Neutron monitors – Study of solar and galactic cosmic rays

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1. Project description

The Physikalisches Institut at the University of Bern, Switzerland, operates two standardized neutron monitors (NM) at Jungfraujoch: an 18-IGY NM (since 1958) and a 3-NM64 NM (since 1986). NMs provide key information about the interactions of galactic cosmic radiation (GCR) with the plasma and the magnetic fields in the heliosphere and about the production of energetic CRs at or near the Sun (solar cosmic rays, SCR), as well as about geomagnetic, atmospheric, and environmental effects. The NMs at Jungfraujoch are part of a worldwide network of standardized CR detectors. By using the Earth's magnetic field as a giant spectrometer, this network determines the energy dependence of primary CR intensity variations near Earth in the energy range ~500 MeV to ~20GeV. Thereby, NMs ideally complement space observations which mainly cover the energy range below the range of NMs.

Furthermore, the high altitude of Jungfraujoch provides a good response to solar protons ≥3.6 GeV and to solar neutrons with energies as low as ~250 MeV. NMs also play an important role in the space weather domain.

In 2018, operation of the two NMs at Jungfraujoch was pursued without major problems. No technical modifications were necessary. The recordings of the NM measurements are published in near real-time in the neutron monitor database NMDB (http://www.nmdb.eu). Figure 1 shows the relative monthly count rates of the IGY neutron monitor at Jungfraujoch (lower panel) since it was put into operation in 1958. The GCR are always present, and their intensity shows an 11-year variation in anti-correlation with the solar activity characterized by the smoothed sunspot number plotted in the upper panel of Figure 1.

The dosimetric measurements with a GammaTracer device inside the detector housing of the NM64 neutron monitor were continued in 2018.

Bieber et al., 2007 have shown that the 1997 peak count rate of the South Pole NM was ~8% lower than the 1965 peak count rate. However, this decrease was not observed at other South polar NM stations. In their investigations Bieber et al. therefore do not outrule detector tube ageing as the reason for the decline in the count rate. If this hypothesis is correct, a detector tube aging effect should also be present at the NM64 NM at Jungfraujoch, because the NM64 NM at Jungfraujoch has the same type of counter tubes and a similar counting rate per tube as the South Pole NM, i.e. 100 cts/second.

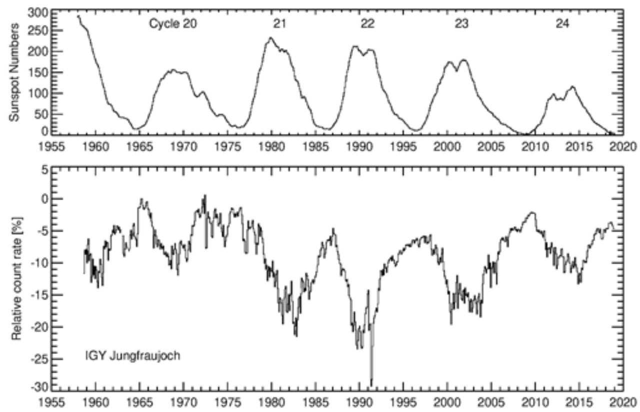

Figure 1. Smoothed monthly total sunspot numbers (Source: WDC-SILSO, Royal Observatory of Belgium, Brussels (www.sidc.be/silso/datafiles), top panel), relative pressure corrected monthly average counting rates of IGY neutron monitor at Jungfraujoch (bottom panel) for the years 1958-2018. The neutron monitor count rate is expressed in relative units with respect to May 1965.

Figure 2 shows the yearly averaged count rate ratios of the NM64 NMs at Jungfraujoch (JUNG1, 3-NM64, R_c = ~4.5 GV) and selected NM stations: Oulu (OULU, 9-NM64, R_c = ~0.8 GV), Kiel (KIEL, 18-NM64 R_c = ~2.4 GV), Jungfraujoch IGY (JUNG, 18-IGY, R_c = ~4.5 GV), and Hermanus (HRMS, 12-NM64, R_c = ~4.6 GV) for the time period 1986-2018 (OULU, JUNG, HRMS), 1989-2017 (KIEL). The ratios were approached by a linear regression in the time interval from 1989 until the end of the corresponding data series. All the ratios show a decrease during the considered time interval which would confirm the effect of NM counter tube aging. The relative change per year of the count rate ratios with its errors are listed in Table 1. As the solar activity in the last solar activity cycles shows a decrease as can be seen from Figure 1 (upper panel), an increase in the trend of the counting rates of NMs over the last several solar cycles is expected.

This trend is larger at polar NM stations compared to NM stations at mid-latitudes and low latitudes. As a consequence, the count rate ratio of Jungfraujoch NMs and the NM stations OULU and KIEL is expected to decrease as is observed, see Table 1. The ratios of the count rates of the two NMs at Jungfraujoch, N_{JUNG1}/N_{JUNG}, as well as N_{JUNG1}/N_{HRMS} also decrease with time. The NM station HRMS has almost the same cutoff rigidity as the NM stations at Jungfraujoch, i.e. all three NMs measure cosmic rays over the same rigidity range, and therefore it is expected that the ratios N_{JUNG1}/N_{JUNG} and N_{JUNG1}/N_{HRMS} should be constant. Indeed, the trend of N_{JUNG1}/N_{HRMS} is small and not significant, see Table 1. There may be different reasons for a changing of N_{JUNG1}/N_{JUNG} with time. Apart from the ageing of counter tubes, also other effects may lead to a drift of the NM count rates, e.g. drift in an electronic component of the pre-amplifier and discriminator electronics, drift in the barometer readouts, influence of the weather (e.g. snow coverage of detector housing, temperature trend). The detectors are located at different positions at Jungfraujoch. The NM station JUNG is located at the roof of the Sphinx labs, whereas JUNG1 is located on the roof of the research station. JUNG is exposed to strongly winds, i.e. snow accumulations on the roof and around the detector housing are almost fully swept away by the wind. In addition, the custodians remove the snow around the detector housing and from the roof in the morning and in the afternoon, if needed. I.e. there is almost no effect of snow accumulation at the count rate of JUNG NM. In contrast, JUNG1 NM is located in the shadow zone of the slope of Jungfraujoch and there are large snow accumulations mainly around the detector housing, but also on the roof of the detector housing. At JUNG1 the snow is not removed from the roof of the detector housing because of danger of avalanches. The influence of snow accumulation in the surrounding of JUNG1 can be seen in its counting rate, see Flückiger and Bütikofer, 2010.

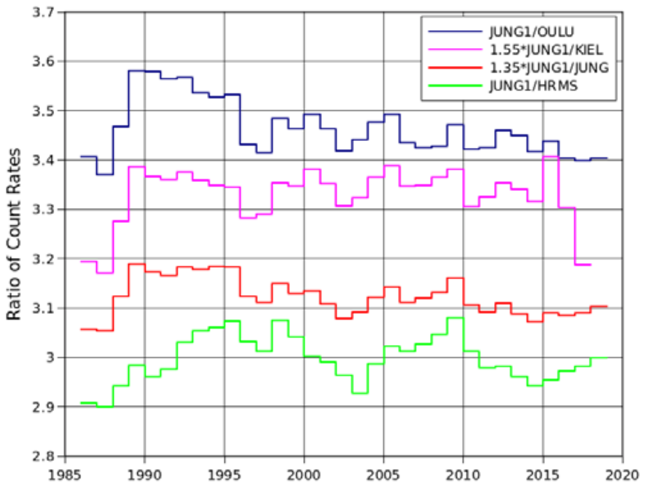

Figure 2. Ratios of the yearly averaged count rates of the Jungfraujoch NM64 NM and selected NM stations. For details see the text.

Table 1. Change of NM count rate ratio for Jungfraujoch NM64 and selected NM stations per year.

	Change of count rate ratio per year [%]
JUNG1/OULU	-0.51±0.07
JUNG1/KIEL	-0.1±0.06
JUNG1/JUNG	-0.24±0.04
JUNG1/HRMS	-0.015±0.008

Figure 3 shows the yearly sum of the measured precipitations at the nearby meteo station Grimsel operated by MeteoSwiss (no precipitation measurements are performed at Jungfraujoch by MeteoSwiss). The linear regression of the precipitation measurements over the time interval 1989 until 2018 shows a decreasing trend of 2 cm/year. This does not support the decreasing trend in N_{NM64}/N_{IGY}. However, it must be considered that the amount of the yearly sum of precipitation may not necessarily be used to assess the amount of water equivalent accumulation over time on and around the detector housing.

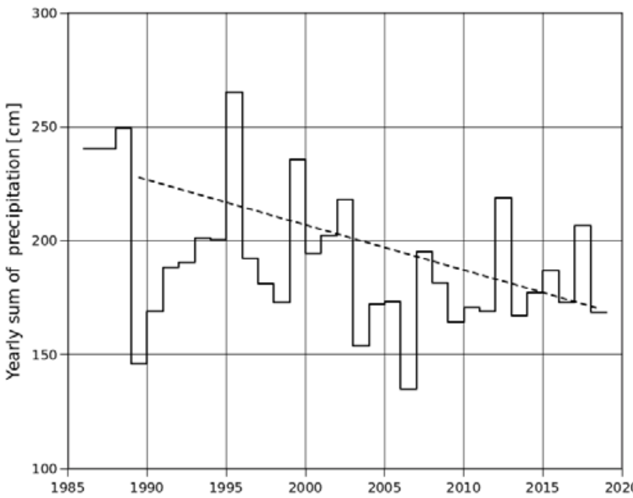

Figure 3. Yearly sum of precipitation at the meteo station Grimsel during the time interval 1989 until 2018. The dashed line shows the linear regression over the time interval January 1986 until December 2018.

The difference in the measurements between the used barometers at the locations of the two NM stations at Jungfraujoch seems to show no drifts with time.

From this investigation it cannot be concluded that the NM64 counter tubes show an ageing effect. The behaviour of the count rate at the NM stations JUNG1 compared to the other NM stations of the worldwide network of NMs must be investigated in the future. However, one must also keep an eye on the behaviour of each NM station, i.e. the measurements of the NM count rates at the different locations must be compared over long time periods.

References

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Flückiger, E., and Bütikofer, R., Neutron monitors – Study of solar and galactic cosmic rays, International Foundation HFSJG, Activity Report 2009, 2010.

Internet data bases

http://cosray.unibe.ch
http://www.nmdb.eu

Collaborating partners / networks

European FP7 Project Real-Time Database for High Resolution Neutron Monitor Measurements (NMDB): http://www.nmdb.eu

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