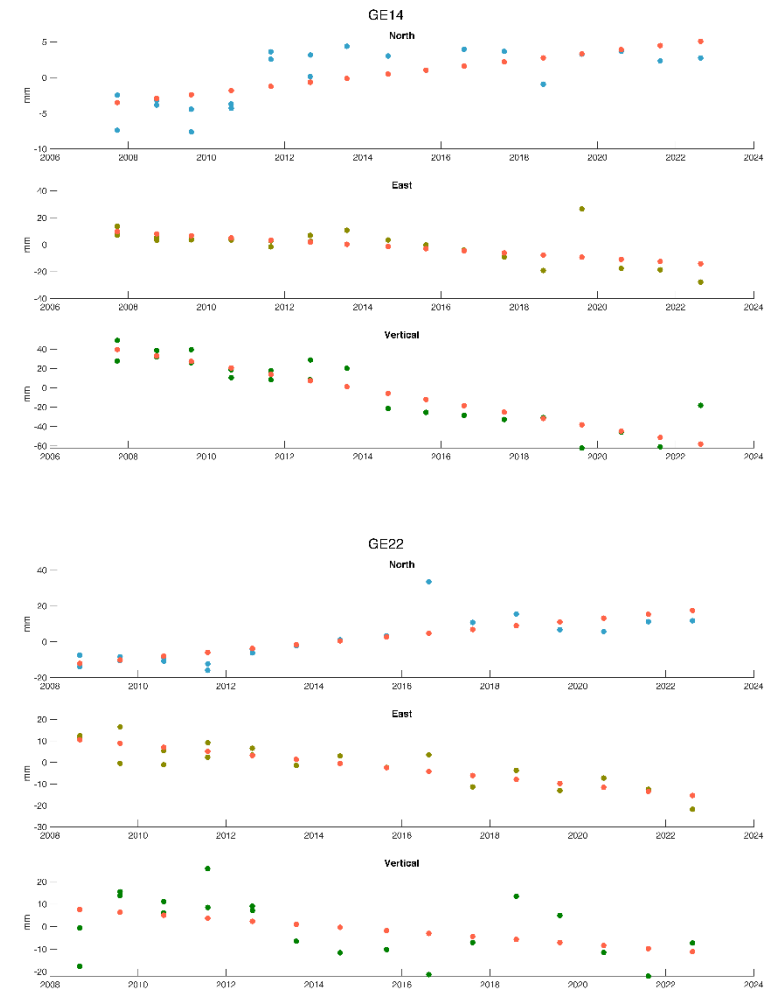
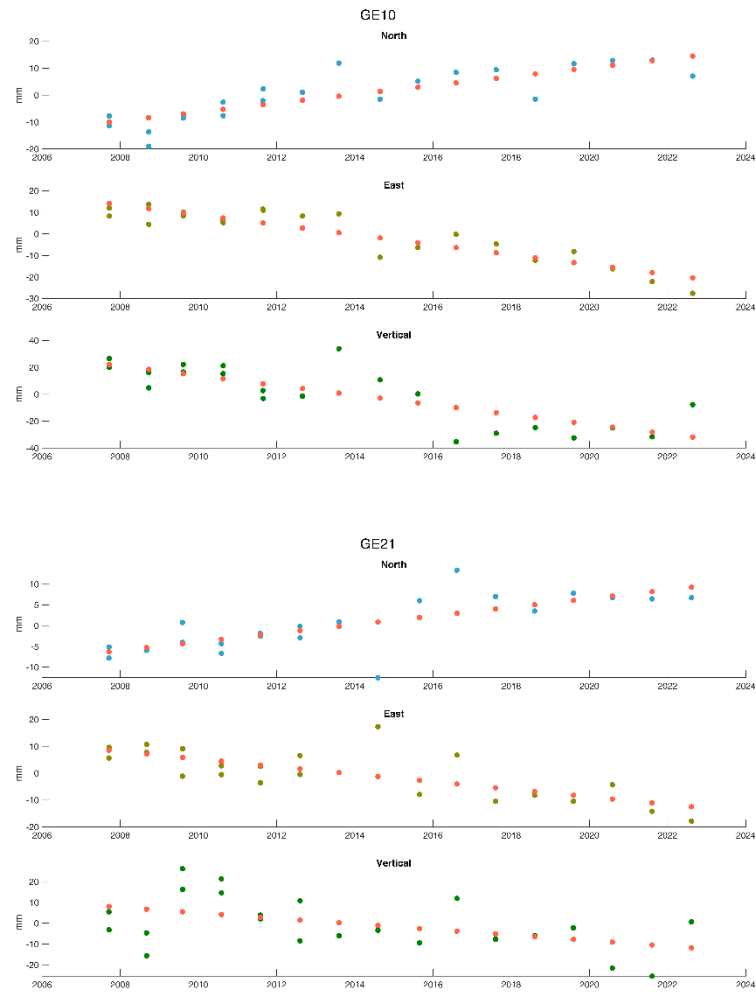


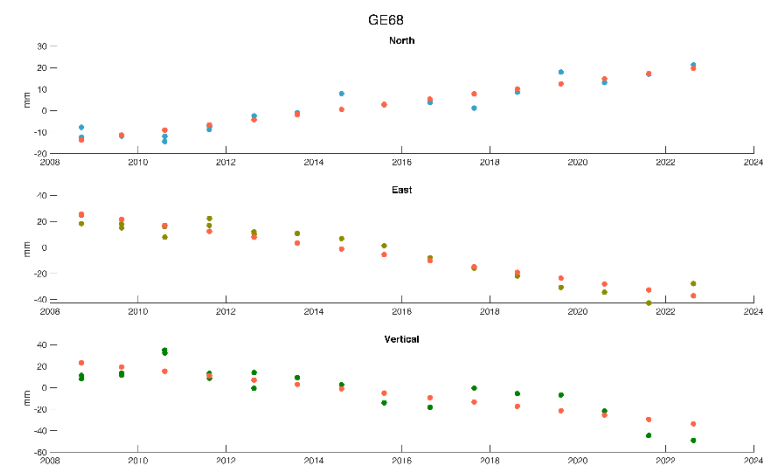
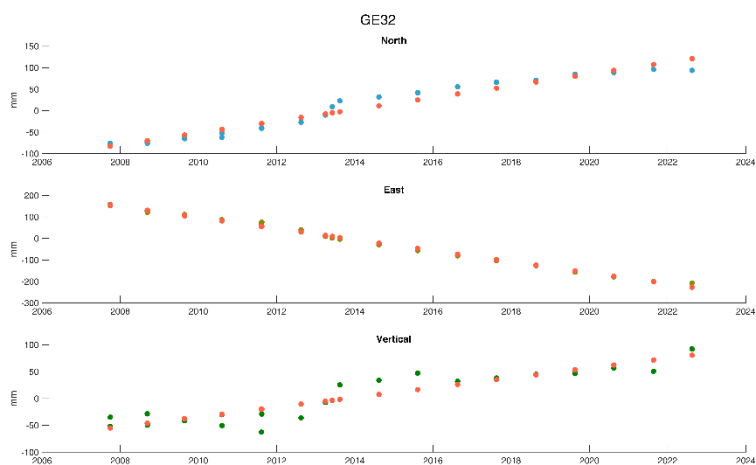
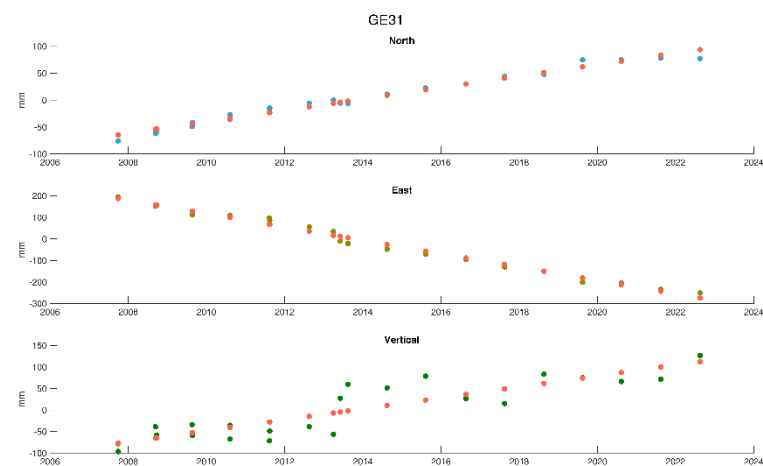
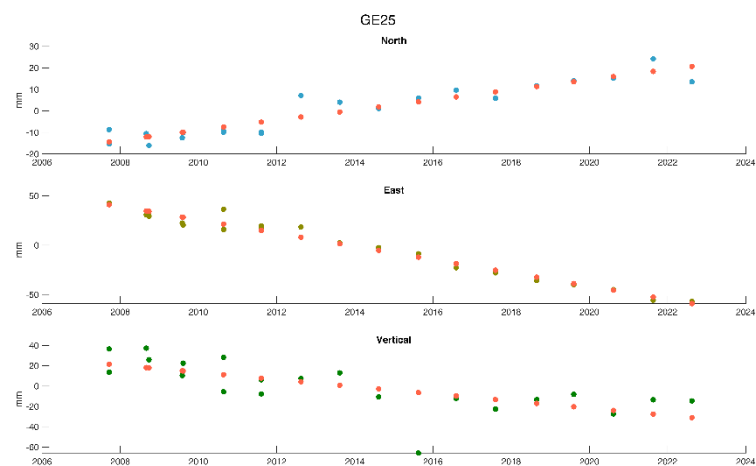


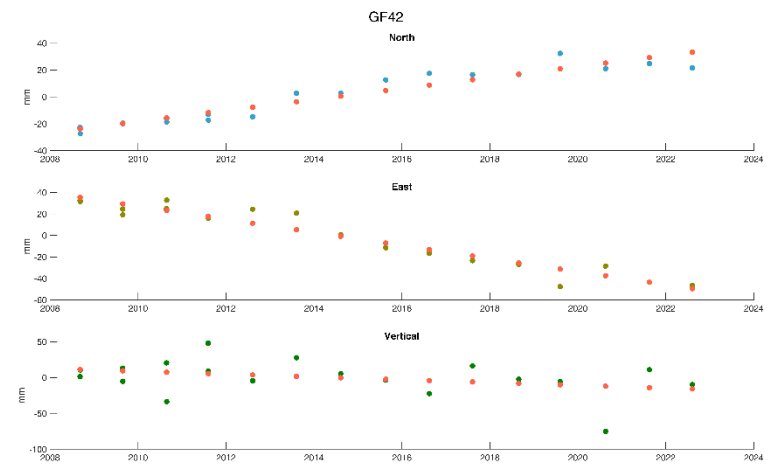
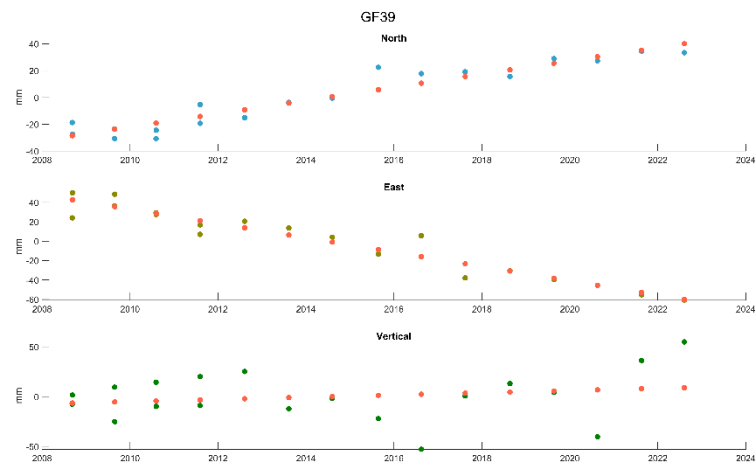
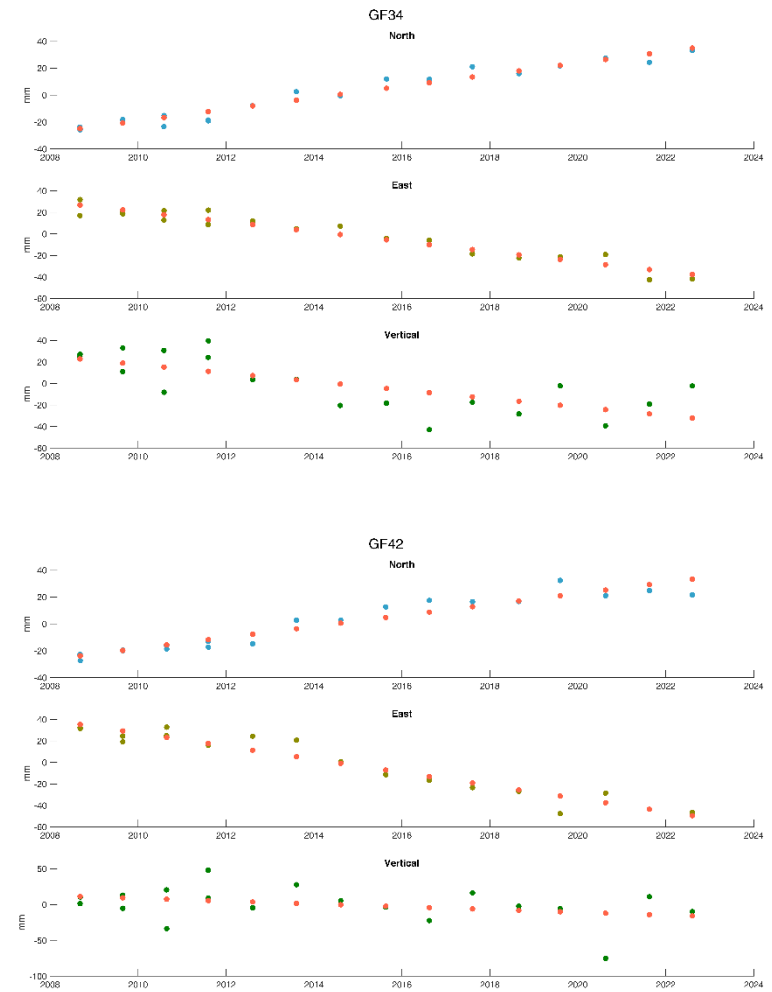
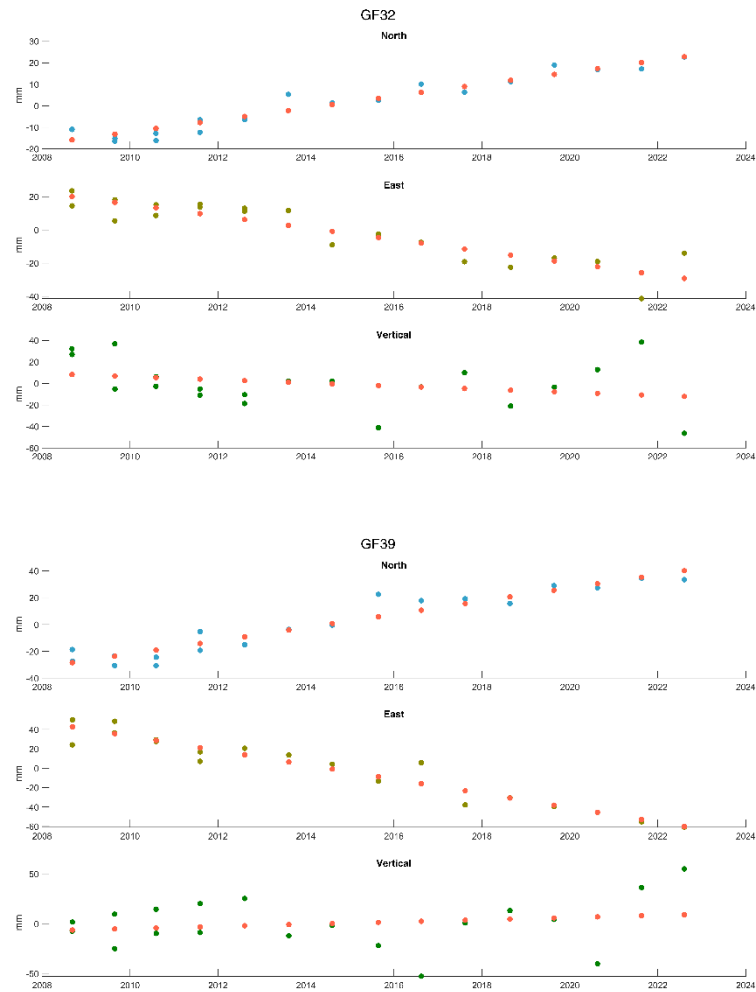


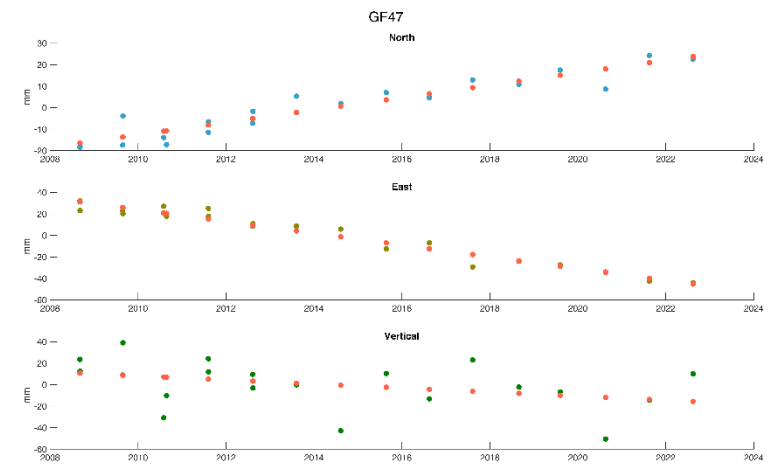
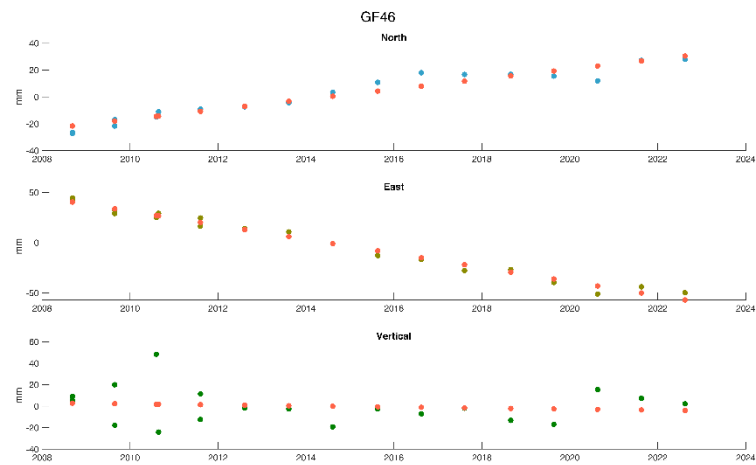
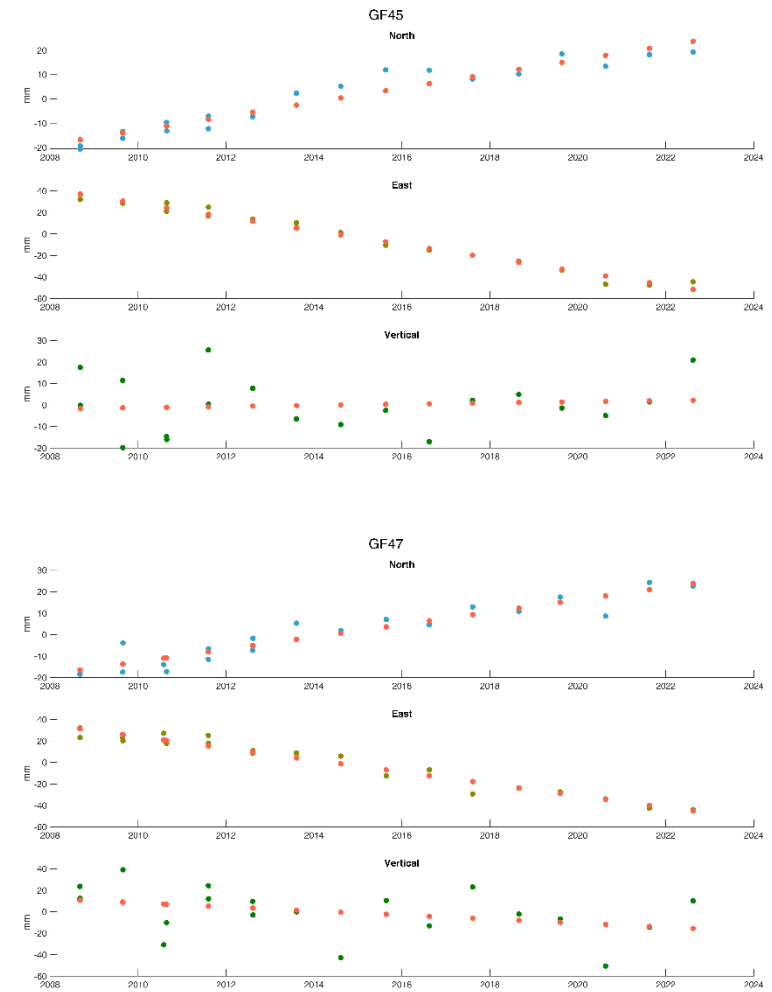
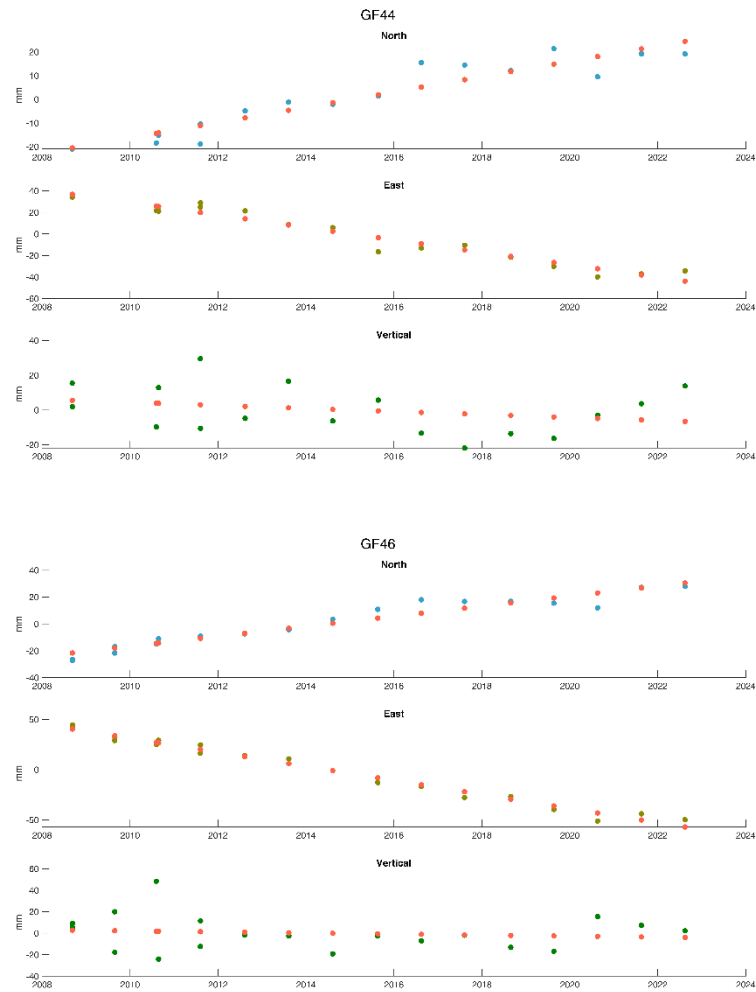


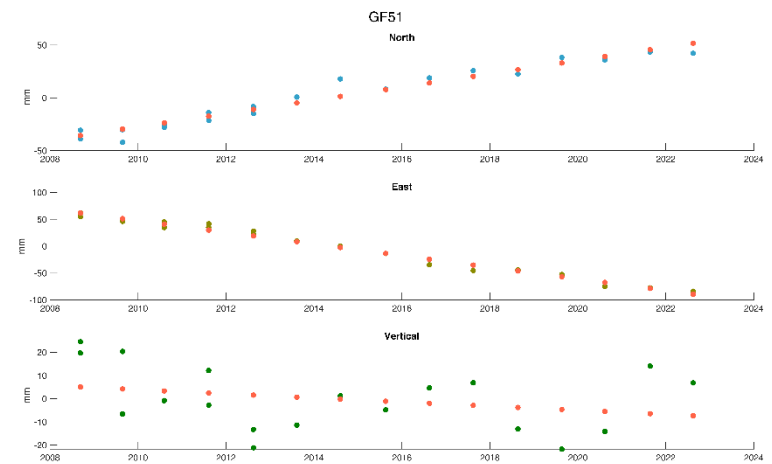
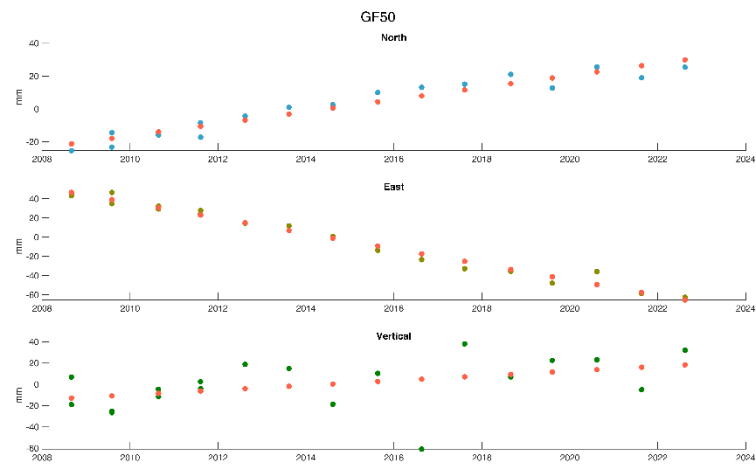
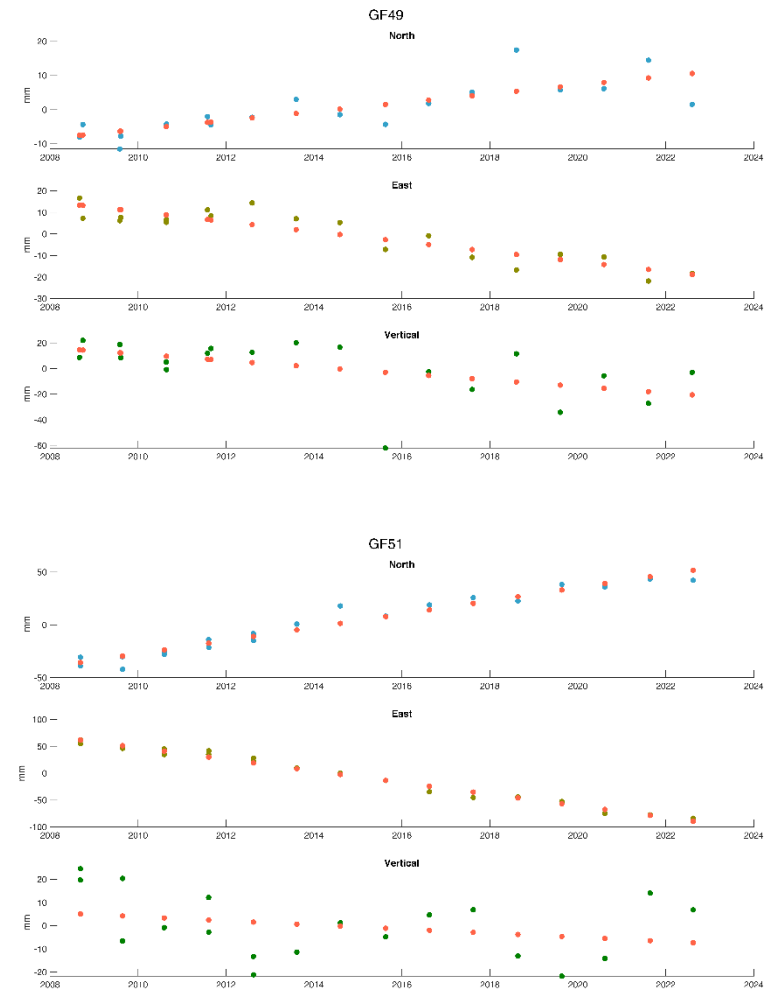
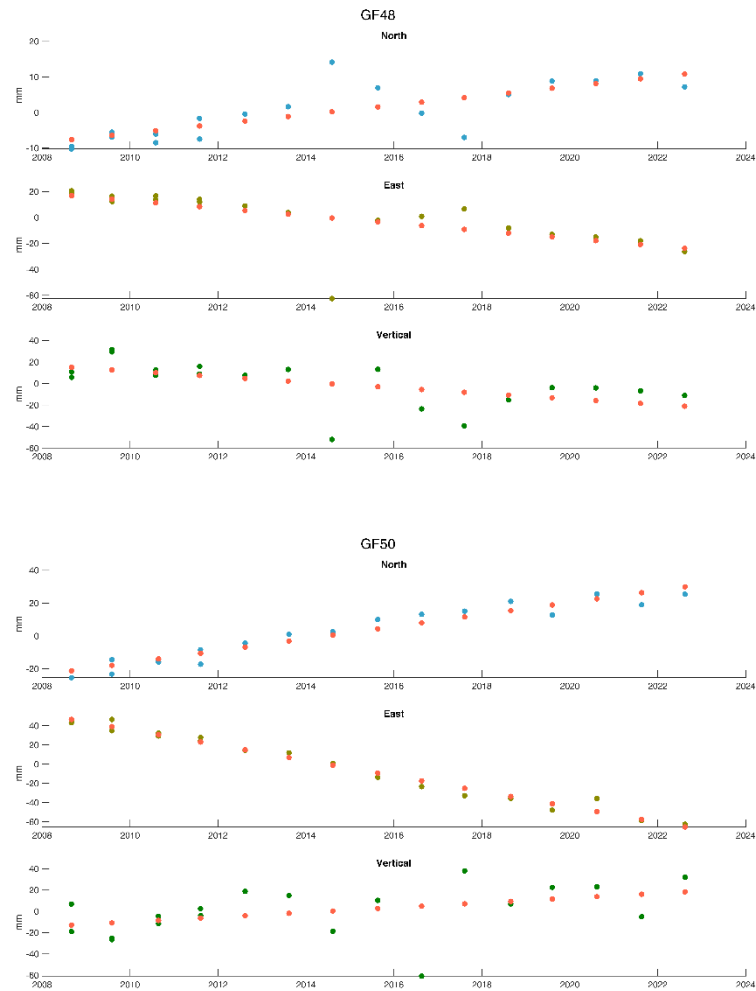


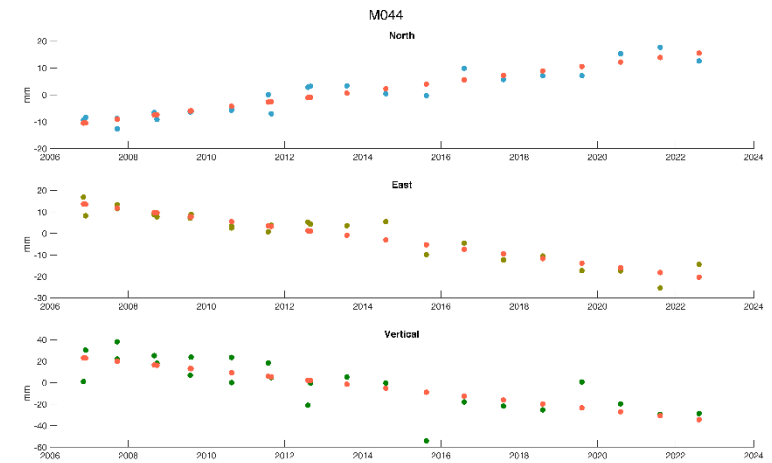
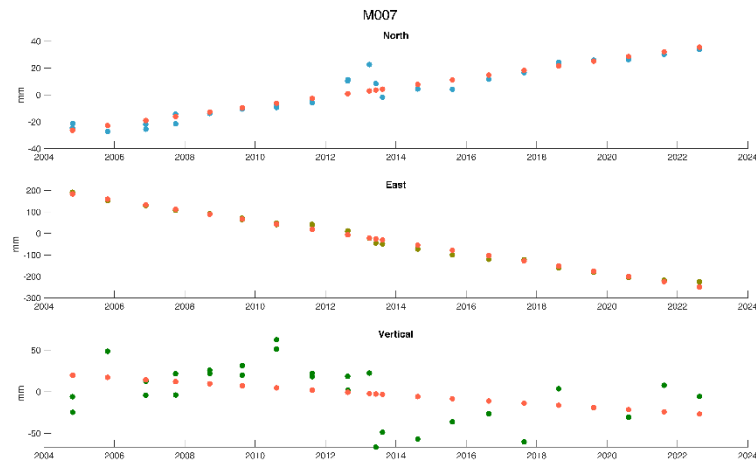
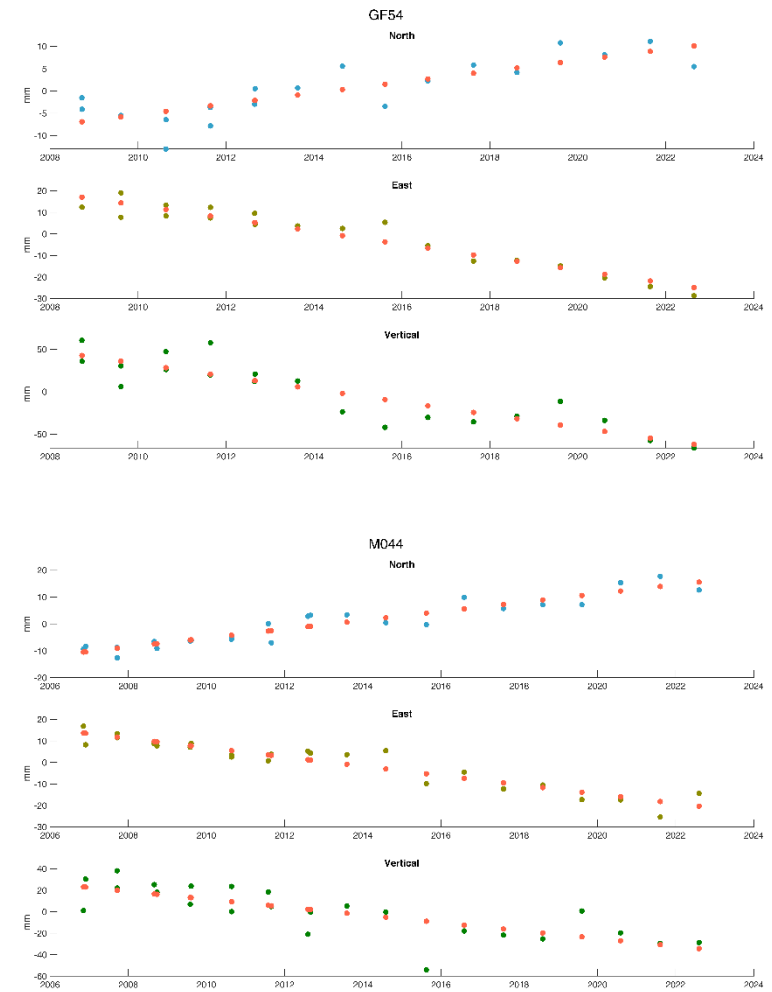
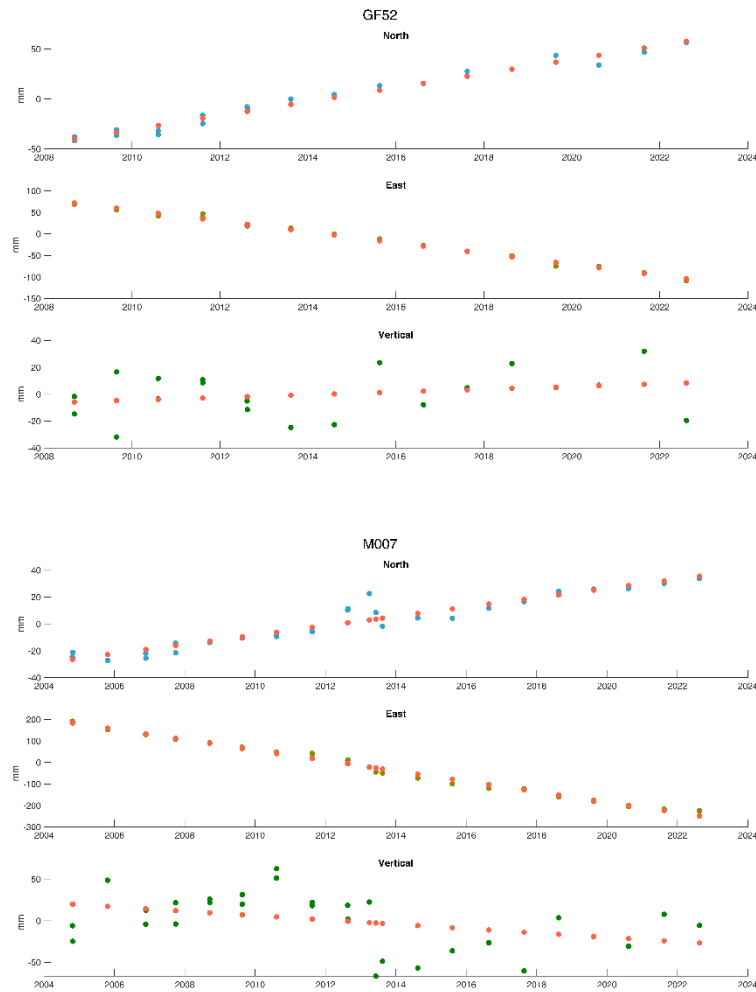


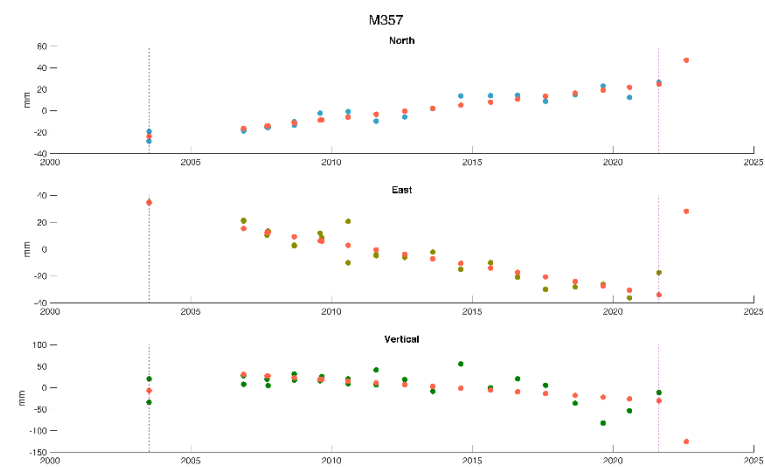
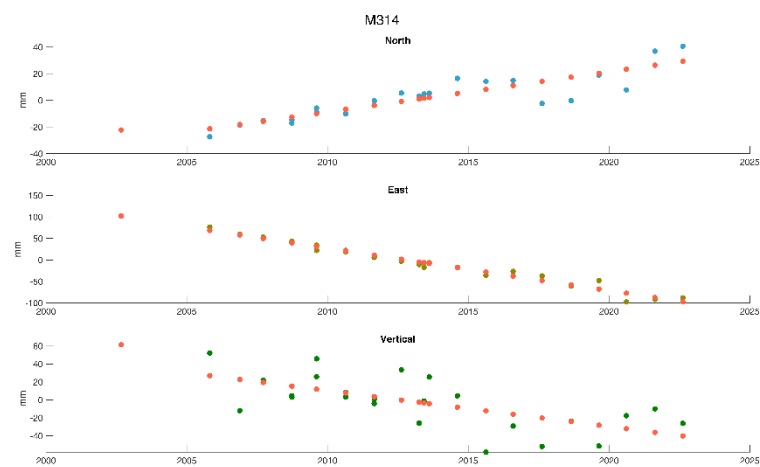
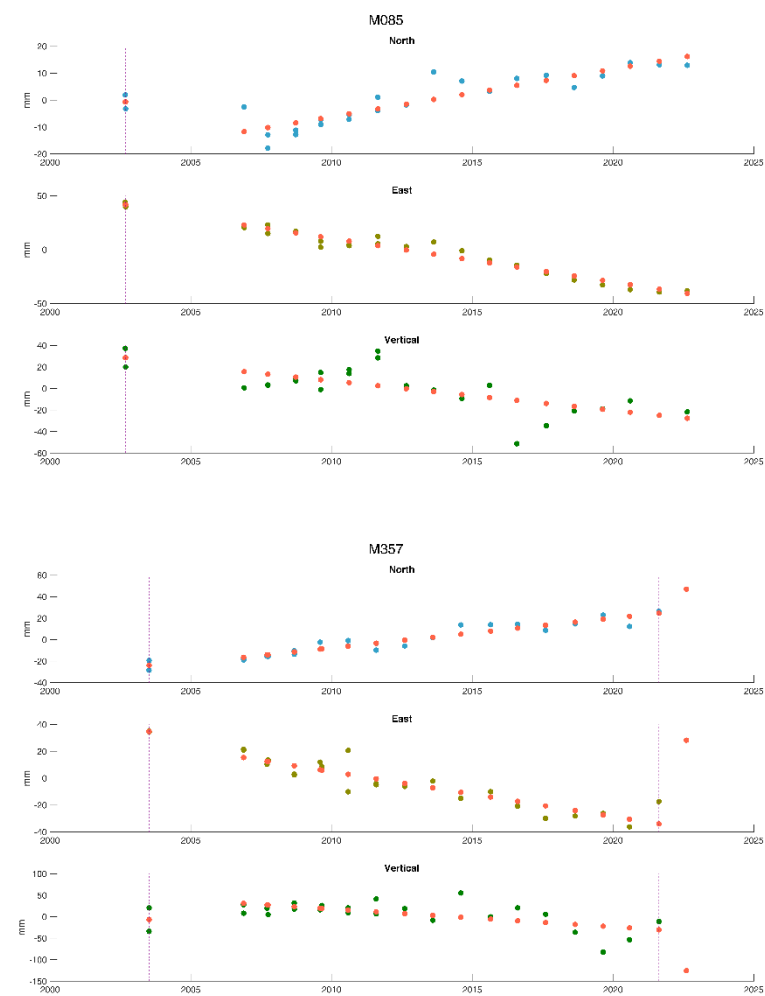
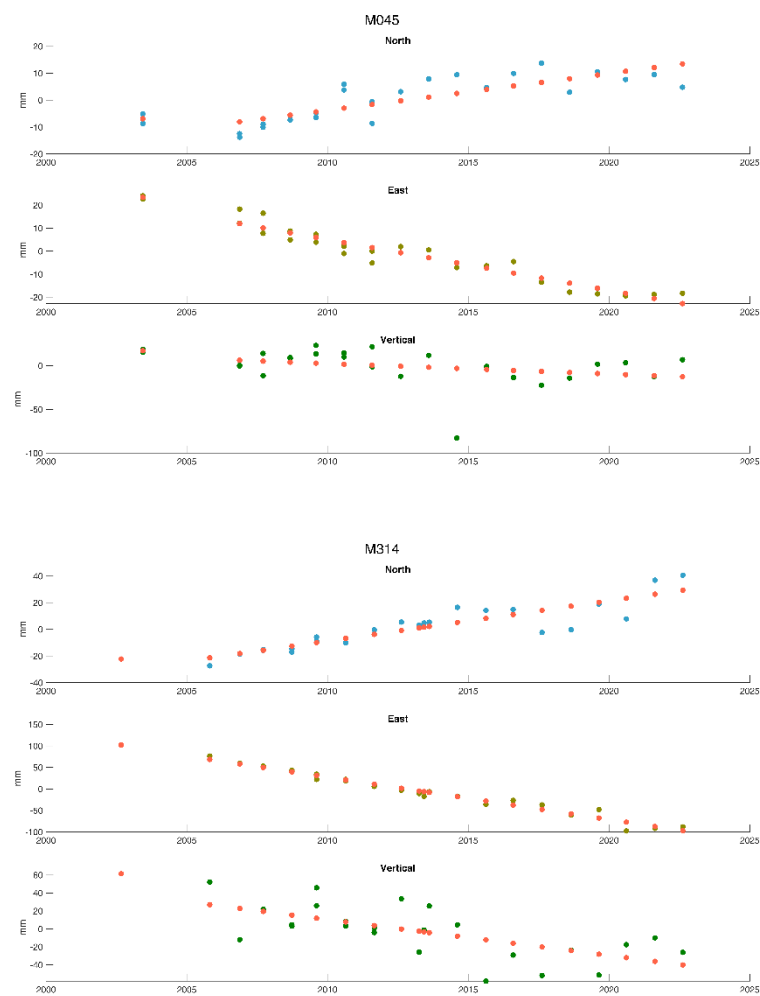


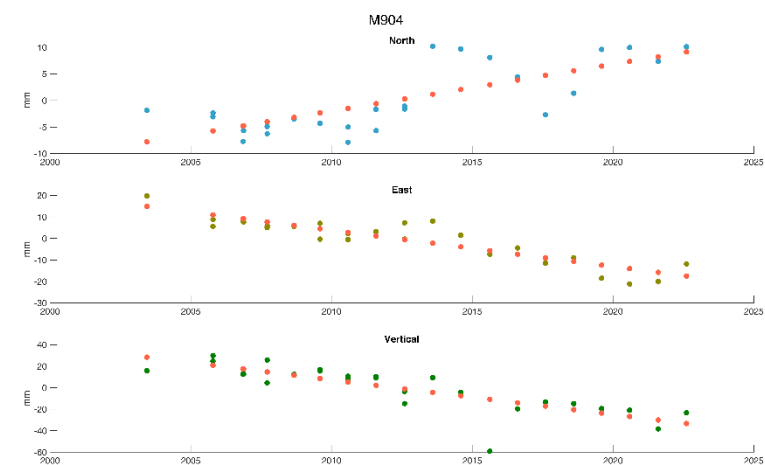
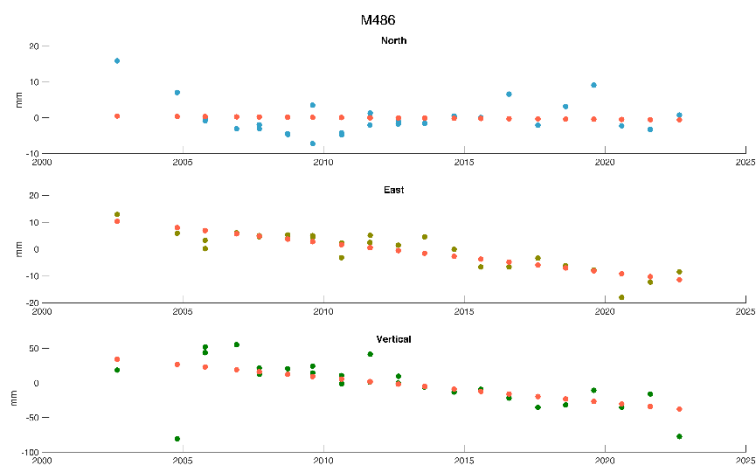
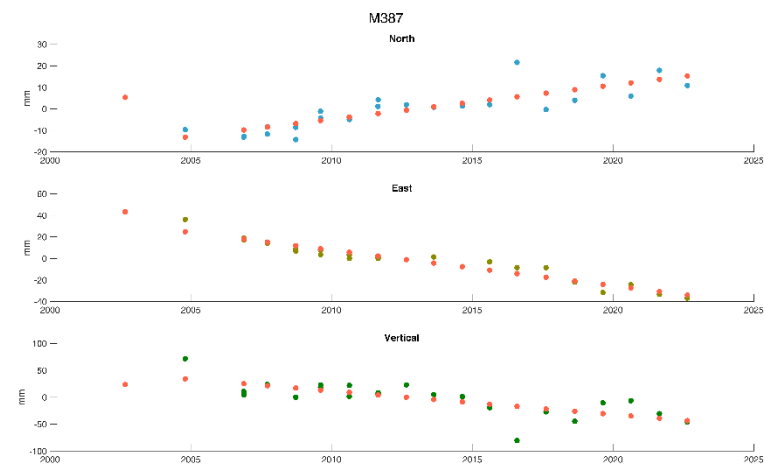
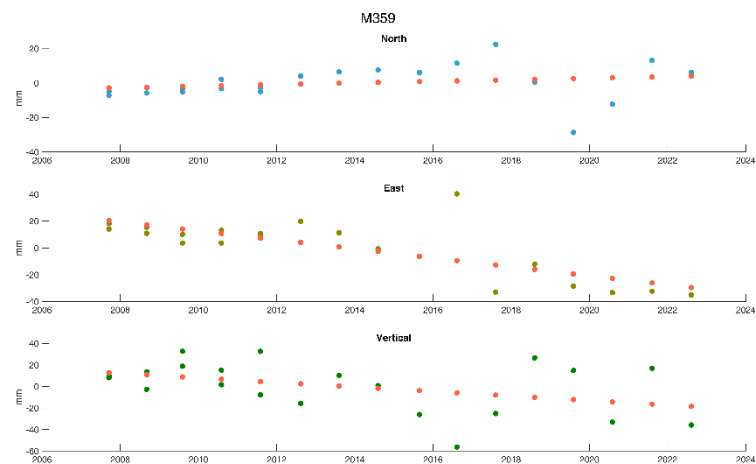


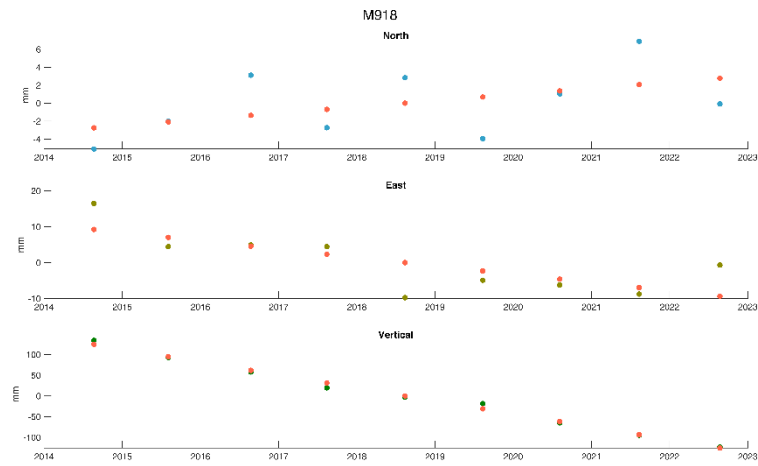








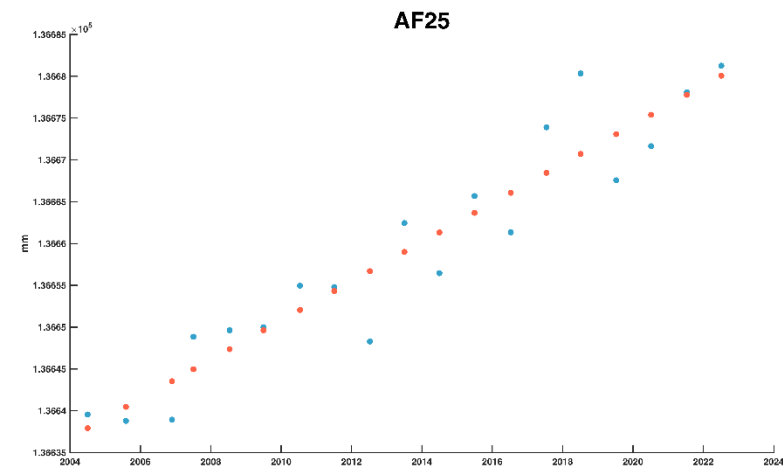
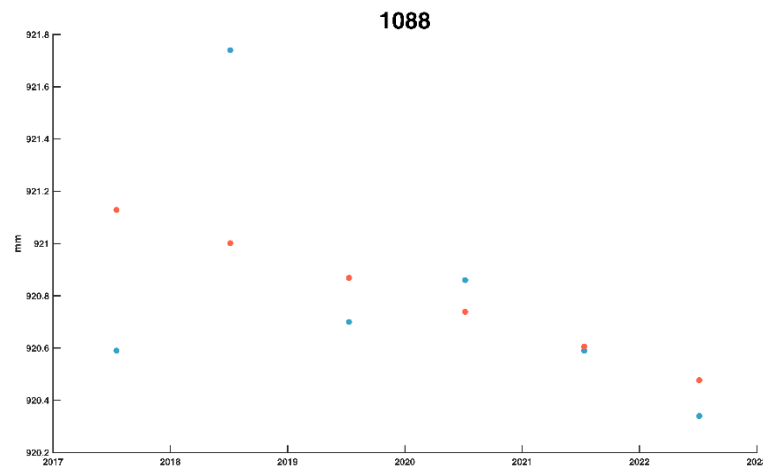


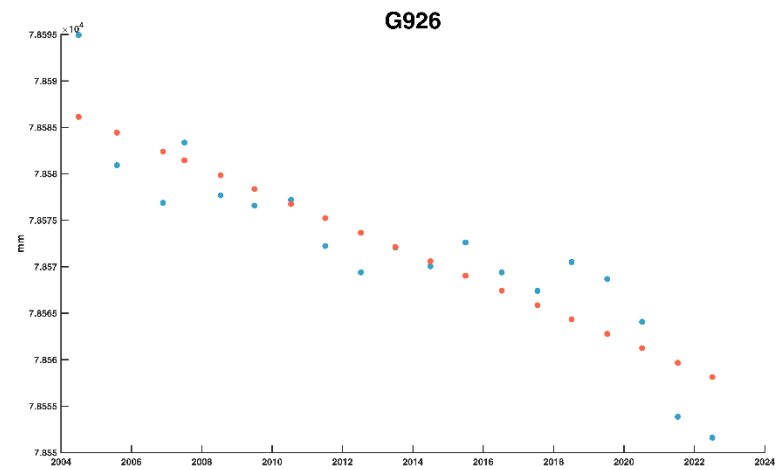
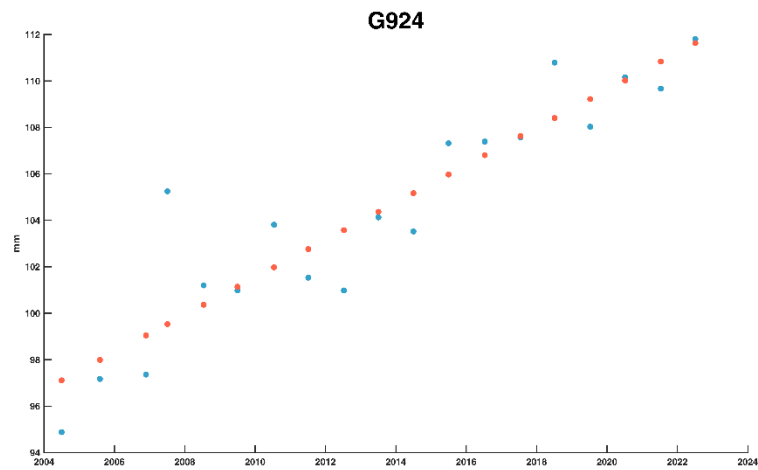
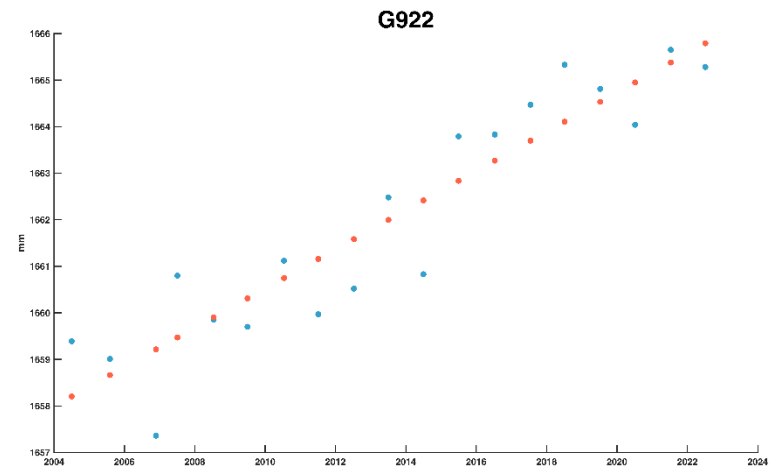
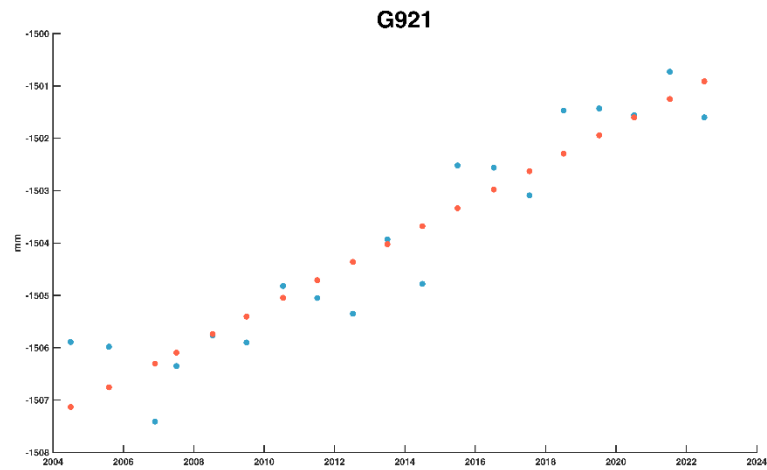


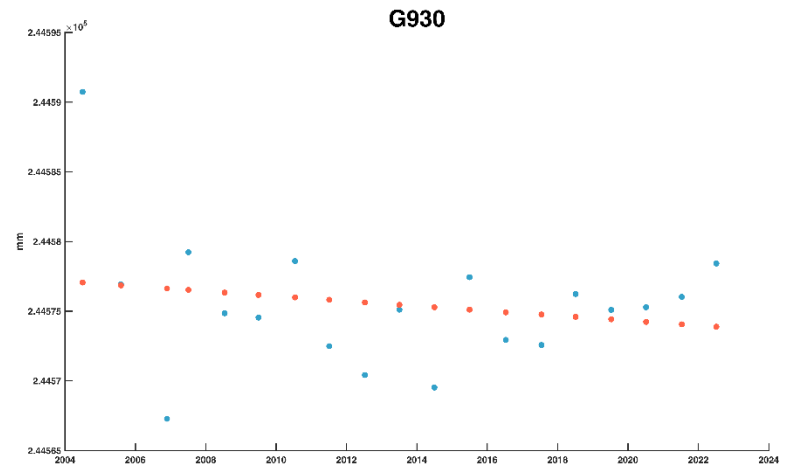
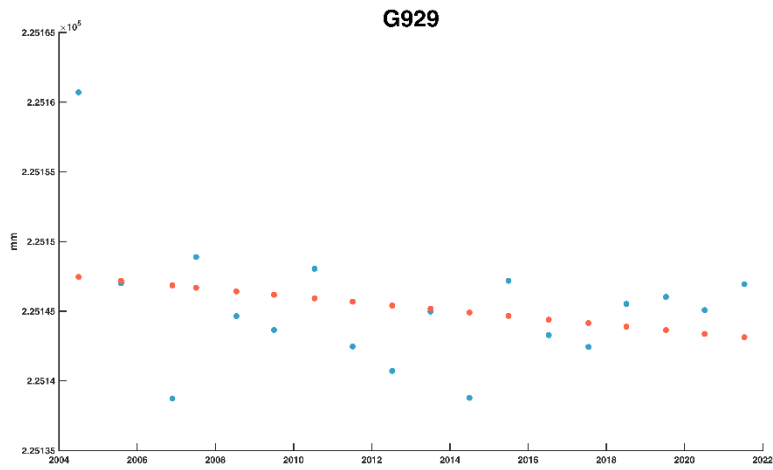
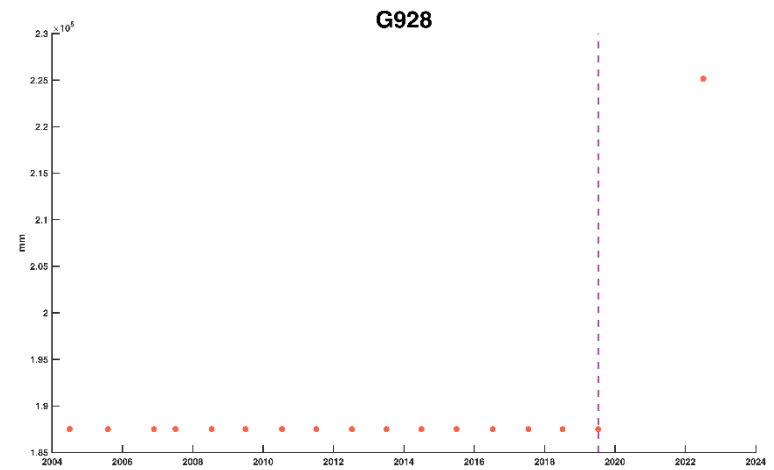
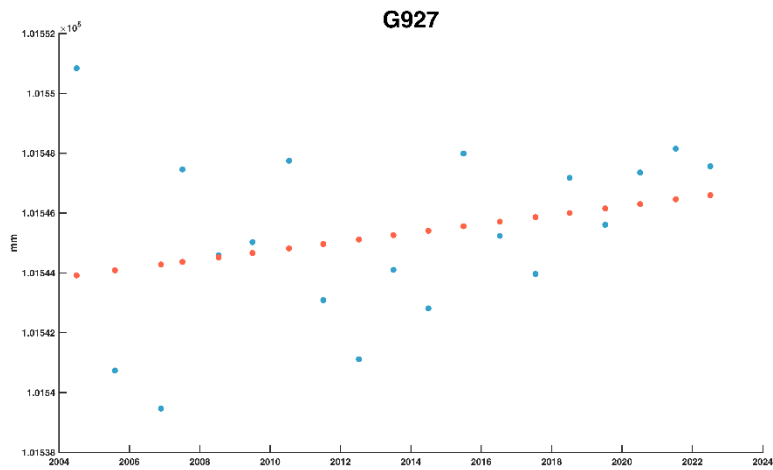
## Appendix D3: Leveling

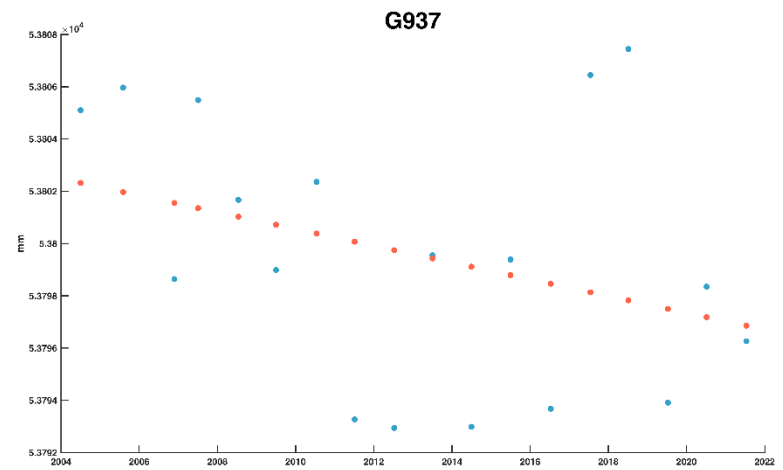
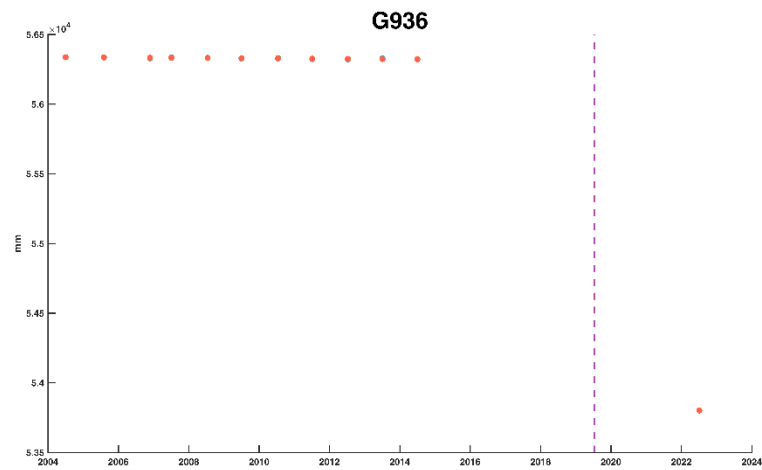
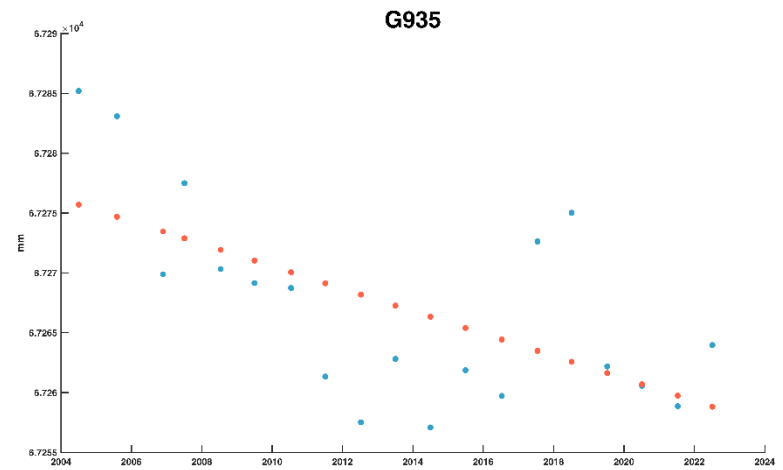
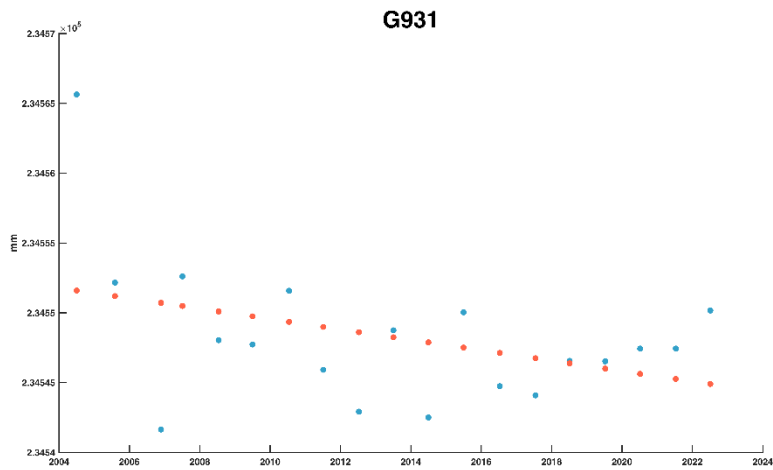
## Appendix A: Leveling route 11

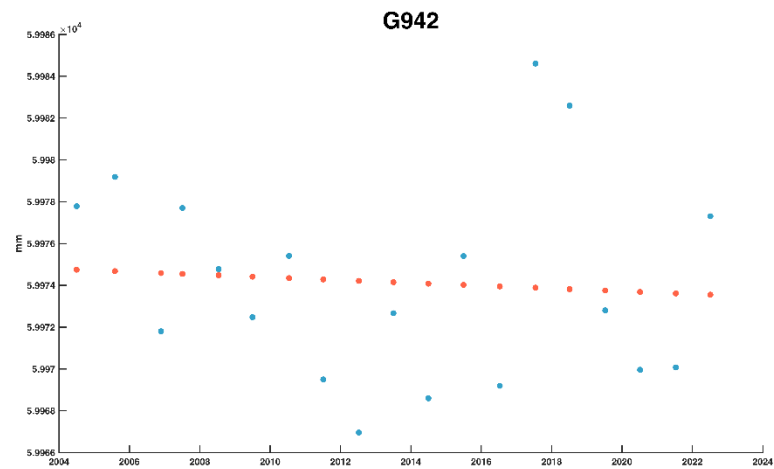
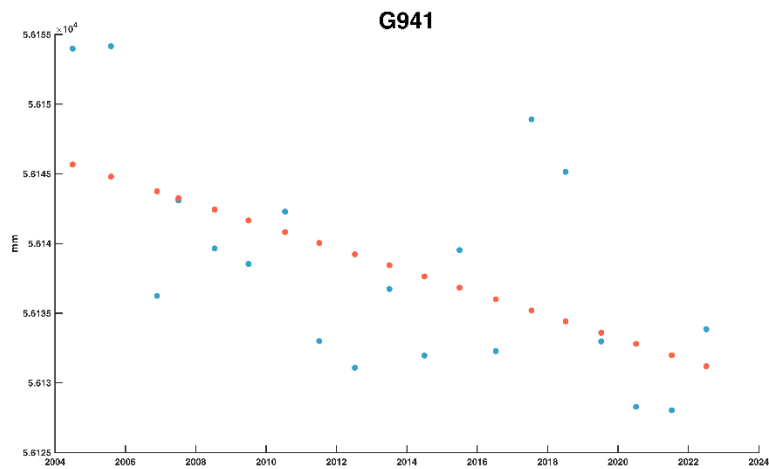
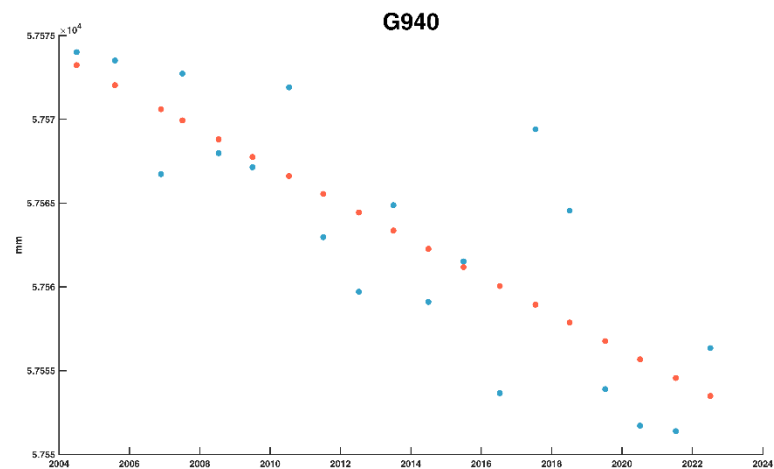
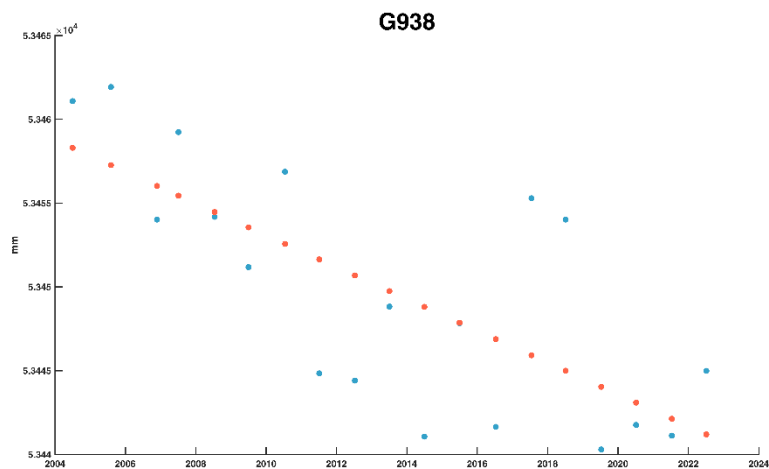
Here are the fitting results of leveling data. Red points are the fitting results. Purple dashes indicate the Heaviside step function. Blue dashes indicate the change of velocity.

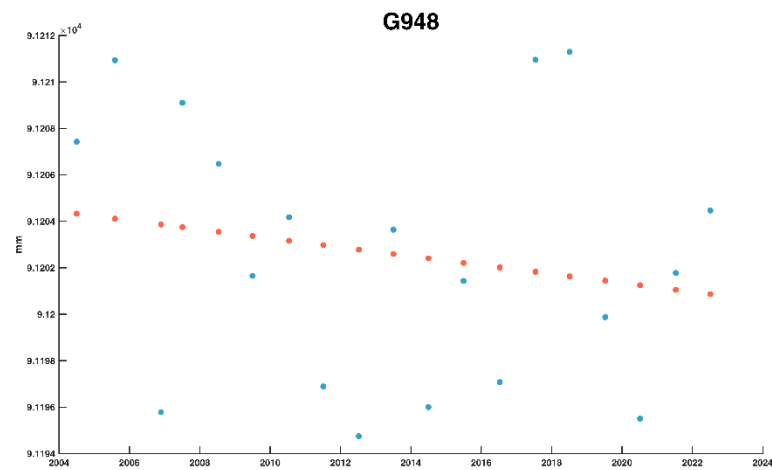
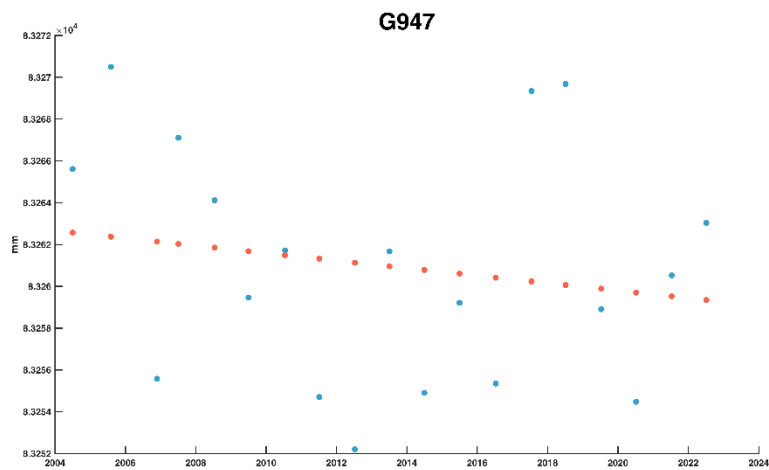
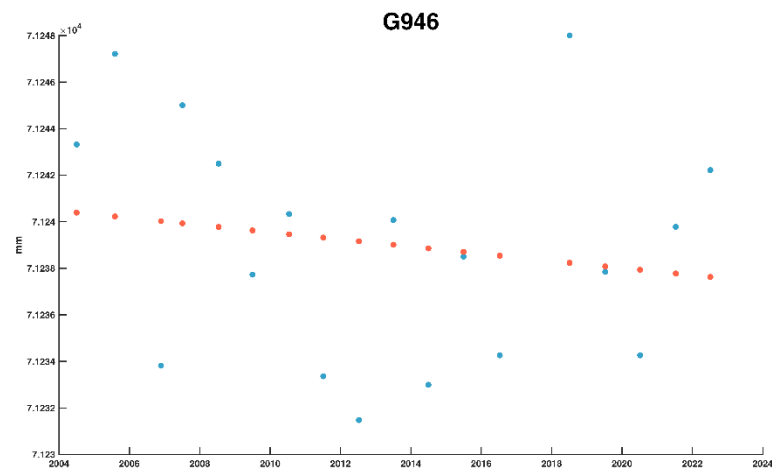
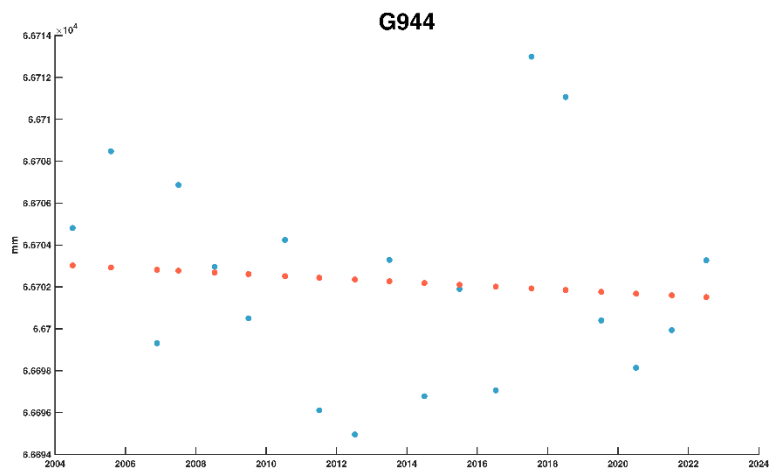


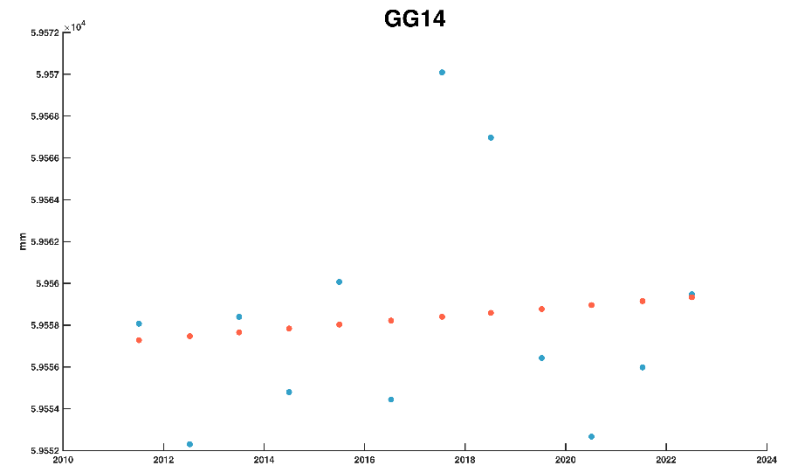
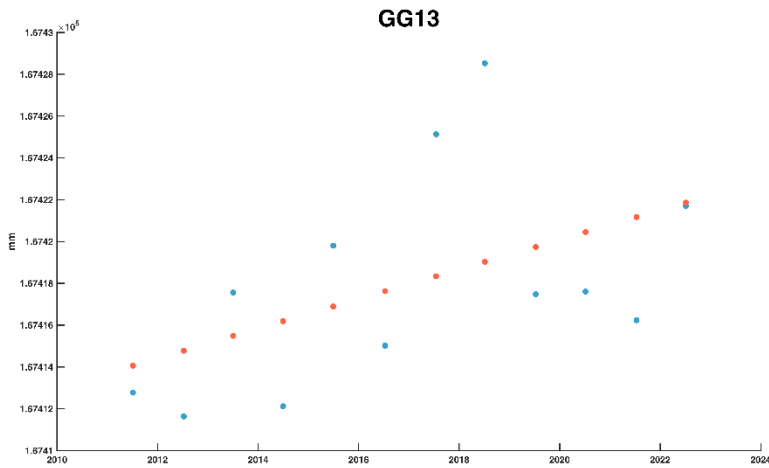
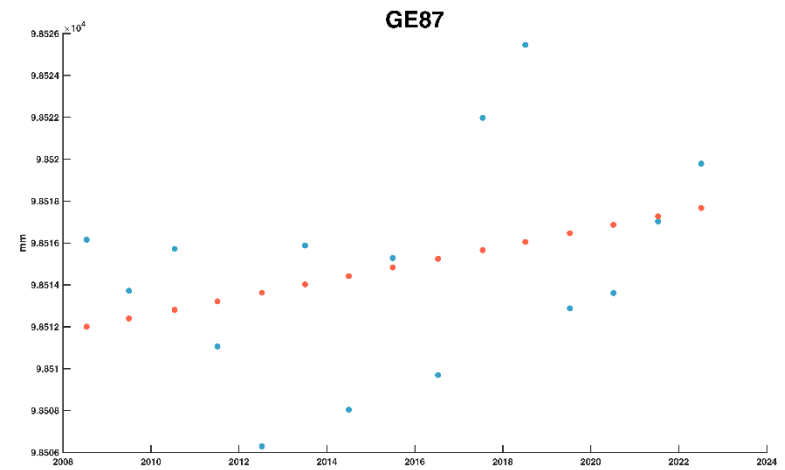
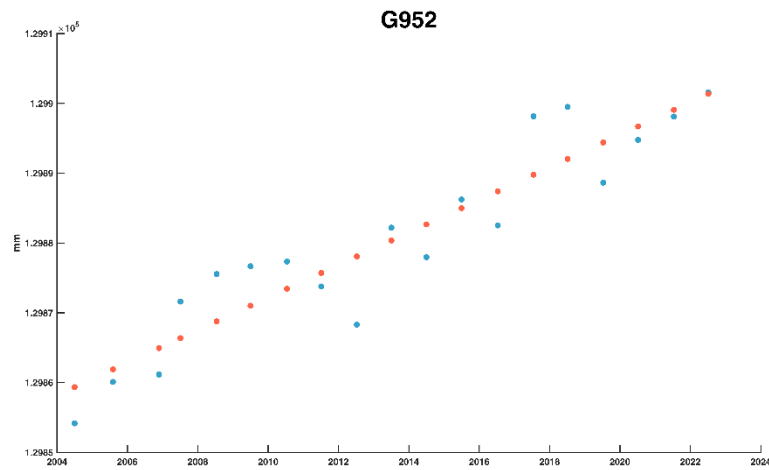


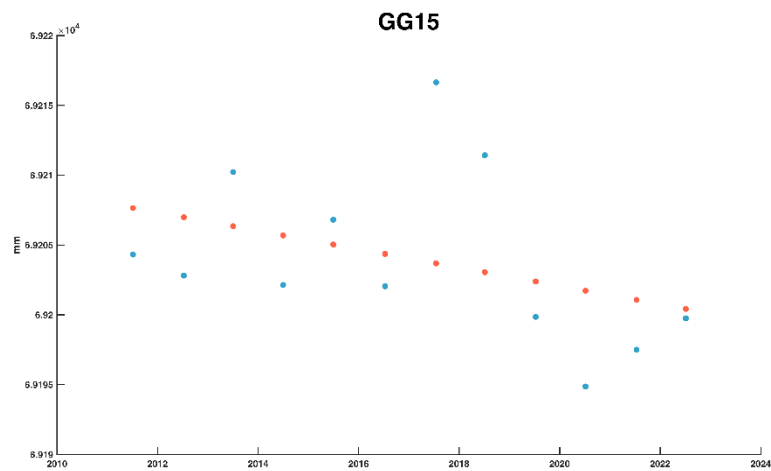






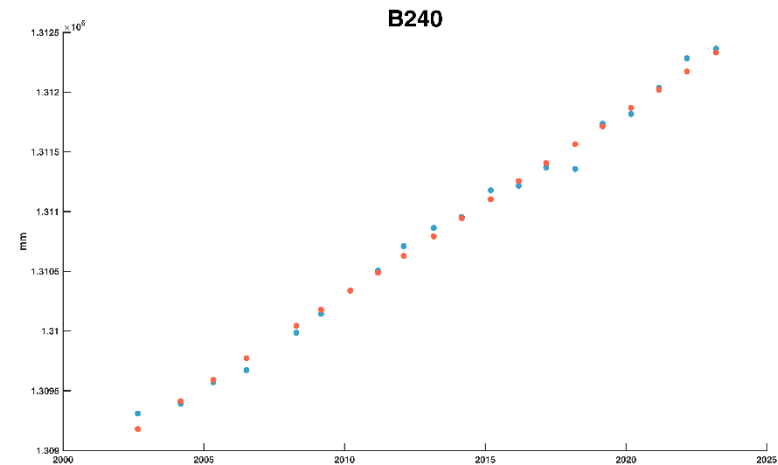
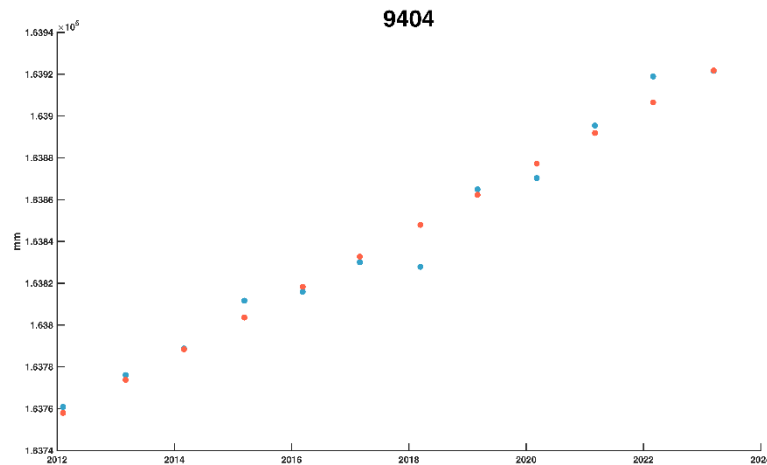


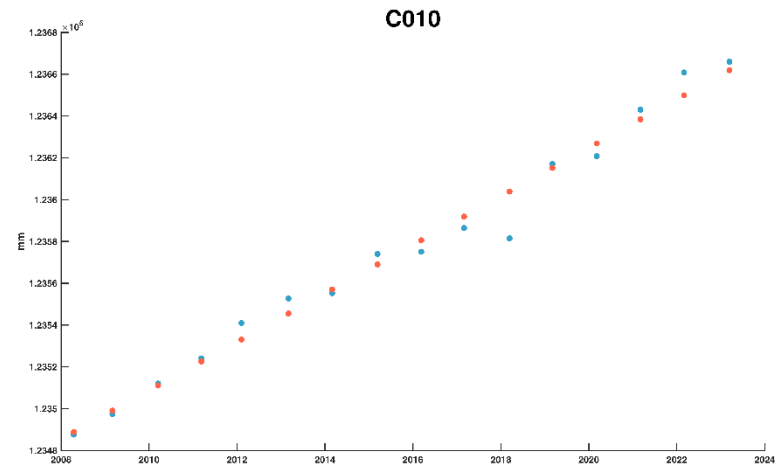
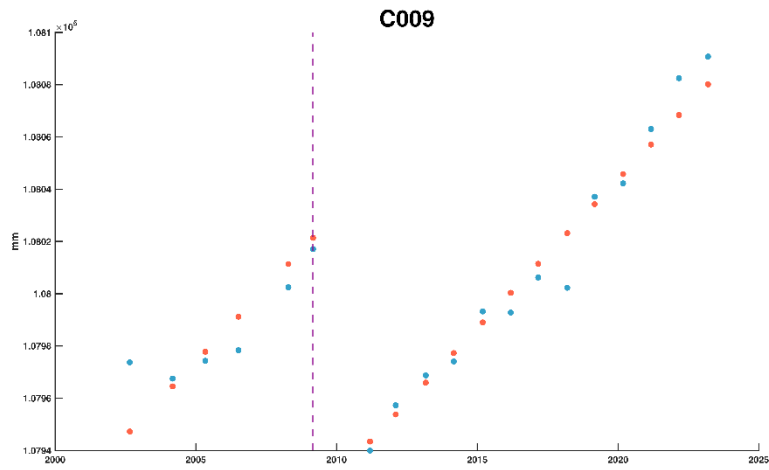
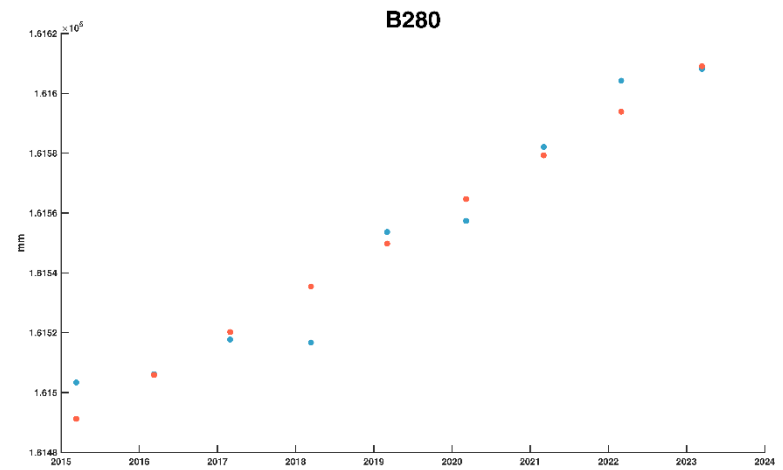
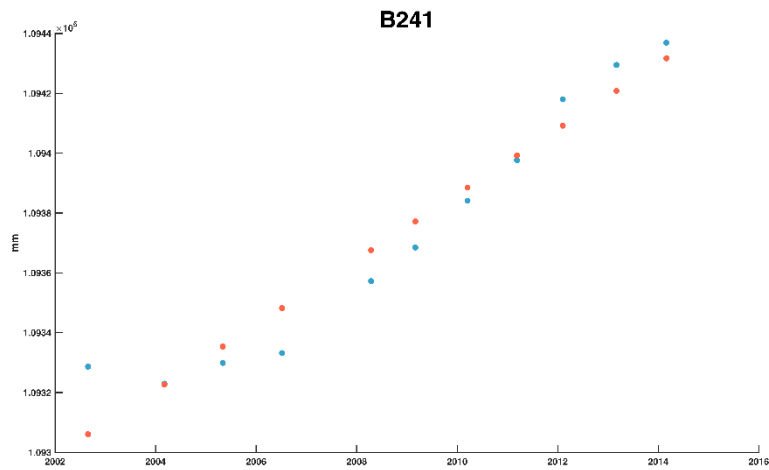


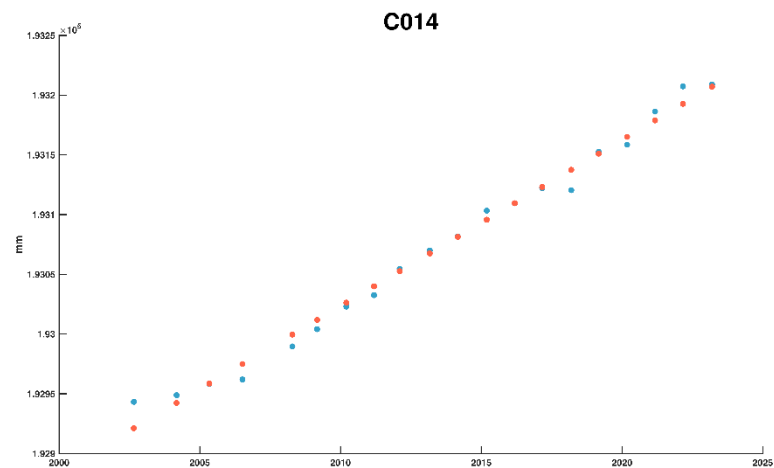
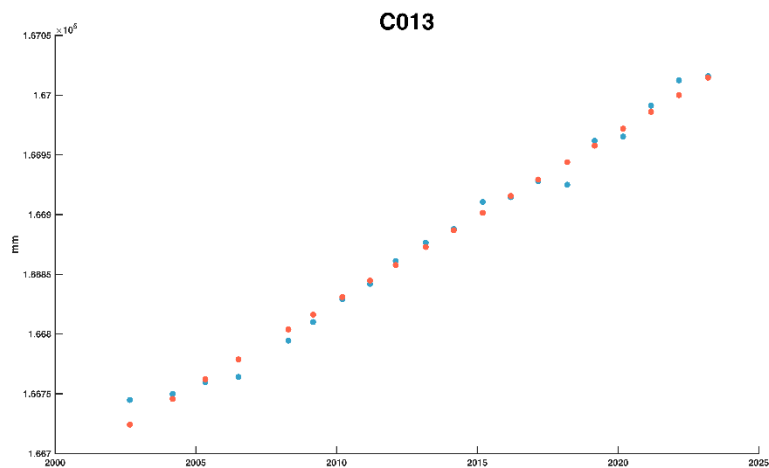
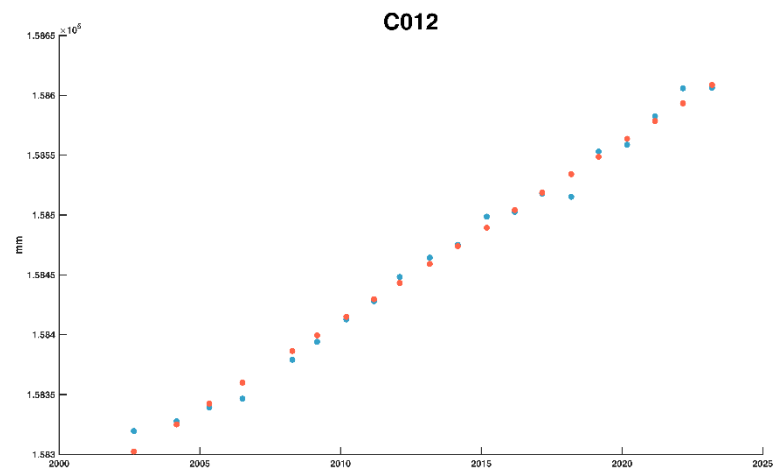
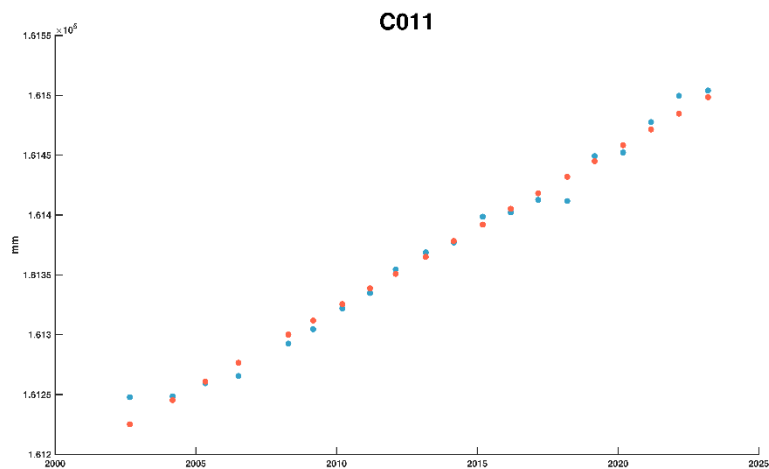


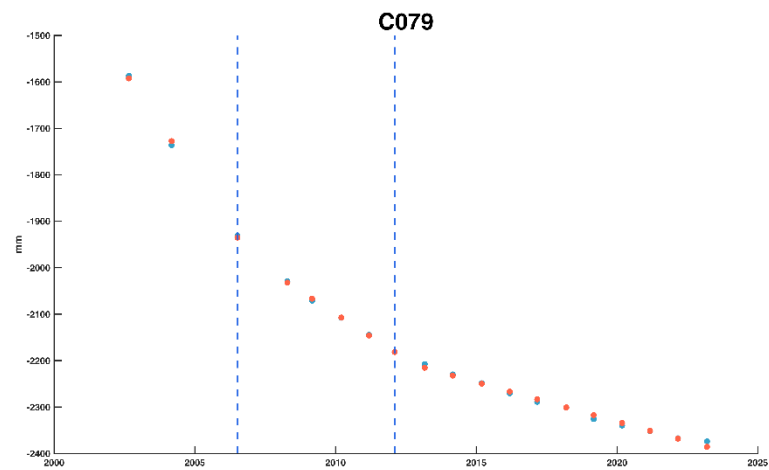
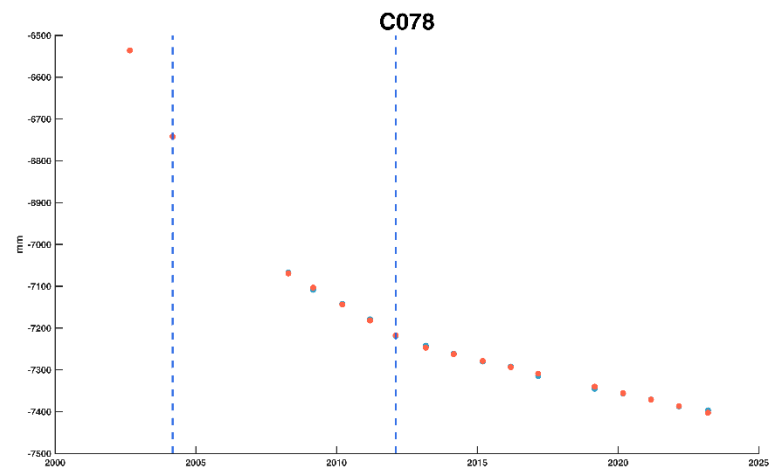
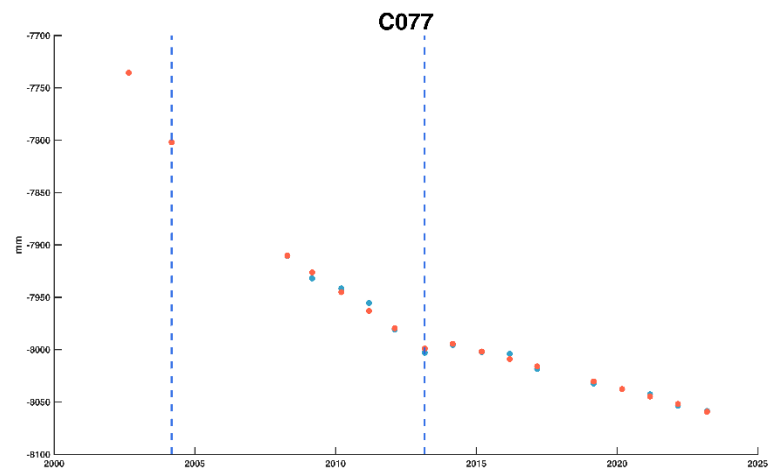
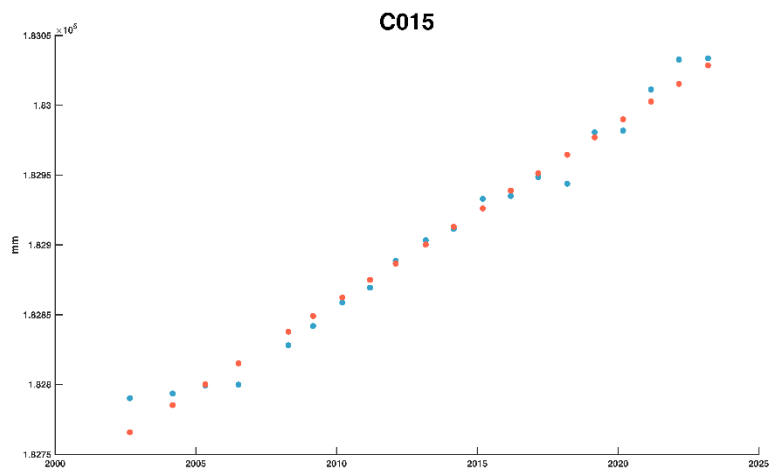
## Appendix B:Leveling route 17/18

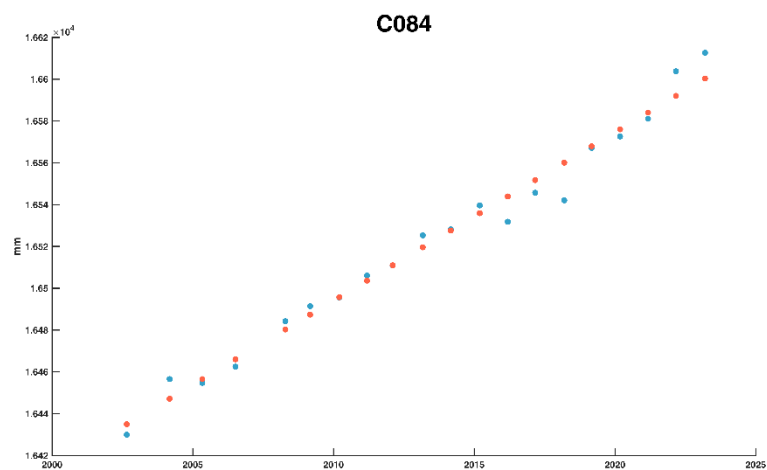
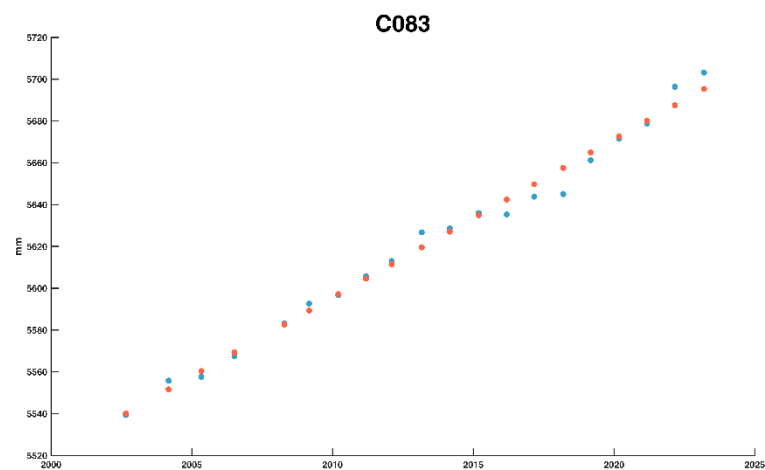
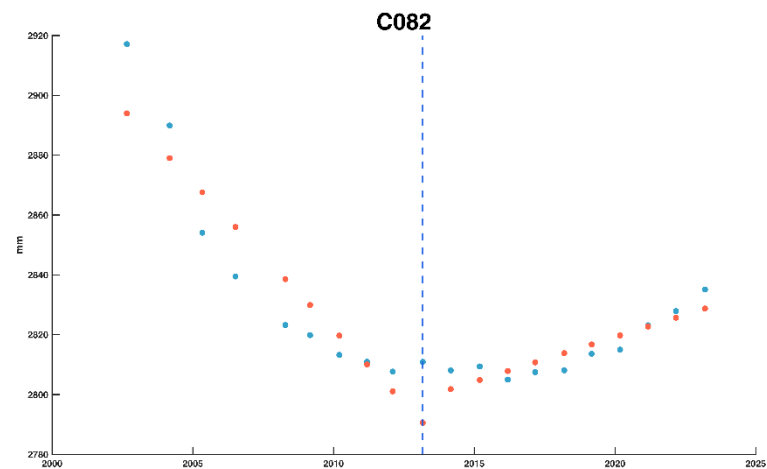
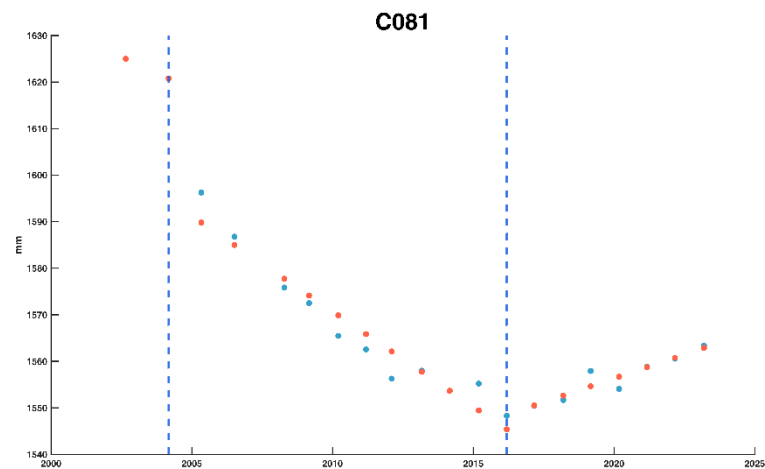
Here are the fitting results of leveling data. Red points are the fitting results. Purple dashes indicate the Heaviside step function. Blue dashes indicate the change of velocity.

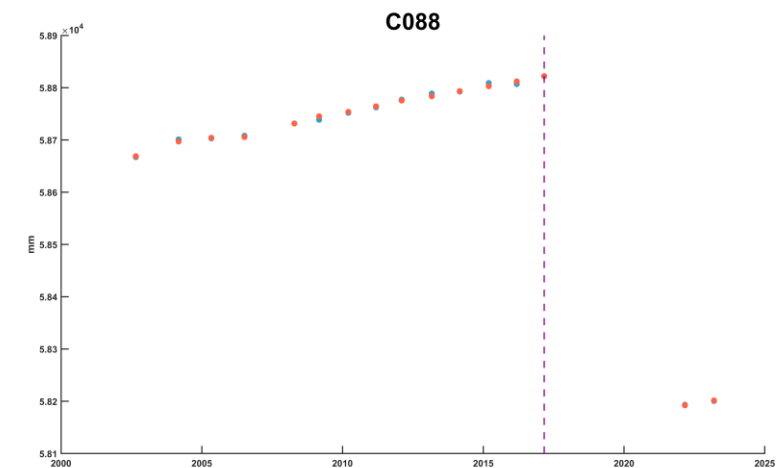
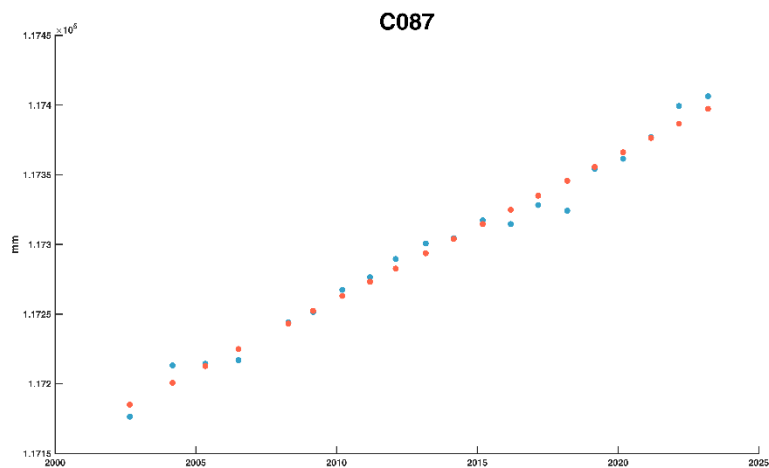
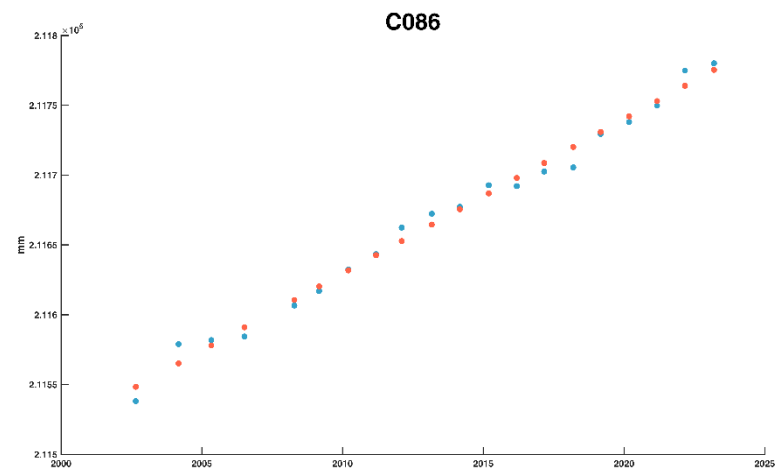
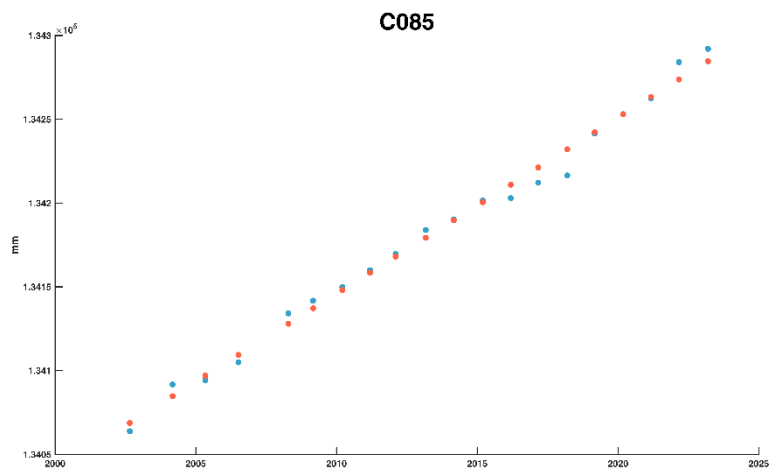


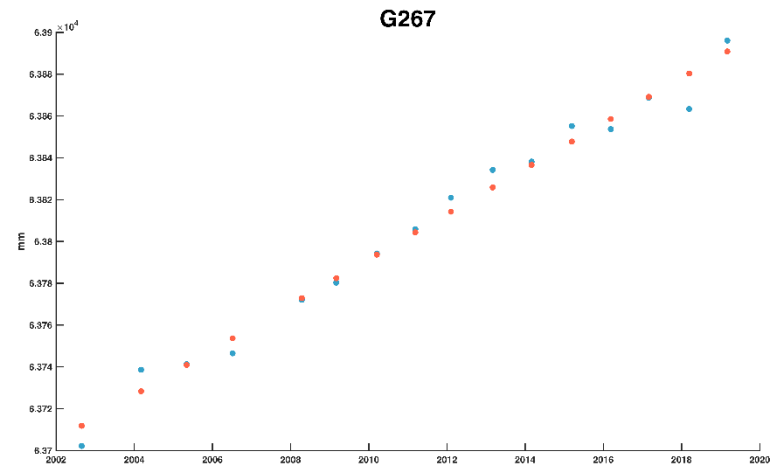
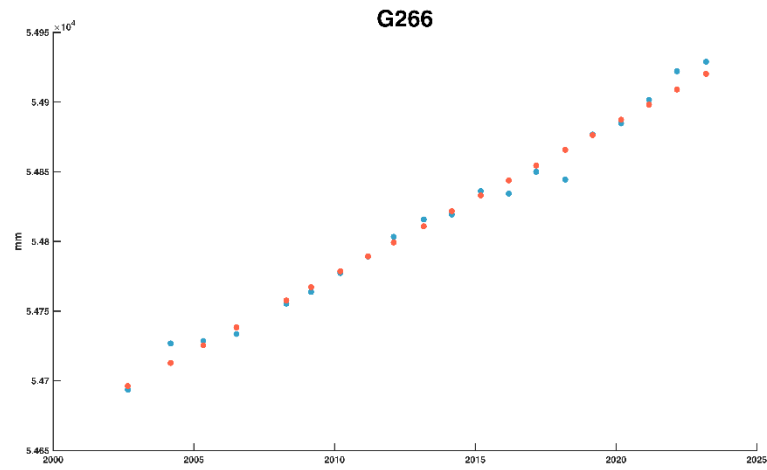
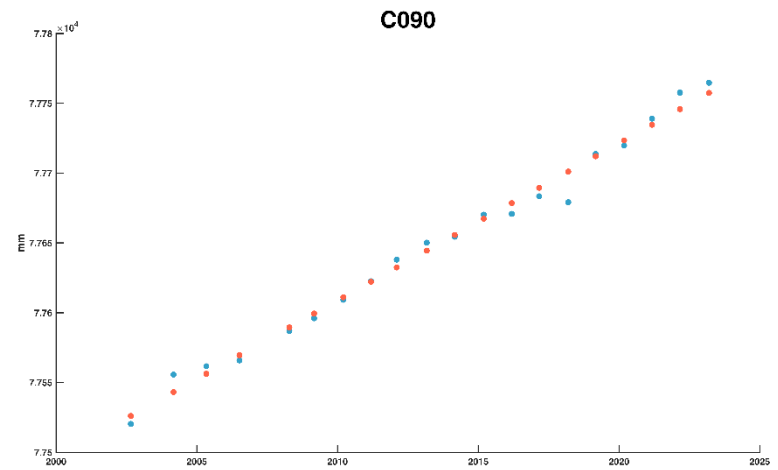
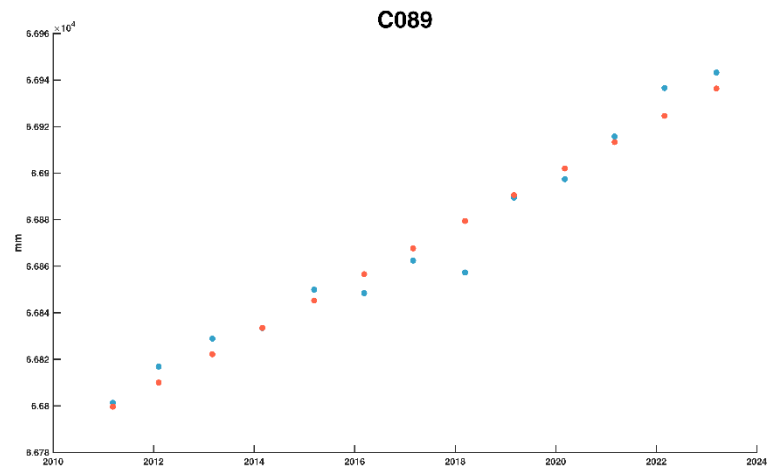


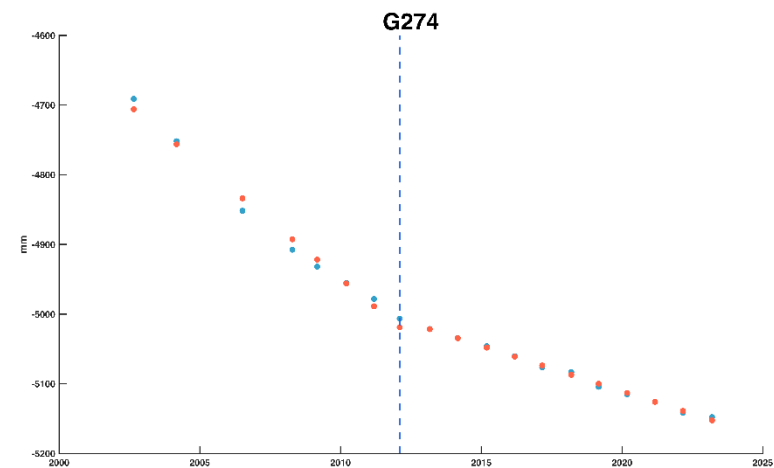
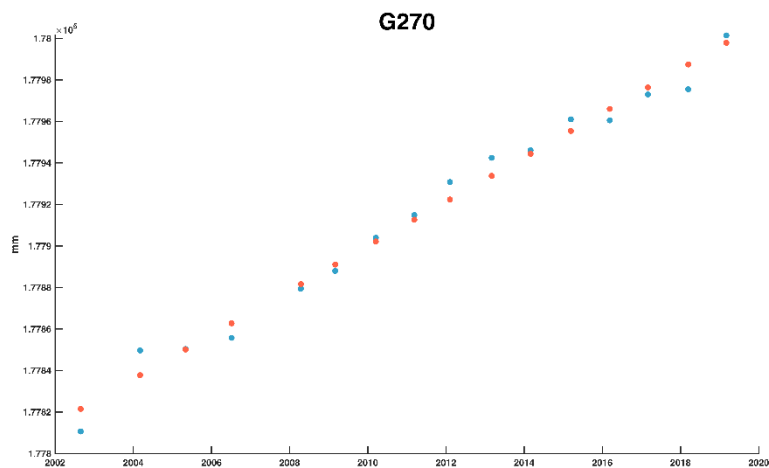
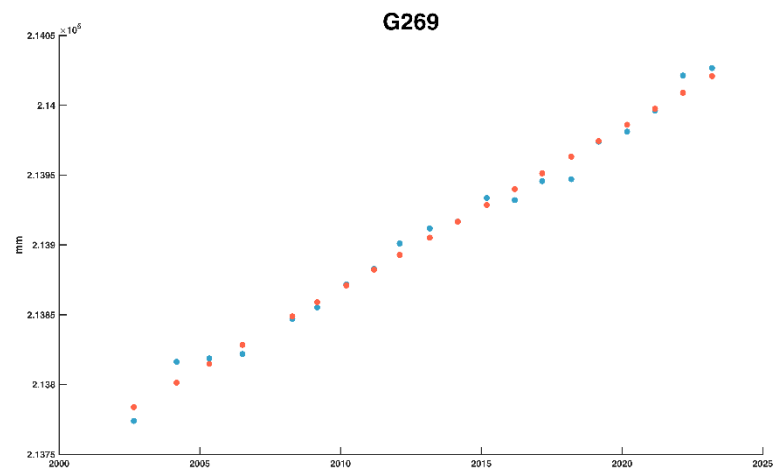
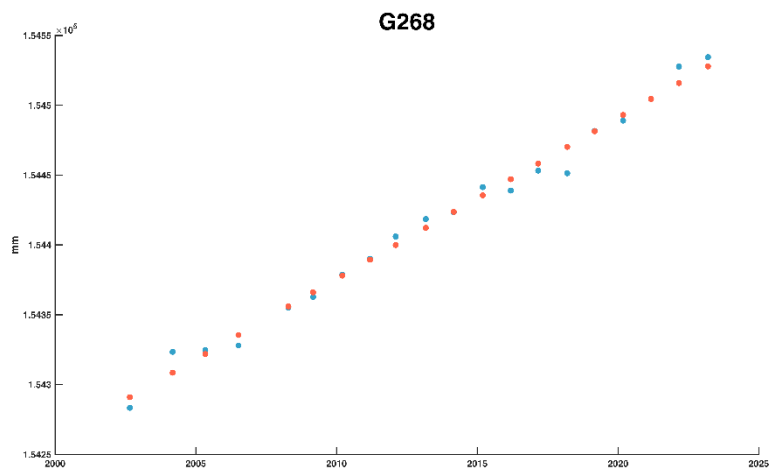


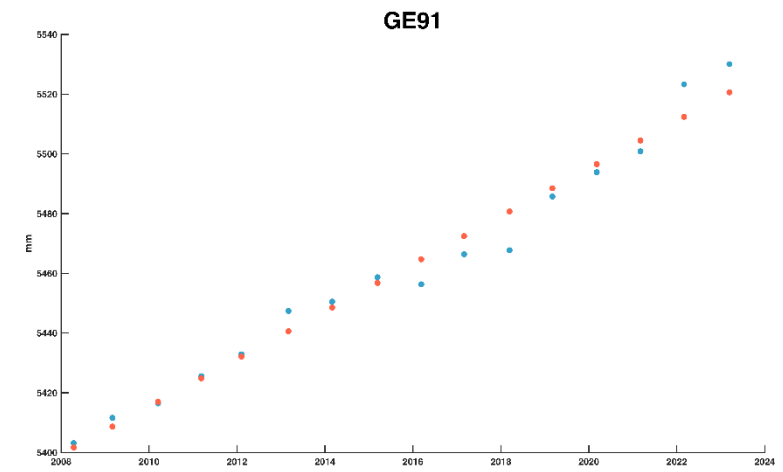
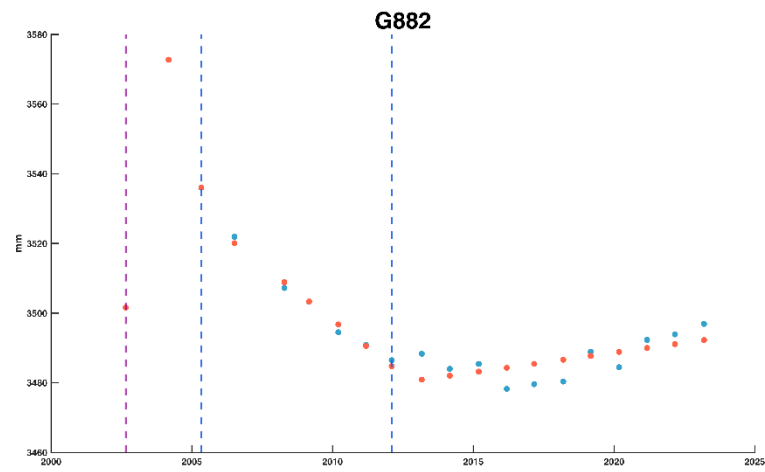
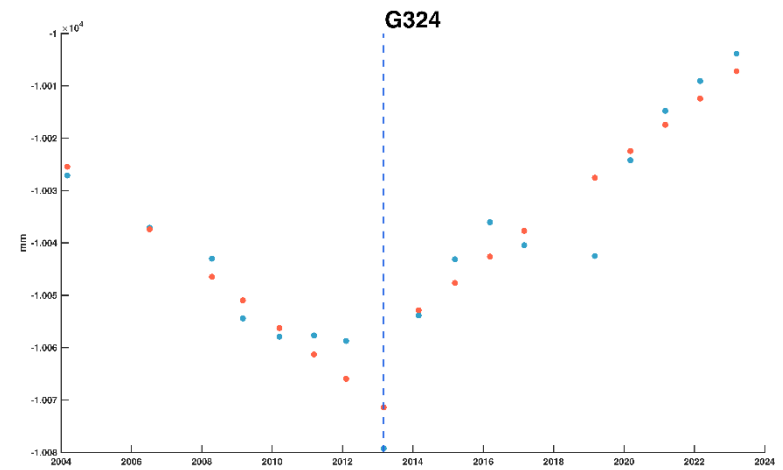
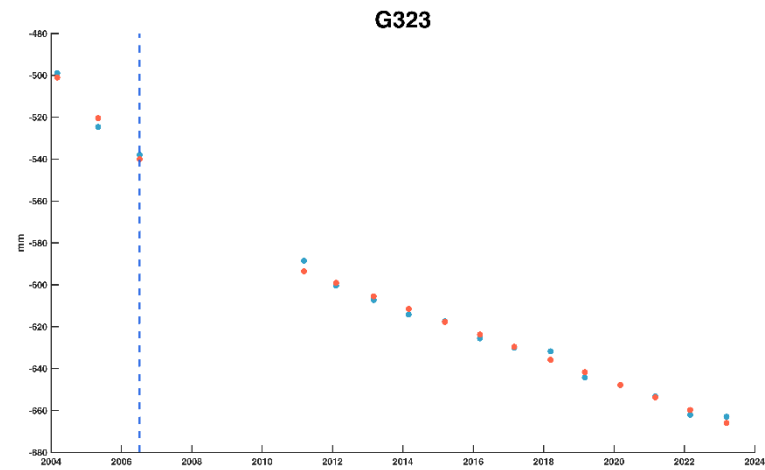


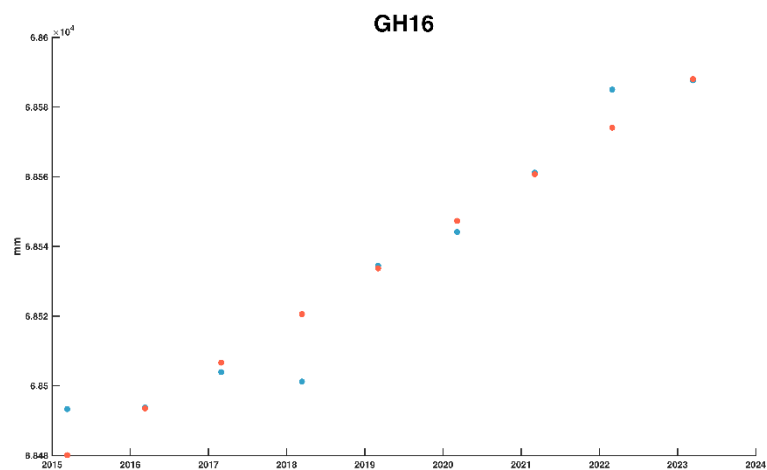
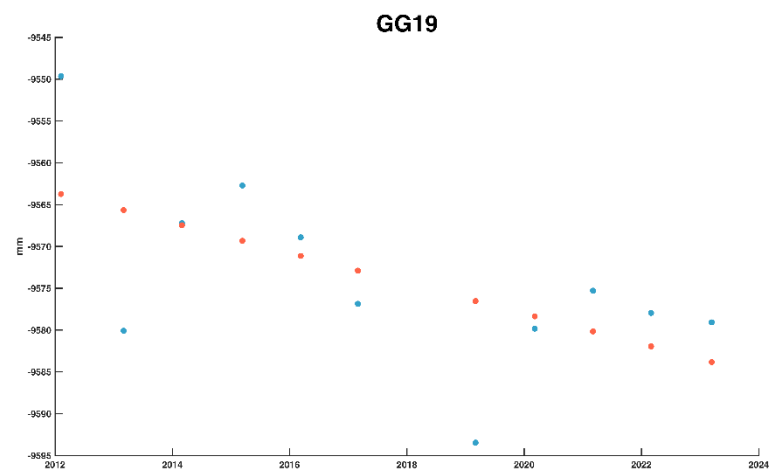
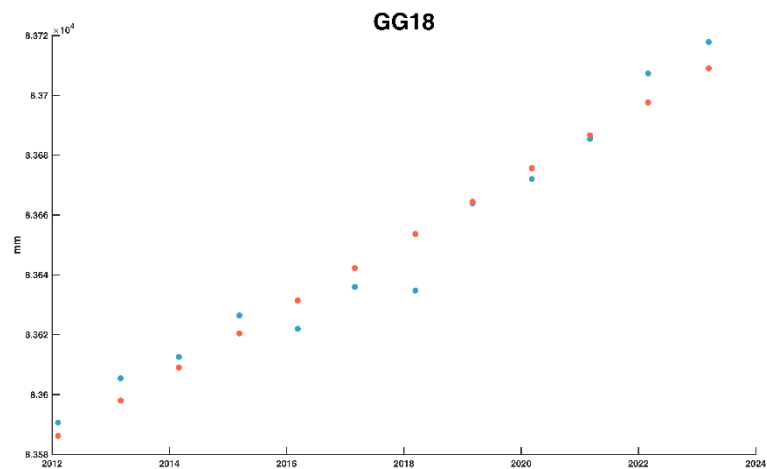
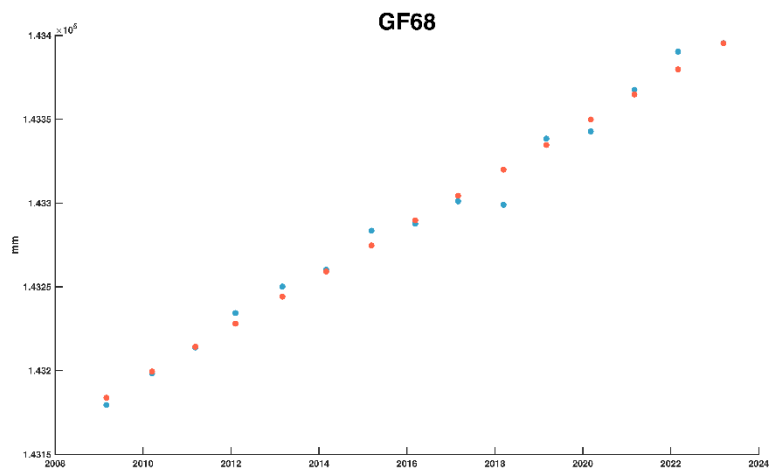


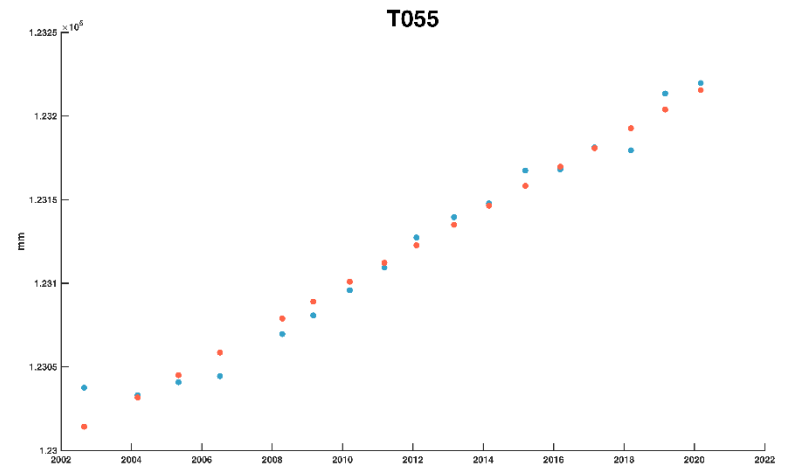
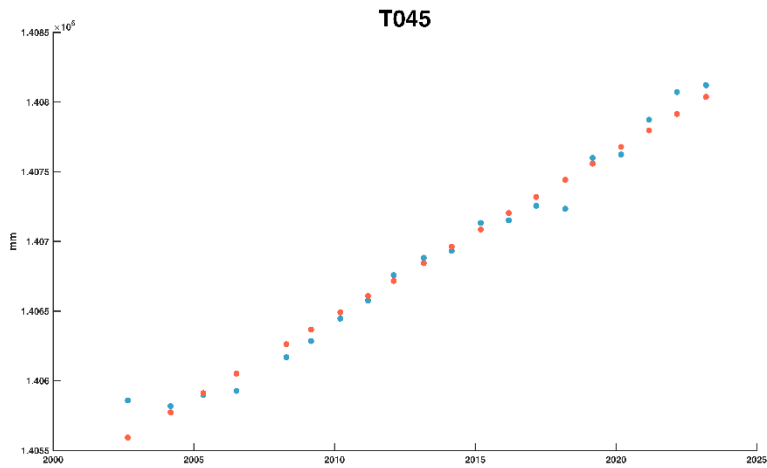
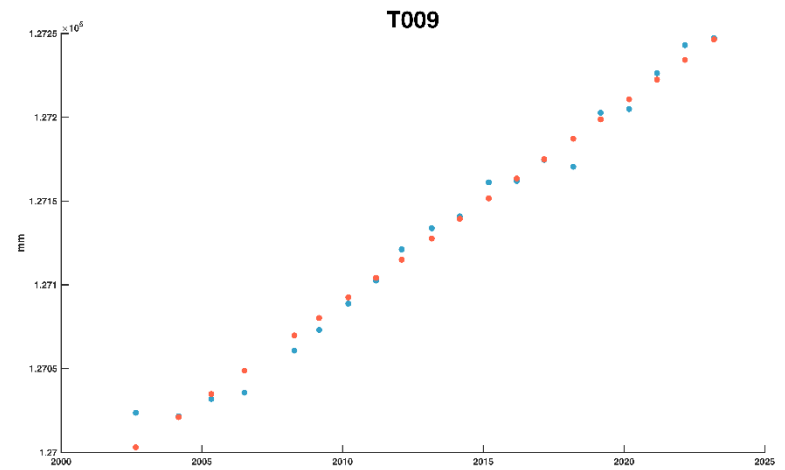
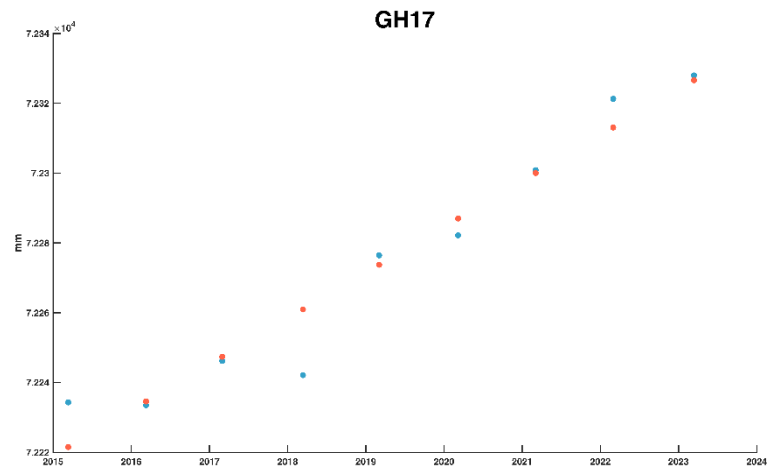


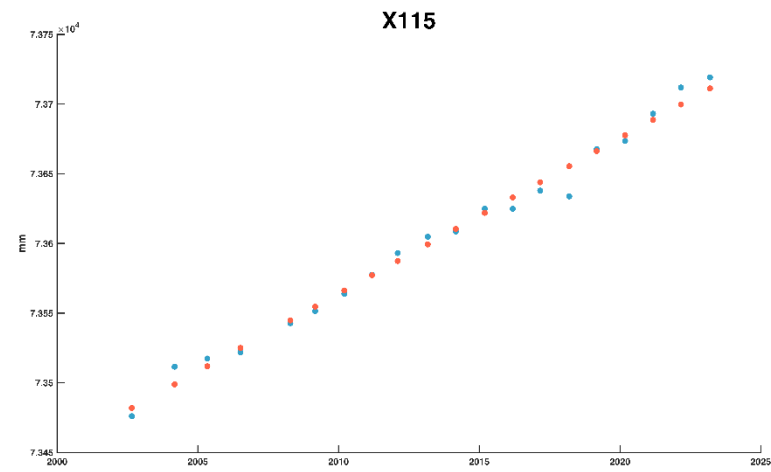
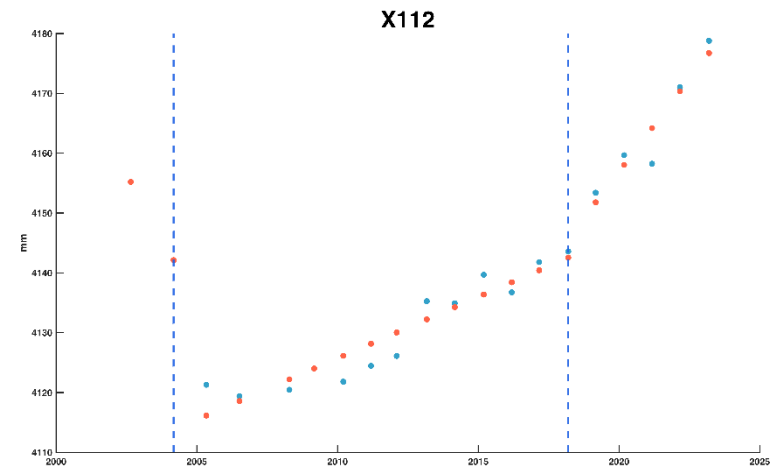
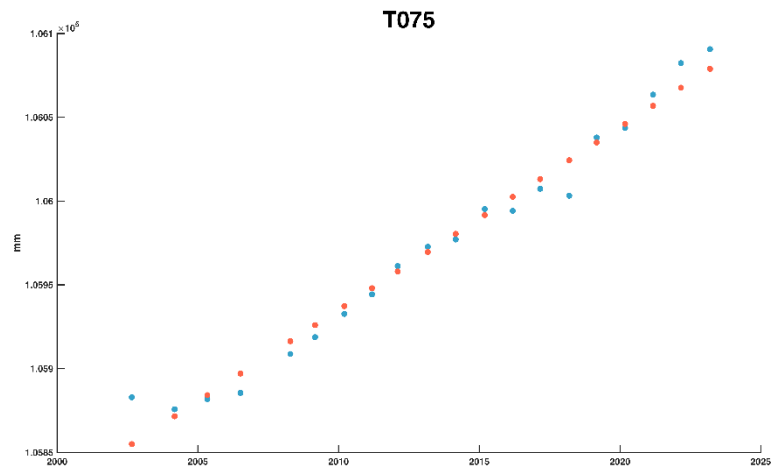












## Appendix E: Posterior distribution of 2-D model results

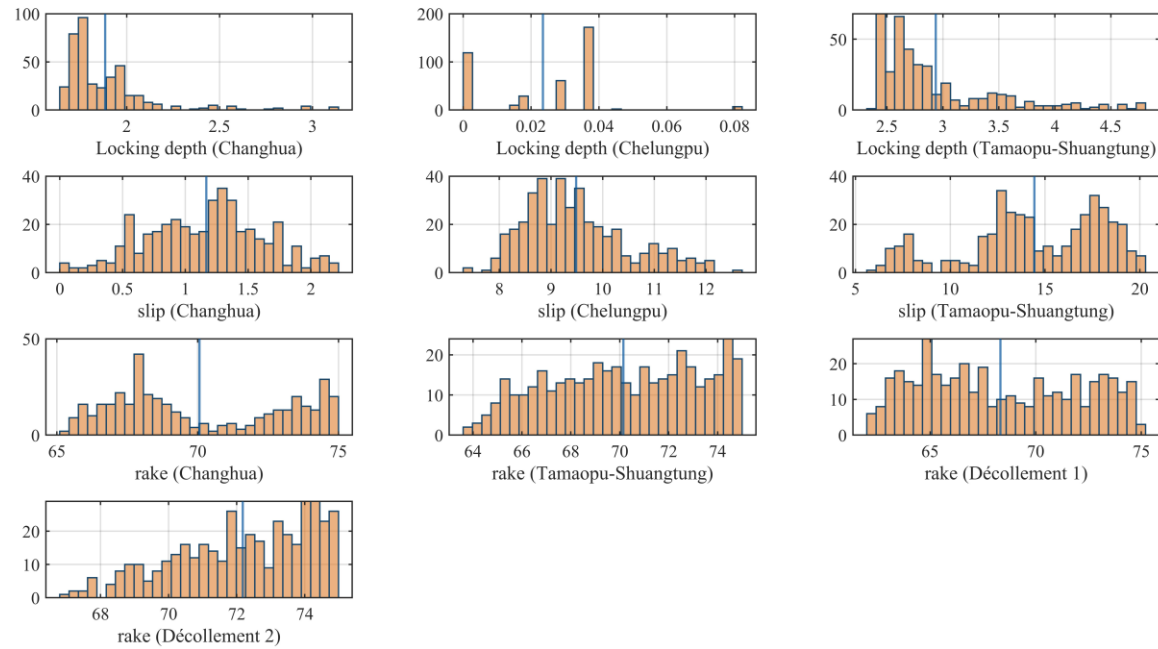


**Figure A1** Posterior probability distributions for the southern shallow profile of inversion of 2-D model.

Y-axis indicates sample number.

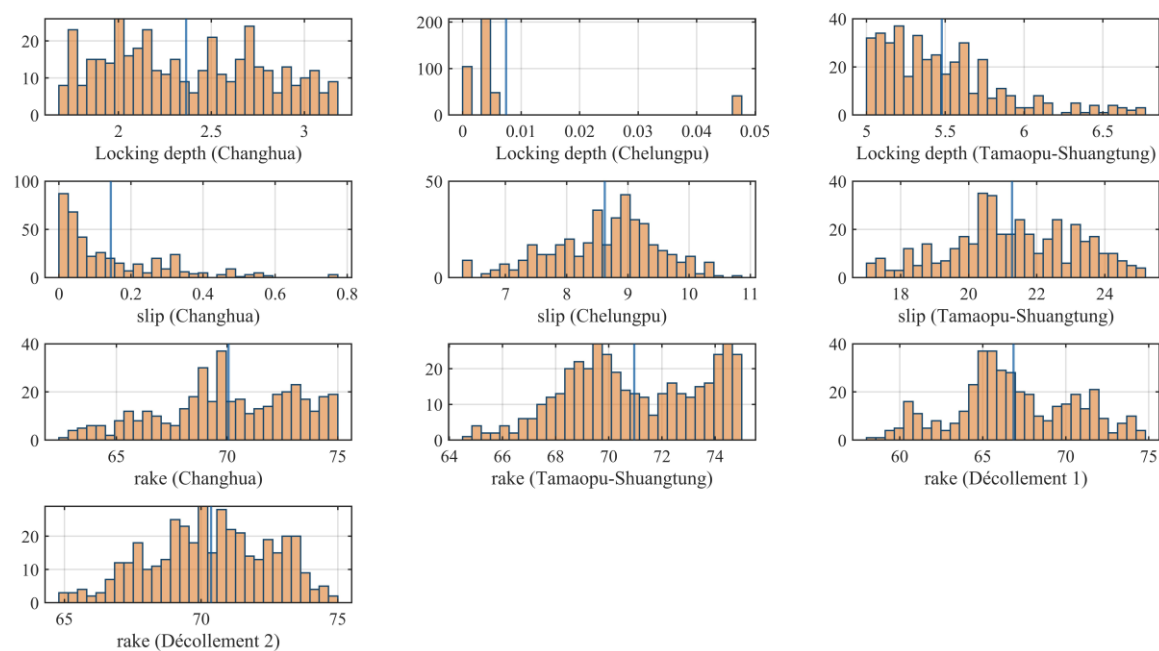


**Figure A2** Posterior probability distributions for the southern deep profile of inversion of 2-D model. Y-axis indicates sample number.

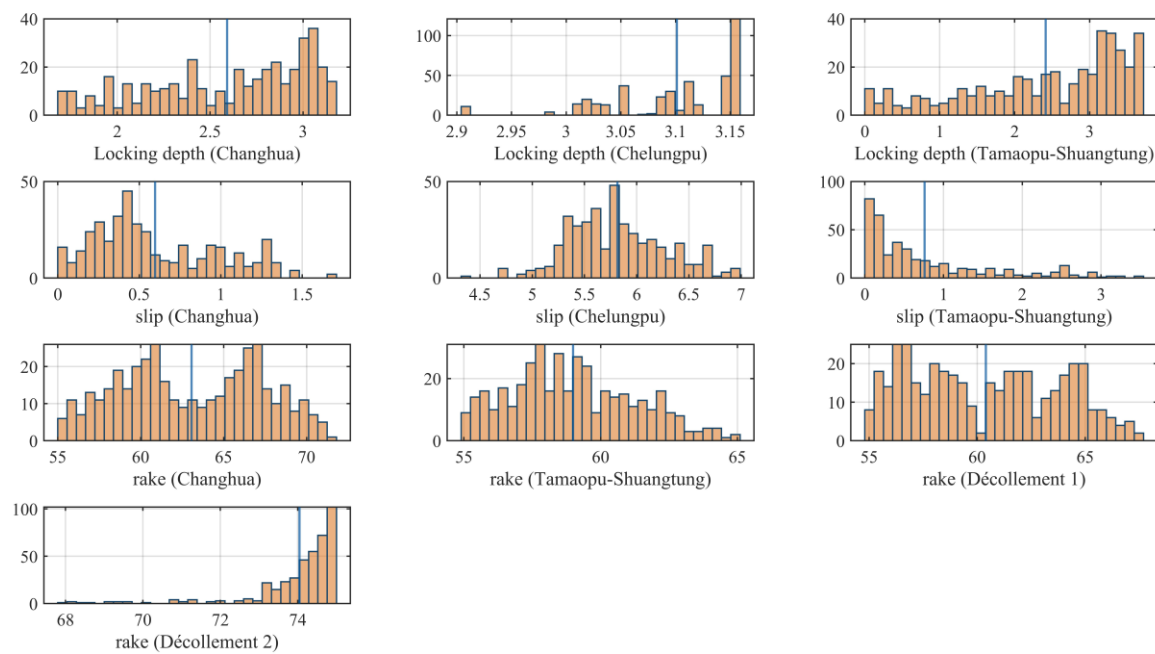


**Figure A3** Posterior probability distributions for the northern profile of inversion of 2-D model. Y-axis indicates sample number.

Appendix F: The 3-D model results

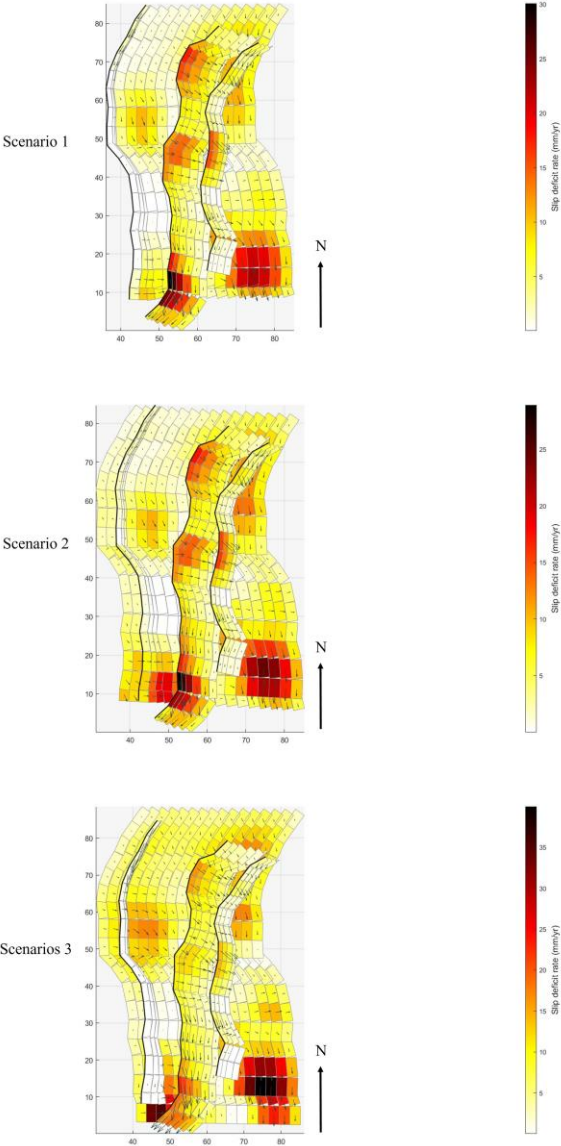


**Figure A4** The 3-dimensional model output of the three scenarios in the top view direction.

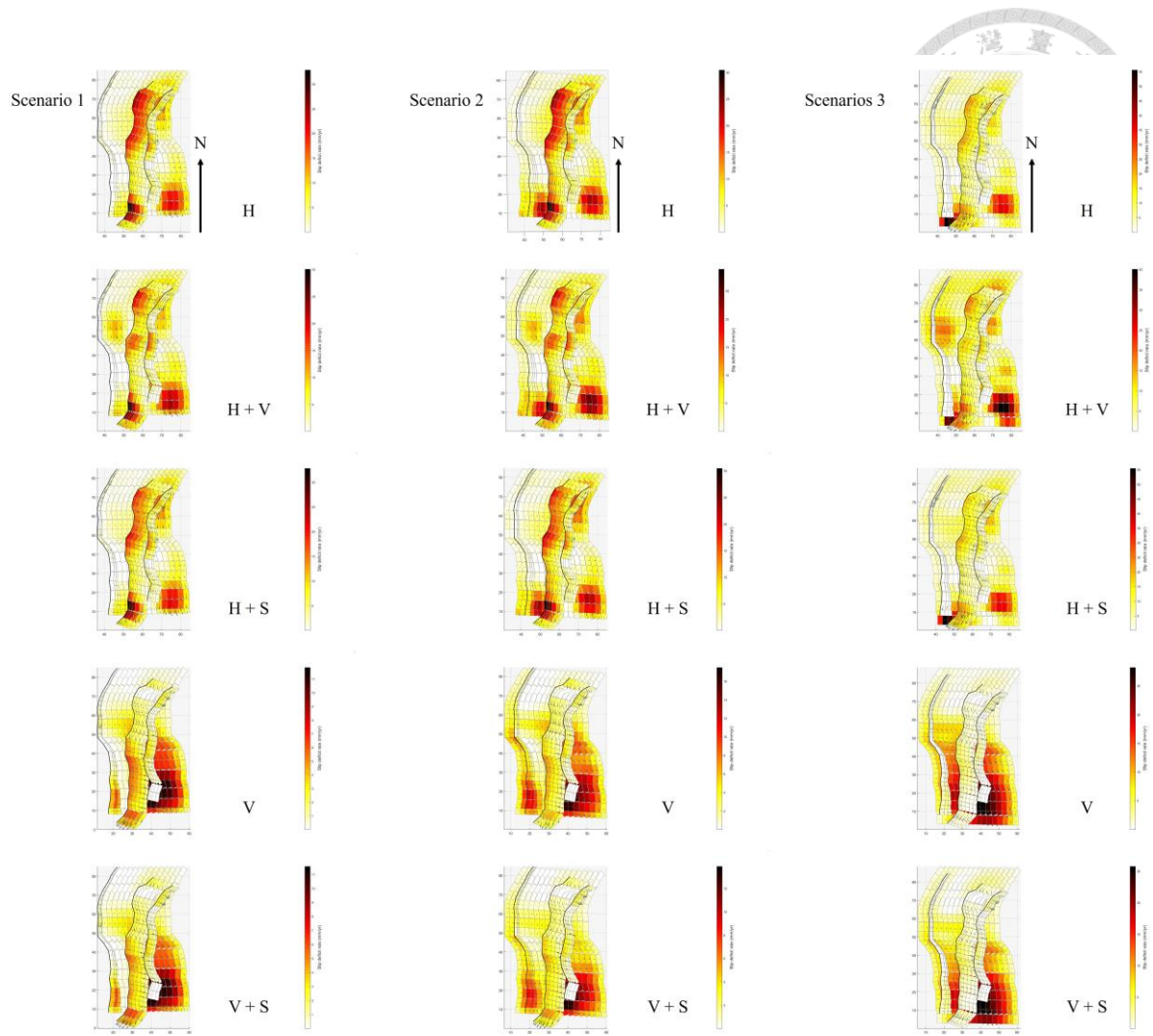


**Figure A5** The 3-dimensional model output of the three scenarios for different data in the top view direction. "H": Horizontal velocity is one of the input data. "V": Vertical velocity is one of the input data. "S": Line-of-sight velocity is one of the input data. The left column is Scenario 1. The middle column is Scenario 2. The right column is Scenario 3.

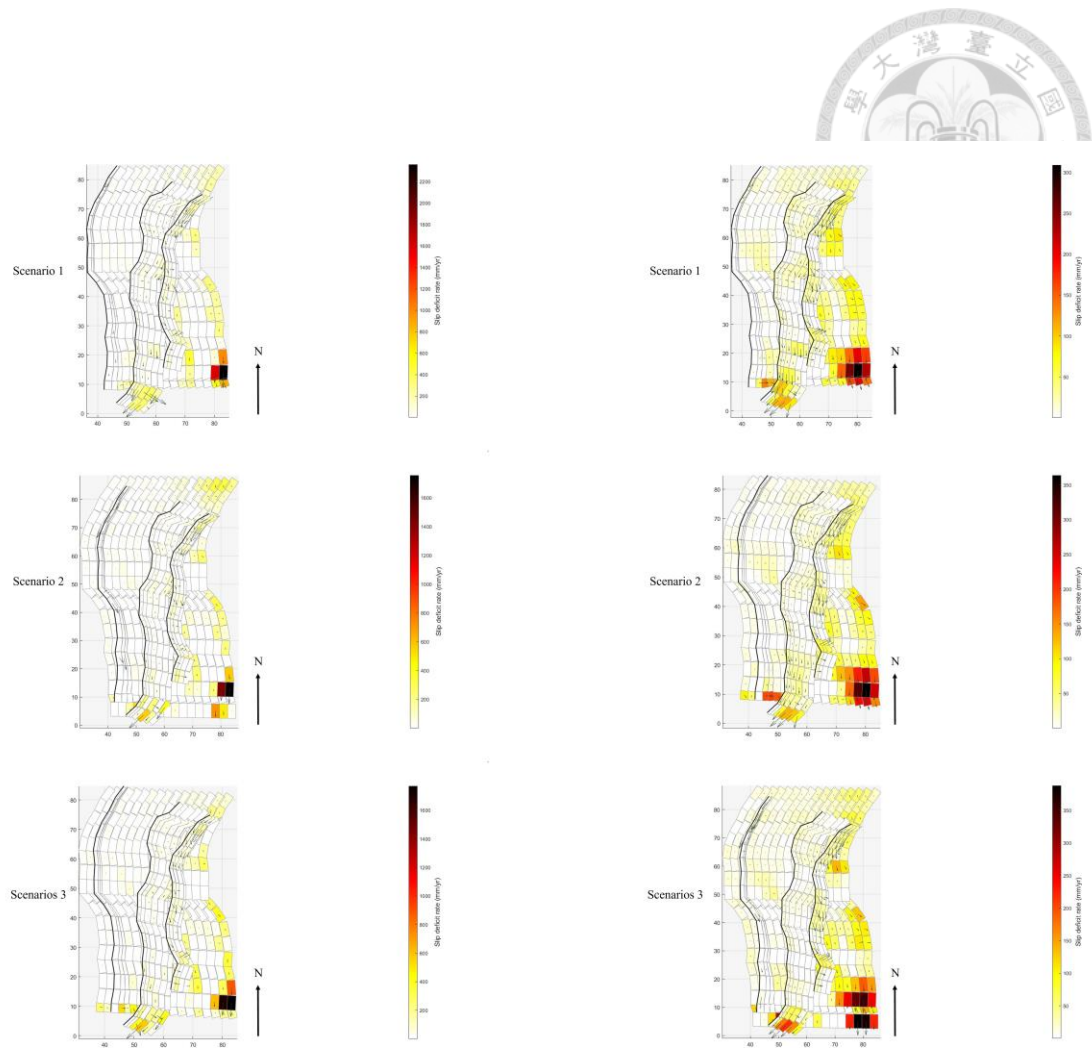


**Figure A6** The 3-dimensional model output in the three scenarios for different smoothing parameters in the top view direction. The left parameter is 0.0977. The right parameter is 0.9772.

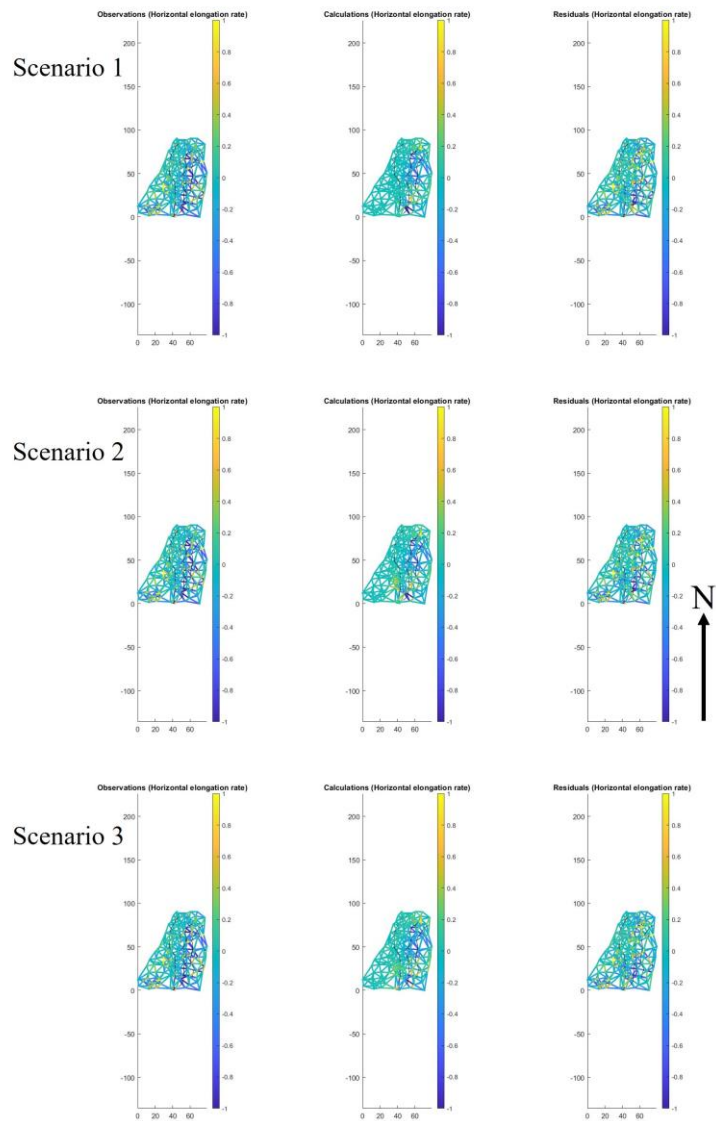


**Figure A7** The 3-dimensional model misfits of the three scenarios for only horizontal input data.

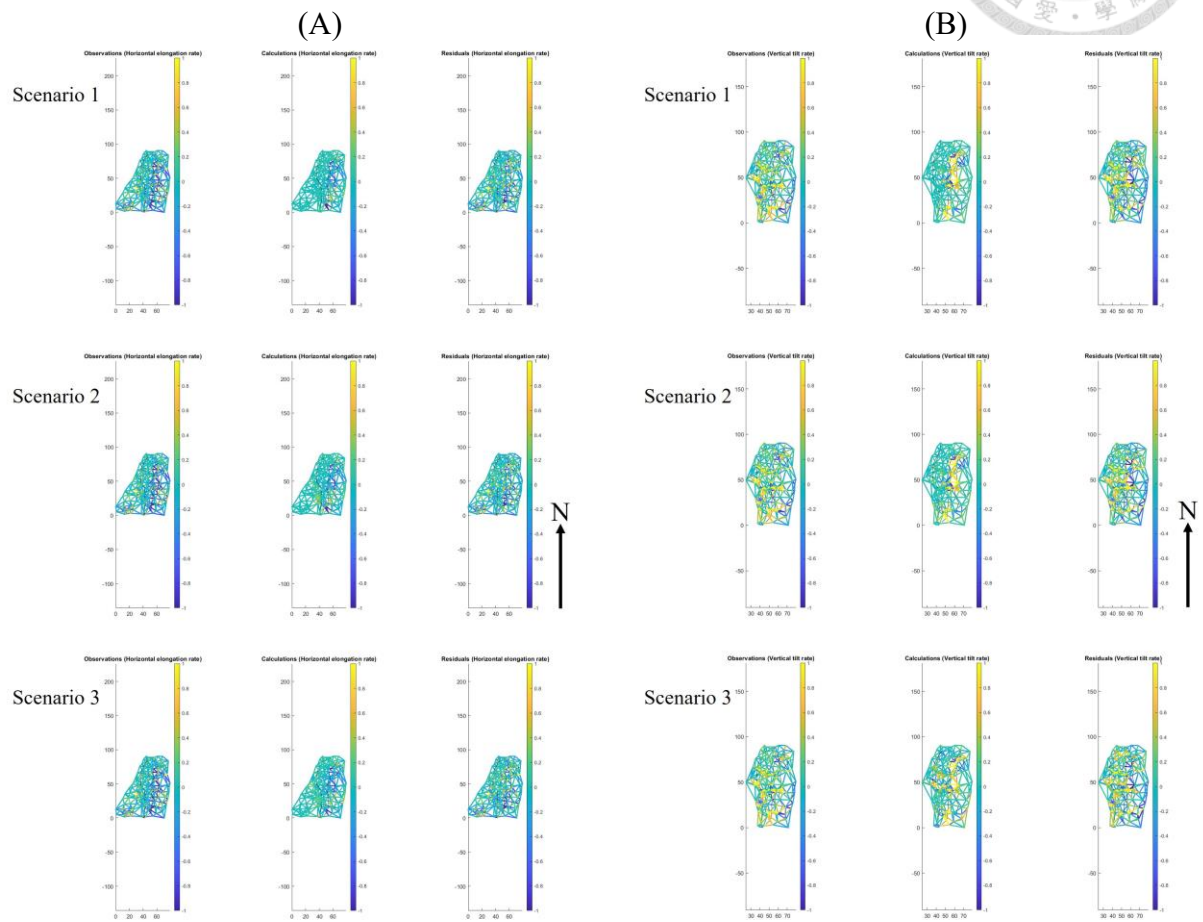


**Figure A8** The 3-dimensional model misfits of the three scenarios for horizontal and vertical input data. (A) Horizontal model misfits. (B) Vertical model misfits.

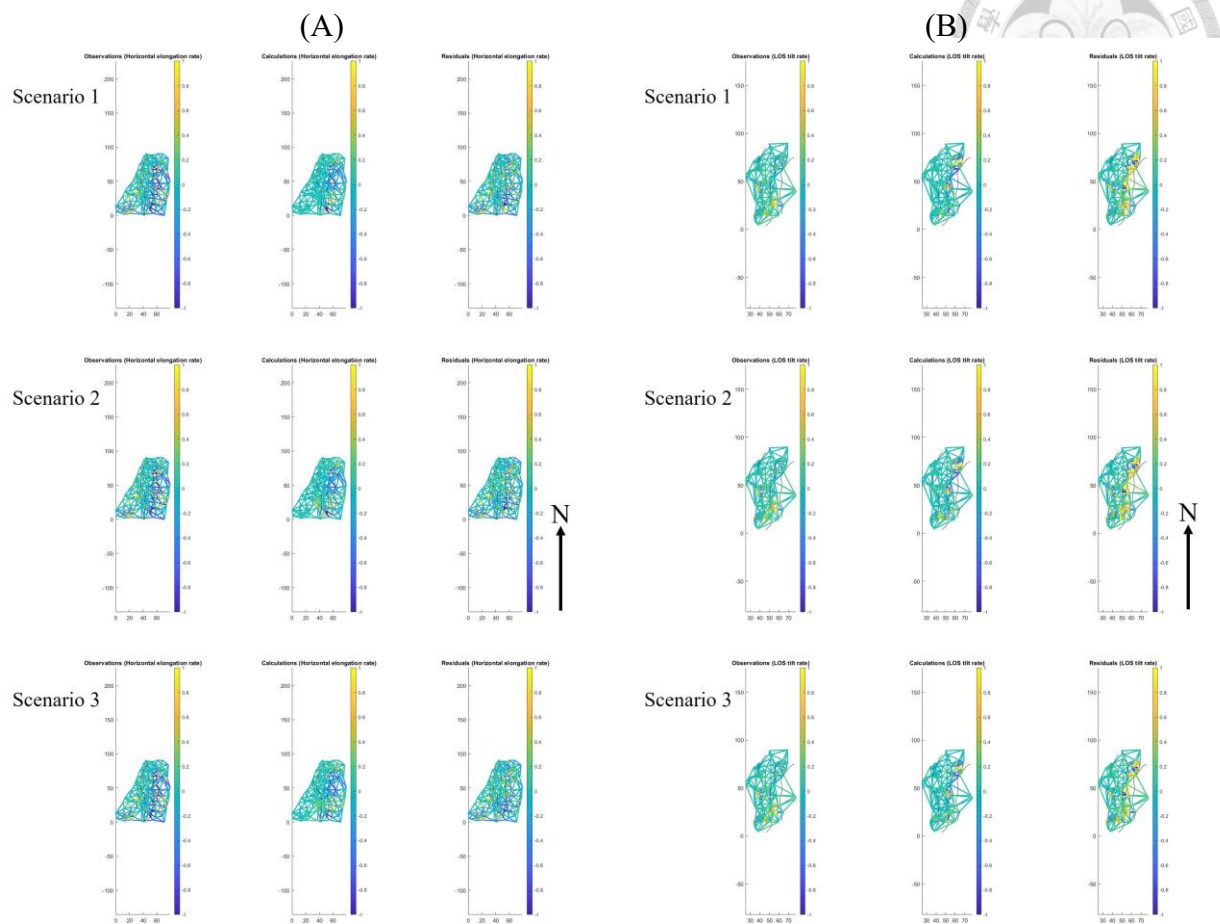


**Figure A9** The 3-dimensional model misfits of the three scenarios for horizontal and LOS input data.

(A) Horizontal model misfits. (B) LOS model misfits.

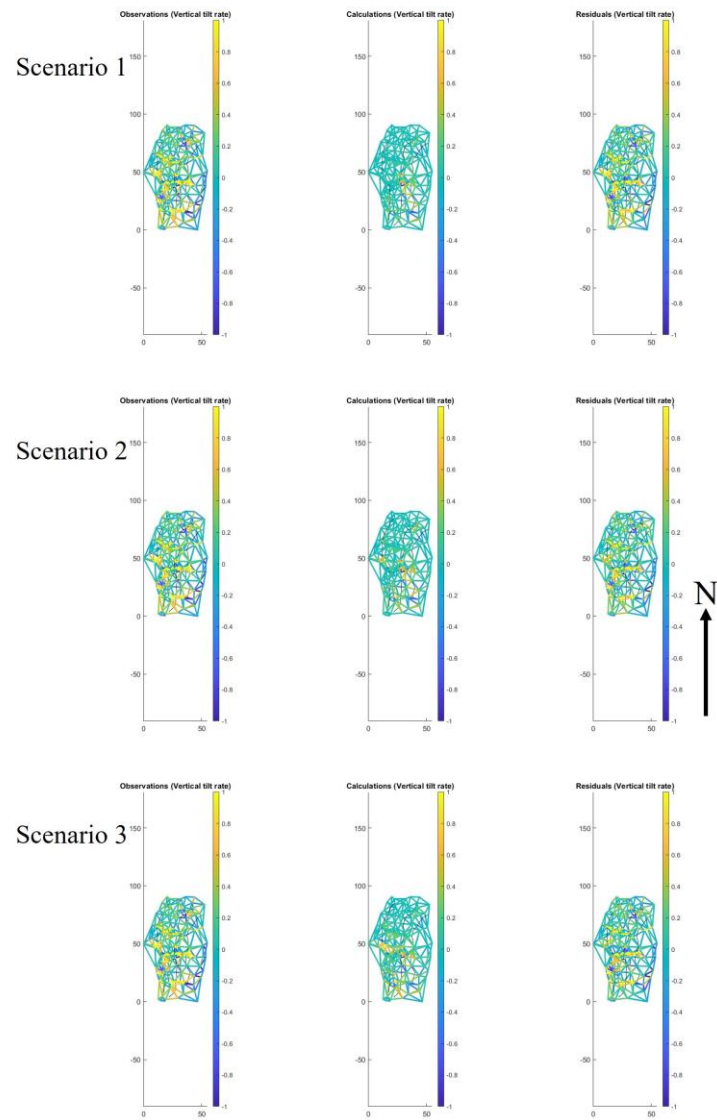


**Figure A10** The 3-dimensional model misfits of the three scenarios for only vertical input data.

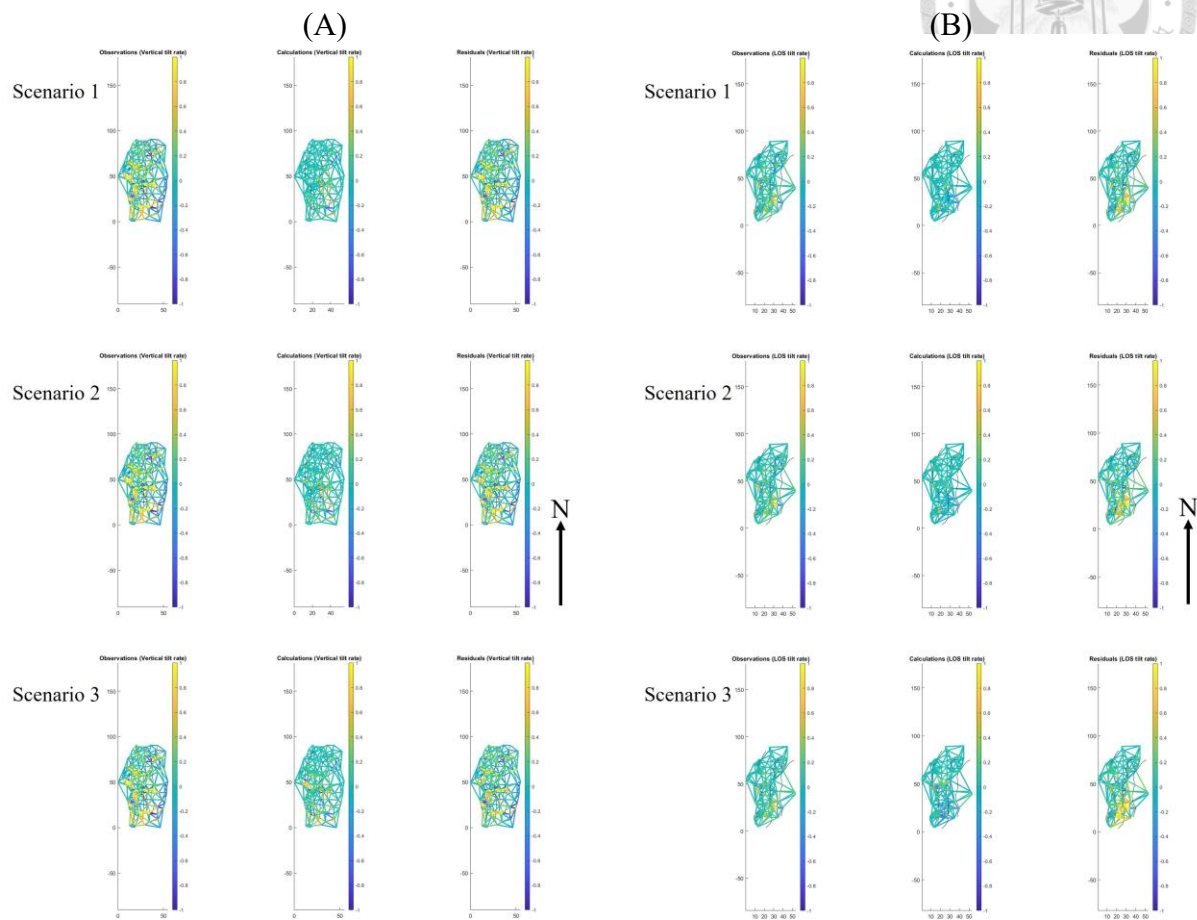


**Figure A11** The 3-dimensional model misfits of the three scenarios for vertical and LOS input data.  
 (A) Vertical model misfits. (B) LOS model misfits.