SEISMICITY AND ACTIVE FAULTS IN MONGOLIA: ANALYSIS OF MICRO SEISMICITY

Ganzorig D[1]., Ulziibat M[1]., Yann Klinger[2]

ganzorig@iag.ac.mn., ulzibat@iag.ac.mn., klinger@ipgp.fr

[1]Institute of Astronomy and Geophysics, MAS, Mongolia
[2]Institut de Physique du Globe de Paris, France

ULAANBAATAR
2025.08.11

Overview

- Tectonic Context and Seismicity of Mongolia
- Characteristic of Large fault and Seismicity of Western Mongolia
- Recent Large HÖVSGÖL Lake Earthquake: seismically analysis
- Relocation of Micro-Seismicity events in active regions (Bulnay-Tsetserleg and HÖVSGÖL Lake region)

Dataset and Methods

1. *Seismic networks & Waveform dataset*
2. *GT criteria for event selection*
3. *Double-Difference Algorithm and Cross-correlation*

- CONCLUSION

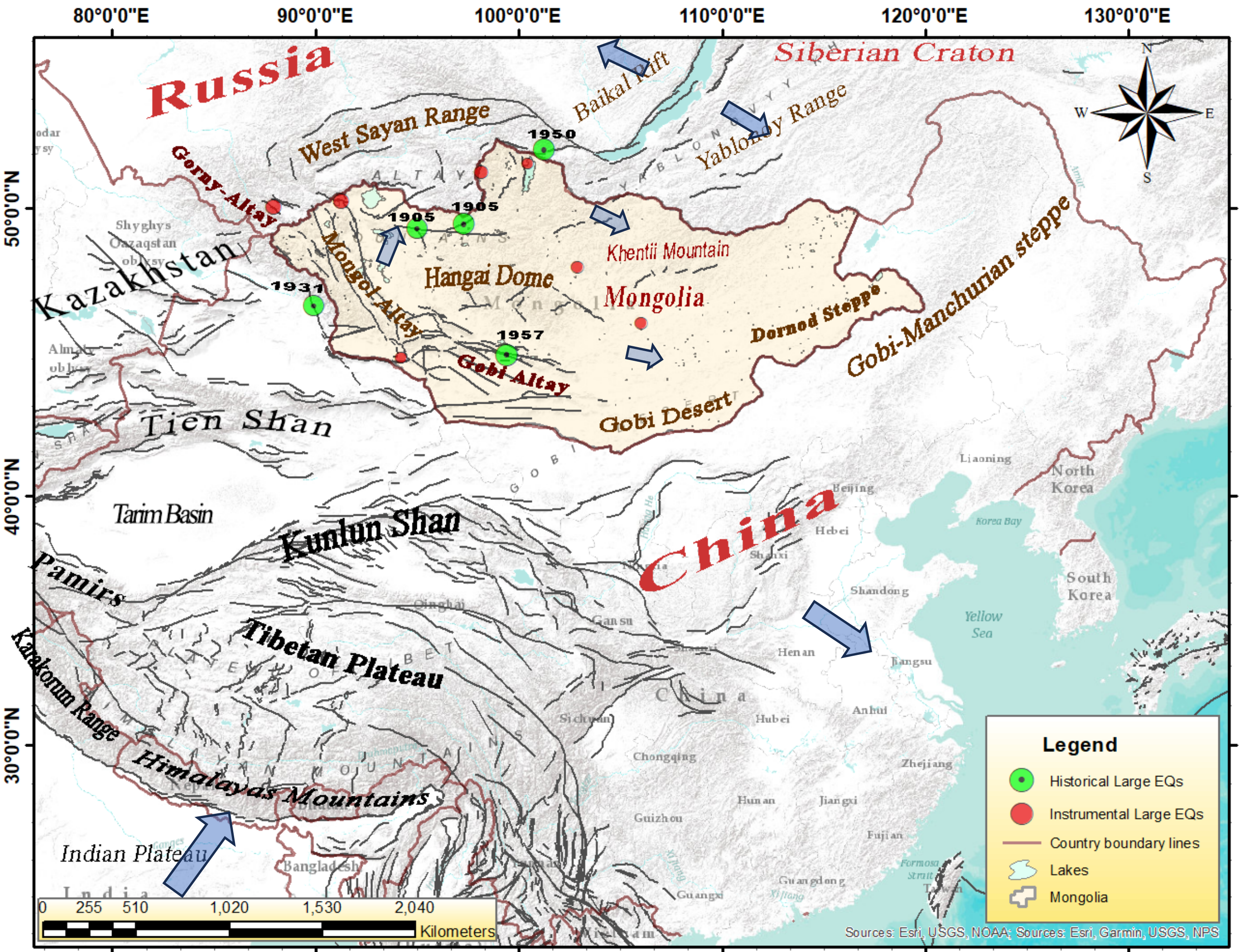


Figure1 - Simple schematic map of regional tectonics and large faults in Eastern Asia. [Tapponnier et al., 1982; Styron. R, & Marco. P, 2020]

The Central Asian deformation domain has been described from several different models and ideas that were advanced over the prior century by many scientists and numerous studies by different researchers explain that the active deformation and active fault systems of **western and central Mongolia are dominantly** the results of the India-Eurasia collision.

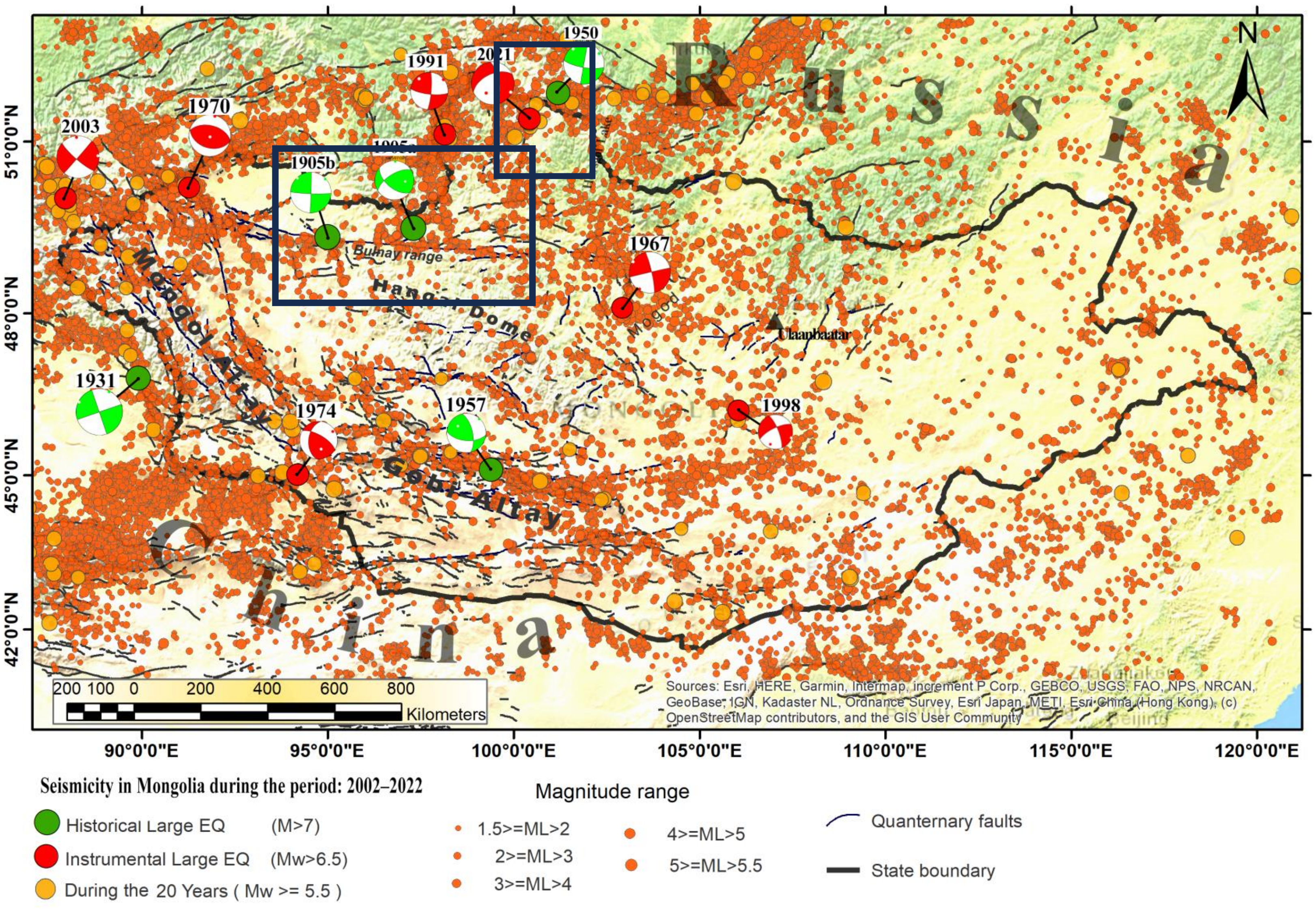


Figure 2 - Seismicity map of Mongolia during the period 2002-2022.

Since 1900, occurred several earthquakes with magnitude M ≥7, four of them with magnitude M ≥ 8 and greater which have occurred in Tsetserleg (1905 June 09), Bulnay (1905 June 23) southern Fu-Yun (1931 August 10) and Gobi-Altay (1957 December 04).

These large earthquakes are associated with coseismic displacement along the faults between 5 and 12 meters and ruptured three major fault systems for about ~190 km and ~455 km (Tsetserleg and Bulnay), ~180 km (Fu-Yun) and 180km and ~270 km (Gobi-Altay)

[Baljinnyam et al., 1993, Schlupp, 1996; Schlupp and Cisternas,2007; Klinger et al., 2011; Choi et al., 2018].

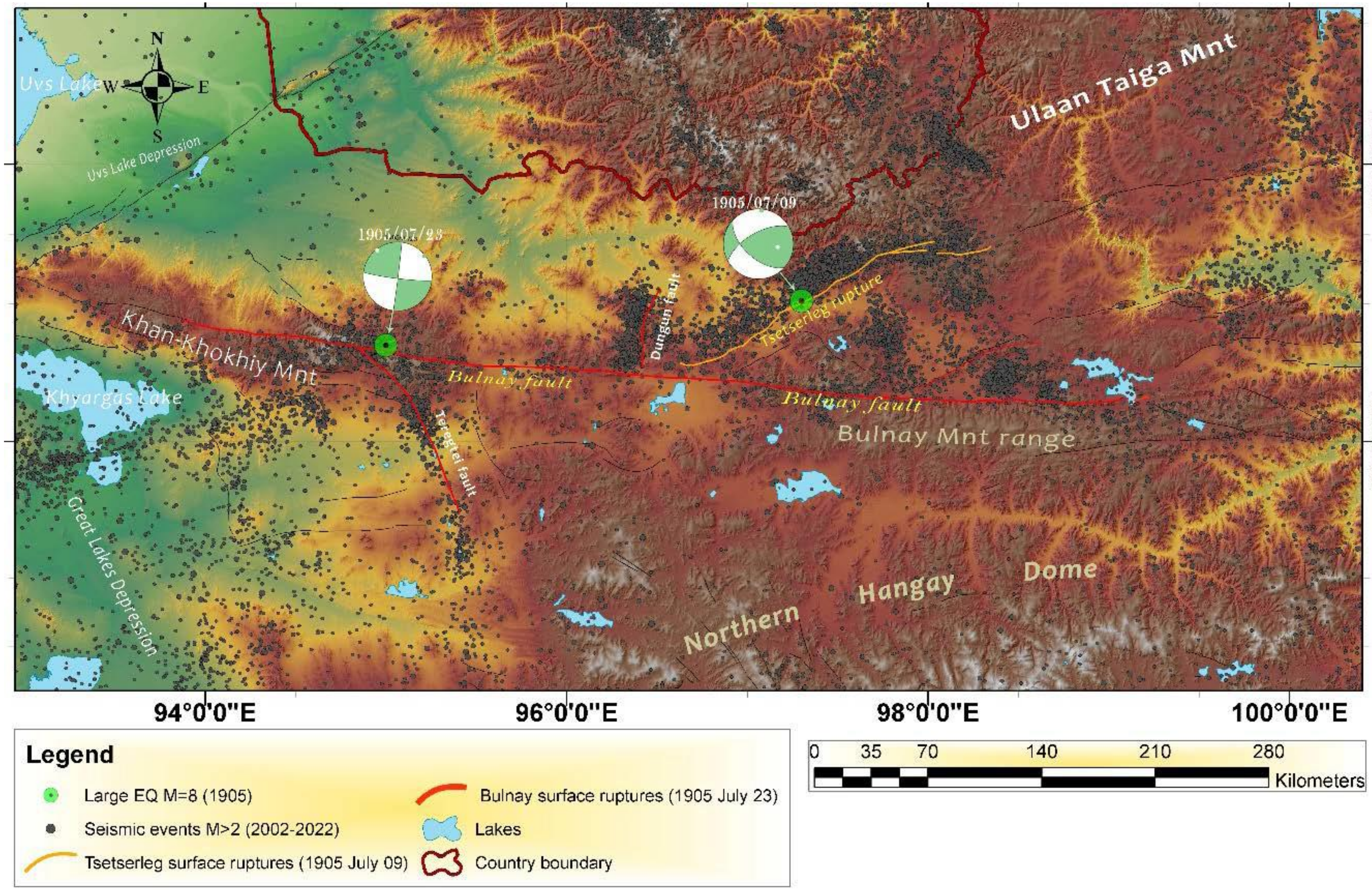


Figure 3 - Topographical and seismicity map around the Bulnay-Tsetserleg fault system.

Tsetserleg earthquake of July 9, 1905, which had a magnitude of Mw ≥ 8. This earthquake produced approximately 130 km of surface ruptures oriented to about N60°, with a left-lateral strike-slip and a reverse component. Fourteen days after, on the 23rd of July 1905, the Bulnay EQ occurred at the intersection of the main left-lateral, strike-slip Bulnay fault and the right-lateral, strike-slip Teregtei fault.

Tsetserleg: Source parameters of strike 238°, dip 64°,slip37° focal depth of 15 km

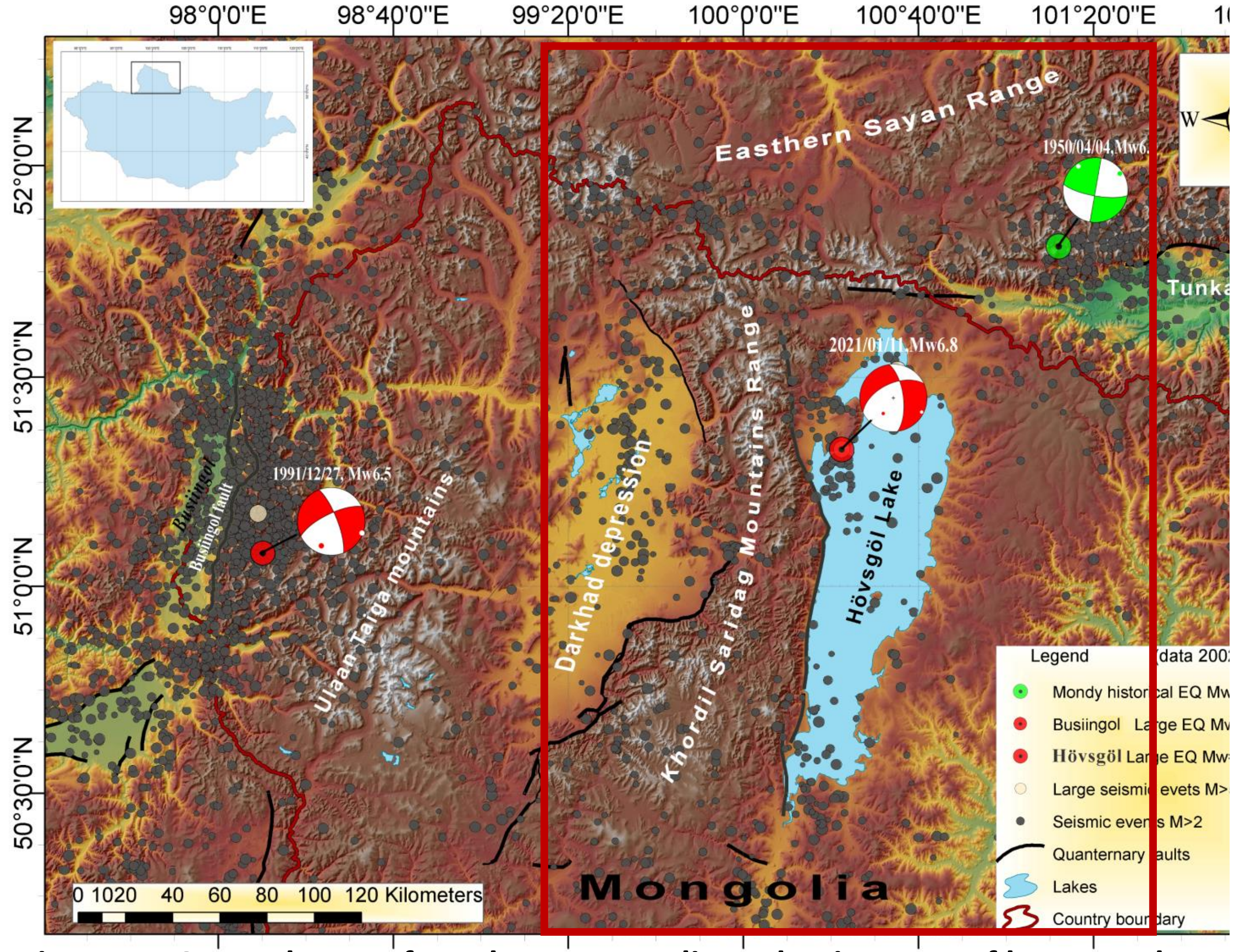
Bulnay: Source parameters of strike 88.4°, dip88.5°, slip 6.4°, and a focal depth of 16.5

[Schlupp and Cisternas, 2007]

THE INTERNATIONAL CO

OF THE

ADVANCES IN A



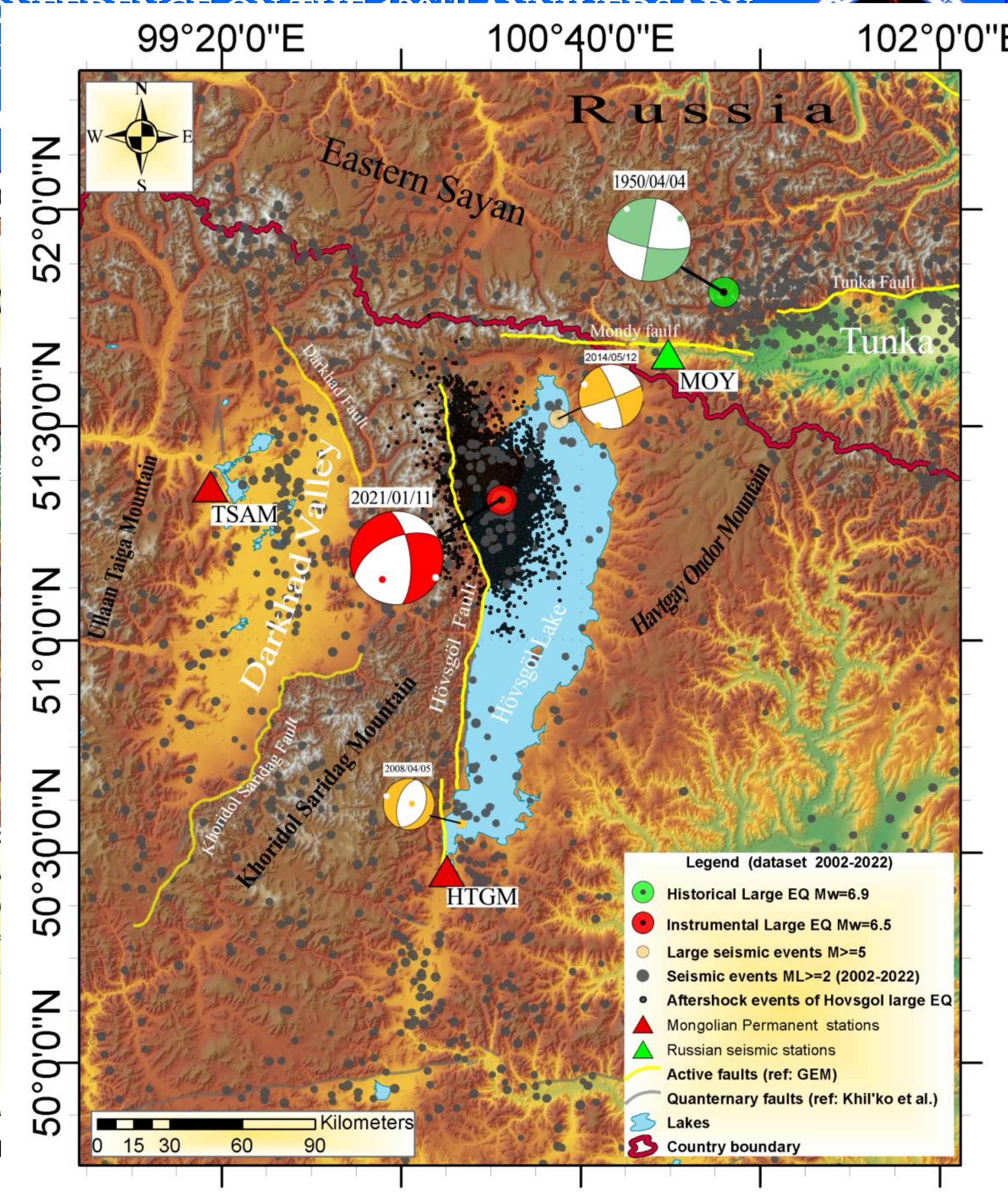
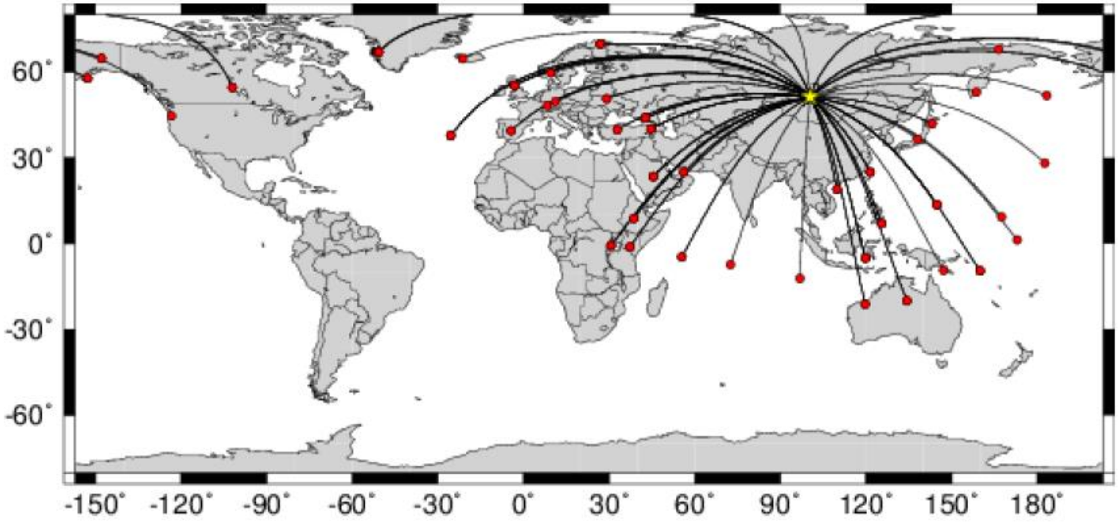
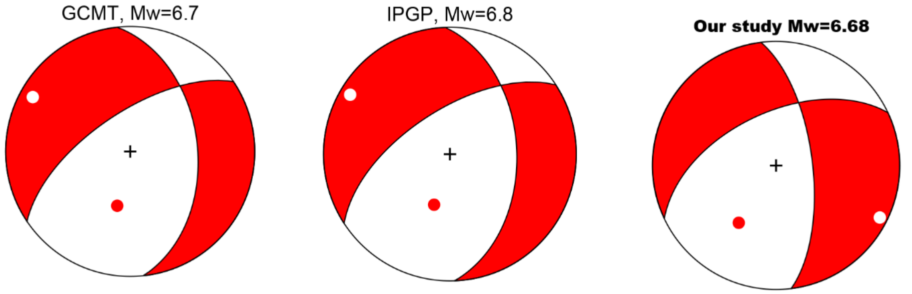


Figure 4 - General map of northern Mongolia and epicenters of large earthqua

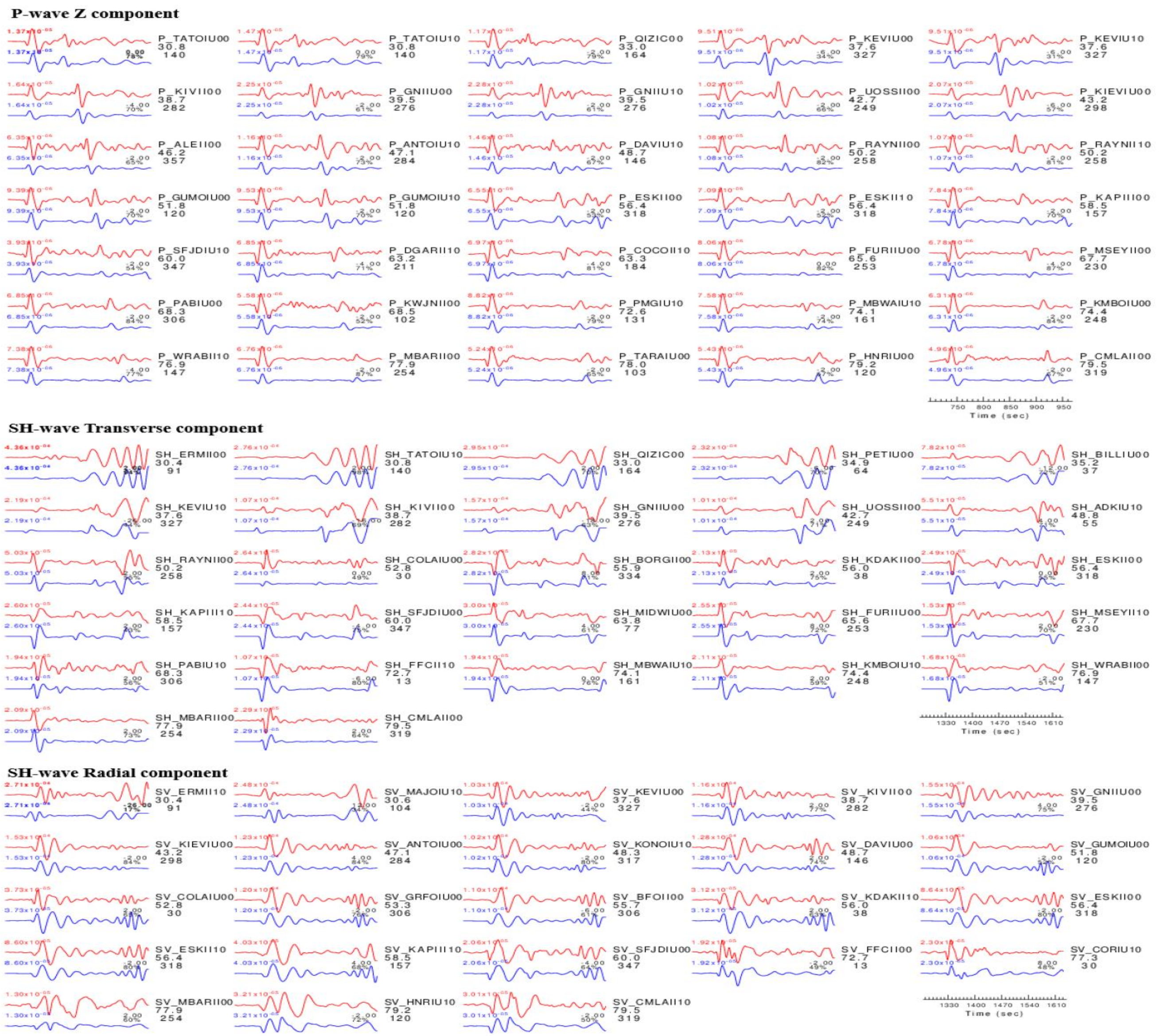
THE INTERNATIONAL CONFERENCE ON THE 120TH ANNIVERSARY OF THE BULNAY EARTHQUAKE: ADVANCES IN ASTRONOMY AND GEOPHYSICS

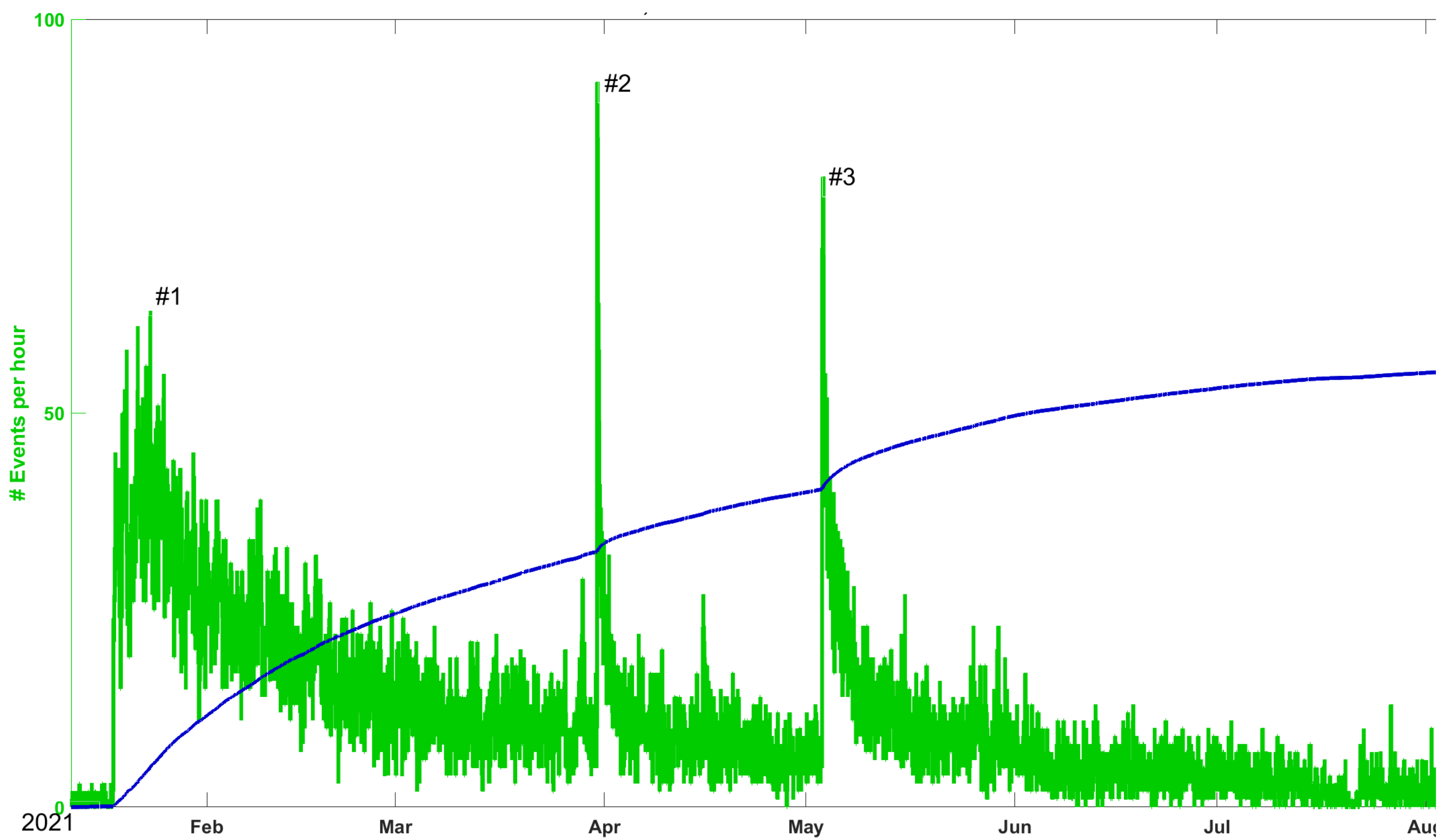




Lat (N)	Lon (E)	Depth(km)	Mw	Strike	Dip	Rake	Data center name
51.310	100.390	14.3	6.8	354	45	-143	GCMT
51.240	100.440	13.0	6.8	358	46	-139	IPGP
51.380	**100.430**	**12.0**	**6.68**	**353**	**57**	**-156**	Our study

Figure5. Focal mechanism solutions [Robert B. Herrmann, 2013].





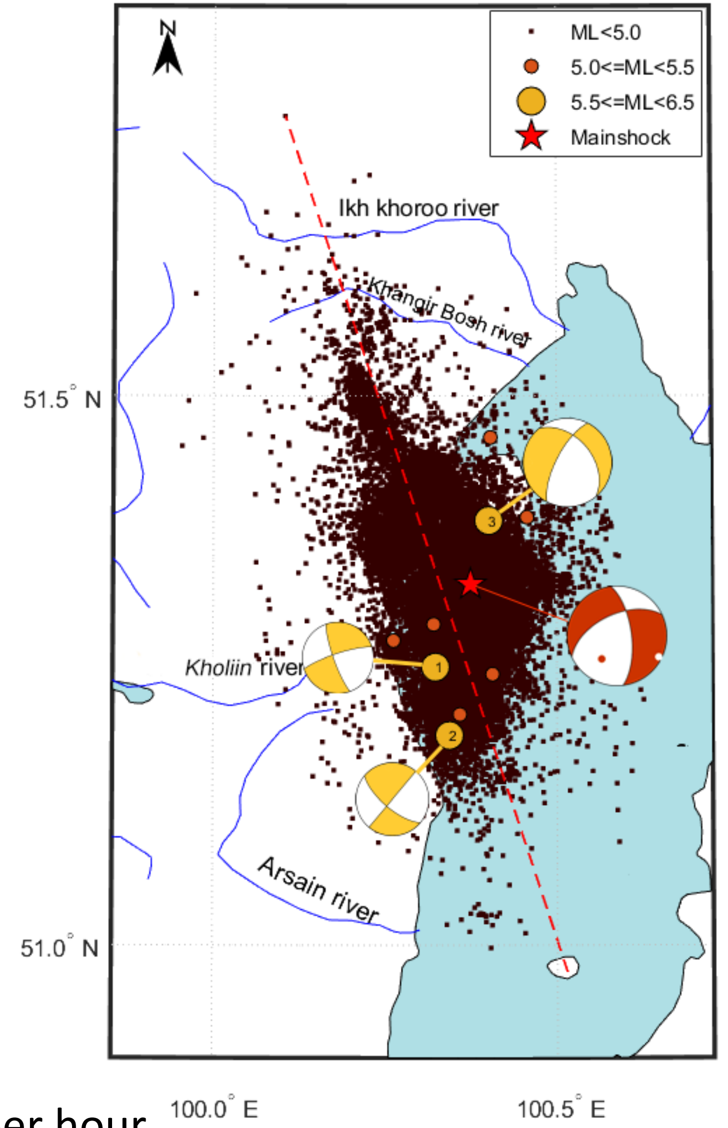
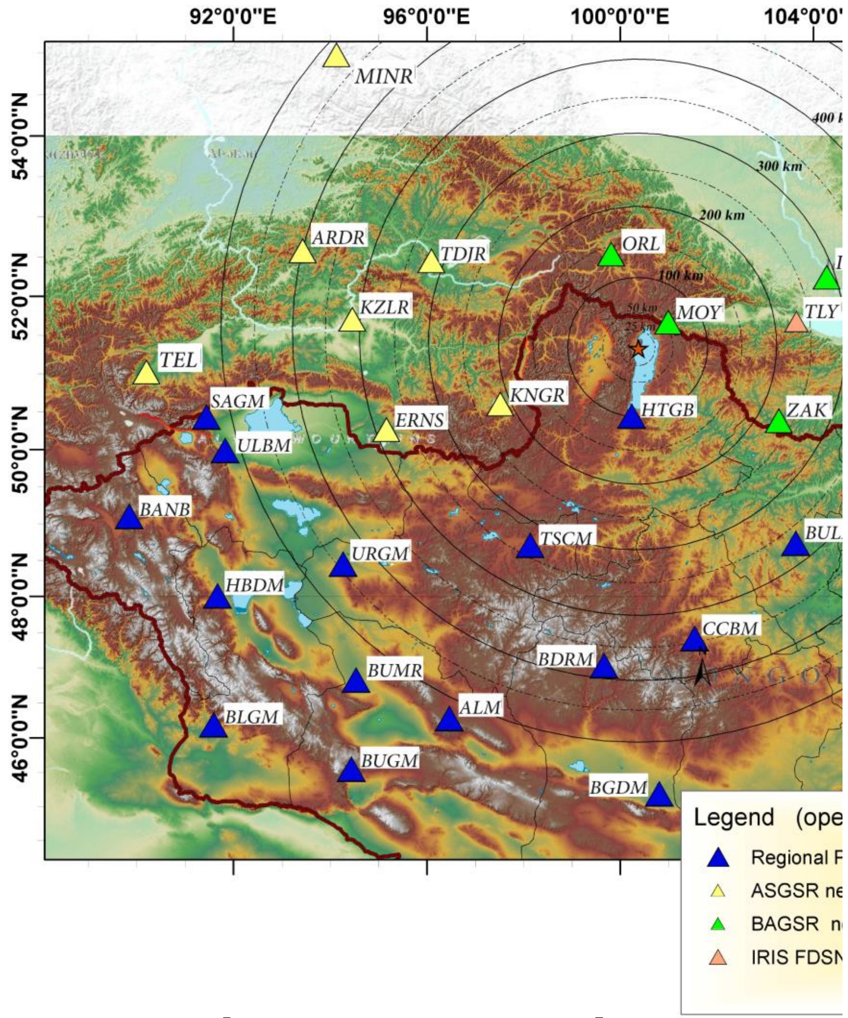


Figure 7. **Aftershock sequence rate in the epicentral area.** The number of aftershocks per hour.



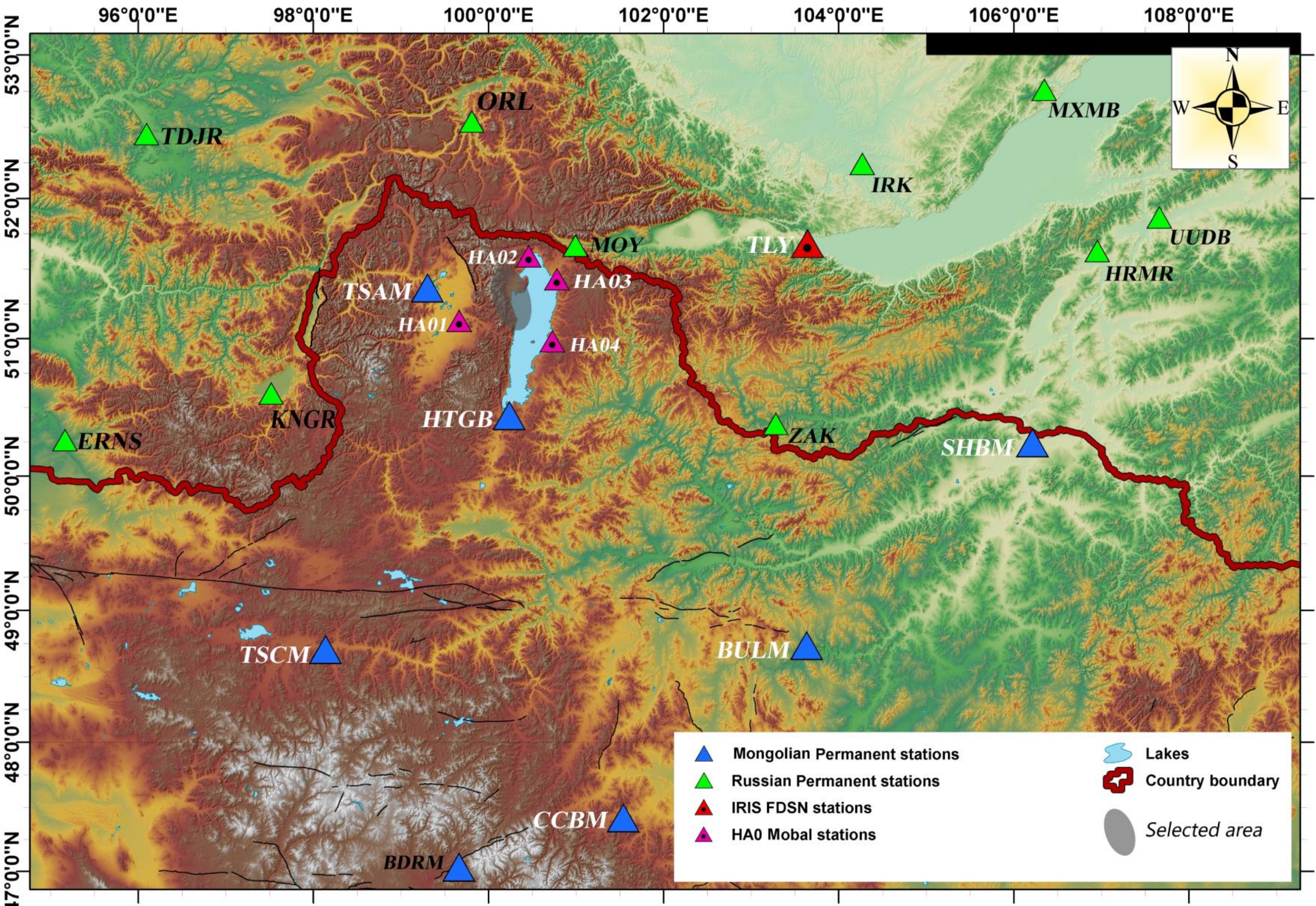
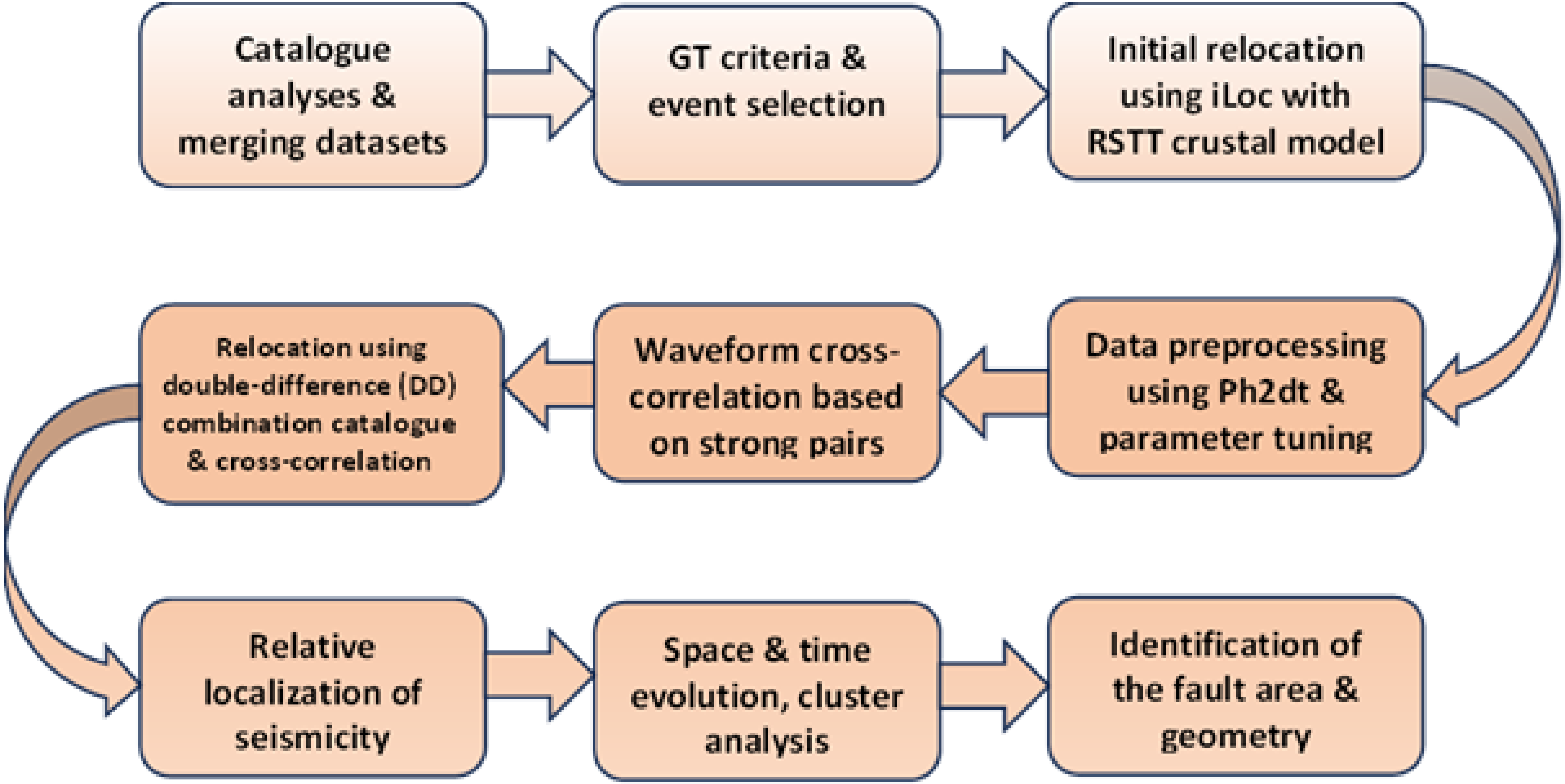


Figure 6.The seismic stations locations. Tri
yellow is the Altay-Sayan branch network,
and blue Mongolian network.

Relocation of Micro-Seismicity events in active regions



GT criteria for event selection

We have considered the criteria to weigh the events such as epicenter distance to be closer to the station, the station number and picked phases used to estimate the relocation of earthquakes and the well-constrained azimuthal gap of the event.

1. at least one station within 35 km from the epicenter distance
2. with an azimuthal gap of less than 100 deg
3. within 6 stations, all within 250 km.
4. network quality metric $\Delta U \leq 0.3$

$$\Delta U = \frac{4\sum_{i=1}^{N} |esaz_i - (unif_i + b)|}{360N}, \; 0 \leq \Delta U \leq 1$$

if ΔU=0, the station of network azimuth distribution is uniformly and ΔU=1 when all stations are at the same azimuth.

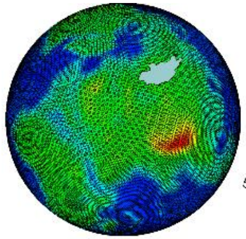
Where: N - number of stations,

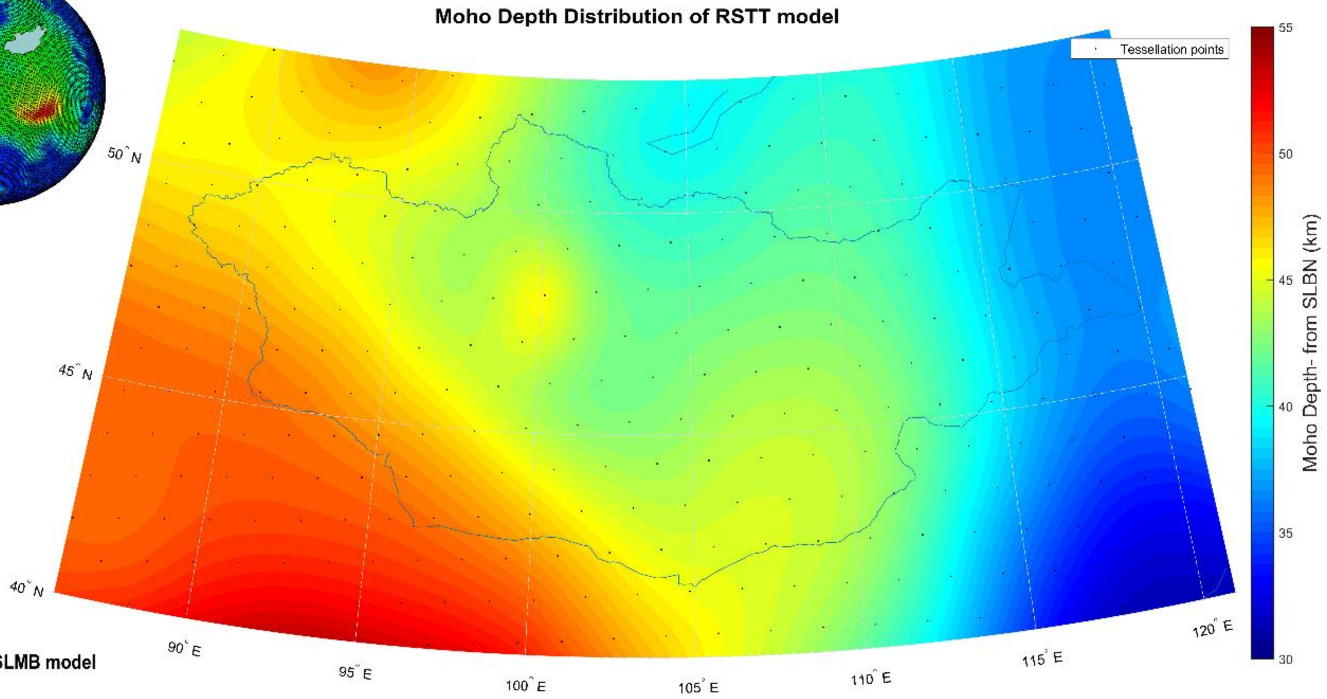
$esaz_i$ - i_{th} – event-to-station azimuth

$unif_i$ =360i/N (i=0, 1, ..., N-1) and b=avg($esaz_i$)-avg($unif_i$)

[Istvan Bondár et al., 2001; Istvan Bondár and K.L. McLaughlin, 2009]

iLoc relocation software: The iLoc relocation process is represented by regional stations using the RSST crust model.





Source from SLMB model

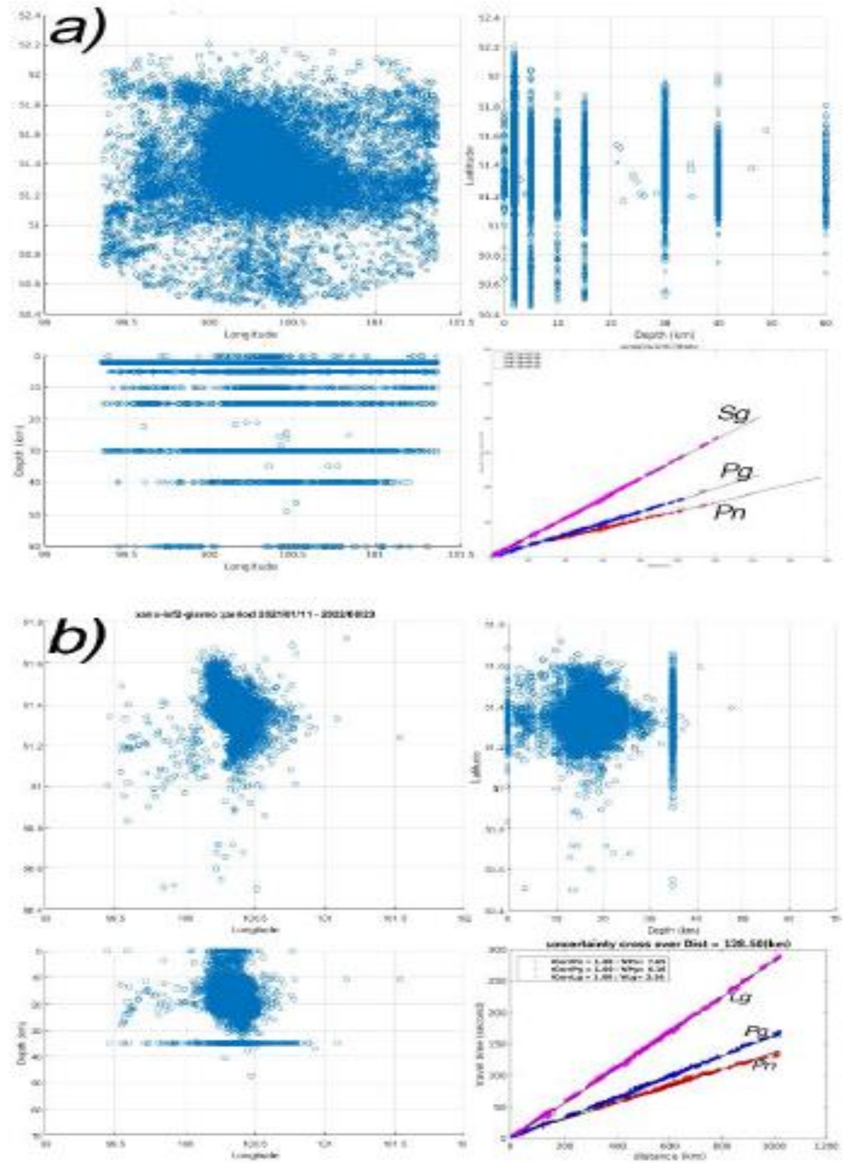


Figure 8. Moho Depth distribution of RSTT crust model

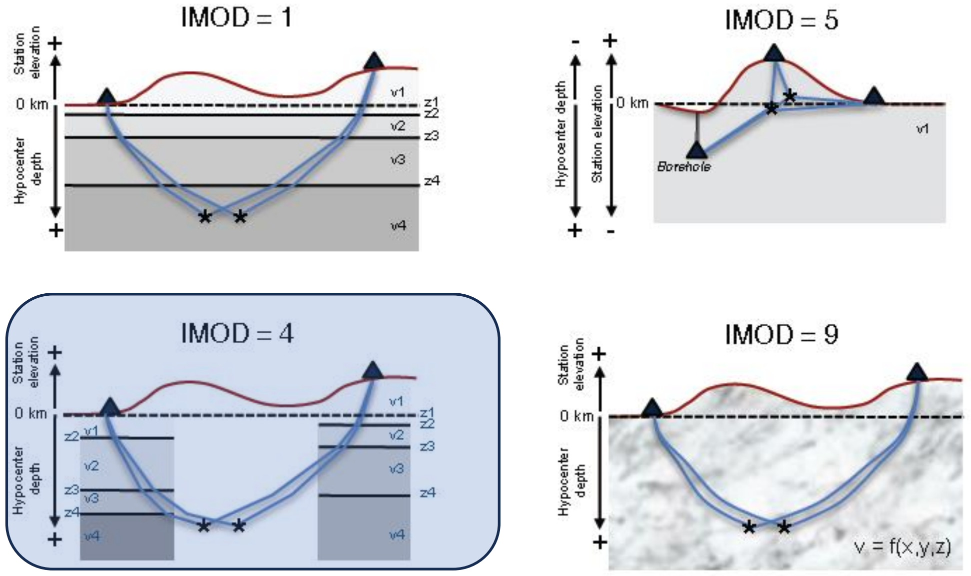
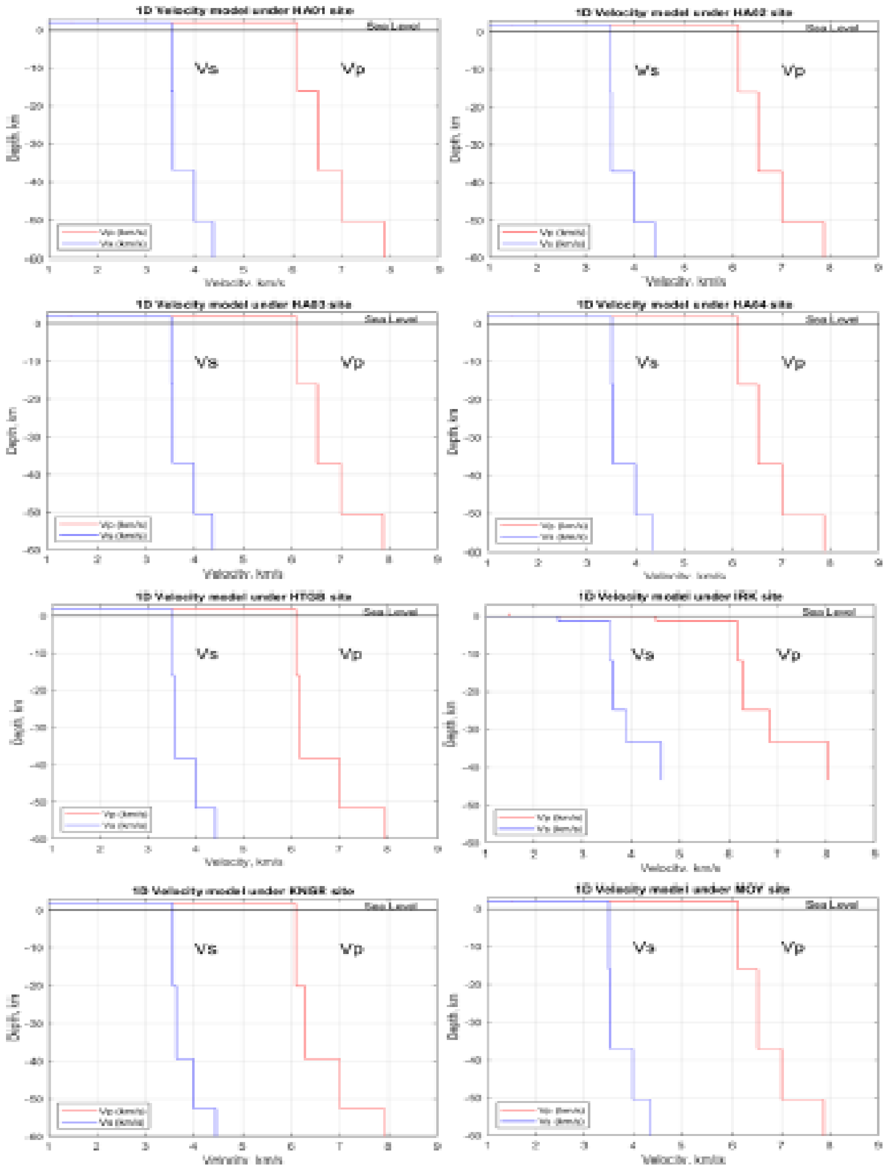
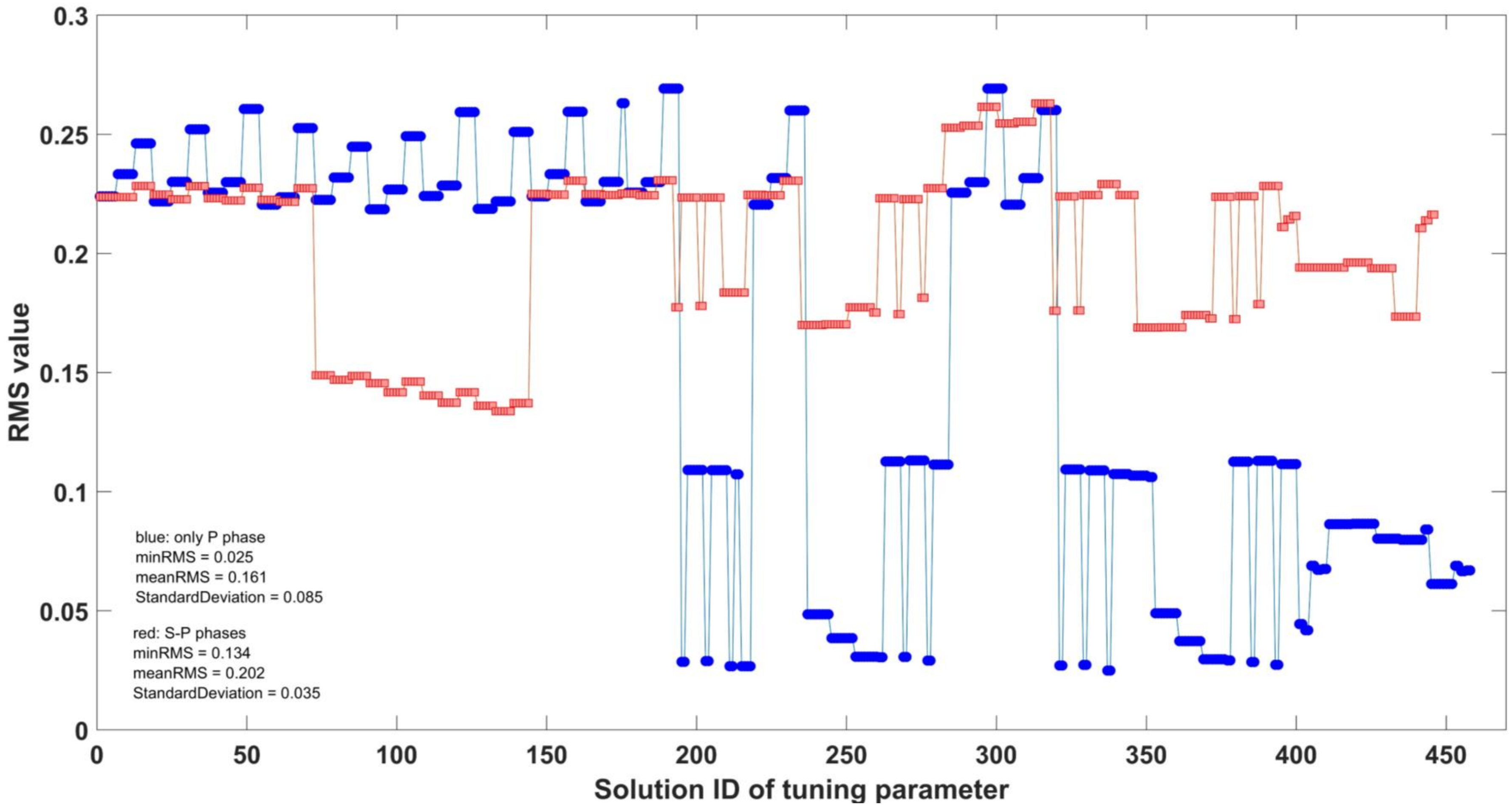


Figure 9. **Overview schema solutions to the forward problem in HypoDD**

The HypoDD technique, developed by Waldhauser and Ellsworth (2000), is a Fortran-based software designed to determine highly precise and accurate earthquake hypocenter locations over large distances. The technique solves the inverse problem by combining absolute travel time measurements with cross-correlation of waveform (P and S) differential travel time measurements between pairs of closely spaced events recorded at common stations.



Catalog analysis to optimized ph2dt turning parameter solution by RMS.



The blue curve is only P phase (IPHA =1, only P phase) catalogue data. Red curve is the P and S (IPHA =3, P and S phases) catalogue data

Waveform cross-correlation method

The methodology used here leverages the definition of waveform cross-correlated events, which are defined as seismic events that are spatially closest to each other. These events generated similar waveforms, which distributed common ray paths from the source to receivers

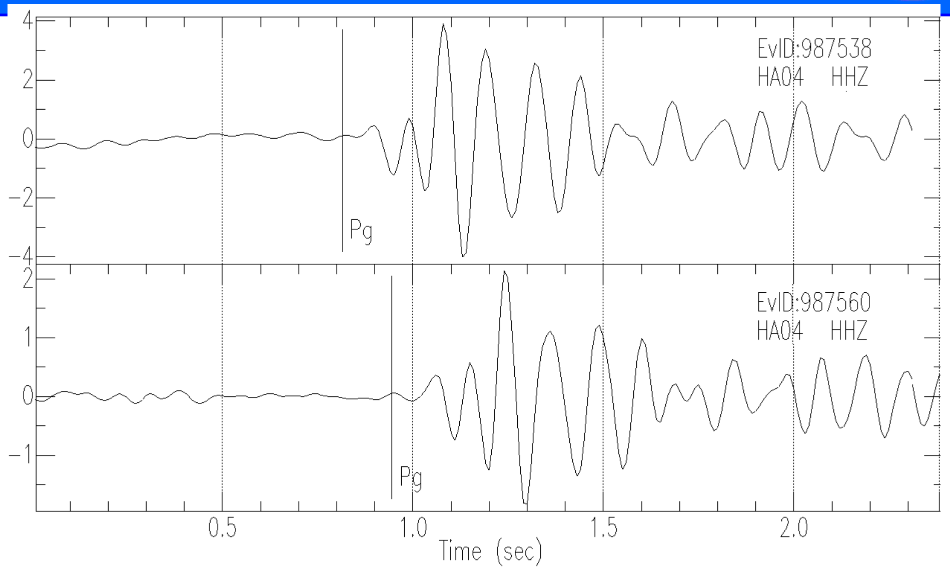
$S = (G * F * R) \pm N$:recorded individual waveforms at the station S:

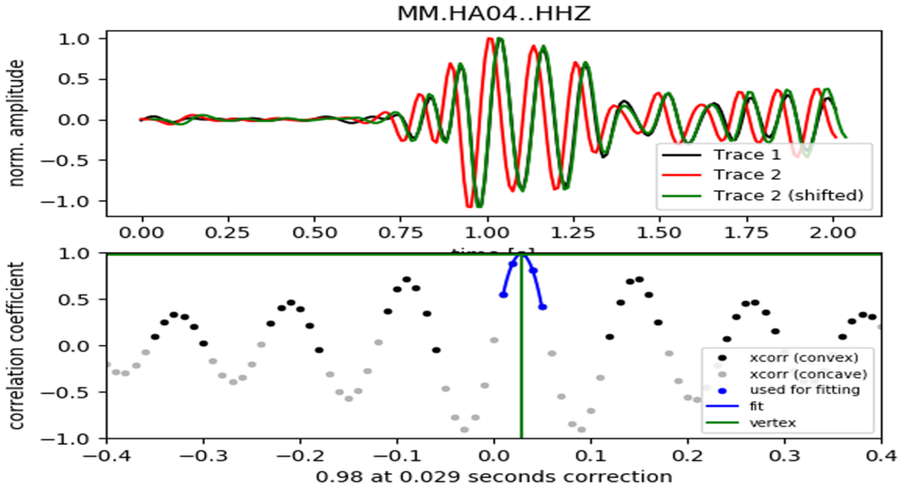
Where: * - is the convolution operator, G – is Green's function of the path, R – is station response, *F* – is the source function and N – is the additional random noise.

$$CC_f(\tau) = n \int S_1(t) S_2(t+\tau) dt \ \ and\ then\ n = \frac{1}{\sqrt{\int S_1^2(t)dt \int S_2^2(t)dt}}$$

Where τ is the delay time for the correlation coefficient, CC=max(c(τ)) measures the time lag between two seismograms

If the CC coefficient falls between 0.7 and 0.8, it indicates multiplet events. When the CC coefficient is extremely close to 1 or exceeds 0.95, it signifies repeater events.





Cross-Correlation Pick Correction: Signal pick is fit to the concave part of the cross-correlation function around its maximum, following the approach by [Deichmann1992].

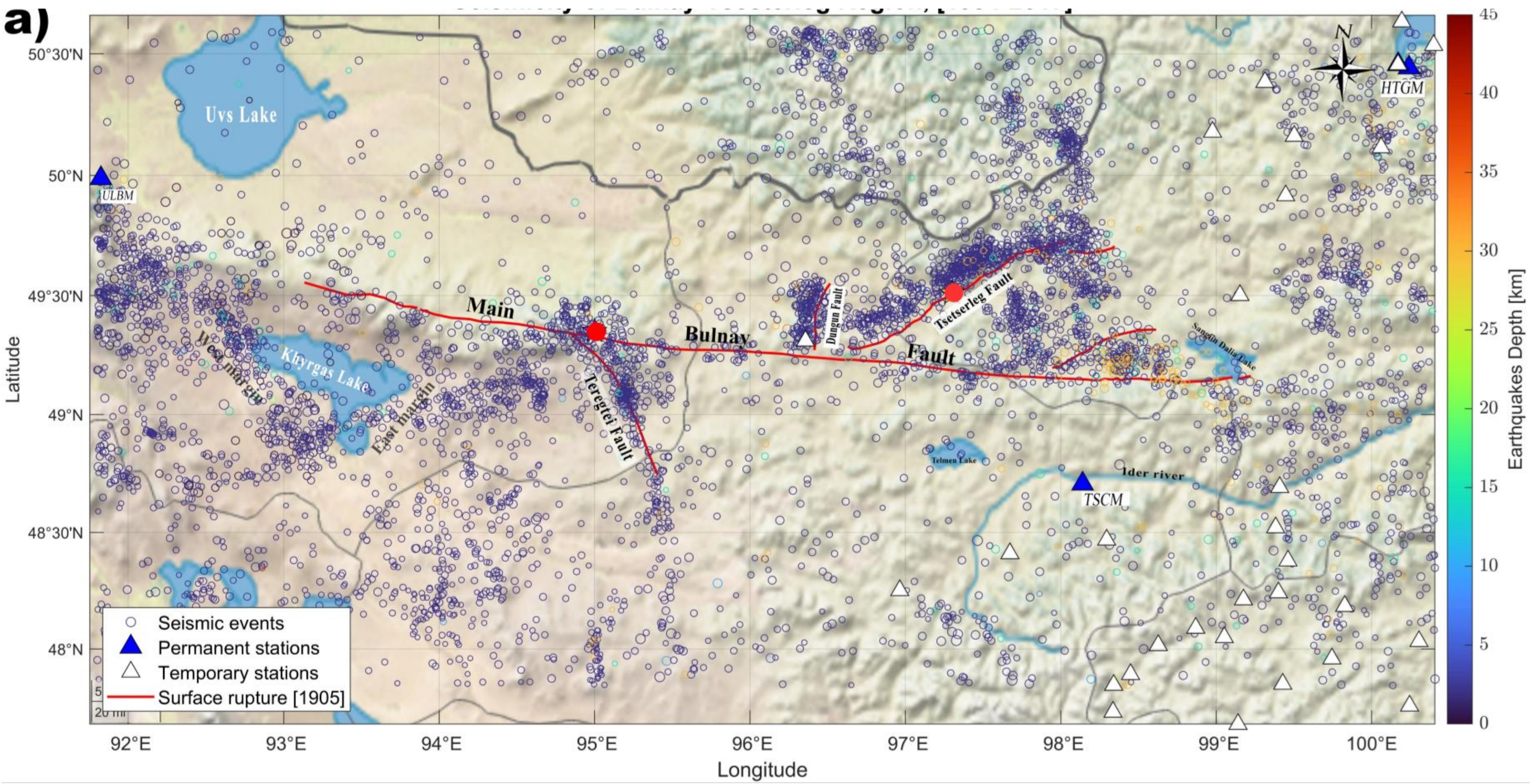


Figure 10. Seismicity map of the relocated events along the Bulnay-Tsetserleg fault region. a) Seismicity of relocated events used iLoc relocator which events selected with GT criteria. **Blue** triangles are 3-component permanent stations and **white** triangles are “HD” temporary seismic stations.

We display seismicity of the relocated events, using iLoc for relocation application.

We selected approximately 11,500 events in the Bulnay-Tsesterleg region [latitude: 47.5–50.5, longitude: 91.8–100.5] based on GT criteria.

We used the “Hangai-DOME” (HD temporary seismic network) HD temporary network was installed for 2 years (2012-2014) and covers Hangay Dome.

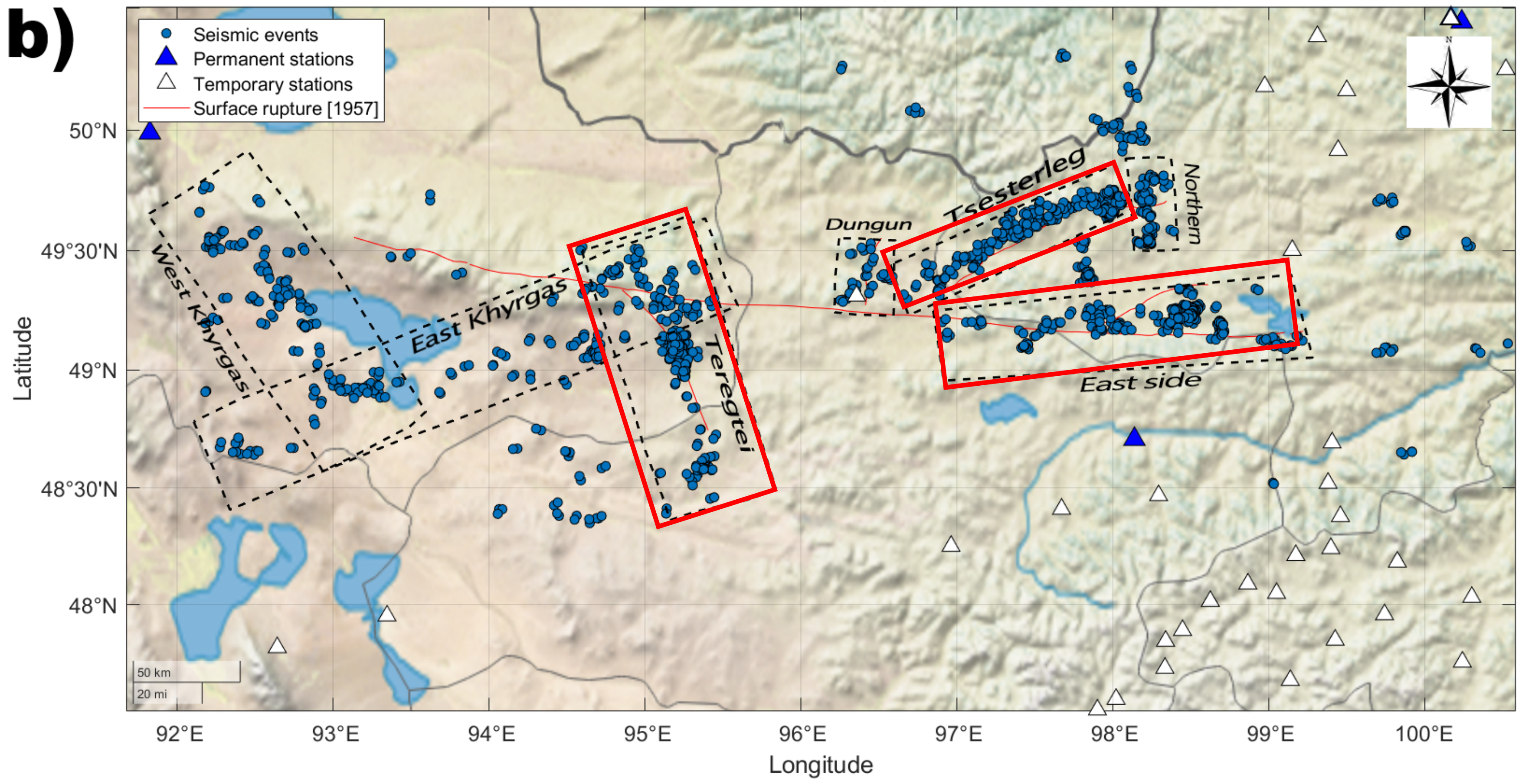
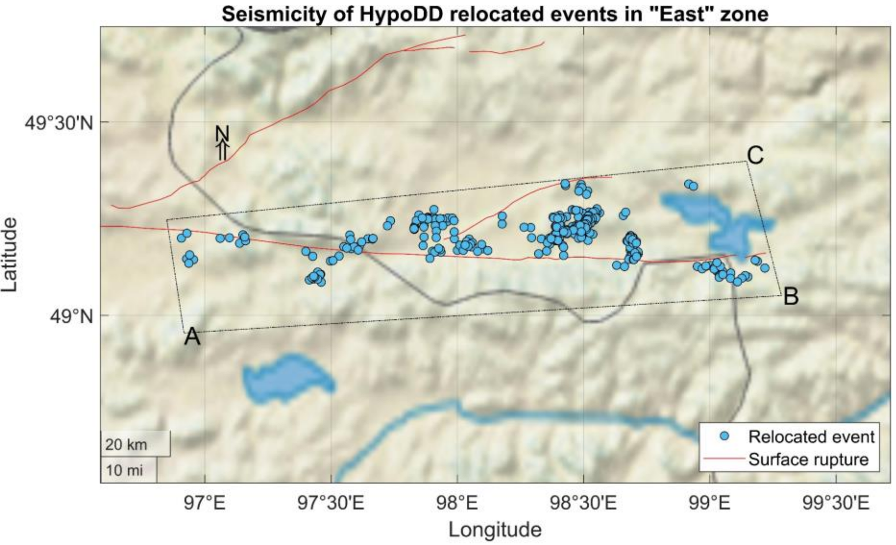
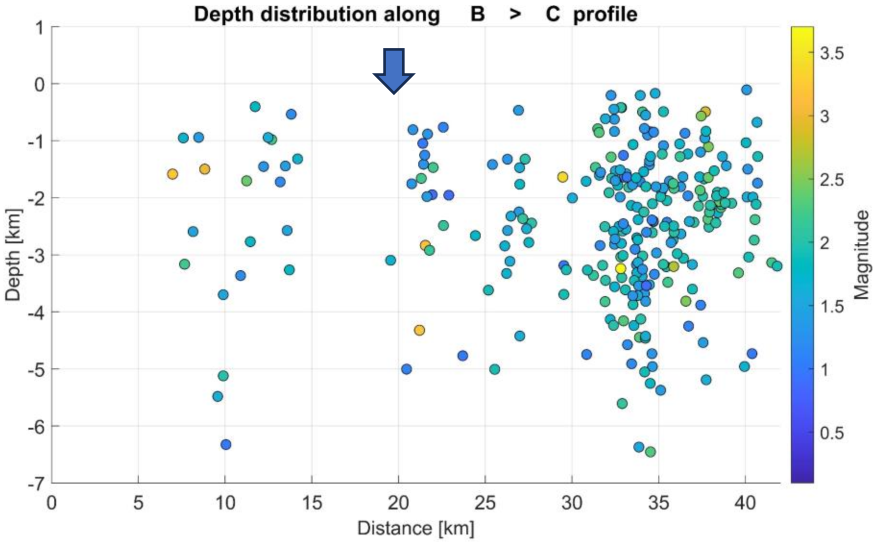
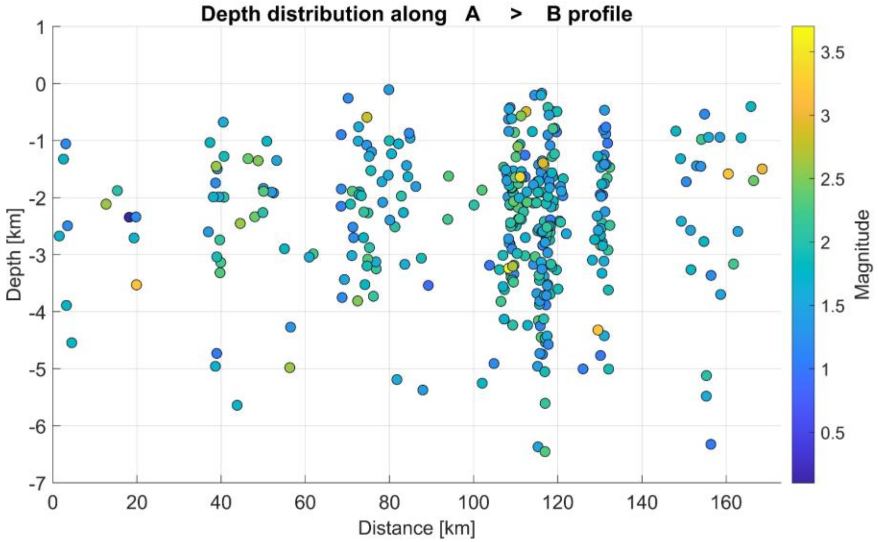


Figure 11. **Seismicity map of the HYPODD relocated events along the Bulnay-Tsetserleg fault region.**

Following the HypoDD relocation, we categorized the region into seven cluster sectors: the **Bulnay East Side Zone (BE), the Tsesterleg Fault Zone (TS), the Teregtei Zone (TG),** the East Khyrgas Zone (EK), the West Khyrgas Zone (KW), the Dungun Zone (DN), and the Northern Side of Tsetserleg fault (NT). These clusters reflect variations in seismic activity and the spatial distribution of seismicity

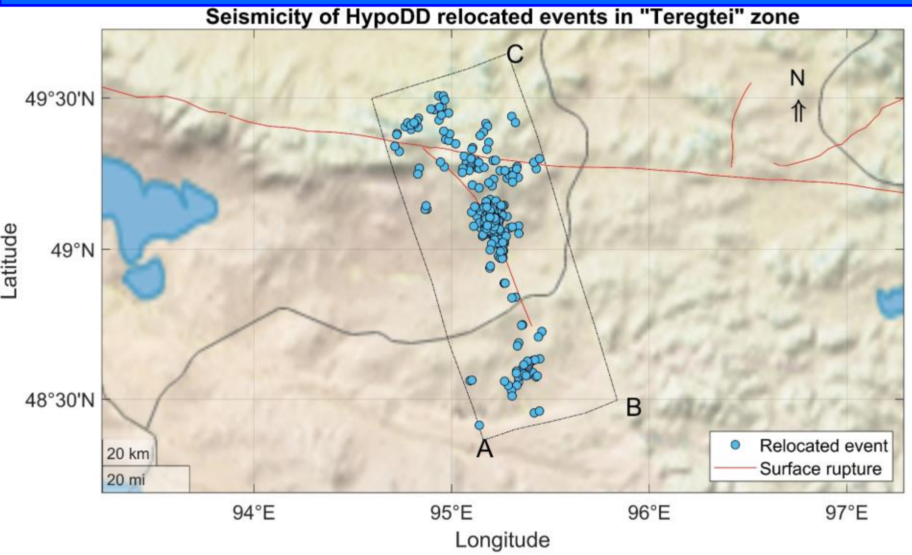


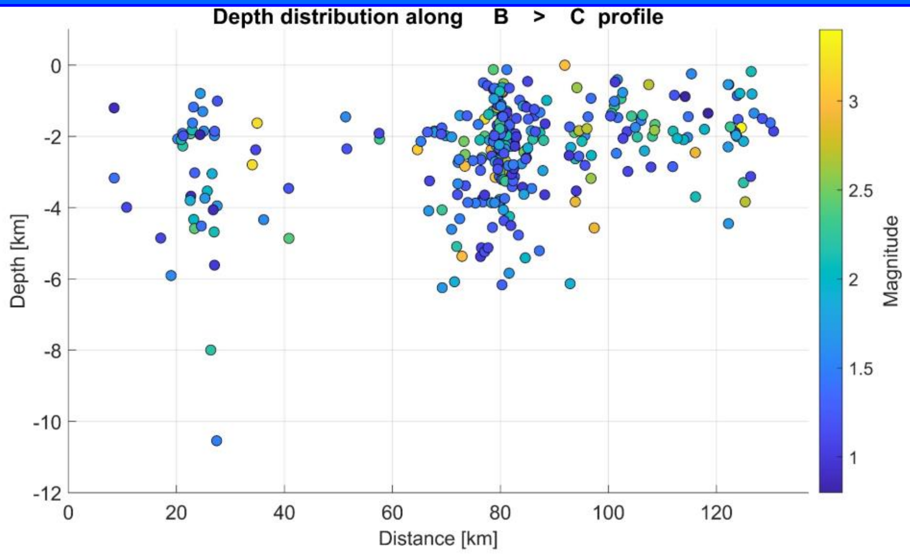


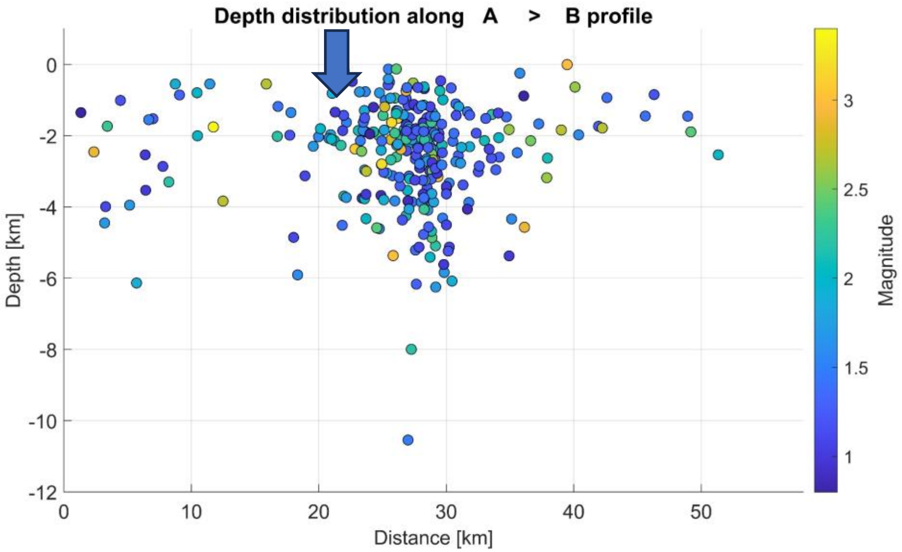


In the eastern zone (BE) of the Bulnay Fault, seismicity is more dispersed into separate clusters compared to other regions. Some clusters are aligned and extended in a SW-NE direction, particularly in the western and central parts of the selected polygon. Notably, a higher number of events were recorded in 2012, coinciding with the deployment of HD temporary stations in this area. The relocated seismic events occur at depths of 0–8 km and predominantly exhibit vertical structures

Figure 12. The seismicity map of relocated events of Bulnay eastern side

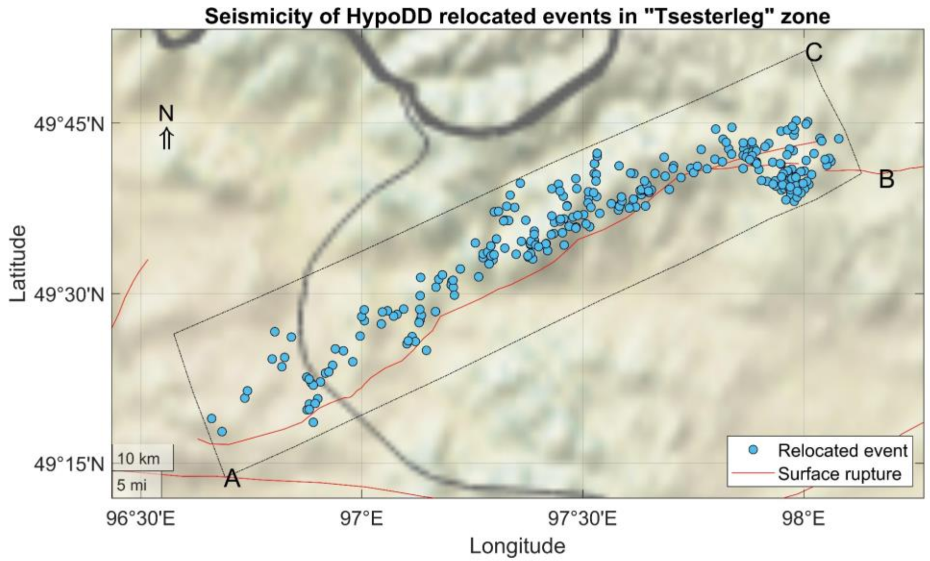


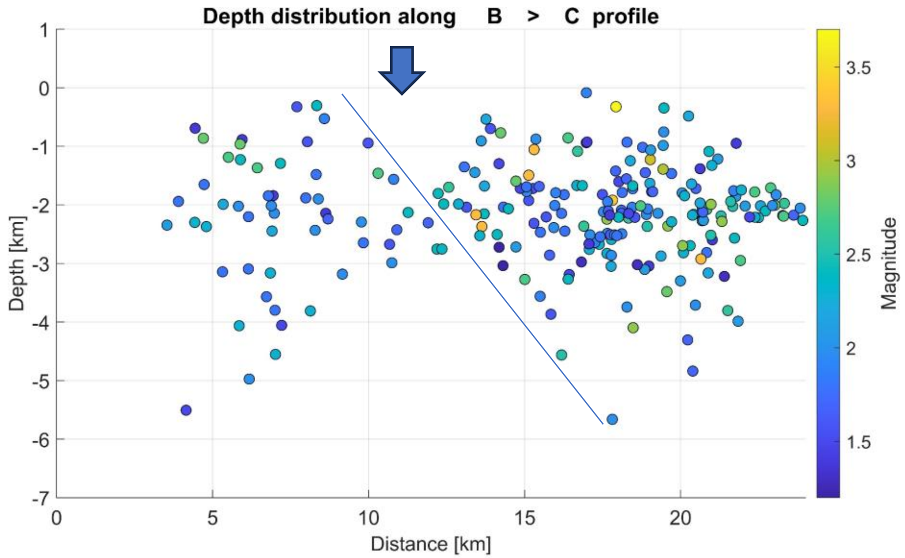


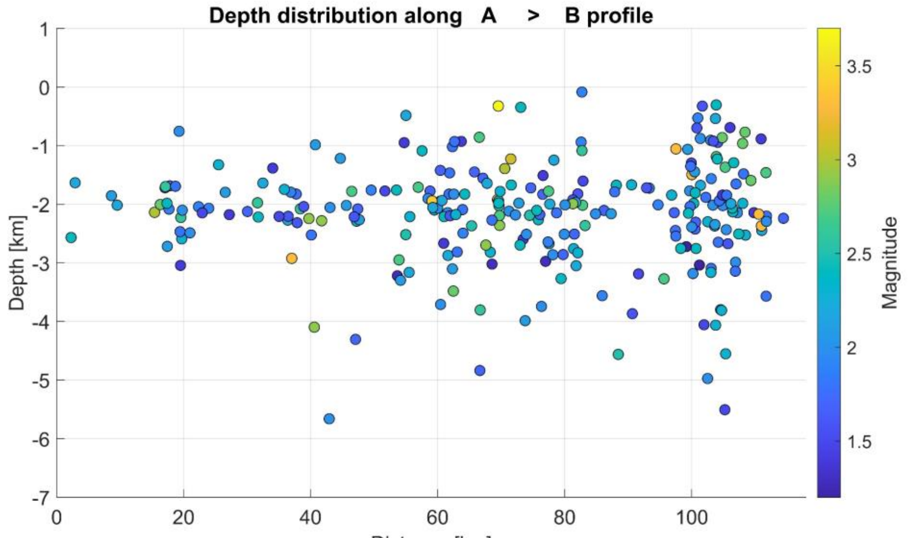


In the Teregtei Fault (TG Zone), seismicity is predominantly observed in a direction perpendicular to the Tsetserleg fault. Seismic events are located mostly center of that fault, and at depths ranging from 0 to 8 km, exhibiting vertical structures.

Figure 13. The seismicity map of relocated events of Teregtei fault



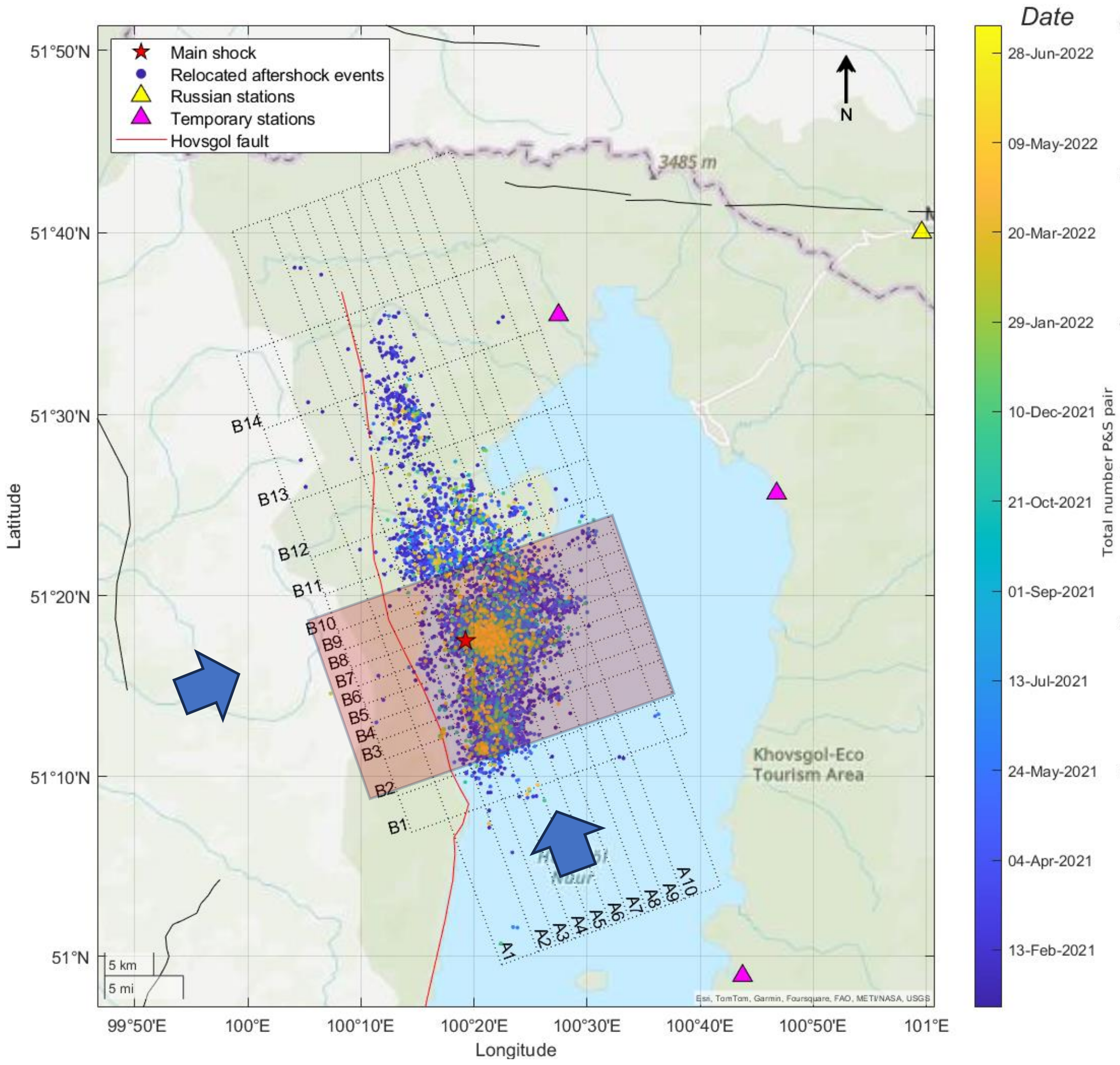




Seismicity in the TS zone, there are primarily associated with the Tsetserleg Fault. The relocated seismic events exhibit a SW-NE trend, with event depths ranging from 1 to 6 km and a SE to NW dip. The majority of events are located northwest of the surface rupture.

Figure 14. The seismicity map of relocated events of Tsetserleg fault

THE INTERNATIONAL CONFERENCE ON THE 120TH ANNIVERSARY OF THE BULNAY EARTHQUAKE:
ADVANCES IN ASTRONOMY AND GEOPHYSICS



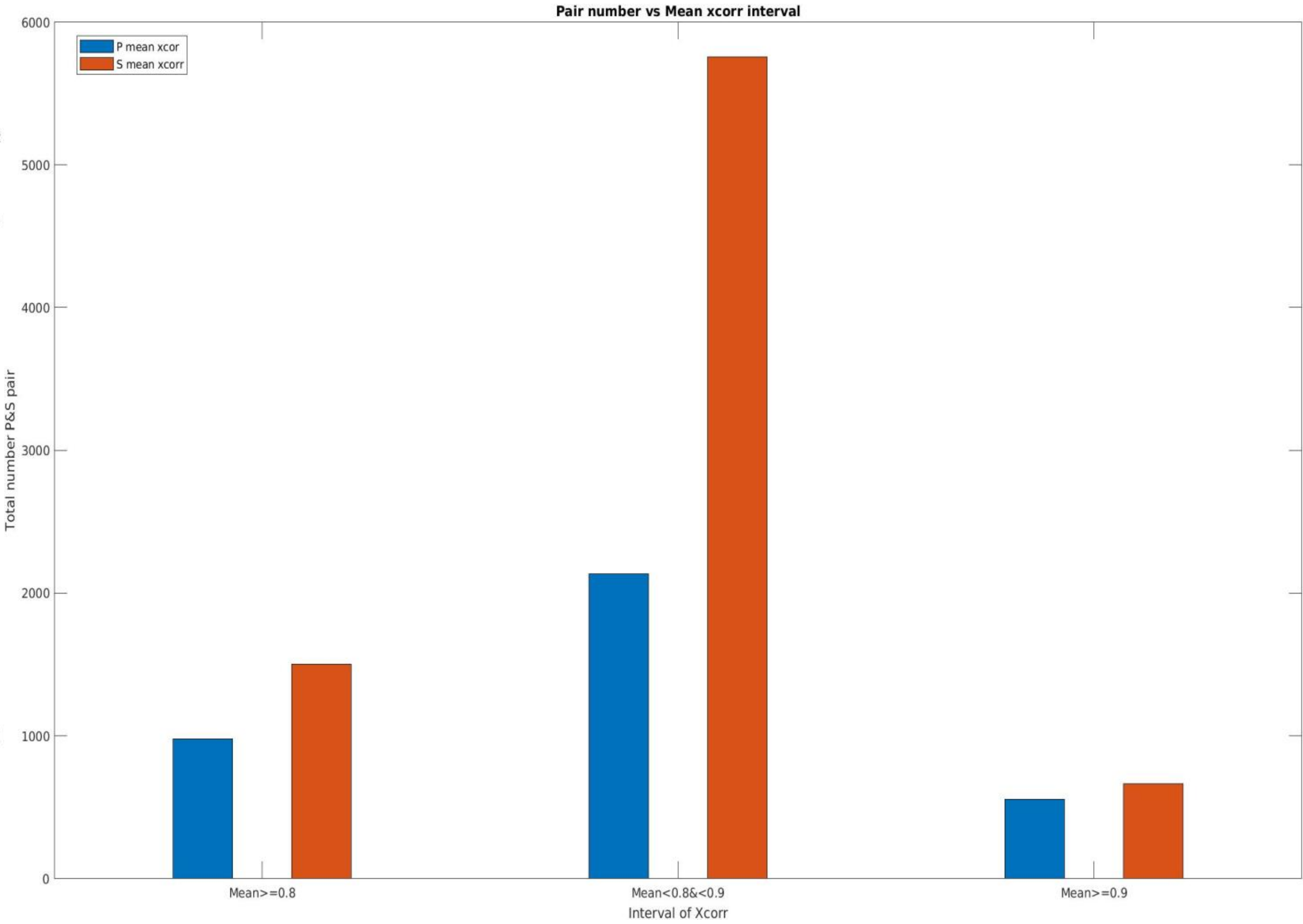


Figure 15. The seismicity map of relocated aftershock events of Hövsgöl earthquake.

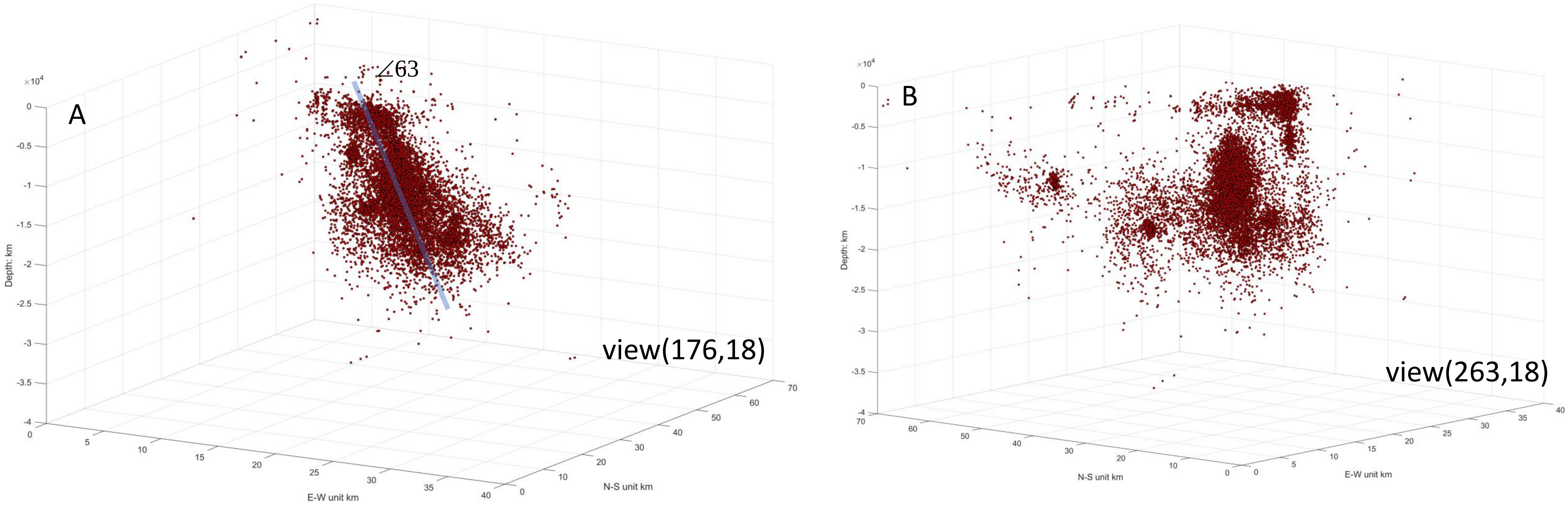
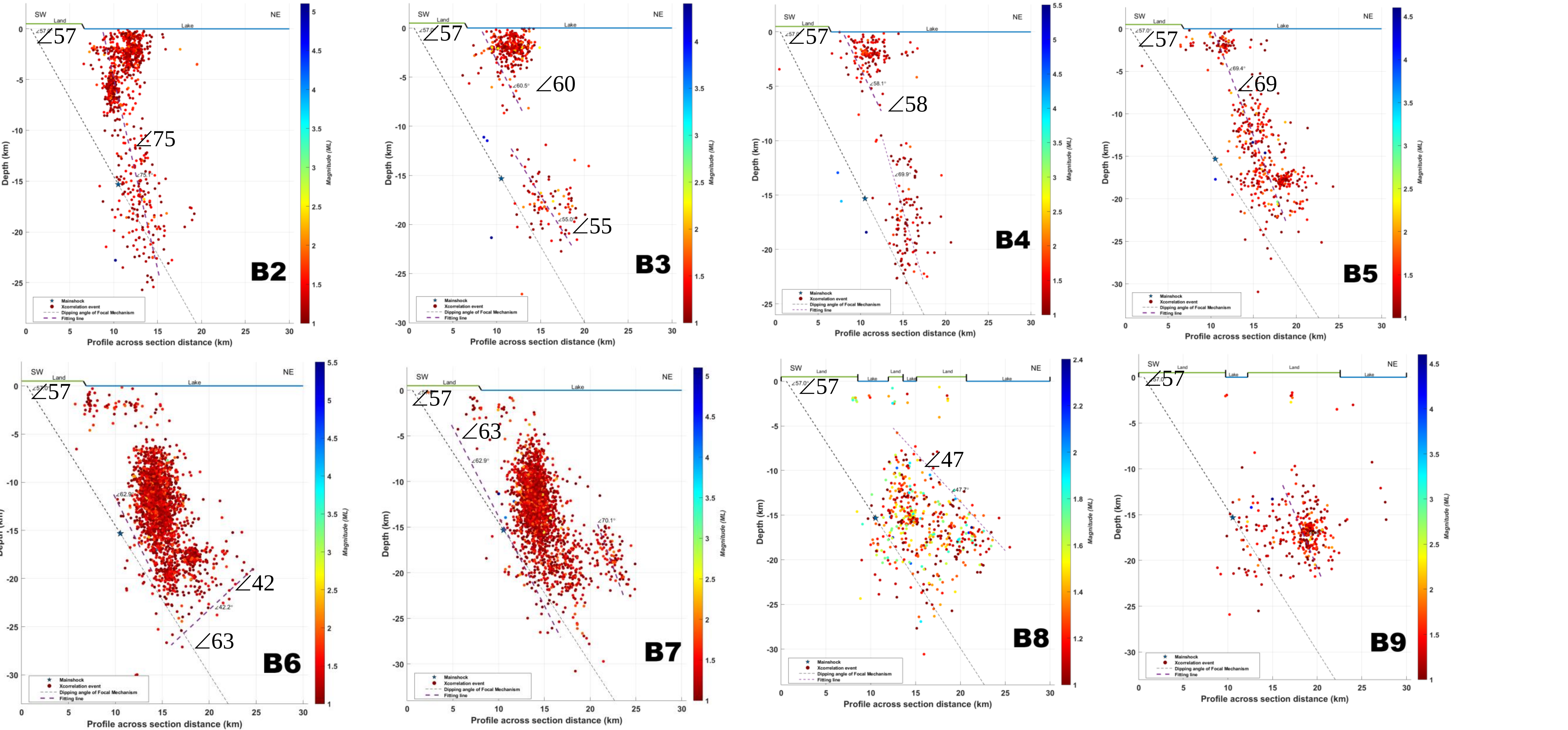


Figure 16. The relocated aftershock events at depth, along A and B profiles. 3D rotating to SE to NW (A) & SW to NE(B)

THE INTERNATIONAL CONFERENCE ON THE 120TH ANNIVERSARY OF THE BULNAY EARTHQUAKE:

ADVANCES IN ASTRONOMY AND GEOPHYSICS



Conclusion

1. Mongolia’s seismicity is concentrated along major active fault systems, where both historical and recent large earthquakes pose significant hazards.
   In the Bulnay–Tsetserleg region, many events were poorly relocated, with most failing to meet GT3.5 criteria due to limited phase counts and insufficient azimuthal station coverage—factors crucial for achieving accurate relocations.
2. The relocated seismic events exhibit a SW–NE trend, with depths ranging from 1 to 6 km and a SE-to-NW dip along the Tsetserleg Fault. Most events are located northwest of the surface rupture.
3. Seismicity along the Bulnay and Teregtei faults occurs at depths of 0–8 km, with event distributions indicating predominantly vertical fault geometries
4. Recent events, such as the 2021 Hövsgöl earthquake, demonstrate the utility of high-resolution relocation results derived from waveform analysis
5. Temporary network and exchange data improves event detection, relocation accuracy, and understanding of large seismic event of Hövsgöl Lake.
6. we estimated that the focal mechanism solution for the mainshock of the Hövsgöl earthquake indicates right-lateral strike-slip faulting with a normal component. The focal depth of the mainshock is approximately 12 km.
7. The relocated aftershocks are mostly distributed at depths between 3 and 20 km, with seismicity dipping angles ranging from 47° to 65°, which is reasonably consistent with the focal mechanism solution.

Thank you for your attention