RECENT SOLAR-PROTON FLUXES. R. C. Reedy[1], [1]Institute of Meteoritics, Dept. of Earth and Planetary Sciences, MSC3-2050, 1 University of New Mexico, Albuquerque, NM 87131-1126 USA (rreedy@unm.edu)

Summary: The event-integrated fluences of energetic solar protons up to 2004 at the Earth have been determined and compared to previous data. The current solar cycle has been very active, and very large fluxes of solar protons have been observed that have had serious effects in the solar system and will have produced many radionuclides in the surfaces of meteorites. Such huge events are not expected again until about 2008 or 2009.

Introduction: The fluxes of solar energetic particles (SEPs) are used for many studies, such as the study of the Sun and recent histories of extraterrestrial samples. High solar-proton fluxes are a very serious radiation hazard in the inner solar system and have had serious effects on interplanetary spacecraft and on material exposed to these energetic protons.

Modern fluxes of solar protons need to be known to compare with those inferred from long-lived or stable cosmogenic nuclides in lunar samples [1]. In 1997, modern solar particle events were more intense than during previous periods. Since then, the solar cycle (number 23) that started in 1996 has been a very active one, continuing the trend. Fluxes of energetic solar protons through 2001 were reported in [2].

In 2002 and especially in 2003, there were several solar particle events (SPEs) with very high fluxes of solar protons. These recent SPEs have affected spacecraft, including Mars Odyssey at the end of October 2003, when the spacecraft went into a safe mode and its MARIE instrument ceased to work [3]. The event-integrated fluences of solar protons in these recent solar particle events were compiled and the results for the current solar cycle compared here to those for the 4 previous solar cycles.

Event-Integrated Solar-Proton fluxes: The websites for solar-proton-flux data from the GOES satellites in geosynchronous orbit were used to get the fluences of energetic solar protons integrated over several SPEs, including the very large one around Halloween in 2003. Fig. 1 gives the event-integrated fluxes of solar protons >10 and >30 MeV from 1996 until the end of 2003. Also shown is the smoothed monthly sunspot number.

Year 2002 was an active one with many events producing energetic solar protons observed at Earth. There were not many SPEs in 2003, as might be expected for a period of fairly low sunspot number (about 75). However, as documented by [4], there still can be huge fluxes of solar protons whenever the sunspot number is above about 50, as was the case for near the end of 2003. The year 2004 only had a few mild SPEs, and their fluences have not been compiled and are not shown in Fig. 1.

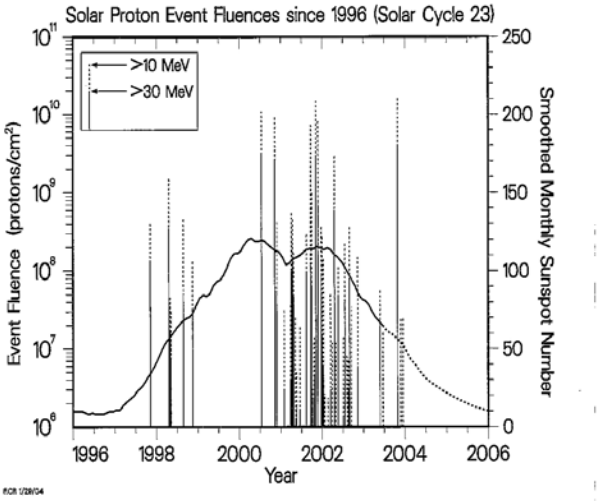

Fig. 1. Sunspot numbers and event-integrated fluxes of solar protons for solar particle events from 1996 through 2003 (most of solar cycle 23). The curve is the smoothed monthly sunspot number (with a dashed curve for estimated values) and the vertical lines are the event-integrated fluxes of solar protons >10 MeV (dashed lines) and >30 MeV (solid lines).

Discussion: These results for solar cycle 23 are combined with previous results since 1954 [1,2] in Fig. 2. The number of very large SPEs (fluences above ~10^{10} protons/cm^2) was the largest since solar cycle 19 (1954-1964). (As noted in [5], the fluences for 1956-1962 probably are ~0.6 of those shown here.) Thus the number of very big solar particle events since 2000 has been unusually high and the fluences of energetic solar protons have been very high.

The effects of these very large SPEs since 2000, especially on spacecraft, have often been noted elsewhere. Some comments were made in the popular press that the huge SPE near Halloween 2003 was unexpected. However, as can been seen in Fig. 2 and noted by [4], very large SPEs can occur almost any time during a solar cycle. The only time when very large SPEs are absent is during the 2 years on either side of the minimum in the monthly smoothed sunspot number, when this number is less than about 50. The next solar minimum is expected in 2006, so there

should not be any very large SPEs from now until about 2008 or 2009. This is good news for spacecraft, including Mars Odyssey, which was hit by several large SPEs. The reduced level of solar activity since the start of 2004 has also allowed the intensity of GCR particles in the inner solar system to increase, which is enhancing the fluxes of gamma ray made by GCRs in Mars and measured by the Mars Odyssey Gamma Ray Spectrometer.

Meteorites that have fallen recently or that fall during the next year or so should have fairly high concentrations of shorter-lived radionuclides, such as 312 day ^{54}Mn and 2.6 year ^{22}Na, made in their outer centimeter [cf., 6]. The presence of such solar-proton-produced radionuclides in recent falls would indicate that the sample was from with ~1 cm of the original surface of the meteorite. Such near-surface samples are very rare as usually much of a meteoroid is removed by ablation during passage through the Earth's atmosphere. One of the very few falls with high concentrations of solar-proton-produced radionuclides was Salem [7,8].

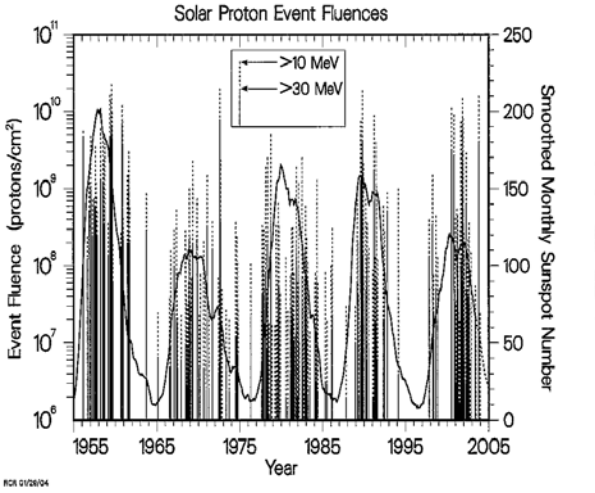

Fig. 2. Sunspot numbers since 1954 and integrated fluxes of solar protons since 1956. See caption for Fig. 1 for details.

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References: [1] Reedy R. C. (1998) *Proc. Indian Acad. Sci. (Earth Planet. Sci.), 107,* 433-440. [2] Reedy R. C. (2002) *LPS XXXIII,* abstract #1139. [3] Zeitlin C. et al. (2002) *LPS XXXIV,* abstract #1954. [4] Feynman J. et al. (1990) *J. Spacecraft Rockets, 27,* 403-410. [5] Sisterson J. M. et al. (1996) *LPS XXVII,* 1207-1208. [6] Reedy R. C. (2001) *Meteoritics 36 (Suppl.),* A172. [7] Evans J. C. et al. (1987) *LPS XVIII,* 271-272. [8] Nishiizumi K. et al. (1990) *Meteoritics 25,* 392-393.