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Forbush decreases and lunar cycles in the thermal neutron counting rate for the period from May 2015 to February 2019 by using the experimental data of "Neutron" setup

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Introduction

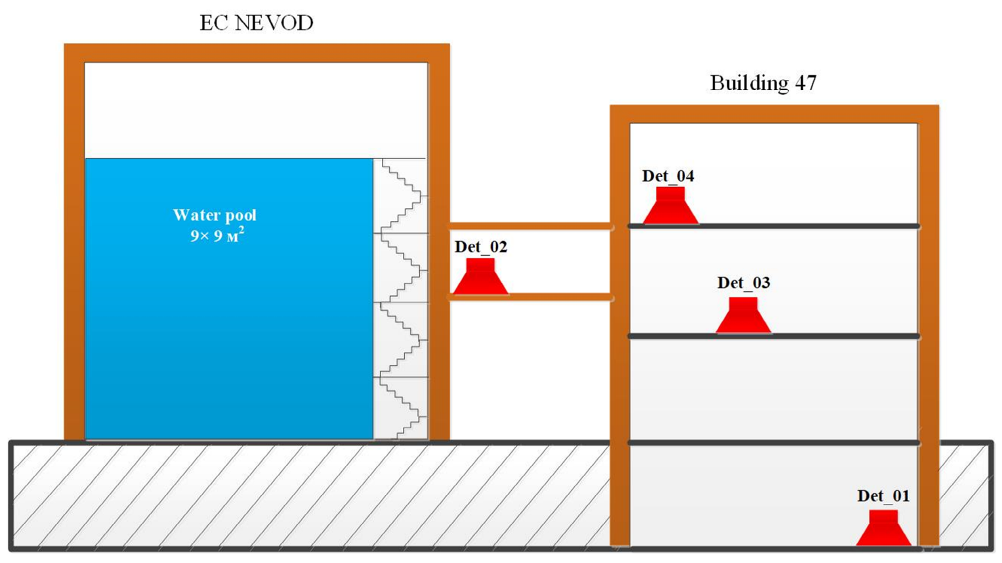
The neutron flux observed near the Earth surface has two main different sources. The first one is created as a result of galactic particles interactions with nuclei of the atmosphere, that generate a huge shower of secondary particles (extensive air shower: EAS). The second source of neutrons was confirmed by the group of B.M. Kuzhevckij, the neutrons are generated through the interaction of α-particles, emitted by the naturel radioactive gas (radon isotopes), with nuclei of the elements of the atmosphere or the ground. On the neutron flux near the surface of the Earth influence variety of effects: changes in the flux of cosmic rays, meteorological parameters (the atmospheric pressure and temperature near the detector), the Sun and the Moon, the tectonic activity of the Earth crust, weather conditions (amount of precipitation) etc. In this work two effects were studied: the Furbush-Decrease (FD) and the impact of the Lunar movement around the Earth. The FD is a sudden decrease of the count rate, caused by a powerful activity of the Sun that produces interplanetary coronal mass ejections (ICMEs).The Moon acts on the Earth by its gravitational force, especially when the Moon, the Earth and the Sun are aligned and the tidal forces from Moon and Sun are added up. The Moon procure an increase of the count rate, by stimulation if the emanation of the radon isotopes at the Earth surface. This work was done in the Experimental complex NEVOD [1], by analyzing the data of thermal neutron count rate collected on the "Neutron" setup [2].

Description of the "Neutron" setup

The "Neutron" setup is designed to monitor the neutron background near the Earth surface. It consists of four identical scintillation detectors, which have a pyramidal metal housing, they are located inside the NEVOD building at different altitudes from the ground surface (-3 m to 10.5 m). The setup operates since 2010 in a continuous mode and records the thermal neutron count rate every five minutes.

The long operation time of the setup has been sufficient to prove its effectiveness and reliability. These advantages are due to the use of a special inorganic scintillator, in the form of a granular alloy of ZnS(Ag) and LiF, enriched up to 90% in the ^{6}Li isotope. The average thickness of the scintillator is only 30 mg/cm^2 and an area is 0.75 m^2. This scintillator is viewed by a PMT-200 photomultiplier .

Layout of neutron detectors of the "Neutron" setup



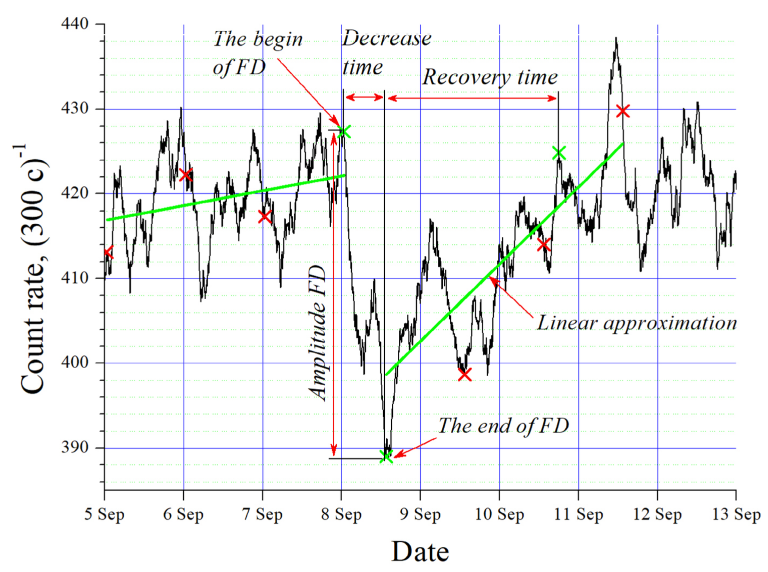
Methods

A long-term data of thermal neutron count rate from May 2015 to February 2019 were analyzed. Corrections for the barometric effect were evaluated and introduced by month. 20 FDs were found, for each of them the FD amplitude and recovery time were estimated. A comparison with the results of the FD studies of two other setups the Moscow neutron monitor (MNM) and the muon hodoscope (MH) URAGAN (MEPhI, Moscow) was done.

To find the amplitude of FD, a method based on step-by-step averaging of the counting rate before and after FD in different time intervals was used. Three days of counting rate before and after FD at first were corrected for slope (with the help of linear approximation), then were averaged over 1, 2, and 3 days. Therefore, a set of 36 different amplitude estimates were obtained and their average value was taken as the amplitude of the Forbush effect [3].

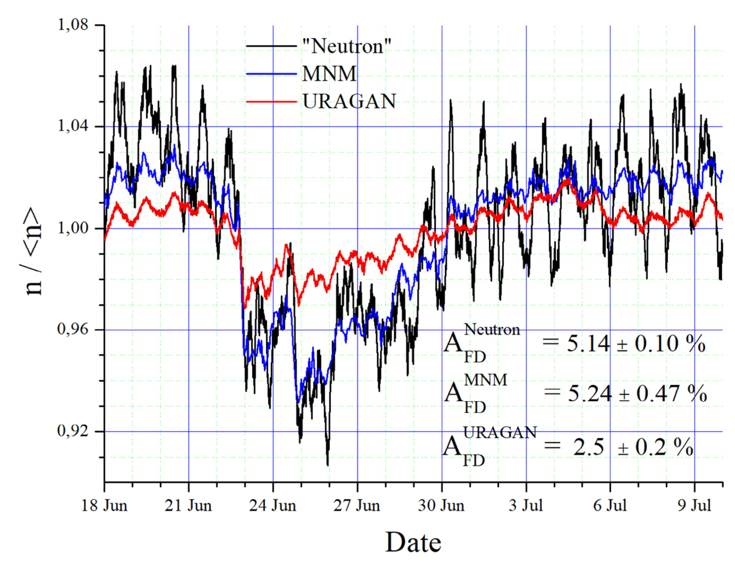
The epoch superposition method was used to study different lunar waves (diurnal tidal wave (M2) and synodic month wave). It consists in summing of many overlapped periods, i.e. the counting rate of the first hour of the first period was summed up with that of the first hour of the second period, and so on, then the data were divided by the number of experimental points that fell into the corresponding interval.

FD parameters (FD 09 September 2017 recorded by Det_02)

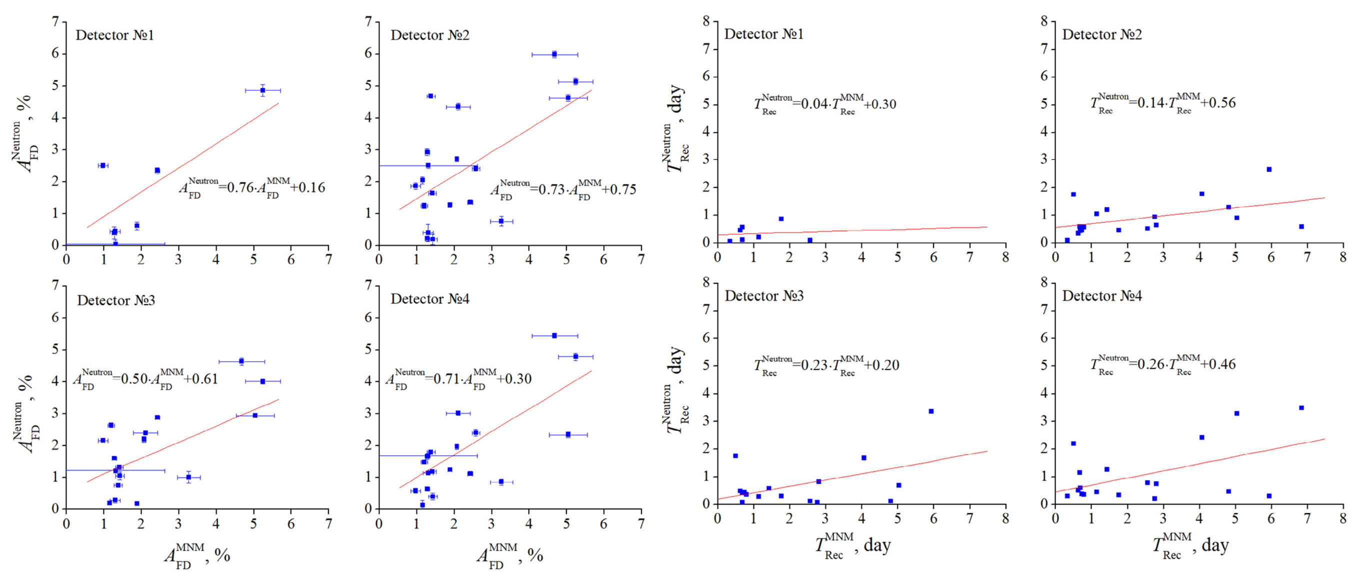


Forbush Decrease results

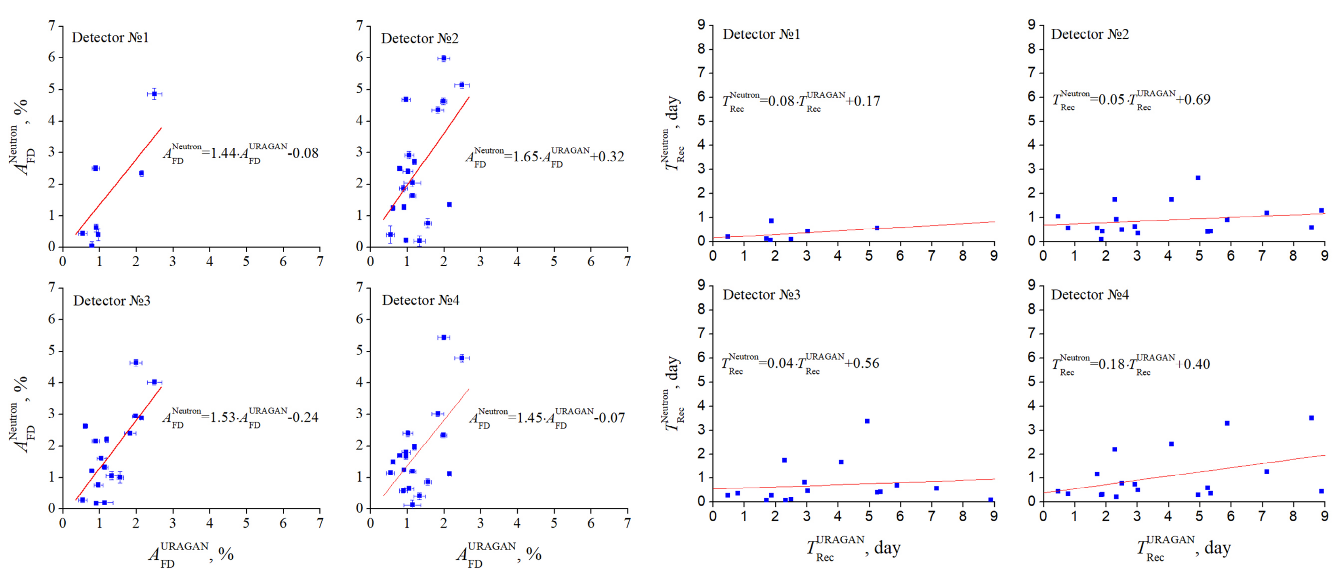
On the example below (FD 22 June 2015) a good agreement between MNM, MH URAGAN and "Neutron" setups is observed. This event is a "cascade" event (two FDs follow one another, the count rate after the first FD does not have time to recover). For such an event, the amplitude of 1st FD can be estimated, but not the recovery time.



Comparison of the amplitudes and the recovery times of the FD registered by "Neutron" detectors and MNM setup



Comparison of the amplitudes and the recovery times of the FD registered by "Neutron" detectors and muon hodoscope URAGAN



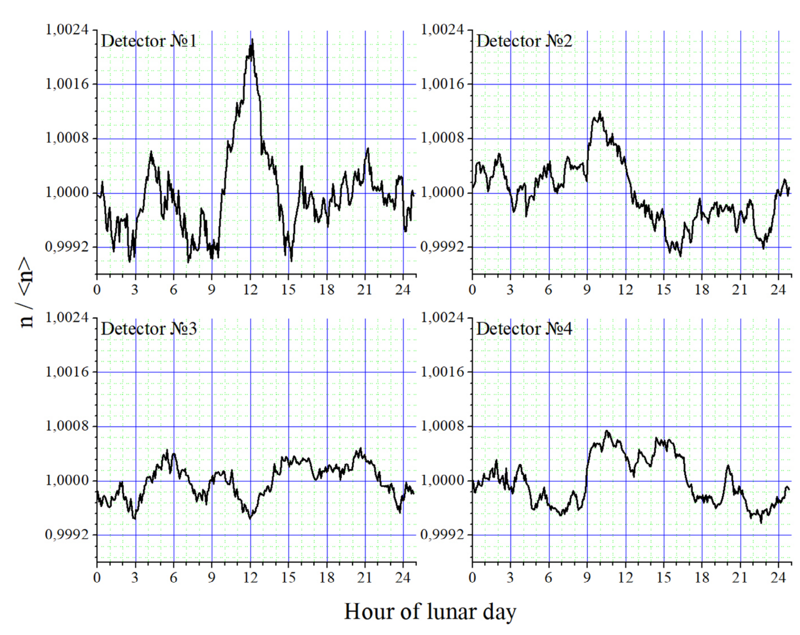
The amplitudes of 20 FDs measured by the "Neutron" setup detectors are comparable with those of MNM (on average, less by about 30%), and about 1.5 times more than for the muon hodoscope URAGAN. The counting rate recovery of the four detectors of the "Neutron" setup is much faster than for MNM and MH URAGAN.

Lunar effect results

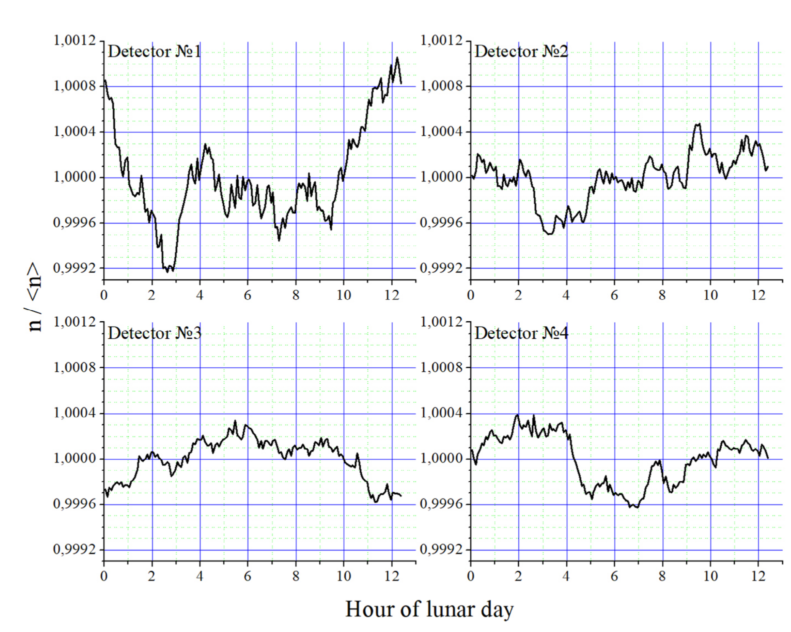
The diurnal Lunar wave (1st harmonic) was obtained by the data of 1st detector with a clear peak (amplitude ~0.32%), that corresponds to the upper culmination around midday. The second peak of upper culmination (at midnight) does not appear, instead this wave the semidiurnal wave shows two peaks. For the other three detectors this waves are not visible, their absence can be explained by a stronger effect of changes in the weather, soil temperature, soil moisture, etc.

The synodic Lunar wave (4th harmonic) was obtained by the data of 1st and 2nd detectors with an amplitude of 0.8% and 0.6% respectively during the full moon. For the other detectors the effect is less seen. Its absence is essentially due to the detectors placement within the NEVOD building and its shielding effect.

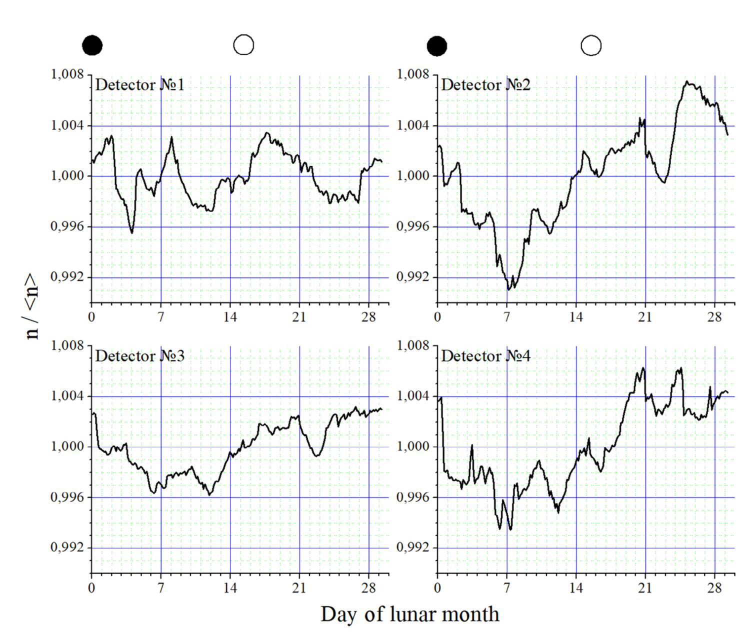
Lunar diurnal tidal wave (M2)



Lunar semidiurnal tidal wave (M2)



Synodic Moon month wave. Black circle- new moon; white circle- full moon.



Conclusion

- A search for the response of "Neutron" setup detectors to Forbush-Decreases during a long period (05.2015 - 02.2019) was carried out. Comparison between different FDs studies showed that the FD amplitudes of "Neutron" are comparable with those of MNM, and about 1.5 times more than for MH URAGAN. The counting rate recovery of "Neutron" setup is much faster than for MNM and MH URAGAN.
- The semidiurnal wave obtained by the data of the first detector located in the building basement, gives maximum increase (~0.32%) of count rate at the middle day (upper culmination) compared with the other detectors.
- The synodic month wave was found for the 2nd and 4th detectors with an amplitude 0.8% and 0.6% respectively during the full moon. For the other detectors, the effect is less seen.

References

1. http://ununevod.mephi.ru/en/
2. D. M. Gromushkin et al. Thermal neutron flux detection near the Earth's surface. Bull. Russ. Acad. Sci.: Phys., 2009 Vol. 73, № 3, pp. 425–427.
3. N. S. Barbashina et al. Specific Features of Studying Forbush Decreases in the Muon Flux. Bull. Russ. Acad. Sci.: Phys., 2009, Vol. 73, № 3, pp. 343–346.