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Solar-lunar-terrestrial interactions: Bursts of neutron emission and seismic activity

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Abstract. In 1990–1991 an increase in the neutron emission intensity was observed at the new Moon and full Moon in seismically active regions of the Pamir mountains. In 1997, principally new data indicating that neutron bursts result from tidal phenomena in the Earth's crust were obtained. On the other hand, it is known that tidal forces can act as a triggering mechanism for seismic activity. Examination of homogeneous global data on earthquakes for 1964–1992 allowed us to reveal a 2-week lunar periodicity of earthquakes associated with the new Moon and full Moon phases. A further study of neutron bursts and their correlation with seismic activity can lead to the formulation of a new type of precursors of an increase in seismic activity: neutron bursts due to solar-lunar-terrestrial gravitational interactions.

1. Introduction

The correlation between the bursts of low-energy neutron fluxes from the Earth's crust and the periods of passage of the largest tidal waves through the Earth's crust at the new Moon and full Moon discovered in our experiments was explained by *Volodichev et al.* [1996, 1997]. The essence of the phenomenon is as follows: When the angle between the Earth–Sun and Earth–Moon lines is the smallest, the total gravitational effect exerted by these cosmic bodies on the Earth is the highest and deformations in the Earth's crust are the strongest. This leads to an increase in the neutron concentration in the surface layer of the Earth's crust and atmosphere due to two processes: mechanical emission (that is, a release of various atomic and nuclear particles due to the deformation-induced cracking of the rocks of the Earth's crust) and enhancement of the flow of radioactive gases (isotopes of radon). This leads to a stronger flux of energetic alpha particles that undergo nuclear interactions with the elements of the Earth's crust and atmosphere. As a result, neutrons are ejected.

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2. Observations

An important role of tidal forces acting on the Earth's crust in the formation of neutron bursts can be demonstrated using measurements carried out in 1997 in the Pamir mountains in the region of Jerino at a height of 1100 m above sea level, 30 km to the north of Dushanbe. Figure 1 shows daytime measurements of the counting rates of neutrons N_n and electrons N_e with energies $E_e \geq 150$ keV conducted from 16 to 26 July 1997. From 16 to 24 July the approximating dashed curve passes approximately through the maximum neutron counting rates during every day. This value is the highest on 20 July at 0537 UT (± 03 min). On the same day the Moon passed through the full Moon phase at 0320 UT. An increase in the neutron counting rate at the maxima during the period 16–20 July and a subsequent decrease till 24 July can be due to matched tidal effects of the Moon and the Sun. The sum of these effects reaches its maximum at a full Moon and decreases in subsequent days, which probably demonstrates the sensitivity of neutron emission to relatively small variations in tidal forces. At night (local time) from 21 to 22 July, measurements of neutrons and electrons were also carried out. The results are shown in Figure 2. From 1722

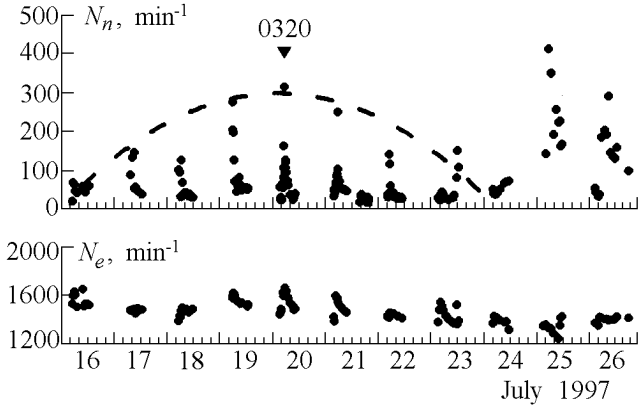

Figure 1. Neutron N_n and electron N_e counting rates in the Pamir mountains in the daytime. The Full Moon phase time is 0320 UT. The dashed line approximates the positions of N_n maxima on 16–24 July.

UT to 1909 UT on 21 July, approximately 12 hours after the daytime 21 July burst, a multi-impulse burst of neutron emission exceeding at its maximum the background value by a factor of 100 was detected. The maximum value of the neutron burst in the daytime on 22 July was also reached in approximately 12 hours after the nighttime burst. Thus a 12-hour periodicity in the bursts of 21 and 22 July corresponding to the tidal wave period was observed.

Earlier we put forward the hypothesis that one of the reasons for formation of neutron bursts at the new Moon and full Moon are increases in the release of radioactive gases. Measurements of fluxes of alpha particles in various regions of the Pamir mountains in July and August 1997 revealed that fluxes of alpha particles were present and that they considerably (by a factor of tens) exceeded the average fluxes in the Earth's crust. The presence of considerable fluxes of alpha particles which are an intermediate product between a radioactive gas and neutrons indicates that an increase in the release of radioactive gases can be a probable reason for neutron bursts.

3. Relation to Seismic Activity

Since strong neutron bursts were observed at the new Moon and full Moon, that is, when the tidal deformation of the Earth's crust was stronger, it was interesting to obtain the evidence of two-week variations in the seismic activity associated with the Moon's phases. To find a correlation between seismic activity and the new Moon and full Moon phases, the catalog of earthquakes with a magnitude $m \geq 4$ for 1964–1992 was analyzed. Using the obtained results, we began a systematic search for series of earthquakes. We call a series of earthquakes a set of earthquakes with the epicenters within the area of several square degrees and following each other with a frequency of $\leq n$, where n is some number of earthquakes per day. At the first stage, when we were looking for a correlation between the Moon phases and seismic activity, we were taking $n = 50$ per day (or 80 per 2 days). We have found 13 such series during 1964–1992. All the events of the series were located in the Pacific seismic ring: 7 series in its northern part at latitudes $\leq 40°$ and 6 series between 25°N and 5°S. It was also found that all 6 series at latitudes above 40° were starting in the days close to the full Moon (the difference was not more than 3 days). The series 7 observed at longitudes of 40–41° began on the fourth day after the full Moon. A hypothesis appeared that large series (with a large number of earthquakes per day) with epicenters at longitudes of $\leq 40°$ start predominantly on the new or full Moon days or on the days close to them.

To obtain a new earthquake series to check this hypothesis, we began to look for series for which the number of earthquakes were $30 \leq n < 50$ per day or $40 \leq n < 80$ per 2 days. We have found 24 such series also located in the Pacific belt. However only 4 series were at latitudes $\leq 40°$. At the same time, series appeared at latitudes $> 5°$S. This fact moved us to widen the hypothesis into the Southern Hemisphere. It would be desirable to find arguments in favor of such uniting of the north and south and also of the asymmetry in the choice of the latitudinal boundaries (since there is no series southward from 40°S). Large differences in the time dependence between the high-latitude (above 40°) and low-latitude (below 40°) regions in 1920–1980 have been reported earlier [see *Mogi*, 1988, Figure 5.8]. We are able to obtain the latitudinal asymmetry of the seismic activity considering the latitude distribution of the total (for 1964–1992) number of earthquake with $m_b \geq 4$. It was found that the symmetry axis relative the equator is as follows: 40°N correspond to 10°S. Thus the asymmetry in the determination of latitudinal boundaries and the splitting series to high latitude and located at central latitudes all manifest the global distribution of the seismic activity and its time differences between the high-latitude and low-latitude regions. We think that this distribution is due to the geography of the tectonic platforms and the direction of their movement.

As a result, we have come to a new edition of the hypothesis: large series of earthquakes with magnitudes $m_b \geq 4$ and epicenters located at latitudes of $\geq 40°$N or $\geq 10°$S begin

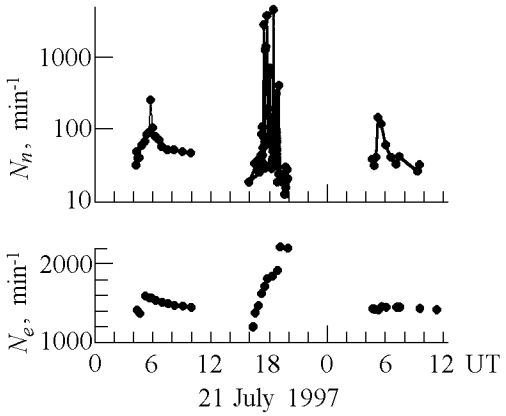

Figure 2. Neutron and electron counting rates in the Pamir mountains including the night-time measurements on 21 July.

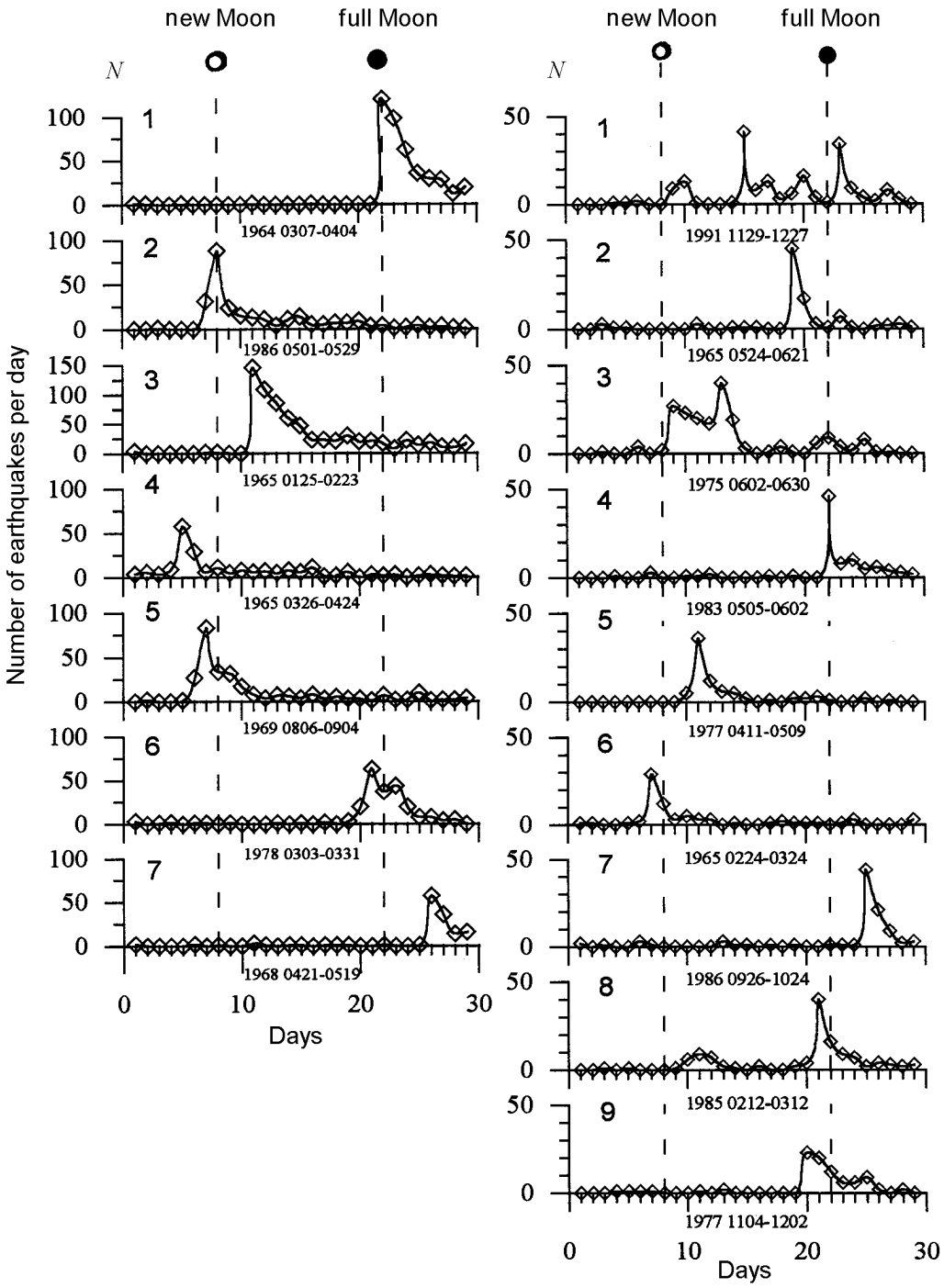

Figure 3. Distributions of the number of earthquakes over the days of synodic months in the (left) largest and (right) large series of earthquakes at the latitudes northward of 40°N or southward of 10°S in 1964–1992.

predominantly on the days of new and full moon or adjacent days. To check this hypothesis, the time dependence of nine earthquake series corresponding to the assumptions of the hypothesis is been considered (Figure 3, right). Figure 3 shows that some series have a complicated time profile, but all of them begin in the days of full or new Moon or within 3 days (the beginnings of the first and eighth series are 1 and 2 days from the new Moon, respectively).

The days remote from the days of new or full Moon by 0–3 days are met in a calendar as often as the days remote by 4–7 days. Therefore, if the grouping at the 0–7 interval is homogeneous, the probability of a random grouping of the

beginnings of all nine series in one of its half (0–3 days) is equal to 2^{-9} or 0.002. We believe that this result confirms the hypothesis presented above.

4. Summary

The analysis of the catalogs of earthquakes has shown that the lunar 2-week modulation manifested itself in the large series of earthquakes in the region of the circum-Pacific seismic ring at the latitudes northward of 40°N and southward of 10°S. Our analysis considerably expands the geography of the regions where the 2-week lunar periodicity is observed. It also confirms that the Moon's phase can affect the time of the earthquake onset in the cases when the characteristic time of the energy accumulation before the earthquake is much longer than a month [*Allen,* 1936]. Deformation of the Earth's crust caused by maximum tidal forces at the new Moon and full Moon can be probably a triggering mechanism for the release of the earthquake energy accumulated during a long period. It is precisely at these days of the synodic months that bursts of neutron emission considerably exceeding (by a factor of tens) the background neutron fluxes are observed in seismically active regions. This suggests that neutron bursts can be regarded as precursors of earthquakes.

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