Application of Optical Astronomical Time-Latitude Residual Anomalies in Strong Earthquake Prediction—Postprint Commemorating the Tangshan Earthquake and the 40th Anniversary of the Discovery of Optical Astronomical Time-Latitude Residual Anomalies

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Abstract

To further investigate the role of optical astronomical time-latitude residual anomalies in earthquake prediction, this study introduces the discovery of pre-earthquake anomalies in optical astronomical time-latitude residuals and the associated research practices in earthquake prediction, as well as the correspondence between anomalous variations in time-latitude residuals from the photoelectric astrolabe at Yunnan Observatory and strong earthquakes in its surrounding region. Finally, in a discussion format, possible geophysical mechanisms underlying this association, current limitations in earthquake prediction, and potential solutions are presented. Importantly, prediction practices since X10 have further demonstrated that utilizing synchronous anomalies in optical astronomical time-latitude residuals to provide earthquake prediction information has resulted in neither false alarms nor missed reports. This indicates that it can serve as a viable method for earthquake prediction to be implemented in operational practice, deserving greater attention and more in-depth research.

Full Text

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Abstract

To further investigate the role of optical astronomical time-latitude residual anomalies in earthquake prediction, this paper introduces the discovery of pre-earthquake anomalies in optical astronomical time-latitude residuals and their research application in earthquake prediction practice. We present the correspondence between time-latitude residual anomalies from the photoelectric astrolabe at Yunnan Observatory and strong earthquakes in its surrounding region, and discuss the possible geophysical mechanism underlying this relationship. Forecasting practice since 2010 particularly demonstrates that utilizing synchronous anomalies in optical astronomical time-latitude residuals to provide earthquake prediction information has generated neither false alarms nor missed forecasts for major earthquakes. This indicates that the method can be fully implemented as an earthquake prediction tool in operational practice and deserves greater attention and more intensive research.

Keywords: optical astronomical time-latitude residuals; plumb line variation; underground mass motion; earthquake

1. Introduction

The discovery of optical astronomical time-latitude residual anomalies originated from observations at Beijing Observatory (now the National Astronomical Observatories). Researchers in the time service group had long been troubled by anomalous observations from a visual equal-altitude instrument that had otherwise performed excellently for determining Earth rotation parameters, primarily Earth' s rotation rate. These anomalies reappeared during the Tangshan earthquake period, when deviations between measurements from this instrument and the combined values from other instruments nationwide exceeded the normal error range by 2–5 times. While researchers were puzzling over these irregularities, the Tangshan earthquake struck on July 28, 1976, shocking the world. Against this backdrop, and while the nation was mobilized in rescue and relief efforts, Beijing Observatory researchers suddenly realized that the 1966 Xingtai earthquake and the Tangshan earthquake shared similarities: the Xingtai epicenter was located southwest of Beijing Observatory at a distance of 160 km, while the Tangshan epicenter lay to the east-southeast, with both producing noticeable shaking in Beijing. After careful analysis and discussion of the observational data, they discovered that Beijing Observatory' s optical astronomical time and latitude determinations showed anomalies during the months preceding the 1976 Tangshan earthquake.

To further verify the objectivity and authenticity of this phenomenon, the researchers collected observational results from 1966 to 1976 from globally distributed, high-quality instruments and conducted systematic analysis. They found that in years with strong earthquakes near stable observatories, the observations showed short-term anomalies in astronomical time-latitude residuals before seismic events, which they termed "short-term anomalies of astronomical time-latitude residuals preceding strong earthquakes" [1]. In contrast, such anomalies were essentially absent in years without earthquakes. This discovery demonstrated that precise optical astrometric results could not only determine Earth rotation parameters but also provide warning information for earthquake prediction near observatories, thereby confirming the relationship between anomalies and seismic activity.

These findings attracted attention from domestic and international colleagues. Academician Chen Yong, former deputy director of the State Seismological Bureau, recognized this research as an innovative approach in exploring the complexity of earthquake precursors. Resolutions at International Astronomical Union general assemblies repeatedly noted that optical astrometric observations could monitor plumb line variations and contribute to earthquake prediction. At the 7th National Geodynamics Symposium held in November 1989, geodynamics experts urgently called upon the State Seismological Bureau and relevant departments to take prompt measures to ensure that China' s optical astrometric capabilities could continue contributing to earthquake prediction, identifying these observations as a promising predictive tool.

While Beijing Observatory conducted in-depth studies on the relationship between astronomical observation anomalies and strong earthquakes [2-4], Shanghai Observatory also initiated research in this area [5-9]. Shanghai Observatory detected significant anomalies in time determination residuals from a transit instrument and simultaneous time-latitude residuals from a photoelectric astrolabe before the magnitude 5.0 Taicang, Jiangsu earthquake on January 27, 1990 [6].

2. Yunnan Observatory Studies

Given its location in a seismically active region, Yunnan Observatory began collaborating with the Yunnan Seismological Bureau after the 1985 Luquan earthquake to investigate correlations between photoelectric astrolabe time-latitude residual anomalies and strong earthquakes in the surrounding area, providing several important references for earthquake prediction. This collaboration successfully predicted several strong earthquakes in the neighboring region, particularly since 2010.

Following the magnitude 6.3 Luquan earthquake on April 18, 1985, which occurred only 93 km from Yunnan Observatory with strong shaking felt in Kunming, researchers from Beijing Observatory and our team analyzed pre-earthquake observations from Yunnan Observatory' s photoelectric astrolabe and identified clear anomalies in the observational data from the preceding months [5].

To thoroughly investigate the relationship between Yunnan Observatory' s photoelectric astrolabe time-latitude residual anomalies and surrounding strong earthquakes, we systematically analyzed all observational records since the instrument' s commissioning using the defined methods for optical astronomical time-latitude residuals. We discovered a good correspondence between the two, finding that synchronous anomalies in both time and latitude residuals serve as important indicators distinguishing seismic from aseismic periods. These results have been published previously [5]; to provide readers with a more complete understanding, we reference that work here while adding more empirical evidence accumulated over time.

shows the actual correspondence between time-latitude residual anomalies at Yunnan Observatory and strong earthquakes in the surrounding region. The table includes earthquake date, geographic latitude (ϕ) and longitude (λ), distance (D) and azimuth (A) relative to the observatory, the constant variation (S) of time-latitude residuals, and the number of precursor days (T). Y/N indicates whether anomalies were synchronous.

3. Statistical Characteristics and Spatial Range

The anomalies in optical astronomical time-latitude residuals share similarities with other earthquake-related geophysical phenomena. Statistical results indicate that when earthquake magnitude exceeds 6.0, numerous anomalies appear two to three months before the event. The warning signals from these anomalies can involve epicentral distances up to 400 km, though generally no response is observed when the epicentral distance exceeds 700 km, as was the case before the 2008 Wenchuan earthquake [7].

During the research period, Yunnan Observatory provided 11, 12, 13, 15, and 16 pre-earthquake warnings to the Yunnan Seismological Bureau, specifying time, location, and magnitude. However, because a single station does not constitute a monitoring network, the three essential elements of earthquake prediction could not be provided. Since multiple earthquakes occurred at the same location during the study period, Figure 1 only marks earthquake dates and magnitudes without indicating specific locations. Figure 1 shows the geological structure of the Sichuan-Yunnan rhombic fault block where Yunnan Observatory is located.

4. Prediction Practice Since 2010

Since 2010, for several years, Yunnan Observatory has provided the Yunnan Earthquake Forecasting Research Center with monthly photoelectric astrolabe time-latitude residual data up to the end of the previous month at the beginning of each month for analysis and prediction. Within a 700 km radius of Yunnan Observatory, four earthquakes occurred in Yunnan Province in 2013 and 2014:

the April 20, 2013 Lushan earthquake (magnitude 7.0), the May 30, 2014 earthquake (magnitude 6.1), the August 3, 2014 earthquake (magnitude 6.5), and the October 7, 2014 earthquake (magnitude 6.0). Their epicentral distances from Yunnan Observatory were 580 km, 480 km, 240 km, and 280 km respectively, with azimuths of 12°, 10°, 10°, and 16° northeast of north. All four earthquakes caused varying degrees of casualties and property damage.

Analysis of the monthly reported time-latitude data from Yunnan Observatory' s photoelectric astrolabe revealed synchronous σ anomalies before these earthquakes. Reviewing the warnings reported since 2010, there were only these four synchronous anomalies—no false alarms and no missed forecasts. The anomalies preceded the earthquakes by approximately 200–300 days.

[Figure 2: see original paper] shows the time-latitude residual curves from Yunnan Observatory' s photoelectric astrolabe from 2010.0 to 2016.0.

5. Geophysical Mechanism

Optical astrometric instruments observe using the local plumb line as a reference. After eliminating the effects of Earth rotation parameters and other factors, the residuals primarily reflect local plumb line variations. Appropriate data processing removes random errors, leaving variations mainly caused by underground mass movement during earthquake preparation, such as groundwater activity and intraplate block movement [10–11]. This can also monitor gravity variations over larger regions after accounting for Earth' s overall motion.

Synchronous anomalies in optical astronomical time-latitude residuals can indeed provide early warning information for impending earthquakes around the observatory. However, the current understanding of the temporal relationship between these anomalies and earthquake occurrence remains qualitative. The time delay between anomaly appearance and major earthquake occurrence is generally 5–10 days, though some anomalous geophysical phenomena appear months, half a year, or even longer before earthquakes. Some anomalies emerged at the end of 2009 for earthquakes occurring in 2010.

6. Limitations and Future Prospects

The study has not yet established quantitative relationships between anomaly signals and earthquake magnitude or epicenter location. Moreover, smaller magnitude earthquakes and those at greater epicentral distances cannot be reflected in optical astronomical time-latitude residuals. If several high-precision, highly automated instruments—such as the digital zenith telescope developed by the National Astronomical Observatories [12]—were deployed to establish an observation network in seismically active regions, the abundant data obtained would positively contribute to researching and estimating earthquake magnitude and location [11]. However, optical astrometric observations can only be conducted on clear, cloudless nights, and rainy weather seriously affects data continuity.

Prediction practice since 2010 further demonstrates that using synchronous anomalies in optical astronomical time-latitude residuals for earthquake prediction has produced neither false alarms nor missed forecasts. This indicates that anomalies in optical astronomical time-latitude residuals may represent an effective earthquake precursor worthy of greater attention and deeper research.

7. Conclusion

The synchronous anomalies in optical astronomical time-latitude residuals can serve as a reliable method for earthquake prediction in operational practice, particularly for providing early warning information for strong earthquakes within several hundred kilometers of observatories.

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