Name of research institute or organization:

Physikalisches Institut, Universität Bern

Title of project:

Neutron monitors - Study of solar and galactic cosmic rays

Project leader and team:

Dr. Rolf Bütikofer

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 the Sun, as well as about geomagnetic, atmospheric, and environmental effects. They ideally complement space observations. 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 in the GeV range. Furthermore, the high altitude of Jungfraujoch provides good response to solar protons ≥ 3.6 GeV and to solar neutrons with energies as low as ~250 MeV. Neutron monitors play also an important role in the space weather domain.

In 2011, operation of the two NMs at Jungfraujoch was pursued without major problems. No significant technical modifications were necessary. The recordings of the NM measurements are published in near-real time in the neutron monitor database NMDB (www.nmdb.eu). Figure 1 shows the measurements of the IGY neutron monitor at Jungfraujoch (lower panel) since it was put into operation in 1958. This unique dataset reflects the variations of the primary CR over four solar sunspot cycles. The GCR 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. Figure 2 shows the development with time of the cycles 20, 21, 22, 23, and the start of cycle 24 plotted one upon the other. The value “0” of the x-axis corresponds to the start of the corresponding solar cycle. The start month as well as the duration, and the maximum and minimum smoothed sunspot numbers of the solar cycles 20-24 are listed in Table 1. The rise time to the maximum sunspot number of the cycles 20 and 23 is significantly longer than for the cycles 21 and 22 as can be seen from Figure 2. The minimum solar activity phase during the transition from cycle 23 to 24 lasts longer than in the other cycles shown here. This effect can also be seen in the data of the IGY neutron monitor Jungfraujoch, see Figures 1 and 3. Figure 3 shows the relative counting rate of the IGY neutron monitor at Jungfraujoch during the solar cycles 21/22 and 23/24. In Figure 3 two solar cycles are shown in sequence at a time as the magnetic field of the Sun reverses during each solar cycle, i.e. the magnetic poles return to the same state after two reversals. As the curvature and gradient drifts of charged particles in the interplanetary magnetic field play an important role in the transport of the galactic cosmic rays in the heliosphere and as these drift effects are charge dependent, the polarity of the solar magnetic field has an influence on the galactic cosmic ray flux inside the heliosphere. As a consquence the

neutron monitor counting rate shows different shapes during the solar activity minima with reversed solar magnetic field polarity. Judging by the extremely low solar activity at the end of cycle 23 (lowest sunspot number in the era of neutron monitor measurements), an extremely high galactic cosmic ray flux near Earth can be expected, i.e. highest neutron monitor counting rates recorded ever. From Figure 1 we see that the maximum in the IGY neutron monitor Jungfraujoch counting rate was indeed higher than the maximum in 1987 and 1997, however the maxima in the neutron monitor counting rate of the preceding solar cycles were still higher. This is in contrast to other stations of the worldwide network that show an absolute maximum in the counting rate at the end of 2009. It is possible that the IGY neutron monitor at Jungfraujoch has shown in the past or still shows a small long-term drift in the counting rate.

Solar Cycle	Start month	Duration [years]	Max. sunspot number	Min. sunspot number
20	October 1964	11.7	110.6	12.2
21	June 1976	10.3	164.5	12.3
22	September 1986	9.7	158.5	8.0
23	May 1996	12.6	120.8	1.7
24	December 2008			

Table 1. *Start date, length, maximum and minimum smoothed monthly sunspot numbers of solar cycles 20-24.*

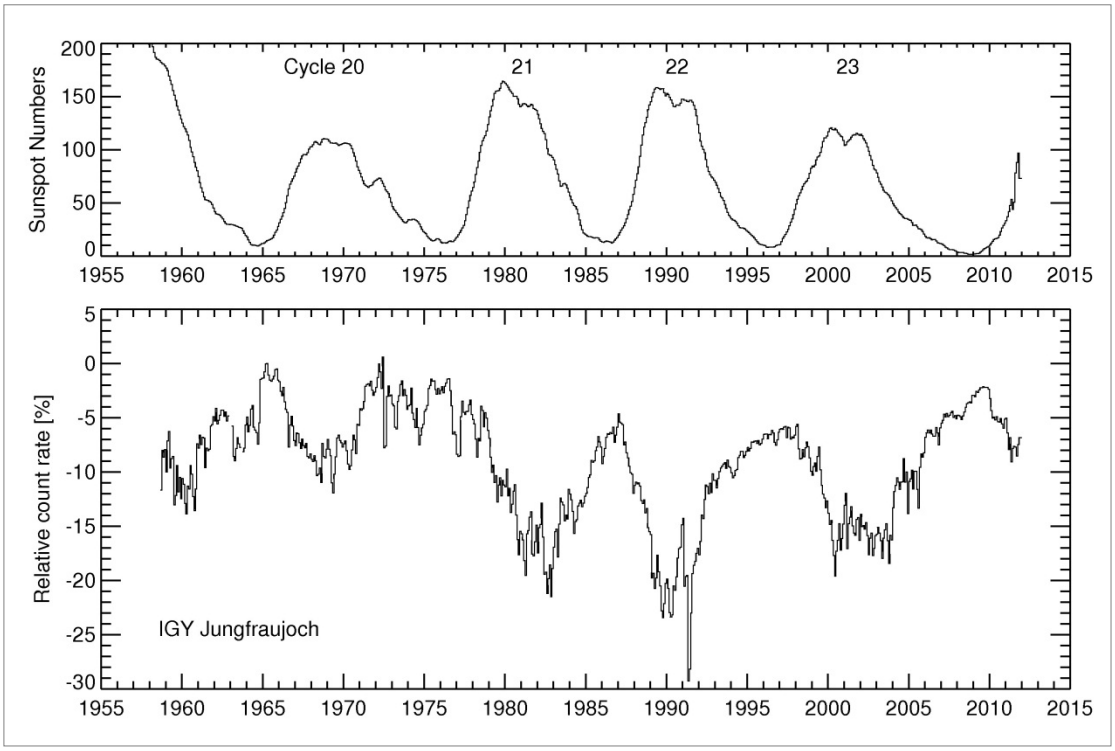

Figure 1. *Smoothed sunspot numbers (top panel), pressure corrected monthly average counting rates of IGY neutron monitor at Jungfraujoch (bottom panel) for the years 1958-2011. The neutron monitor count rate is expressed in relative units with respect to May 1965.*

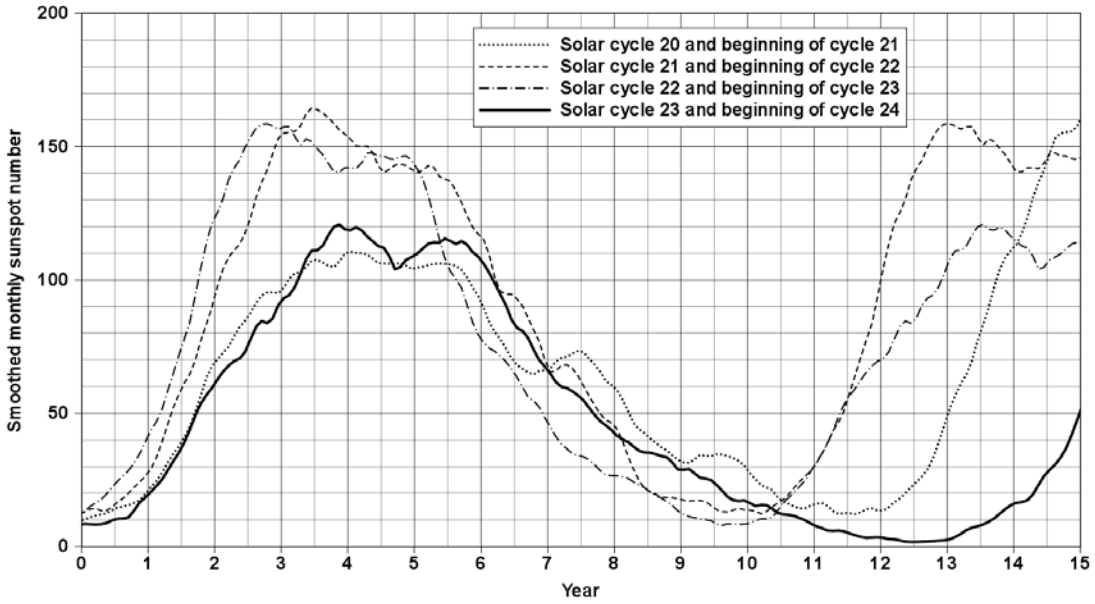

Figure 2. *Smoothed sunspot numbers during the solar cycles 21-24 in which the cycles are plotted one upon the others. The year "0" corresponds to the start of the corresponding solar cycle.*

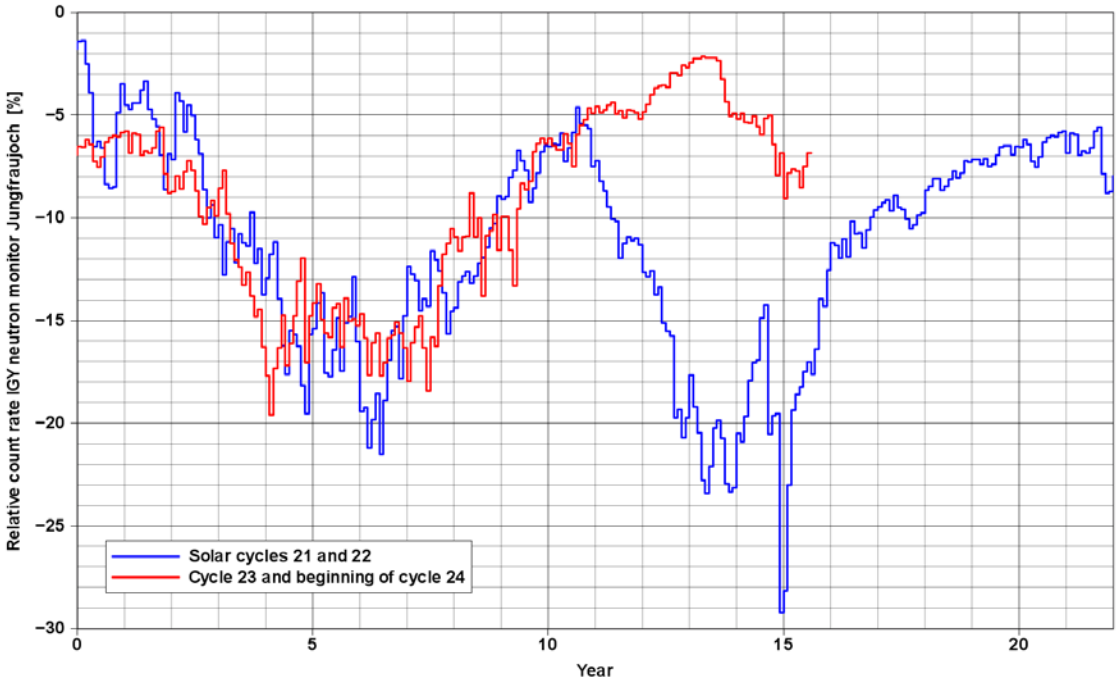

Figure 3. *Monthly relative count rates of IGY neutron monitor Jungfraujoch during the solar cycles 21-24 in which every two cycles are plotted one upon the others. The year "0" corresponds to the start of the corresponding solar cycle.*

Key words:

Astrophysics, cosmic rays, neutron monitors; solar, heliospheric and magnetospheric phenomena

Internet data bases:

http://cosray.unibe.ch

Collaborating partners/networks:

International Council of the Scientific Union's (ICSU) Scientific Committee on Solar-Terrestrial Physics (SCOSTEP)

World Data Centers A (Boulder), B (Moscow), C (Japan), International GLE database

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

Scientific publications and public outreach 2011:

Refereed journal articles and their internet access

Bütikofer, R., E.O. Flückiger, Radiation doses along selected flight profiles during two extreme solar cosmic ray events, Astrophys. Space Sci. Trans., Volume 7, Issue 2, pp.105-109, 2011.
http://www.astrophys-space-sci-trans.net/7/105/2011/astra-7-105-2011.pdf

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