



FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

The coupling evolution of seismic faults in the eastern margin of the Bayan Har block before and after three $\geq M7.0$ earthquakes

Junyi Wang^a (PhD), Caijun Xu^{a,b,c,*}, Xiaohang Wang^a, Xiong Zhao^a, Kefeng He^a

- a. *School of Geodesy and Geomatics, Wuhan University, Wuhan 430079, China*
- b. *Key Laboratory of Geospace Environment and Geodesy, Ministry of Education, Wuhan University, Wuhan 430079, China*
- c. *Key Laboratory of Geophysical Geodesy, Ministry of Natural Resources, Wuhan 430079, China*

Email: jywang@whu.edu.cn

ORGANISED BY



PLATINUM SPONSORS





FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

1. Introduction

2. Method

3. Results

4. Conclusion

ORGANISED BY



PLATINUM SPONSORS



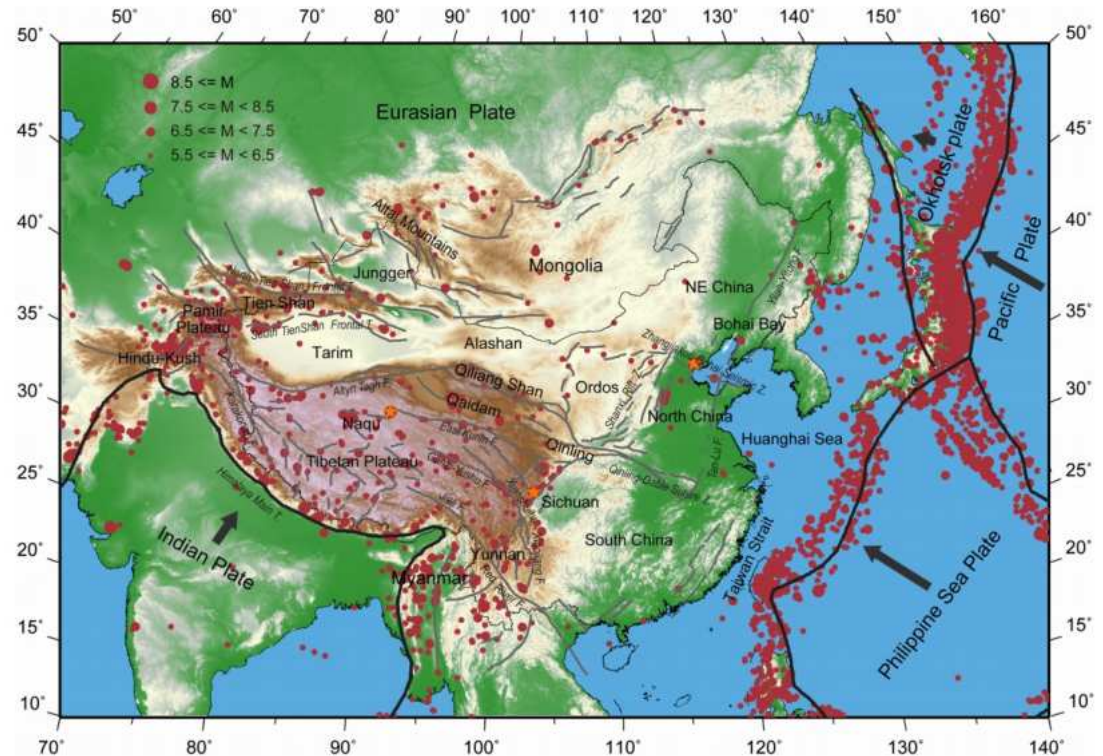


FIG Working Week 2024

19-24 May

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

1.1 Tectonic setting and Seismic hazard in China



Wang et al., 2020

- The northward indentation of the Indian plate into the Asia continent caused **widespread deformation in faults**
- **~ 800 earthquakes** ($\geq M6$) caused the death of **~550 thousand** since the 21st
- Understanding the **crustal deformation** processes and mechanisms is therefore important



FIG Working Week 2024

19-24 May

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

1.2 GNSS monitoring crustal deformation

All-day, High precision, and Global scale



Global Navigation Satellite System

BDS

GPS

GLONASS

Galileo

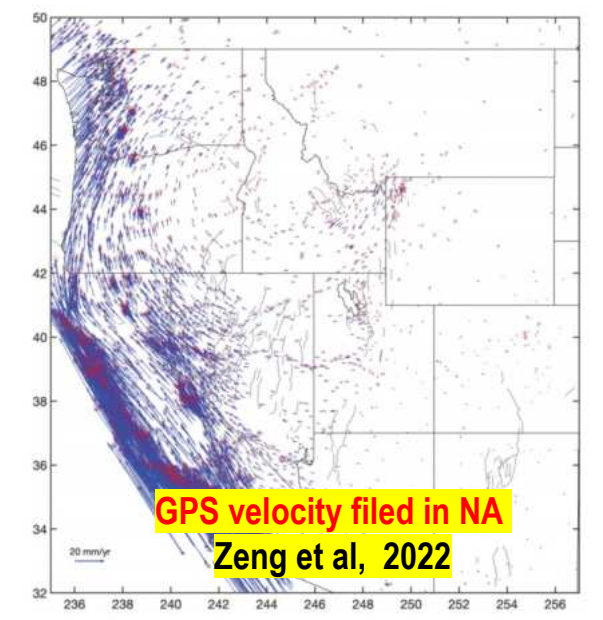
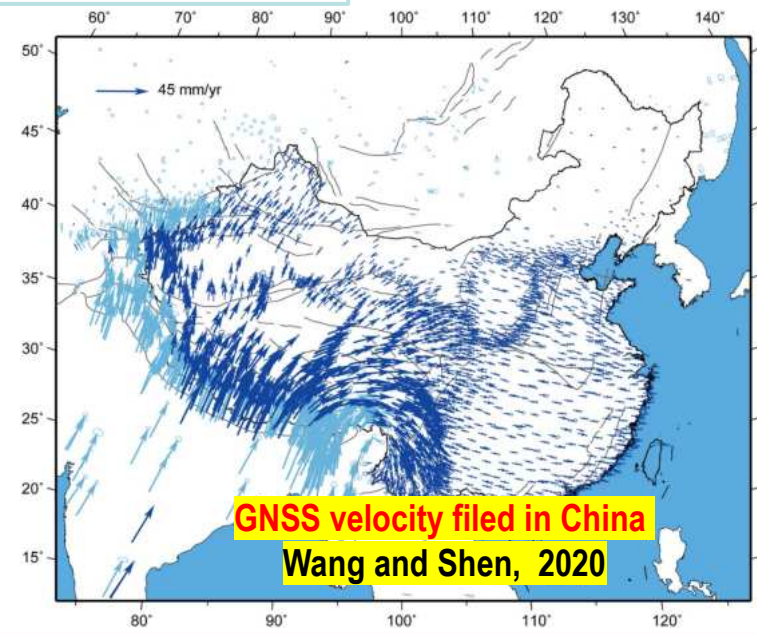
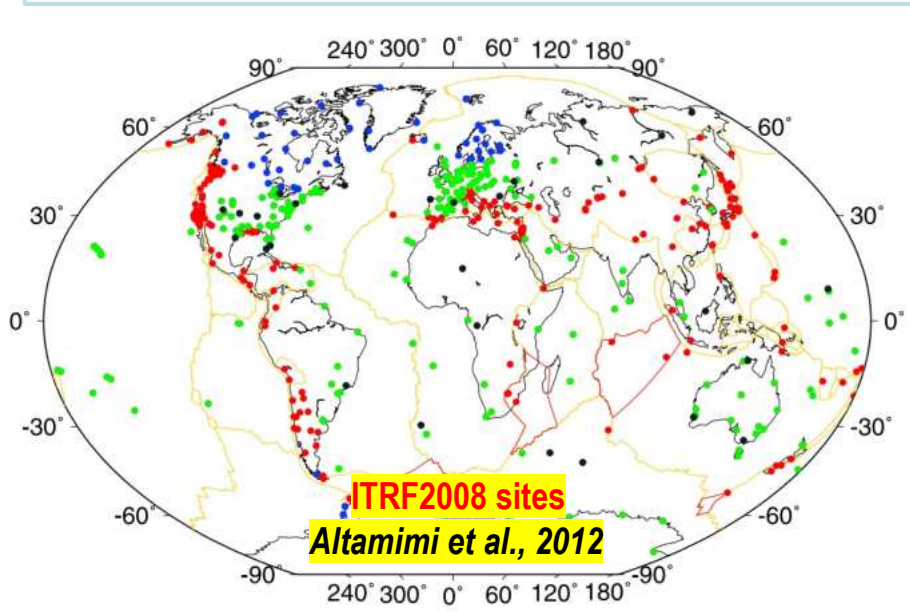




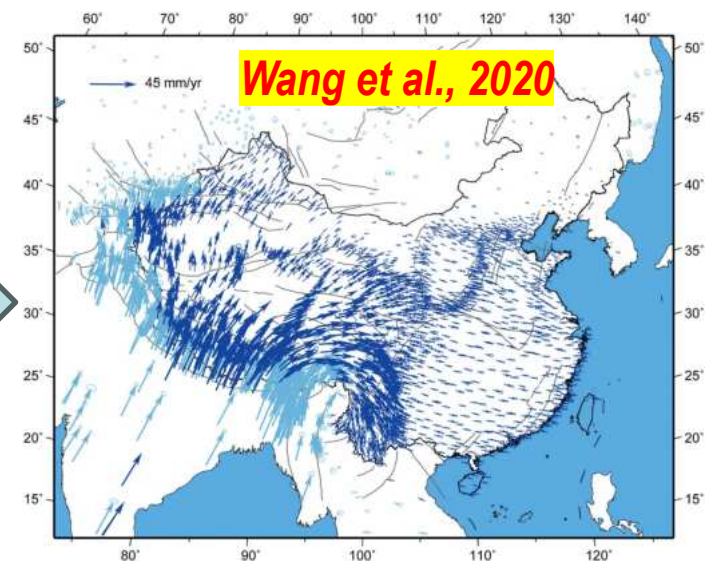
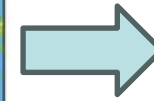
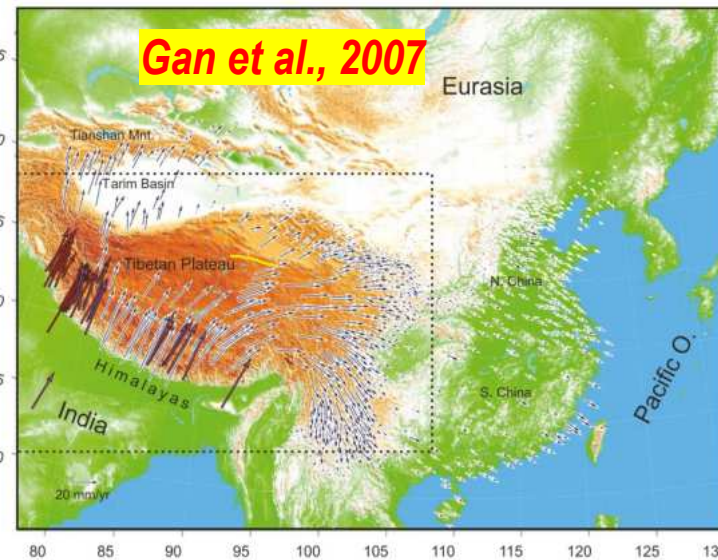
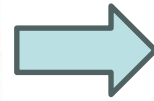
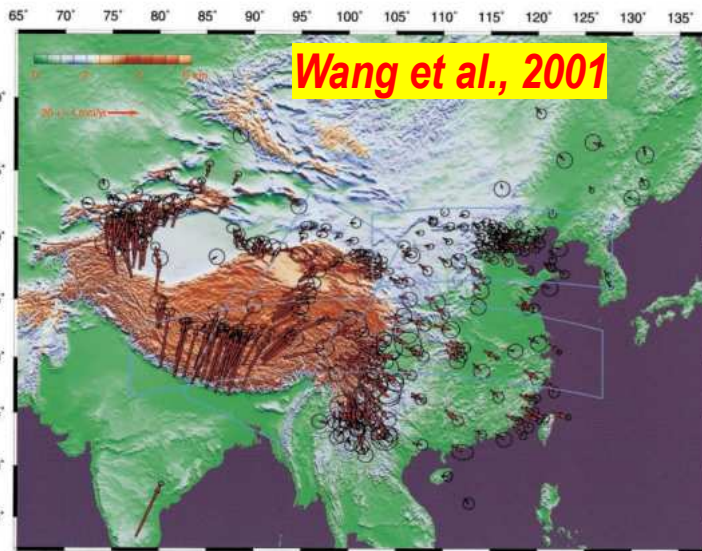
FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

1.2 Development of GNSS stations and network in China



- The Crustal Movement Observation network of China (CMONOC) includes **27** base stations, **55** basic stations and more than **1000** regional stations from 1998 till now (<http://data.earthquake.cn>).

ORGANISED BY



PLATINUM SPONSORS





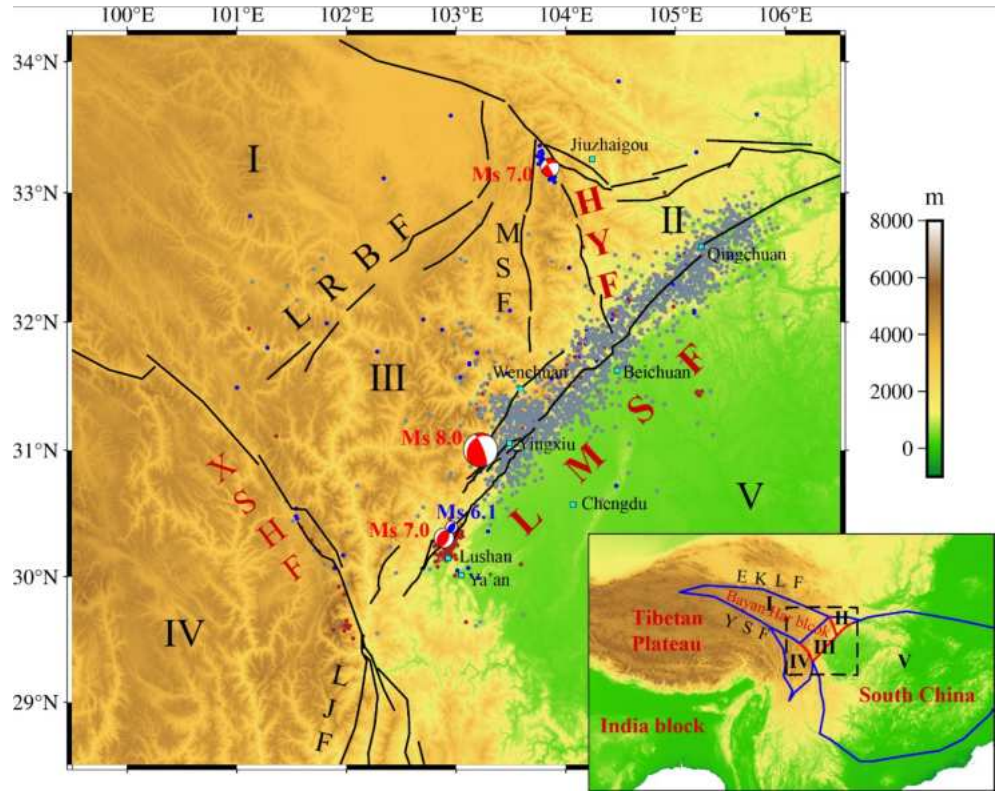
FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

1.3 Background of this study area



The Bayan Har block is an important area for the **eastward extrusion** of the Tibetan Plateau; However, this movement is blocked by the stable South China Block.

The M8.0 Wenchuan earthquake on May 12, 2008 and the M7.0 Lushan earthquake on April 20, 2013 occurred in the **Longmenshan fault (LMSF) zone**

The M7.0 Jiuzhaigou earthquake on August 8, 2017 occurred in the **Huya fault (HYF) zone**



FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

1.4 Contents of this study

Establish a **3-D model of multi-faults system** in the eastern margin of the Bayan Har block.

Study the **spatiotemporal evolution characteristics of deformation** of the LMSF and HYF quantitatively using four periods GPS velocity fields.

The effects of the three earthquakes on the regional block motion and activities of different segments of seismic faults.

ORGANISED BY



PLATINUM SPONSORS





FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

1. Introduction

2. Method

3. Results

4. Conclusion

ORGANISED BY



PLATINUM SPONSORS





FIG Working Week 2024

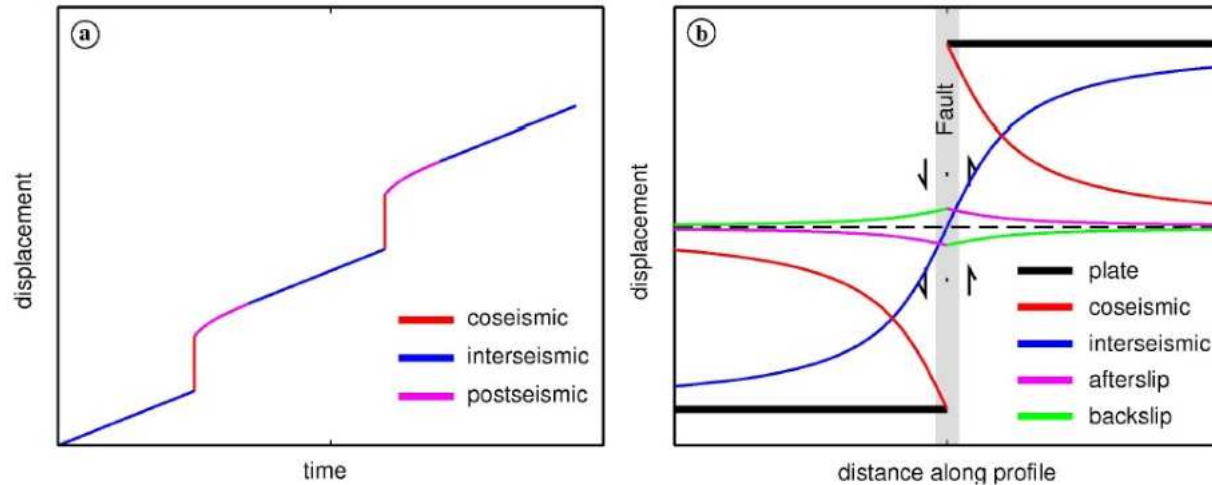
19-24 May

Accra, Ghana

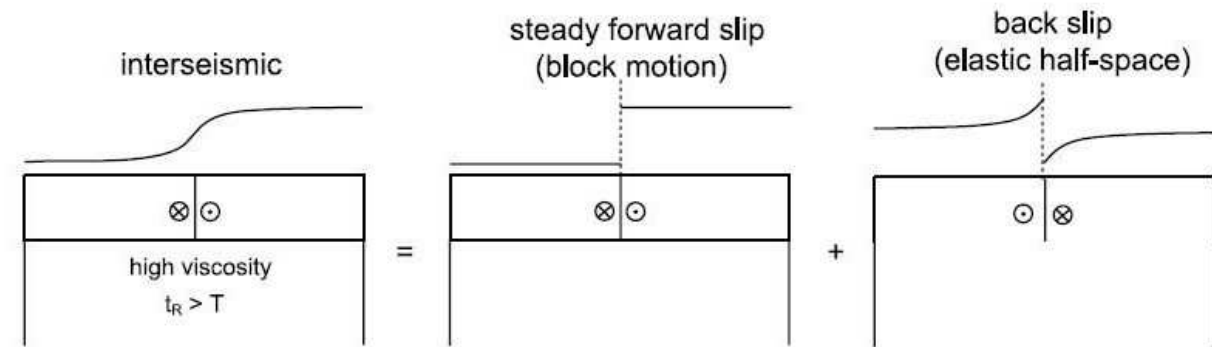
Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

2.1 Theoretical basis

Elastic-rebound theory (Thatcher, 1986)



2-D Interseismic model (Savage, 1983)



- The energy accumulated in the fault during the **interseismic period** is released during the **coseismic**.
- The interseismic deformation is mainly caused by the **block motion** and **fault locking in fault**.



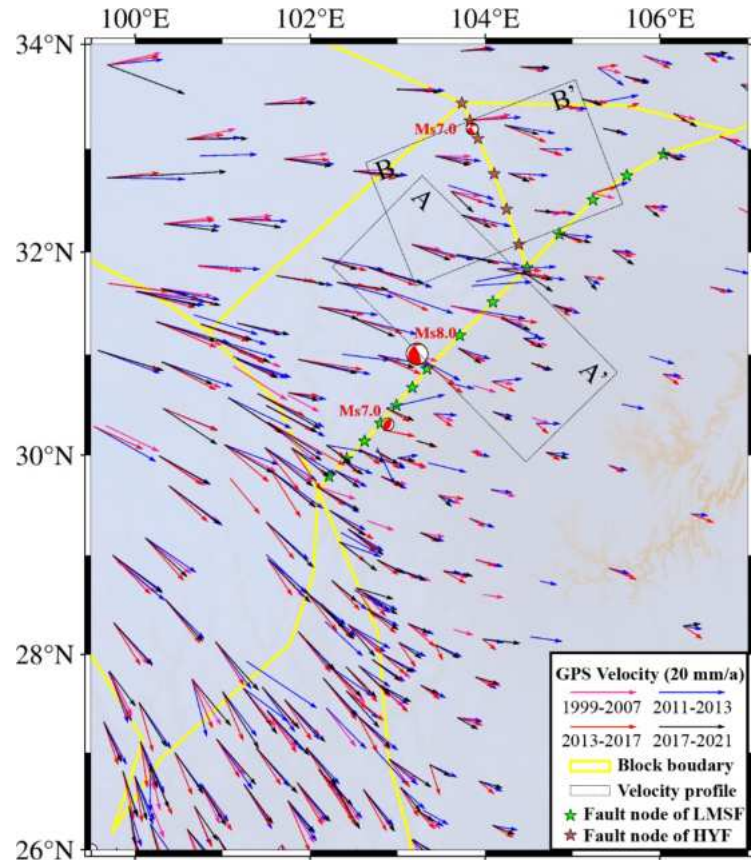
FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

2.2 GNSS velocity fields



- Spanning the 1999-2007, 2011-2013, 2013-2017, and 2017-2021 periods from the CMONOC.
- Using GAMIT/GLOBK to estimate four GPS velocity fields under the ITRF2014.
- The displacement offsets due to moderate-to-large earthquakes (e.g., the 2013 M7.0 Lushan earthquake and 2017 M7.0 Jiuzhaigou earthquake) have been deducted.

ORGANISED BY



PLATINUM SPONSORS





FIG Working Week 2024

19-24 May

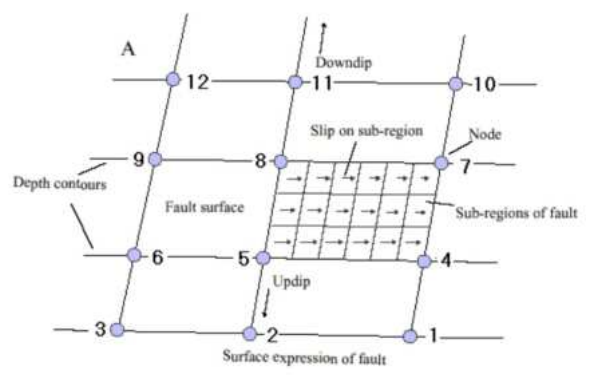
Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

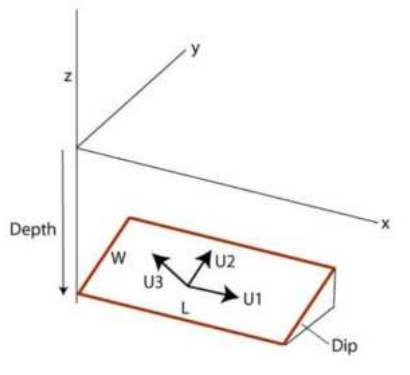
2.3 3-D elastic block model

$$V_i(X) = \sum_{b=1}^B H(X \in \Delta_b) [{}_R \Omega_b \times X] \cdot i + \dot{\epsilon}_{ii} \Delta X_i + \dot{\epsilon}_{ij} \Delta X_j$$

$$- \sum_{k=1}^F \sum_{n=1}^{N_k} \sum_{m=1}^2 \phi_{nk} G_{im}(X, X_{nk}) [{}_h \Omega_f \times X_{nk}] \cdot m$$



Indexing of nodes on the fault surface



Okada rectangular fault plane

- **TDEFNODE** is a Fortran program to model elastic lithospheric block rotations and internal strains, locking on block-bounding faults.
- Interseismic locking (backslip) is applied along faults that separate blocks, based on the routines of Okada (1985)
- The parameters are estimated by **simulated annealing** or **grid search**.

<https://robmccaffrey.github.io/TDEFNODE/TDEFNODE.html>



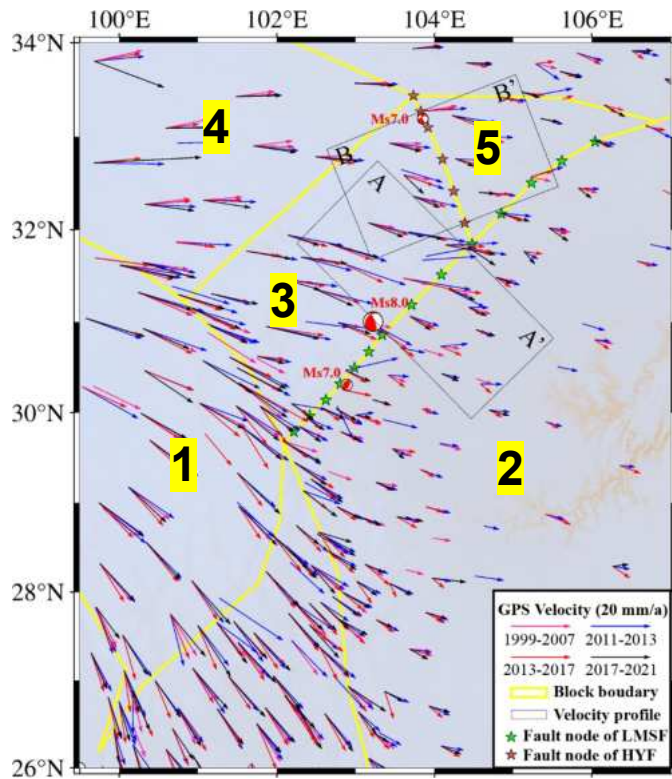
FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

2.4 Modeling Strategies



The study area can be divided into **five tectonic blocks**.

Divide the LMSF into **six segments** along strike and the HYF into **four segments** along strike.

Modeled the XSHF and HYF as **80° southwestward** dipping faults and A fault coupling depth of **20 km** is set for the XSHF and HYF.

ORGANISED BY



PLATINUM SPONSORS





FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

1. Introduction
2. Method
3. Results
4. Conclusion

ORGANISED BY



PLATINUM SPONSORS





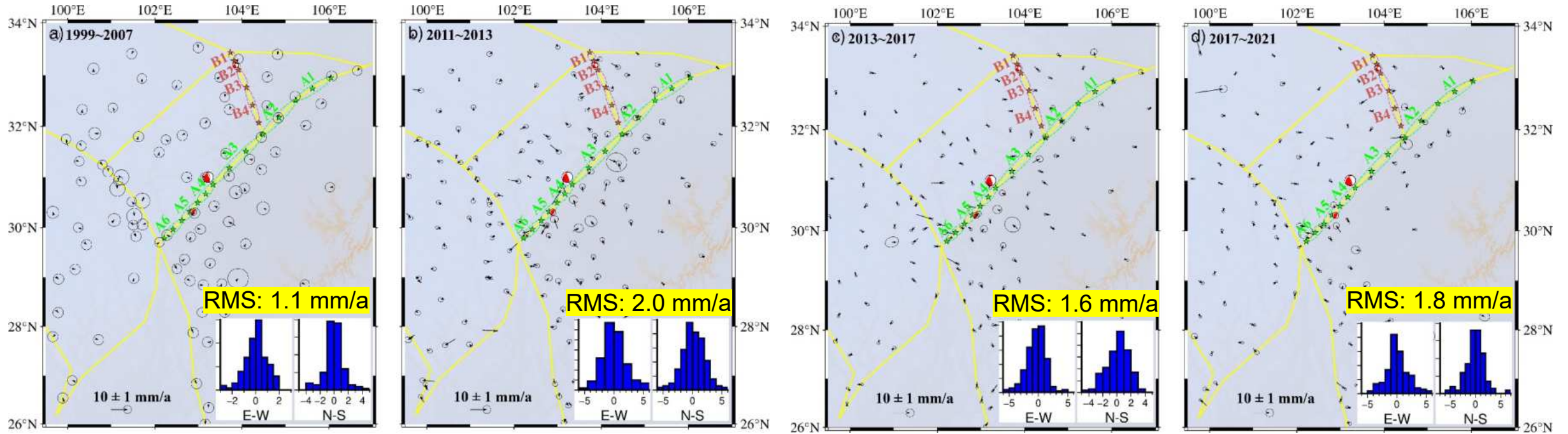
FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

3.1 Model fitting



- Our model fits each GPS velocity field well.



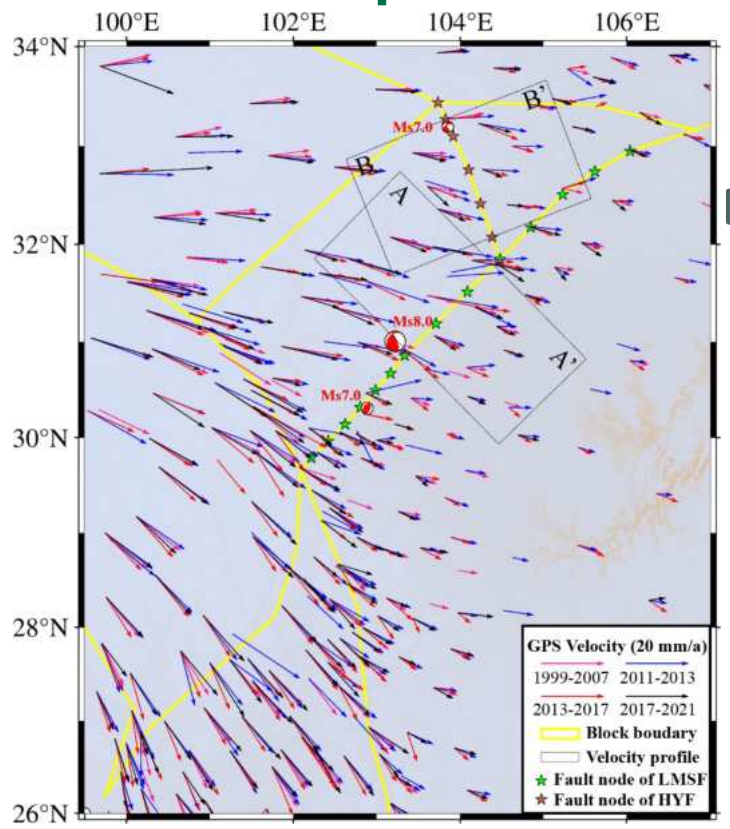
FIG Working Week 2024

19-24 May

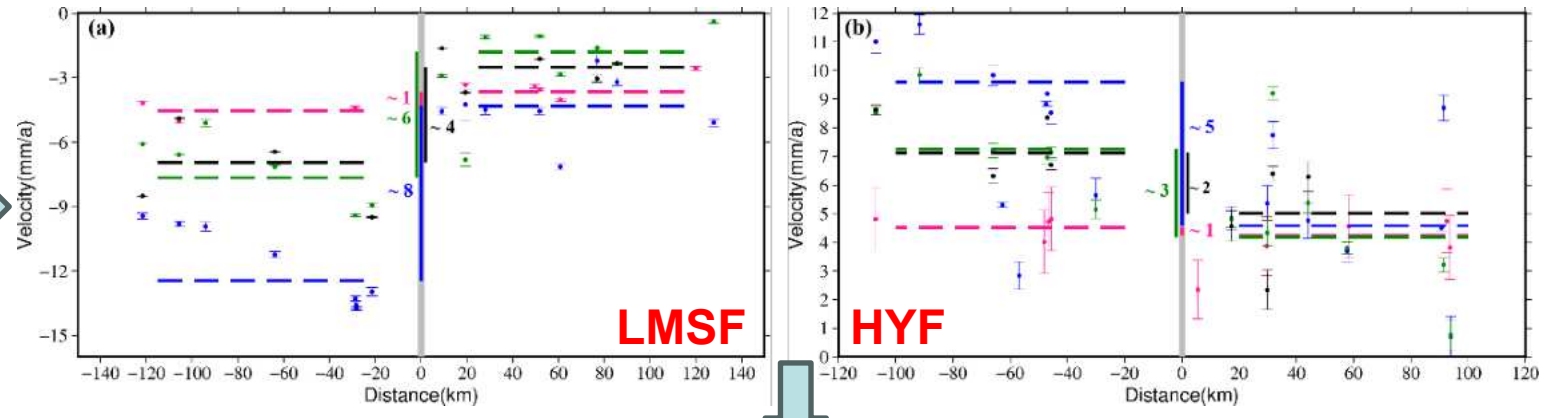
Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

3.2 Fault slip rates



GPS Velocity Profiles



Fault slip rates derived from our model

	LMSF		HYF
	Velocity parallel to fault	Velocity normal to fault	Velocity parallel to fault
1999-2007	~ 1.5	~ 0.1	~ -0.5
2011-2013	~ 10.0	~ 3.5	~ -5.9
2013-2017	~ 4.5	~ 4.1	~ -3.1
2017-2021	~ 4.0	~ 2.1	~ -2.9



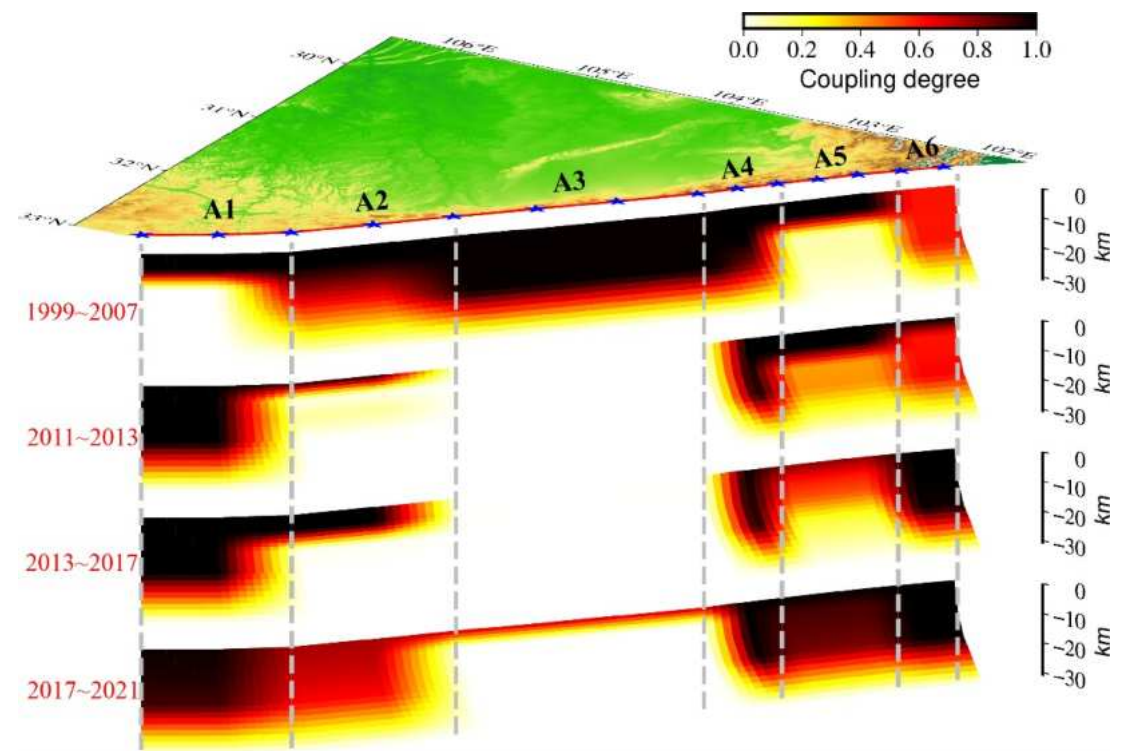
FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

3.3 Coupling degree of the LMSF



From 1999-2007, the rupture segments (A2, A3) of the 2008 Wenchuan earthquake in the LMSF were strongly coupled.

From 2011-2013, the A2 and A3 were dramatically decoupled and the rupture segments (A5) of the 2013 Lushan earthquake indicated an enhanced coupling.

From 2013-2017, The fault coupling of A5 was reduced and the coupling degree of A2 increased.

From 2017-2021, The fault coupling of A2 continues to enhance and begins to extend to its southwestern segment, A3. The coupling degree of A5 also increase.



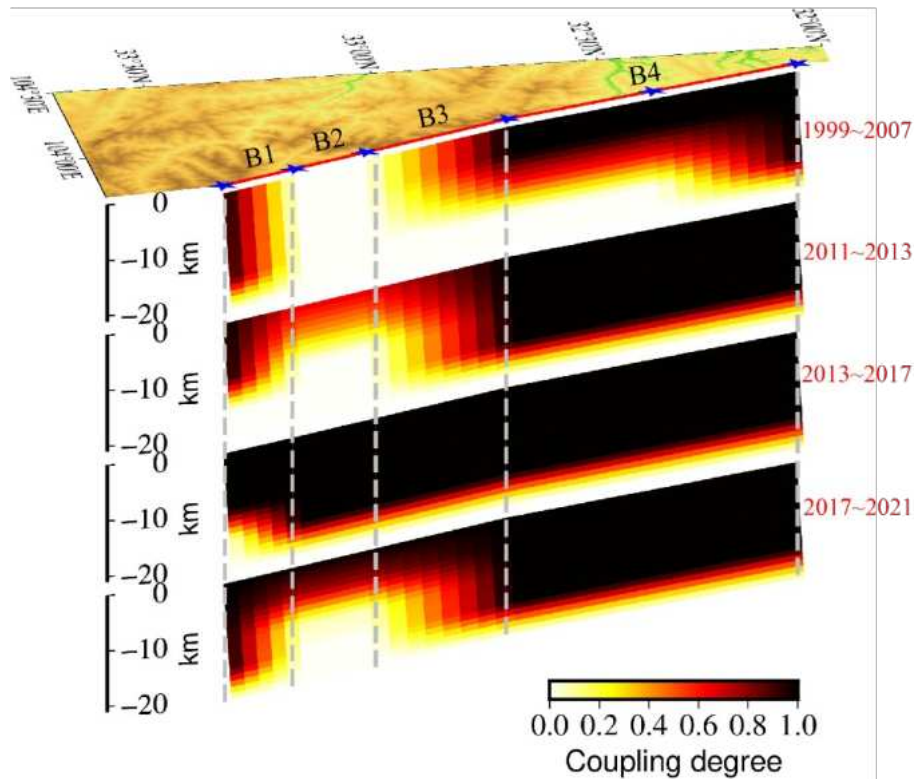
FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

3.4 Coupling degree of the HYF



From 1999-2007, the rupture segment of the 2017 Jiuzhaigou earthquake (B2) was **creep**.

From 2011-2013, the coupling degree of the HYF (B2, B3 and B4) **increased**.

From 2013-2017, the rupture segment of the 2017 Jiuzhaigou earthquake (B2) was **strongly locked**.

From 2017-2021, B2 has been **decoupled** sharply due to the 2017 Jiuzhaigou earthquake.



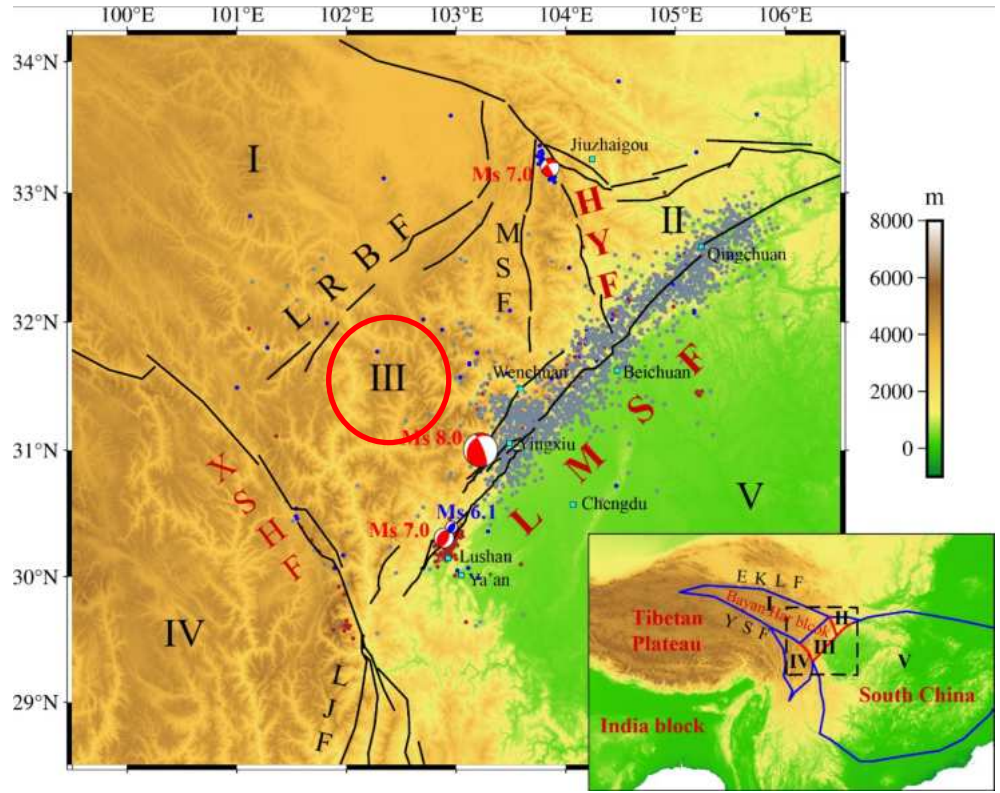
FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

3.5 Movement rates of the Longmenshan block



Period	Block velocity at block centroid (mm/a)	
	East-West (Positive is east)	North-South (Positive is north)
1999~2007	9.5	-1.7
2011~2013	16.2	-2.2
2013~2017	12.5	-3.7
2017~2021	12.6	-3.7

- The movement of block will be affected by the coupling state of its boundary faults.



FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

1. Introduction

2. Method

3. Results

4. Conclusion

ORGANISED BY



PLATINUM SPONSORS





FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

4.1 Conclusion

- Obtain the **movement characteristics** of the Longmenshan block before and after three earthquakes.
- Identify the spatiotemporal evolution characteristics of **fault coupling** of LMSF and HYF.
- Infer the segments of the LMSF zone (A1, A2, A5 and A6) and the southern HYF (B4) have a **high seismic risk**.

ORGANISED BY



PLATINUM SPONSORS





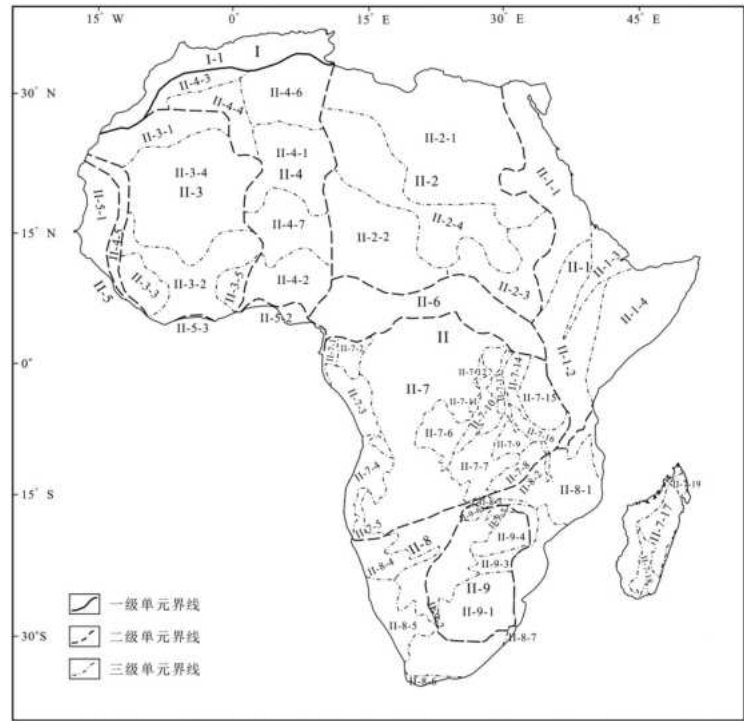
FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

4.2 Seismic hazard on the African



Tectonic units of African
Hu et al., 2022

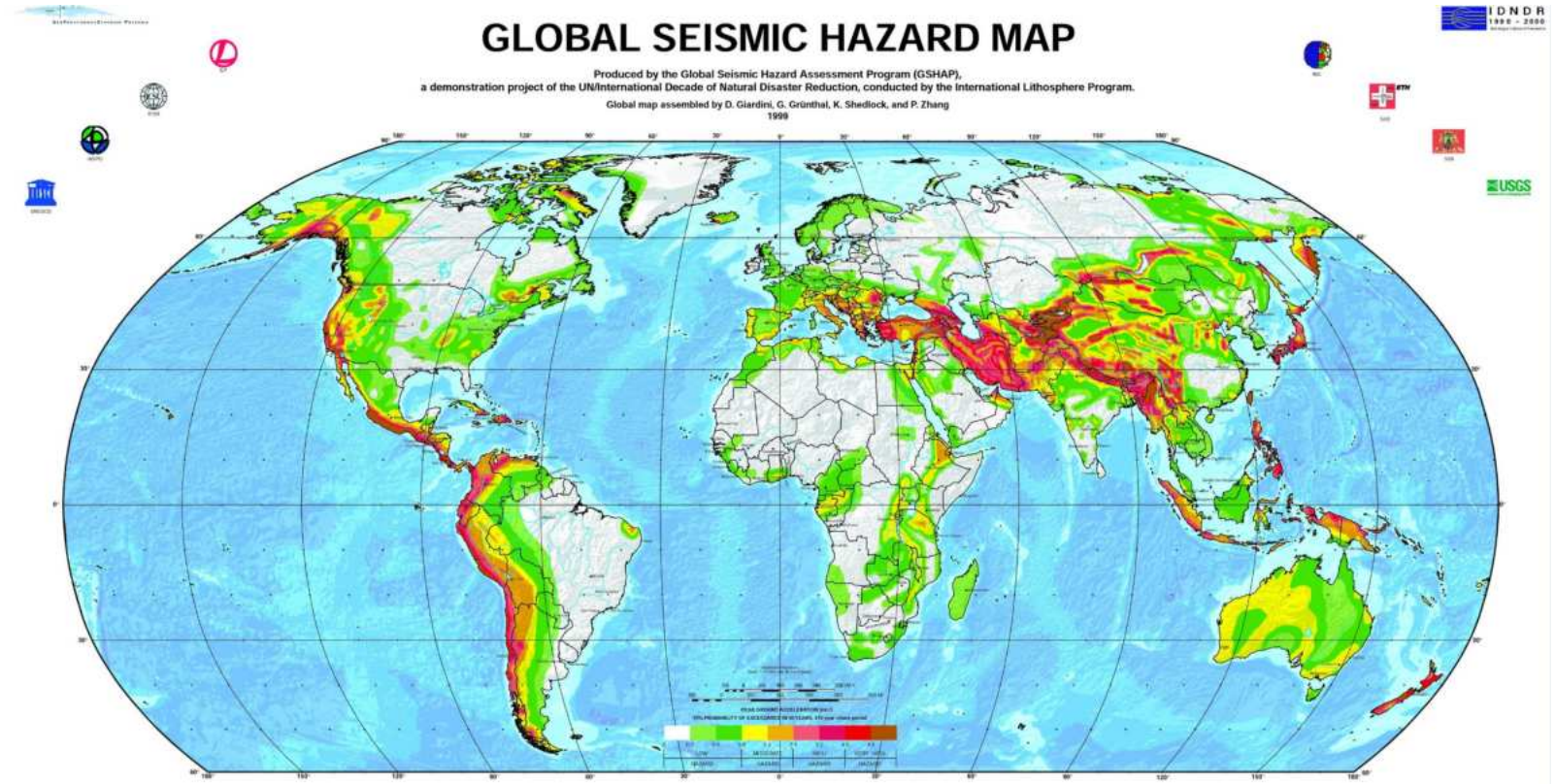




FIG Working Week 2024

19-24 May

Accra, Ghana

Your World, Our World:
Resilient Environment
and Sustainable
Resource Management
for All

SUSTAINABLE DEVELOPMENT GOALS

International Federation of Surveyors supports the Sustainable Development Goals

Commission 5

GNSS CORS Reference Stations and Networks

Serving Society for the Benefit of People and Planet



Email: jywang@whu.edu.cn

