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 2019, 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 neutron monitor stations Oulu (Finland), Kiel (Germany), and IGY Jungfraujoch (lower panel) for the time interval 1958 until end of 2019. 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 solar activity minimum between solar cycle 23 and 24 is shown by a vertical dashed-dotted line. The end of cycle 23 and the start of cycle 24 occurred in December 2008. The maximum in the count rates of the three shown neutron monitors was observed about one year later. The characteristics of the interplanetary magnetic field and plasmas mainly at distances >1 AU from the Sun determine the galactic cosmic ray flux near Earth. As a consequence, it is expected that the cosmic ray characteristics show a delay with reference to changes in the solar activity.

From Figure 1, it can be seen that the neutron monitor stations Kiel and Oulu observed the largest count rate over the last five solar cycles in the late 2009, i.e. after the solar activity minimum in December 2008. This can be explained by the very low solar activity minimum which was lower than during the previous solar activity minima shown in Figure 1 by the smoothed sunspot number. In addition, the duration of solar cycle 23 with 12.3 years was clearly longer than the typical observed duration of 11 years. In contrast to the neutron monitor stations Oulu and Kiel, the count rate maximum of the IGY neutron monitor at Jungfraujoch in September 2009 was about 2.5% lower than the all-time maximum count rate of the Jungfraujoch station in May 1965. The reason for this behaviour of the IGY Jungfraujoch count rate may be the faster degrading of the counter tubes in the Jungfraujoch neutron monitor because of the much higher count rate compared to a sea level neutron monitor, see our Activity Report 2018.

From the top panel of Figure 1, it can be seen that the level of the peaks of the sunspot numbers is decreasing after solar cycle 21. The most distinct decrease is observed from cycle 23 to cycle 24 where the maximum sunspot number in cycle 24 is about 35% below the peak in cycle 23. The sunspot numbers during the minimum phase at the end of 2019 are about 50% of the value during the previous solar activity minimum. What is expected for solar cycle 25? NOAA/SSRC predict in their last forecast from December 2019 that the cycle maximum will occur in July 2025 with a maximum sunspot number in the range of 105-125 which corresponds to the maximum sunspot number during solar cycle 24. In contrast, NASA says that solar cycle 25 will be the lowest in 200 years. They predict that the maximum sunspot number may be 30-50% lower than during solar cycle 24, i.e. a sunspot number of 35-60 which corresponds to the Dalton Minimum level. The global Earth temperatures were lower during the Dalton Minimum compared to times before and after this time period. This effect of lower Earth temperature was observed more distinctly during the Maunder Minimum (Little Ice Age) when the Sun showed almost no solar activity over several decades. If there is a correlation between solar activity and the temperature on Earth and if the solar activity during solar cycle 25 will indeed be low, a decreased or a less increasing global temperature would be expected in the next years.

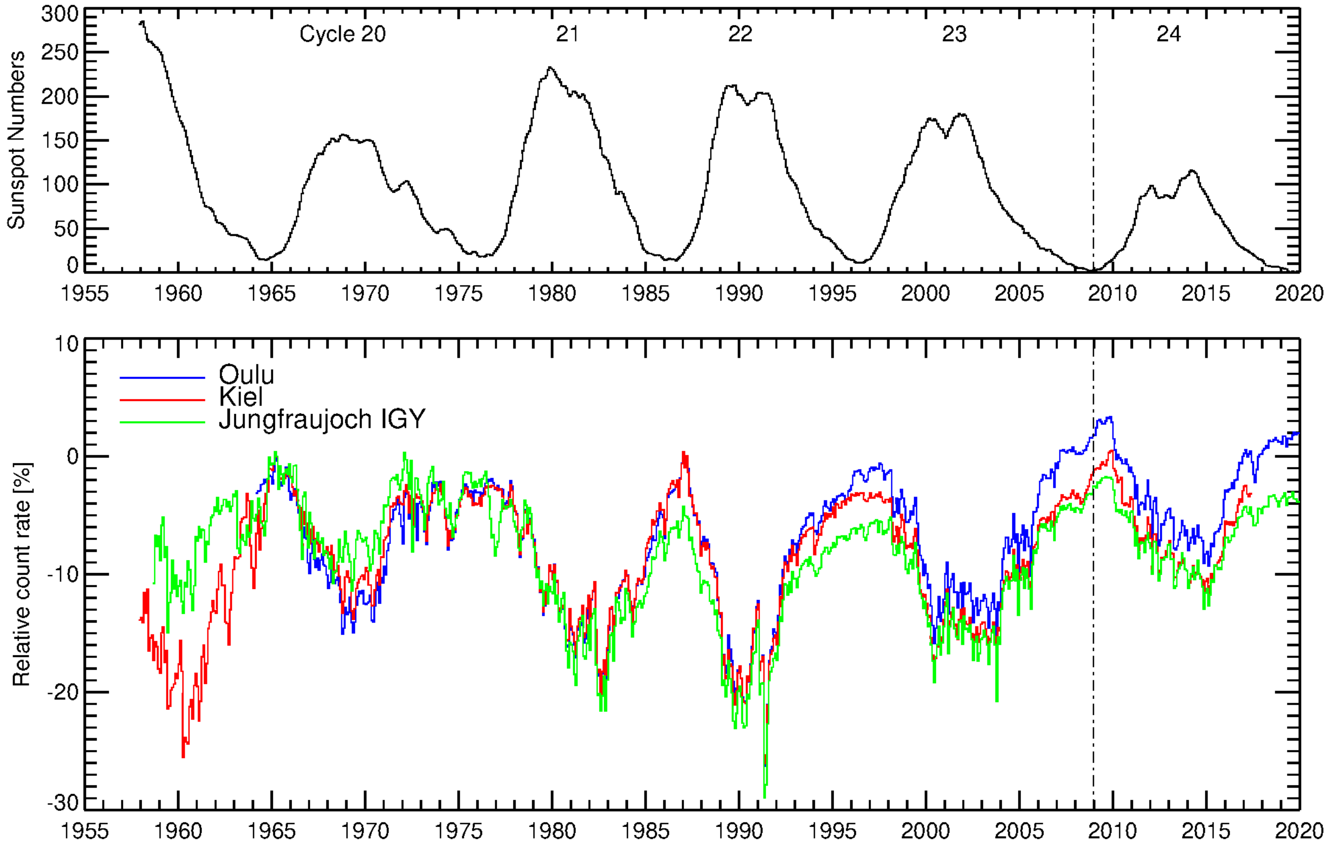

Figure 1. Smoothed monthly total sunspot numbers (Source: WDC-SILSO, Royal Observatory of Belgium, Brussels (www.sidc.be/silso/datafiles), top panel) and relative pressure corrected monthly average counting rates of the neutron monitor stations Oulu (Finland), Kiel (Germany), and IGY Jungfraujoch (bottom panel) for the years 1958-2019. The neutron monitor count rates are expressed in relative units with respect to May 1965. The dashed-dotted line indicates the minimum of the sunspot number between solar cycle 23 and 24.

The dosimetric measurements with a GammaTracer device inside the detector housing of the NM64 netron monitor were continued in 2019.

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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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