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Pre-Earthquake Anomaly Analysis of Geoelectric Field Stations Surrounding the M6.2 Jishishan Earthquake

Weiming Wang , Xiaofeng Liao , Zhiwei Zhang *

Posted Date: 16 July 2024

doi: 10.20944/preprints202407.1103.v1

Keywords: anomalies of geoelectric field; non-uniform variations; tectonic activities; dominant azimuth angle; three elements of earthquake prediction; Jishishan Ms6.2 earthquake

Article

The Analysis of Geoelectric Field Anomaly before Jishishan *M*s6.2 Earthquake in Gansu Province

WANG Wei-ming, Liao Xiao-feng, Zhang Zhi-wei * and Ren Yue-xia

Sichuan Earthquake Agency, Chengdu 610041, China
* Correspondence: zzw1983107@163.com

Abstract: On December 18, 2023, a *M*s6.2 earthquake struck Jishishan County, Linxia Prefecture, Gansu Province, this article conducts a detailed analysis of the observation data from 12 geoelectric field stations located approximately 600 km from the epicenter. Prior to the earthquake, non-uniform changes in the geoelectric fields were observed at various stations, characterized by abnormal changes in correlation coefficients between different orientations (δxy) and between long and short polar distances within the same orientation (δxx). The dominant azimuth angles of the geoelectric field at these stations showed variations ranging approximately 40° to 90°. Analysis indicates that these anomalies reflect local site effects and show quasi-synchronicity in time. The anomalies are influenced by the plate tectonic activities of the Qaidam-Qilian Mountain block, with stations in regions of intense plate tectonic activity, such as Menyuan and Jingtai, demonstrating relatively more significant anomalous changes. Furthermore, the research indicates that when determining the epicenter using multiple stations exhibiting anomalous changes, earthquakes tend to occur internally or near the convergence area predicted by multiple stations. However, no clear relationship was found between the specific occurrence time of the earthquake and the locations or tectonic activities of the stations.

Keywords: Jishishan *M*s6.2 earthquake; geoelectric field; pre-earthquake anomaly; non-uniformity; tectonic activities; three elements of prediction

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1. Introduction

The geoelectric field comprises a telluric field and a natural electric field, the telluric field originates from the space-current system and solar and lunar tides [1–5]. Typically, daily variable waveforms exhibit regional and site-specific characteristics[6]. The natural electric field is generated by physical and chemical processes in underground media and remains relatively stable in areas with consistent tectonic activity, and some sites also show seasonal variations [7].

Based on the variation characteristics and mechanisms of geoelectric field changes, numerous scholars have conducted extensive research. In the 1960s, Chinese scholars conducted routine waveform analysis based on the relatively stable characteristics of geoelectric field variations [8]. However, due to limitations in observation technology and progress in mechanistic research at that time, this waveform analysis method did not yield influential seismic examples. In the 1980s, Greek scholar Varotsos and others utilized geoelectric field observation data to explore pre-earthquake SES signals (Seismic Electric Signals) based on the stability, uniformity, and "point source" model of natural electric field at local site. They proposed an exploratory theoretical approach for earthquake prediction known as the VAN method [9]. Subsequently, the VAN method was introduced to China, catalyzing active research in seismic geoelectric field studies.

In the 1990s, Chinese scholars proposed a polarization azimuth calculation method based on the polarization mechanism of the telluric field. They accumulated earthquake cases such as the 1995 Yongdeng *M*s5.8, 1996 Tianzhu *M*s5.4, and 1998 Zhangbei *M*s6.2 earthquakes [10]. However, due to factors such as significant data discreteness at most sites and insufficient development of non-polarizable electrode technology at the time, the adoption and application of this method were limited.

 doi:10.20944/preprints202407.1103.v1

Since 2000, Chinese scholars have progressively advanced their research on geoelectric fields, delving into variation characteristics, influencing factors, mechanistic understanding, and earthquake prediction. They introduced a physical analytical approach [11] and identified tidal phenomena in the geoelectric field [3,12]. With advancements in computer technology, and based on the understanding of the geoelectric field harmonics, scholars applied digital signal processing techniques to conduct spectrum analysis, revealing prominent harmonic periods in the geoelectric field are typically 24, 12, 8, and 6 hours, among others [3,12], and conducted power spectral analysis [13]. Later on, scholars further combined mathematics, physics, digital signal processing with the mechanism of seismic geoelectric field [3,14], proposing geoelectric field tidal mechanism [4] and model of fissure water(charge) in rock with seepage (movement) [15,16]. In the increasingly complex geoelectric field observation environment, the VAN method distinguishes interference by comparing data of long and short electrode distance, while the dominant azimuth method of telluric electric fields reduces interference effects by selectively applying multidirectional data based on FFT results, grounded in the model of fissure water(charge) in rock with seepage (movement). These two geoelectric field analysis methods have gradually become important approaches for earthquake prediction analysis in China [15–20].

On December 18, 2023, a *M*s6.2 earthquake struck Jishishan County, Gansu Province, marking a significant seismic event that broke a seismic quiescence of 1254 days in the southeastern region of Gansu province. Within approximately 600 km from the epicenter, there are 12 geoelectric field observation stations, all of which are situated near fracture zones (Figure 1h). This unique seismic event provides a rare opportunity to delve deeper into the complexity of seismic electromagnetic phenomena.

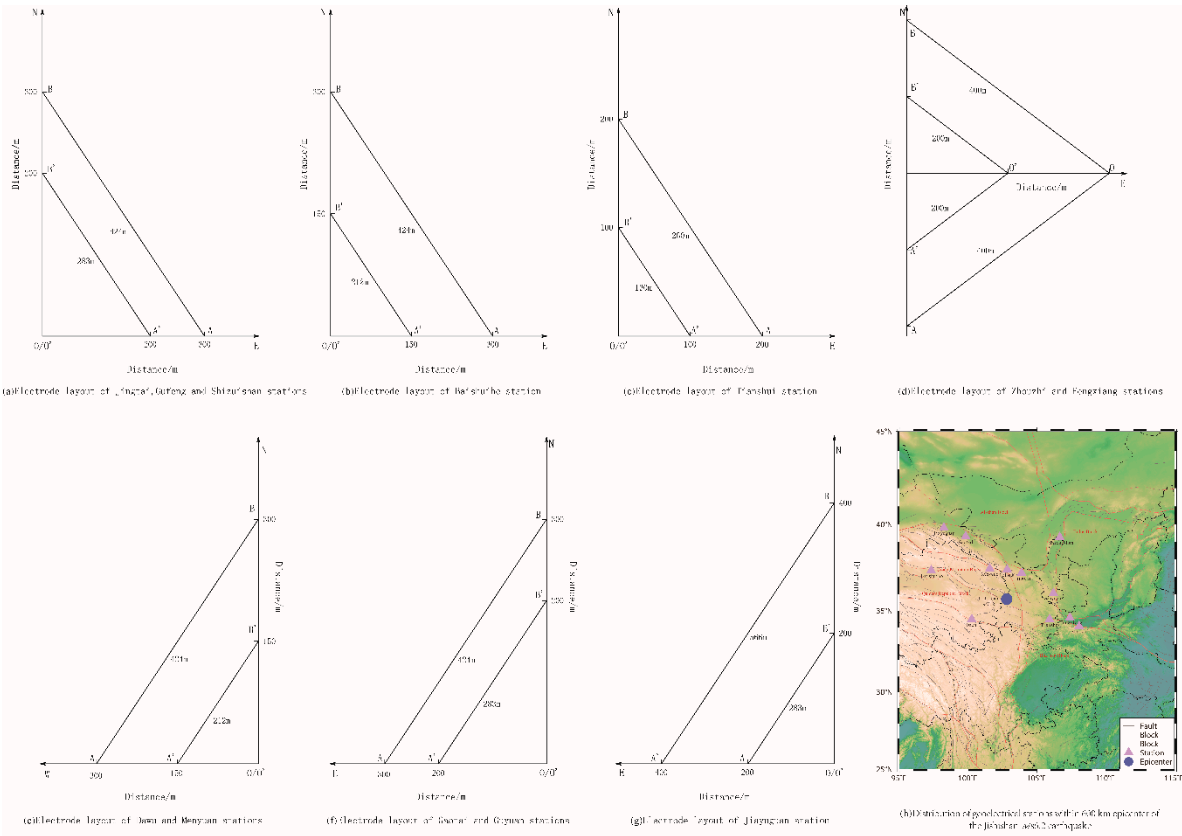

Figure 1. Distribution of geoelectric stations around Jishishan *M*s6.2 earthquake and the layout of the stations.

Using a physical analytical approach to the geoelectric field, this study analyzes observational data from the 12 geoelectric field stations surrounding the epicenter, examining various components of the geoelectric field. It offers new insights into the application of abnormal changes in geoelectric field for earthquake prediction, particularly in terms of predicting the location of earthquake occurrence. These findings contribute positively to understanding the characteristics of geoelectric field variations and predictive analysis.

2. Basic Information and Data Foundation of Geoelectric Field Stations Near the Epicenter

On December 18, 2023, a *M*s6.2 earthquake occurred in Jishishan County, Gansu Province, located within the Qaidam-Qilian Block, the epicenter situated at 35.70ºN, 102.79ºE with a depth of 10 km. The nearest fracture zone to the epicenter is the northern margin fault of Laji Mountain, approximately 3 km away. Within a radius of approximately 600 km from the epicenter, there are a total of 12 geoelectric field observation stations, including the Jiayuguan station situated 608 km away, which is also included in the analysis. The distribution of these 12 stations is shown in Figure 1h. All 12 stations employ geoelectric field observation devices configured in a triangular layout, oriented primarily in north-south and east-west directions, except for the Zhouzhi and Fengxiang stations. According to observation reports, work logs, and quarterly reports spanning 2022 and 2023, the electrode conditions, site environments, and instrument operations at each station were found to be normal (details in Table 1).

Table 1. Statistics on the operation and environmental conditions of geoelectric field observation systems at stations surrounding the Jishishan *M*s6.2 earthquake (2022-2023).

Station	Epicentral Distance（km）	Long polar Distance（m）	Short polar Distance（m）	ΔE_{SP-S}（mV/km）	Environmental Conditions	Operation Conditions	Instrument State
Gufeng	192.40	300/300	200/200	≤10	normal	reliable	normal
Jingtai	196.07	300/300	200/200	≤5	near highway	reliable	almost normal
Menyuan	226.34	300/300	150/150	≤10	almost normal	reliable	almost normal
Tianshui	314.93	200/200	100/100	≤20	normal	reliable	normal
Dawu	267.96	300/300	150/150	≤20	normal	reliable	normal
Guyuan	307.39	300/300	200/200	≤5	normal	reliable	normal
Fengxiang	437.24	400/400	200/200	≤5	normal	reliable	normal
Gaotai	479.24	300/300	200/200	≤5	normal	reliable	normal
Zhouzhi	514.08	400/400	200/200	≤5	normal	reliable	normal
Shizuishan	524.34	300/300	200/200	≤5	normal	reliable	normal
Baishuihe	521.77	300/300	150/150	≤10	normal	reliable	normal
Jiayuguan	608.32	400/400	200/200	≤20	normal	reliable	normal

Note: The polar distances are arranged in NS/EW order.

Typically, researchers consider the daily average of geoelectric field instrument observation data sampled at minute intervals as natural electric field data of the site [21]. Therefore, the magnitude of ΔE_{SP}, the primary jump-change range of the first-order difference of daily averages, can reflect the stability of station equipment and environment to a certain extent. From 2022 to 2023, ΔE_{SP} values at Jingtai, Fengxiang, Gaotai, Zhouzhi, and Shizuishan stations were all below 5 mV/km (Figure 3), indicating stable data. Furthermore, ΔE_{SP} variations at each station exhibited certain seasonal changes. Statistical results in Table 1 indicate that conditions such as equipment and environment at the 12 geoelectric field stations mentioned were generally stable. Two stations occasionally experienced minor environmental or equipment influences, but these had minimal impact on observational data, and the data reliability met the requirements.

Geoelectric field observation data encompass natural electric field $\boldsymbol{E}_{SP}$, telluric electric field $\boldsymbol{E}_{T}$, and interference information $\boldsymbol{E}_{R}$. At geomagnetic field stations, the observed value $\boldsymbol{E}$ can be expressed as:

$$\boldsymbol{E} = \boldsymbol{E}_{SP} + \boldsymbol{E}_{T} + \boldsymbol{E}_{R} \tag{1}$$

Based on the physical analytical approach of geoelectric fields [11,15], this study analyzes the observational data before the *M*s6.2 earthquake in Jishishan County, Gansu Province. The research focuses on uniformity of changes in the total field $\boldsymbol{E}$ of the geoelectric field across various directions and pole distances. It explores the variation characteristics of the natural electric field ($\boldsymbol{E}_{SP}$) and the telluric electric field $\boldsymbol{E}_{T}$) separately, these being components of the geoelectric field.

3. Characteristics of Correlation Changes in the Geoelectric Field

Based on sampled at minute intervals from geoelectric field, formula (2) allows calculation of correlation coefficient (δ) between different directions and between long and short polar distances.

$$\delta = \frac{\sum_i (X_i - \overline{X}) \cdot (Y_i - \overline{Y})}{\sqrt{\sum_i (X_i - \overline{X})^2 \cdot (Y_i - \overline{Y})^2}} \tag{2}$$

In this formula, X and Y denote the geoelectric field values in two distinct directions when calculating the correlation between different directions, when calculating the correlation between long and short polar distances, and in long and short pole distances when calculating the correlation between long and short polar distances. Formula (2) reveals that if X and Y change proportionally as a whole, the correlation coefficient(δ) remains unchanged; however, any partial changes in components will alter the correlation accordingly. In this study, δ_{xy} denotes the correlation coefficient between different directions at the site, and δ_{xx} represents the correlation coefficient between long and short polar distances in the same direction. For convenience, directions NS, EW, and NW/NE are denoted as 1, 2, and 3 respectively.

Typically, after a station is established, and in the absence of significant changes in observation systems and environmental conditions, the data correlation coefficients δ_{xy} and δ_{xx} exhibit relative stability. During the process of earthquake preparation and occurrence, the geoelectric field in local sites may undergo more complex "non-uniform changes" [19]. A *M*s6.2 earthquake occurred in Jishishan County, Gansu Province on December 18, 2023, prompting an analysis of changes in δ_{xy} and δ_{xx} across the 12 surrounding stations. The results are depicted in Figure 2 (The directions with relatively dramatic changes were selected for plotting).

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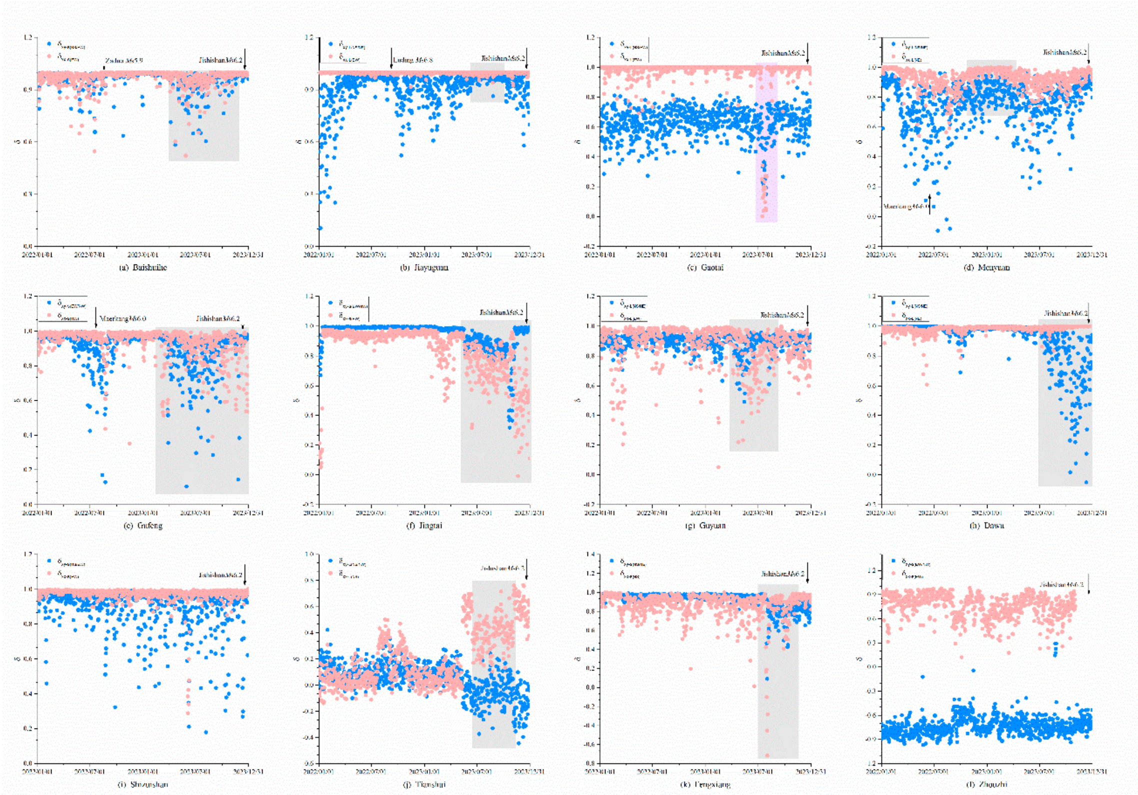

Figure 2. Variation of correlation coefficient in Jishishan *M*s6.2 earthquake of stations (2022.1.1-2023.12.31).

As depicted in the figure, during periods of data stability (such as early 2023), all stations except Tianshui showed correlation coefficients above 0.8, indicating relative stability. Before the earthquake on December 18, 2023, the changes in δ_{13} and δ_{33} at Shizuishan station, δ_{23} and δ_{22} at Zhongzhi station were not significant. Gaotai station's δ_{12} and δ_{22} showed changes due to irrigation effects near the western electrodes, rather than seismic precursors. δ_{13} of Jiayuguan, δ_{13} and δ_{33} of Menyuan, and δ_{22} of Tianshui station showed an increase before the earthquake. δ_{12} of Dawu station and δ_{xy}, δ_{xx} of the remaining five stations showed a significant decrease, but the magnitude of changes in correlation coefficients varied among the stations, with mostly occurring 6 to 3 months before the earthquake. At the same station, the magnitudes of change in δ_{xy} and δ_{xx} were generally similar. Menyuan station showed the greatest difference in magnitude of change between δ_{xy} and δ_{xx}, while Jiayuguan station showed the smallest difference. The magnitudes of change in δ_{xy} and δ_{xx} at each station peaked around August 2023, showing a quasi-synchronicity in time domain. Except for Gufeng and Dawu stations, the anomalous changes in δ_{xy} and δ_{xx} at the other stations gradually recovered after the earthquake, but the duration of recovery varied.

According to formula (3), the relative variation magnitude (m) of correlation coefficients at each station during this earthquake can be calculated as follows:

$$\mathrm{m} = \left| \frac{\Delta\delta_{an}}{\Delta\delta_{n}} \right| \times 100\% \qquad (3)$$

In formula (3), $\Delta\delta_{an}$ represents the magnitude of relatively drastic changes within the study period, while $\Delta\delta_{n}$ represents relatively stable changes. Through calculating and analyzing of the stations with changes in correlation coefficients mentioned above, it was found that the amplitude of relative change (m) ranged from 175% to 1000% (Table 2).

Table 2. The amplitude of relative variation (m) in correlation coefficient of stations around the Jishishan *M*s6.2 epicenter.

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Station	m(δxy)	m(δxy)	Station	m(δxy)	m(δxy)	Station	m(δxy)	m(δxy)	Station	m(δxy)	m(δxy)
Baishuihe	300%	300%	Jiayuguan	500%	/	Gaotai	/	/	Menyuan	220%	400%
Gufneg	500%	400%	Jingtai	400%	400%	Guyuan	200%	400%	Dawu	1000%	/
Shizuisha	/	/	Tianshui	/	175%	Fengxiang	700%	400%	Zhouzhi	/	/

Note: "/" indicates no abnormal changes were observed before the earthquake.

4. Characteristics of Changes in the Natural Electric Field

Typically, the natural electric field (E_{SP}) generated by physical and chemical processes in underground media demonstrates relative stability in tectonically stable regions, but can exhibit instability in areas with intense tectonic activity. In a relatively reliable electromagnetic observation environment and system, E_{SP} and the stability of E_{SP}, denoted as ΔE_{SP} in formula (1) can be calculated as follows [21,22]:

$$E_{SP} \approx \frac{1}{1440} \cdot \sum_{I=0}^{1439} E_i \tag{4}$$

In formula (4), E_i represents the observed value at the i-th minute. ΔE_{SP}, which quantifies the stability (daily jumping) of E_{SP}, is defined as:

$$\Delta E_{SP(j)} = E_{SP(j+1)} - E_{SP(j)} \tag{5}$$

In formula (5), $E_{SP(j)}$ represents the natural electric field value on the j-th day.

Figure 3 illustrates the variation curves of E_{SP} and ΔE_{SP} across 12 surrounding stations before the *M*s6.2 earthquake in Jishishan County (The directions with relatively dramatic changes were selected for plotting).

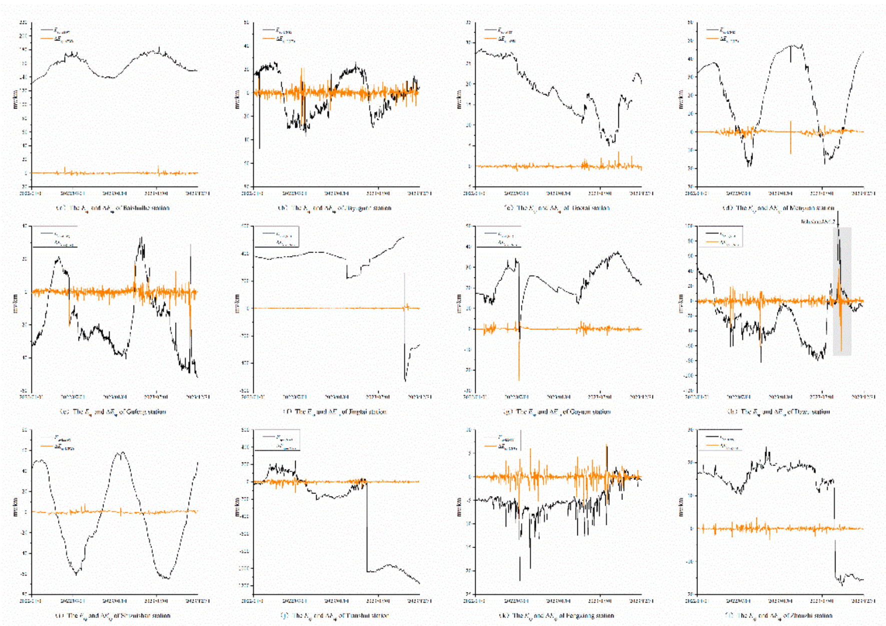

Figure 3. Variation of E_{SP}、ΔE_{SP} of each station in Jishishan *M*s6.2 earthquake.

Figure 3a-l demonstrate varying amplitudes of E_{SP} and ΔE_{SP} among different sites, exhibiting certain site-specific characteristics. Most stations show relatively unstable E_{SP} waveforms, correlated with intense local tectonic activity. Stations such as Jingtai, Guyuan, Fengxiang, Gaotai, Zhouzhi, and Shizuishan exhibit higher stability in E_{SP}, with ΔE_{SP} variations primarily less than 5 mV/km. ΔE_{SP} at each station shows certain seasonal variation, with more pronounced data variability in summer and greater stability in winter. Baishuihe, Gufeng, Shizuishan, Jiayuguan, and Menyuan stations exhibit clear annual sine-like variation patterns.

Over a longer period, E_{SP} variations tend to gradually increase or decrease, while short-term changes involve significant sudden jumps or steps, reflected in sudden jump of ΔE_{SP} (first-order differences). The approximately 100 mV/km E_{SP} observed at Dawu station starting September 4th correlates significantly with the Jishishan *M*s6.2 earthquake, accompanied by a sustained and significant ΔE_{SP} jump. Jiayuguan, Gufeng and Tianshui stations exhibit larger E_{SP} amplitude variations and relatively poorer stability, yet they still exhibit annual variation patterns, albeit with more frequent jumps compared to Baishuihe and other stations.

It's important to note that the substantial E_{SP} decrease observed at Zhouzhi Station in August 2023 resulted from data variations caused by the collapse of NS and NW measurement poles during heavy rainstorms from August 24th to 29th, rather than abnormal variations.

5. Characteristics of Directional Variations in the Telluric Electric Field

The observation data output rate of active seismic geoelectric field stations in mainland China is basically one minute. Based on the model of fissure water(charge) in rock with seepage (movement) in the telluric electric field, NW and NS directions are taken as examples. the dominant azimuth angle α of the telluric electric field can be calculated using the following formula (Tan Dacheng et al., 2014, 2019):

$$\alpha = \pi - \left(\frac{180}{\pi}\right) \cdot \arctan\left(\sqrt{2}\,\frac{\sum_{i=1}^{10} A_{(NW)i}}{\sum_{i=1}^{10} A_{(NS)i}} - 1\right) \quad (6)$$

In formula(6)， A_i represents the amplitudes of the first 10 tidal harmonic constituents, with periods of 24 hours, 12 hours, 8 hours, 6 hours, 4.8 hours, 4 hours, 3.4 hours, 3 hours, 2.7 hours, and 2.4 hours. When measuring in other directions, the corresponding A_i for that direction is used in formula (6).

Generally, when calculating the dominant azimuth α of the telluric electric field, interferences such as space electromagnetic disturbance, HVDC (high-voltage direct current transmission) and environmental changes due to human activities are often negligible [23]. Using the calculation principles derived from formula (6), we obtained the variations in dominant azimuth α of the telluric electric field at 12 stations in the vicinity prior to Jishishan *M*s6.2 earthquake, as depicted in Figure 4.

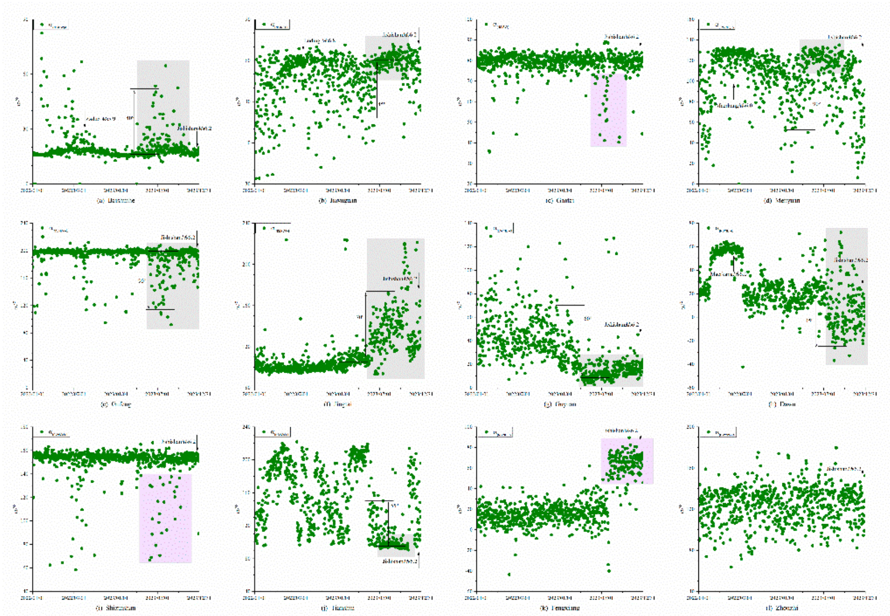

Figure 4. Variation in the dominant azimuth of telluric electric field at each station before Jishishan *M*s6.2 earthquake.

Figure 4 illustrates that Zhouzhi station did not exhibit significant precursory anomalies. The dominant azimuth angle α of the telluric electric field at Baishuihe, Gufeng, Jingtai, and Dawu station showed discrete changes before the earthquake, with variations amplitudes ranging from 40° to 90° (Table 3). These changes indicate intense structural adjustments in rock fissures at these sites, likely

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due to the emergence of new fissures under stress compression. At Jiayuguan, Menyuan, Guyuan and Tianshui station, α narrowed to nearly straight lines, with deflection angles ranging from 45° to 90° (Table 3), suggesting a more ordered structure of rock fissures under stress compression, which gradually returned to its original state after unloading. Jiayuguan station exhibited a deviation angle of 45°, indicating shear fracturing of rock fissures under sustained stress compression. It should be noted that short-term data changes at Gaotai station were attributed to irrigation effects near the electrodes at the western end of the measurement area, while data fluctuations at Fengxiang station increased overall following the indoor observation line reorganization on August 3rd, 2023. Similarly, abrupt data jumps before and after July at Shizuishan station resulted from manual interference during line inspections; these changes at the three stations were not related to precursory anomalies.

Figure 4 shows significant variations in the sudden jump range of the dominant azimuth angle α at the stations, with changes occurring almost quasi-synchronously. Only Guyuan station began to show abnormal changes slightly earlier on April 7th, 2023, while abnormal phenomena at the other stations started around May 2023. Figure 4(a), (b), (d), (f), and (j) show that abnormal changes at these five stations gradually recovered after earthquake, reflecting the gradual restoration of rock elastic deformation as stress unloads post- earthquake.

Table 3. The variation amplitude($\Delta\alpha$) and initiation time of dominant azimuth angle at stations around the Jishishan *Ms*6.2 earthquake.

Station	**$\Delta\alpha$**	**Initiation time**	**Station**	**$\Delta\alpha$**	**Initiation time**	**Station**	**$\Delta\alpha$**	**Initiation time**	**Station**	**$\Delta\alpha$**	**Initiation time**
Baishuihe	40°	2023.5.3	Jiayugua	45°	2023.5.6	Gaotai	/	/	Menyuan	90°	2023.5.23
Gufeng	90°	2023.5.29	Jingtai	70°	2023.5.20	Guyuan	60°	2023.4.7	Dawu	45°	2023.4.28
Shizuisha	/	/	Tianshui	55°	2023.5.13	Fengxiang	/	/	Zhouzhi	/	/

Note: "/" indicates no abnormal changes were observed before the earthquake.

6. Discussion and Conclusion

In actual geoelectric field observations, the instrument-measured data includes the natural electric field ($\boldsymbol{E}_{\mathrm{SP}}$), telluric electric field ($\boldsymbol{E}_{\mathrm{T}}$), and interference information ($\boldsymbol{E}_{\mathrm{R}}$). Historically, research on earthquake cases and analysis of geoelectric field data rarely addressed each component individually. This paper focuses on the Jishishan *Ms*6.2 earthquake on December 18, 2023, and conducts separate studies on the geoelectric field ($\boldsymbol{E}$), natural electric field ($\boldsymbol{E}_{\mathrm{SP}}$), and telluric electric field ($\boldsymbol{E}_{\mathrm{T}}$) at 12 surrounding sites. As a result, some new insights were gained, previous achievements were validated, and some new problems were also discovered.

6.1. "Non-Uniform Variation of "Near-Source" Geoelectric Field Signals

When Varotsos and others proposed the VAN method in 1984, they considered that the variation of the geoelectric field in the same site and direction should be uniform, leading to the establish the principle of multiple polar distance observation. In fact, within the principle of VAN method, scholars [9,17]. classified the variation characteristics of "far-source" and "near-source" signals based on the "point source" model. They deemed SES signals as "far-source" signals, where the variations in long and short polar distances would be essentially equal. For "near-source" signals, the principle of VAN method considers that the variations of geoelectric field in long and short polar distances are not uniform.

In Figure 2, among the 12 geoelectric field stations located approximately 600 km from the Jishishan *Ms*6.2 earthquake, 10 stations exhibited significant abnormal changes in correlation coefficients δ_{xy} (between different directions) and δ_{xx} (between long and short polar distances in the same direction) of geoelectric field raw data (minute values) before the earthquake. This indicates that the geoelectric field at these sites underwent "non-uniform variation," and have characteristic of "near-source" signals. However, the magnitude of variation differed from each site, which embodying the local characteristics of the geoelectric field. Most changes in δ_{xy} and δ_{xx} at each site gradually reverted after the earthquake, the phenomenon that a large proportion of correlation changes and recoveries reflects the influence of regional tectonic activity on the uniformity of geoelectric field. Similar phenomena of variation can also be observed in the dominant azimuth angles of the geoelectric field in Figure 4.

As mentioned in Section 2, during periods of data stability, the absolute values of correlation coefficients at each station are generally high and relatively stable. Consequently, it is evident that under stable regional tectonic conditions, the variations in geoelectric fields at each site exhibit consistent uniformity. However, during preparation and occurrence of earthquakes, this uniformity would be disrupted.

6.2. Influence of Block Tectonic Activity on Anomalies of Geoelectric Field at Local Sites

The primary factors influencing "near-source" signals mainly include observation systems, electromagnetic environment, tectonic activities [24]. Under conditions where observation systems are basically reliable, the method of dominant azimuth of telluric electric field has a certain anti-interference ability [23]. Additionally, by analyzing changes in the dominant azimuth of the telluric electric field, this method allows for the exploration or speculation regarding changes in fissure structures at sites, based on the model of fissure water(charge) in rock with seepage (movement) [15,16] Integrated with block tectonic movement theory, this approach enables the examination of how tectonic activities influence abnormal changes in local geoelectric fields. In Figure 4, abnormal changes in the dominant azimuth α of telluric electric field were observed at 8 stations including Jingtai, Dawu, Guyuan and so on before the earthquake, suggesting possible extrusion and shear cracking in rock fissure structures at multiple sites. During the preparation and occurrence of an earthquake, stress loading and unloading occurred in regions under block tectonic activity, leading to synchronous changes in rock fissures within the local geoelectric field, due to the stress loading and unloading of the region.

Figure 1 depicts that the *M*s6.2 earthquake in Jishishan County occurring on the northern margin fault zone of Laji Mountain [25], situated within the Qilian orogenic belt geotectonically. Among the stations analyzed in this study, Baishuihe, Menyuan, and Gufeng lie on the margins of the Qilian Mountain block, Dawu on the edge of the Qaidam block, Jiayuguan, Gaotai, and Jingtai in the transitional zone between the Qilian Mountain block and Alashan block, with other stations located on the edges of the Hua'nan and Erdos blocks. Scholarly research indicate that the Laji Mountain fault zone is predominantly by compressive deformation [26]. This earthquake was caused by NS-trending thrust fault activity under horizontal compressive stress of N64°E [25]. According to the statistical results in Table 3, the stations showing the most significant changes in the dominant azimuth angle α are Menyuan, Gufeng, and Jingtai, located near the northeastern boundary of the Qilian Mountain block. Structurally, the Qaidam-Qilian block represents the leading edge of the northward extension of the Qinghai-Tibet Plateau. As the Qinghai-Tibet Plateau pushes northeastward, accumulated stress in this region continues to increase, making it the region with the strongest stress response, consistent with the research results of α in Section 4. During this northeastward movement, the Qinghai-Tibet Plateau encounters resistance from the Alashan block located in the north [26]. Therefore, intense and complex deformation occurs near the edge of the Qilian Mountain and in the transitional zone between the Qilian Mountain and Alashan block. This also explains why Jiayuguan, despite its distance from the epicenter, exhibited significant anomalous changes in its geoelectric field before the earthquake due to intense and complex tectonic activity in its vicinity, whereas nearby stations like Zhouzhi and Fengxiang did not show similar changes, which is closely related to the tectonic activity specific to their respective regions. It is noteworthy that Gaotai, also located in an area of intense tectonic activity similar to Jiayuguan, did not have its anomalous changes considered as pre-seismic anomalies this time due to potential interference from agricultural irrigation.

6.3. New Understanding of Further Confirm the Three Elements of Earthquake Prediction

Previous studies primarily focused on using the geoelectric field for predicting moderate-strong earthquakes with magnitudes above 5. This is also related to the stress level of earthquake occurrence; as stronger stress accumulation before moderate-strong earthquakes leads to more intense and clear pre-earthquake anomalies in the geoelectric field.

Regarding the timing of seismic occurrences, anomalies began appearing around May 2023 at various stations, demonstrating quasi-synchronization in the time domain. However, the beginning and duration time of anomalies do not show a clear correlation with the location or tectonic activity of the station. This phenomenon is likely related to the specific environmental conditions at each site of station.

Regarding the epicenter determination, typically, attention is focused on a certain area around the station. and single-station positioning method is often employed, which take station as the center and a fixed epicentral distance as the radius to form the circle, the interior of this circle is considered as potential earthquake location. However, this method often results in a broad area of uncertainty and lacks precision. In this study, most of the stations showed changes in dominant azimuth angles before earthquakes were concentrated within approximately 300 km. Specifically, stations such as Gufeng, Jingtai, Menyuan, and Dawu had epicentral distances within 300 km, stations like Tianshui and Guyuan were within 350 km (see Table 1). Using these six stations as centers with a 350 km radius, Figure 5 illustrates the intersection area shaded in green, where the Jishishan *M*s6.2 earthquake occurred at the edge of this region. If only stations within 300 km were considered, the earthquake would have occurred within the intersection area of the four stations.

Given that abnormal changes within 300 km may be more intense and crucial for identifying anomalies before earthquakes, current prediction rules mainly focus on seismic events within 300 km around stations. However, using the six stations within 350 km results in a smaller and more precise area for the potential earthquake location. The density of stations also affects epicenter determination; the more observation stations, the more accuracy of the epicenter predictions. Additionally, the six observation stations selected in this study are mainly distributed northern of the epicenter, with fewer on the southern side. Therefore, uneven distribution of stations may also interfere with epicenter determination. Increasing station density and strategically planning station locations can enhance the identification of earthquake epicenters.

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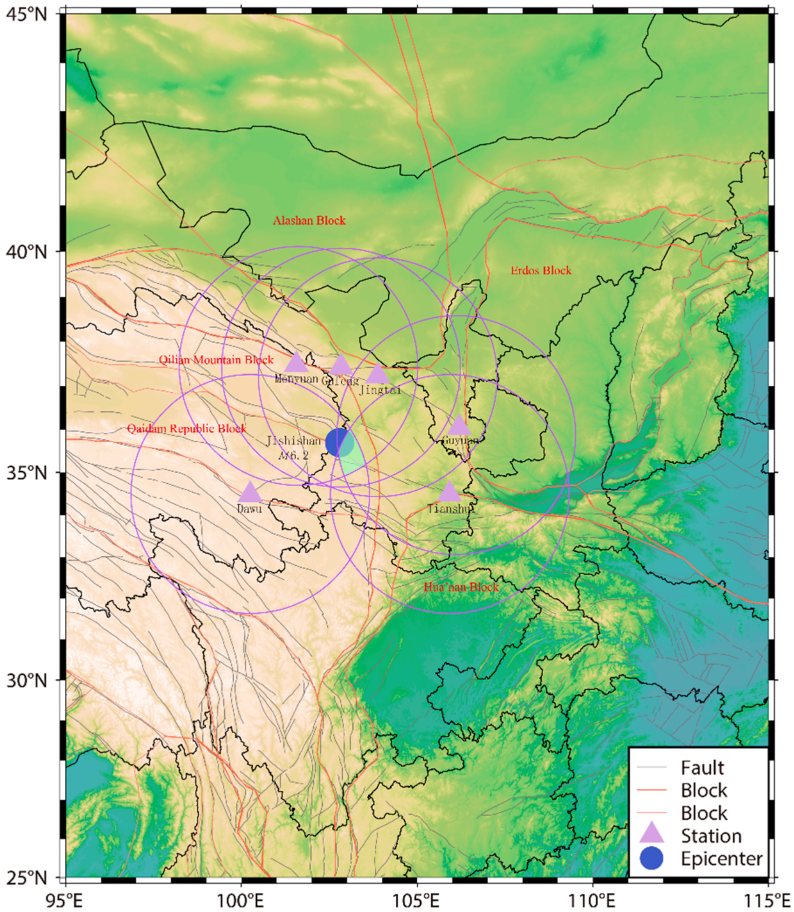

Figure 5. Distribution of geoelectric stations within 350 km of the Jishishan *M*s6.2 earthquake and the epicenter prediction.

6.4. Conclusion

Through the analysis and discussion of minute sampling data from 12 geoelectric fields stations surrounding the *M*s6.2 earthquake in Jishishan County, Gansu Province on December 18, 2023, four insights were obtained as follows:

(1) During periods of stable regional tectonic activity, the geoelectric field variations at each site exhibit relatively uniform characteristics. However, these become disrupted during the preparation and occurrence of earthquakes. Before and after earthquakes, the geoelectric fields show non-uniform changes at sites, often exhibiting localized characteristics.

(2) During the preparation and occurrence of earthquakes, rock fissures in local geoelectric field corresponding change due to the loading and unloading of regional stress. Consequently, significant quasi-synchronous changes are observed in the dominant azimuth angles of the telluric electric fields in the region. Stations located in areas of intense tectonic activity often exhibit more drastic anomalies, suggesting influence from plate tectonic activities on observation data abnormalities within the region.

(3) Currently, observation data in geoelectric field are primarily used for prediction of moderate-strong earthquakes of magnitude above 5. The epicenter can be pinpointed using multiple stations showing abnormal changes. Earthquakes often occur within and around the intersection areas of the predicted ranges of multiple stations. There is no clear correlation between the time of seismic occurrences and the locations or tectonic activities of the stations.

(4) The density of observation stations and the layout planning of stations within the region also affect the determination of the three elements of earthquake prediction. A denser and more evenly distributed layout of stations facilitates smaller-scale and more precise determinations of earthquake epicenters.

It should be noted that this paper preliminarily recognizes the non-uniform changes in local geoelectric field before earthquakes. Therefore, further research on the characteristics of non-uniform changes in geoelectric field, and the relationship between the time of earthquake occurrence and abnormal evolution as well as tectonic activity, especially short-imminent earthquake occurrences, will contribute to a more accurate prediction of the three elements of earthquake and the development of the geoelectric seismology.

Author Contributions: Writing—review & editing, Weiming Wang; Data curation, Xiaofeng Liao; Funding acquisition, Zhiwei Zhang; Investigation, Yuexia Ren. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported in part by the Seismic Monitoring Task of China Earthquake Administration (2024010403), 2024 Science and Technology Special Project of Sichuan Earthquake Administration (LY2403), National Key Research and Development Program (2021YFC3000705-07).

Data Availability Statement: The data presented in this study can be shared on reasonable request to the corresponding author.

Acknowledgements: We would like to express our gratitude to the Seismological Bureaus of Gansu Earthquake Agency, Qinghai Earthquake Agency, and Ningxia Earthquake Agency for providing the observation data. Meanwhile, we sincerely thank the reviewers for their valuable comments and suggestions on the manuscript.

Conflicts of Interest: The authors declared that they have no conflicts of interest in this work.

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