# Variation Of Luni-solar Tidal Force And Occurrence Times Of Earthquakes In Taiwan Island of China

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**Abstract** In this study, we investigate the contribution of the variance ratio of the tidal force to earthquakes from discussing the variance ratio of each component of luni-solar tidal force and 21 major earthquakes（$M_s \geqslant 7.0$）occurred in land and offshore area of Taiwan island of China in 20th century. The result indicates that occurrence times of these earthquakes are correlated with the variance ratio of the luni-solar tidal force, and the luni-solar tidal force plays an important part in triggering earthquakes.

**Keywords:** the luni-solar tidal force; earthquake; variance ratio

## 1 Introduction

Luni-solar tidal force can cause deformation and mass redistribution of the Earth. Global mass redistribution alters gravitation field, Earth rotation and many other geophysical phenomena. The influence of the luni-solar tidal force on some geophysical phenomena, such as earthquake, was paid attention all along. Several workers have compared the luni-solar tidal force and the earthquakes, and found earthquakes were correlated with this force [1-5].

The order of magnitude of the luni-solar tidal force is relatively small, and seemingly can't explain the influence of the luni-solar tidal force acting on earthquakes, especially can't explain the trigger action on earthquakes. But, we note that Heaton has compared the tectonic stress and tidal stress [6]. He found that the variance ratio of the tidal force is greater than the tectonic stress by about 2 orders of magnitude. The variance ratio of tectonic stress is about $10^2$pa per six hours, but the variance ratio of tidal force is about $10^4$pa per six hours. This is a significant phenomenon.

Taiwan Island is located in the circum-Pacific seismic belt. It is subjected to long-lasting press from the Philippine plate and Eurasia plate. There are about 31 intense earthquakes ($M_s \geqslant 7.0$) in this century, nearly about every several years (including earthquakes occurred in adjacent seas). In this paper, we primarily discuss the relationship between the variance ratio of each component of the tidal force and 21 major earthquakes（$M_s \geqslant 7.0$）occurred in land and offshore area of Taiwan island

of China in 20th century.

## 2 Computation of the luni-solar tidal force

Our computation will follow the formulation given by zhao *et al.* [7]. At a location, we can get three components of the luni-solar tidal force, including the radial component $F_r$, the south-north horizontal component $F_{sn}$, and the east-west horizontal component $F_{ew}$. $F_r$ is along the direction of the vertical line. $F_{sn}$ parallels to the tangent direction of the longitude circle and south is the positive direction. $F_{ew}$ parallels to the tangent direction of the latitude circle in a horizontal system of coordinates and east is the positive direction. We also can get $F_{snew}$, the resultant force about south-north component and east-west component of the luni-solar tidal force. The value that N+1 moment of the luni-solar tidal force minus N moment is called variance ratio.

We compute the components' hourly variation and daily variation and the variance ratio of the luni-solar tidal force, altogether 3 months, 2 months before earthquake occurrence and 1 month after it, respectively. In Fig.1, we present the daily value curve of the variance ratio of luni-solar tidal force of Jiji, September 21, 1999 earthquake. In this figure, X-axis is time, and Y-axis is variance ratio of $F_r$, $F_{sn}$, $F_{ew}$, respectively. Arrow position means occurrence time. The positive extreme value is called peak, and the negative extreme value is called valley. The relationship between the earthquakes and the variance ratio of luni-solar tidal force are displayed in Table 1. In this table, the character P means peak and the character V means valley. The negative or positive number means the earthquake date occurred before or after the peak or valley respectively.

We note, most of the earthquakes occur in the period around the extreme value of daily variation and hourly variation of the horizontal component. The vicinity of the extreme value means that the variation of the luni-solar tidal force changes greatly in this period. For example, about 71% of earthquakes occur in the vicinity of the east-west horizontal component extreme value of the daily variation, altogether 6 days, 2 days fore and after the positive extreme value and 1 day after the negative extreme value. About 81% earthquakes occur in the vicinity of the east-west horizontal component extreme value of the hourly variation, 1 hour fore and after the positive extreme value and the negative extreme value and 1 hour after it altogether 5 hours. All the earthquakes occur in the vicinity of the east-west horizontal component extreme value of the hourly variation about 7 hours. The occurrence times of all earthquakes are in the vicinity of the extreme value about 5 hours of the horizontal component of the tidal force.

The result shows that the occurrence times of these earthquakes have obvious

correlation with the variation of east-west horizontal component and the horizontal component of the tidal force in the seismic region, and the luni-solar tidal force maybe play an assignable action in triggering some earthquakes.

Fig1. The daily value curve of the variance ratio of luni-solar tidal force of Jiji Sept. 21,1999 earthquake ($M_s$=7.6)

Table 1. The intense earthquakes ($M_s \geqslant 7.0$) occurred in land and offshore area in Taiwan Island and the variance ratio of the luni-solar tidal force

| Date | Focus | magnitude | $F_{ew}$ rate per day | $F_{ew}$ rate per hour | $F_{snew}$ rate per hour |
|---|---|---|---|---|---|
| 1909.04.15 | Taibei | 7.30 | P -2 days | P +1 hours | P -1 hours |
| 1909.11.21 | Nanao | 7.30 | P -3 days | P +2 hours | P 0 |
| 1922.09.02 | Suao | 7.60 | P +1 days | P -1 hours | V +1 hours |
| 1935.04.21 | Taizhong | 7.10 | P +1 days | P -1 hours | V 0 |
| 1936.08.22 | Dawu | 7.20 | V +3 days | V 0 | P0 |
| 1937.12.08 | Luye | 7.00 | V -3 days | V +1 hours | P0 |
| 1938.09.07 | Hualian | 7.00 | V -3 days | V +1 hours | P 0 |
| 1938.12.07 | Donghe | 7.00 | P -1 days | P +1 hours | P 0 |
| 1941.12.17 | Tainan | 7.00 | P +1 days | P -2 hours | V -1 hours |
| 1951.10.22 | Daan | 7.25 | V +1 days | V +1 hours | P -1 hours |
| 1951.10.22 | Yuli | 7.10 | P +2 days | P 0 | V +1 hours |
| 1951.10.22 | Hualian | 7.10 | P -1 days | P +1 hours | P 0 |
| 1951.11.25 | Donghe | 7.50 | P -1 days | P 0 | V +1 hours |
| 1951.11.25 | Ruisui | 7.30 | P -1 days | P 0 | V +1 hours |
| 1957.02.24 | Hualian | 7.20 | P -1 days | P +1 hours | P -1 hours |
| 1959.08.15 | Gangzi | 7.00 | P 0 | P +1 hours | P -1 hours |
| 1964.01.18 | Jiaxian | 7.00 | P 0 | P -1 hours | V 0 |
| 1972.04.24 | Xikou | 7.30 | P -4 days | P +2 hours | P +1 hours |
| 1986.11.15 | Hualian | 7.60 | P 0 | P 0 | P -1 hours |
| 1990.12.14 | Shoufeng | 7.10 | P +3 days | P -1 hours | V 0 |
| 1999.09.21 | Jiji | 7.60 | P 0 | P -2 hours | V 0 |

**3 Analysis and Conclusion**

The earthquakes in Taiwan block are shallow focus earthquakes on the whole, and their courses of rift system are nearly south-north direction. 9.21 Jiji earthquake occurred because the south-north direction fault in middle part was pressed and leaped. When earthquake preliminary occurred, the fault ruptured from south to north in focus. The variance ratio of luni-solar tidal force's horizontal component and east-west horizontal component have important influence on fault leap, and their variation maybe accelerate leap of south-north direction fault, thus triggering earthquake.

Through the analyses for the variance ratio of luni-solar tidal force and earthquakes in many belts, we find that their correlativity and details are different for

different belts. The luni-solar tidal force influence earthquakes, but the influence extent is related to the geologic property and stress accumulation extent in this area. The stress state is closely related to earthquake's preparation and occurrence in this area. Before the earthquake occurs, frictional stress, terrestrial stress and tidal stress are in balanced state. Removement of former surface of fracture need overcome its static friction force. When the stress accumulation makes fault be in a critical state, in which attached stress from external or internal maybe become the factor triggering sudden change, can cause violent movement. The luni-solar tidal force probably is one of trigger forces influencing this process.

Frictional stress is always determined by surface condition and positive stress. The viscosity coefficient is assumed to keep constant. The positive stress vertical to the course of fault will influence on frictional stress. To a south-north direction fault, the principal axis of stress of earthquake is nearly east-west direction. When the variance ratio of east-west direction force is very big, a great change of the frictional stress is bound to follow. With the action of south-north component of the luni-solar tidal force, the unstable equilibrium in fault interior maybe is destroyed. So violent movement occurs and becomes earthquake. In the meantime, it causes a wide range of stress readjustment and transits to a new balanced state.

Analysis of luni-solar tidal force shows that there had closely relationship between the occurrence times of earthquakes in Taiwan Island and the variance ratio of luni-solar tidal force. The variance ratio of luni-solar tidal force at any area can be computed precisely. By means of this method and result, we can make the earthquake predict precisely. For example, on the basis of the earthquake prediction lasting about several months or several days made by other prediction method, such as geomagnetic method, gravity anomaly, by means of computing the luni-solar tidal force and its variance ratio on different time scale in this period, we can determine a dangerous period that may be about one week in each month or about 5-7 hours in one day.

Further investigation is clearly needed to better understand this interesting problem and help to improve earthquake prediction.

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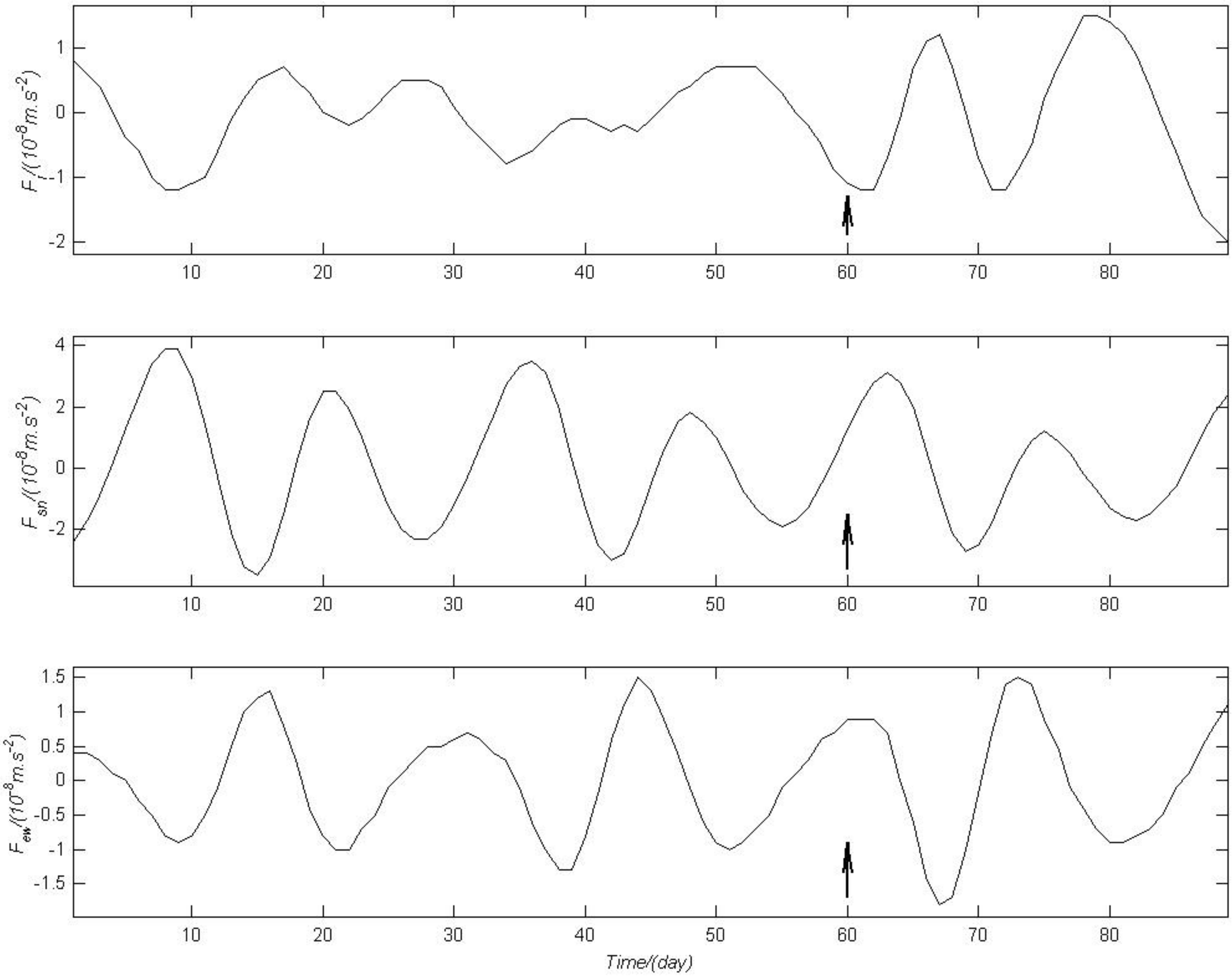
$F_r/(10^{-8}m.s^{-2})$
$F_{sn}/(10^{-8}m.s^{-2})$
$F_{ew}/(10^{-8}m.s^{-2})$
Time/(day)