

# SOLAR INDICES BULLETIN

DECEMBER 1995

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## ◆ SOLAR RADIO EMISSIONS

The quiet sun emits radio energy with a slowly varying intensity. These radio fluxes, which stem from atmospheric layers high in the chromosphere and low in the corona, change gradually from day-to-day, in response to the number and size of spot groups on the solar disk. The table below gives daily measurements of this slowly varying emission at selected wavelengths between about 1 and 100 centimeters. Many observatories record quiet-sun radio fluxes at the same local time each day and correct them to within a few percent for factors such as antenna gain, bursts in progress, atmospheric absorption, and sky background temperature. At 2800 megahertz (10.7 centimeters) flux observations summed over the sun's disk have been made continuously since February 1947.

## ◆ SOLAR FLUX TABLE

Numbers in parentheses in the column headings below denote frequencies in megahertz. Each entry is given in solar flux units--a measure of energy received per unit time, per unit area, per unit frequency interval. One solar flux unit equals  $10^{-22}$  J/m<sup>2</sup>Hzsec.

During low periods of solar activity, the flux never falls to zero, because the sun emits at all wavelengths with or without the presence of spots. The lowest daily Ottawa flux since 1947 occurred on November 3, 1954. On that day the observed noon value dropped to 62.6 units; the highest observed value of 457.0 occurred on April 7, 1947.

The preliminary observed and adjusted Penticton fluxes tabulated here are the "Series C" values reported by Canada's Dominion Radio Astrophysical Observatory in Penticton, British Columbia. Observed numbers are less refined, since they contain fluctuations as large as  $\pm 7\%$  from the continuously changing sun-earth distance. Adjusted fluxes have this variation removed; they show the energy received at the mean distance between the sun and earth. Gaps in the Learmonth, Australia (LEAR) data reflect equipment problems. Fluxes measured either at Palehua on the Hawaiian Islands, or at San Vito, Italy, will be substituted for frequencies at which many Learmonth values are missing.

DECEMBER 1995 PRELIMINARY SUNSPOT NUMBERS AND SOLAR RADIO FLUX

NOV 1995 FINAL FLUX

Day	Sunspot Obs Flux		Solar Flux Adjusted to 1 Astronomical Unit										Observed Adjusted	
	Number	Pentic (2800)	LEAR (15400)	LEAR (8800)	LEAR (4995)	Pentic (2800)	LEAR (2695)	LEAR (1415)	LEAR (610)	LEAR (410)	LEAR (245)	Pentic (2800)	Pentic (2800)	
01	18	73	570	261	123	71	69	52	24	23	9	74.5	73.3	
02	14	73	523	224	122	71	69	51	39	24	12	73.3	72.1	
03	16	73	526	225	122	71	68	52	40	24	13	72.6	71.4	
04	16	73	549	211	122	71	68	51	34	24	10	73.2	72.0	
05	14	74	532	208	121	72	68	51	17	14	7	75.1	73.9	
06	10	74	538	216	124	72	69	52	---	---	5	74.8	73.5	
07	10	74	---	---	---	72	---	---	37	26	15	74.6	73.2	
08	8	74	530	213	122	72	69	52	36	25	12	76.3	74.8	
09	19	74	533	212	122	72	69	52	35	25	12	77.2	75.7	
10	17	73	511	206	121	71	69	51	36	24	12	78.1	76.5	
11	18	73	---	---	---	71	---	---	---	---	---	77.4	75.9	
12	11	72	---	---	---	70	---	---	---	---	---	76.2	74.6	
13	10	73	533	213	119	71	67	51	33	23	12	73.1	71.5	
14	9	70	536	---	109	68	67	51	34	23	10	75.0	73.4	
15	8	70	519	203	120	68	66	54	31	22	11	76.6	75.0	
16	0	70	539	214	118	68	65	52	33	24	13	75.9	74.2	
17	0	69	529	206	118	67	65	50	32	24	13	75.1	73.4	
18	0	69	510	205	118	67	63	53	31	23	14	75.1	73.4	
19	9	69	518	220	118	67	64	49	31	23	13	74.0	72.2	
20	8	70	540	229	118	68	64	47	33	24	13	73.2	71.5	
21	9	70	528	219	118	68	64	48	32	24	13	72.8	71.1	
22	9	71	536	215	119	69	65	50	32	24	12	72.8	71.0	
23	8	72	521	218	120	70	65	52	33	24	13	72.7	70.9	
24	0	72	532	205	122	70	66	53	32	23	13	72.2	70.4	
25	12	73	523	204	120	71	66	51	33	24	13	71.8	69.9	
26	21	74	493	209	122	72	67	53	31	22	13	72.7	70.8	
27	18	74	507	211	122	72	68	52	31	22	12	70.8	68.9	
28	17	76	508	205	123	73	68	55	34	23	11	73.5	71.5	
29	9	76	541	208	124	73	70	55	35	23	11	72.3	70.4	
30	10	75	522	217	125	73	71	62	35	24	12	74.3	72.3	
31	7	75	539	214	125	73	71	58	36	24	14			
Mean	11	73	528	214	121	70	67	52	33	23	12	74.2	72.6	

◆ SUNSPOT COUNTS

In 1848 the Swiss astronomer Johann Rudolph Wolf introduced a daily measurement of sunspot number. His method, which is still used today, counts the total number of spots visible on the face of the sun and the number of groups into which they cluster, because neither quantity alone satisfactorily measures the level of sunspot activity.

An observer computes a daily sunspot number by multiplying his estimated number of groups by ten and then adding this product to his total count of individual spots. Results, however, vary greatly, since the measurement strongly depends on observer interpretation and experience and on the stability of the earth's atmosphere above the observing site. Moreover, the use of earth as a platform from which to record these numbers contributes to their variability, too, because the sun rotates and the evolving spot groups are distributed unevenly across solar longitudes. To compensate for these limitations, each daily international number is computed as a weighted average of measurements made from a network of

cooperating observatories. The international sunspot numbers tabulated on page 1 are provisional values taken from a bulletin prepared monthly by Pierre Cugnon of the SUNSPOT INDEX DATA CENTER, 3 avenue Circulaire, B-1180 BRUXELLES, BELGIUM. The December 1995 data combine observations from 34 stations.

◆ HISTORICAL SUNSPOT COUNTS

How do sunspot numbers in the table on page 1 compare to the largest values ever recorded? The highest daily count on record occurred December 24-25, 1957. On each of those days the sunspot number totaled 355. In contrast, during years near the spot cycle minimum, the count can fall to zero. Today, much more sophisticated measurements of solar activity are made routinely, but none has the link with the past that sunspot numbers have. Our archives, for example, include reconstructed daily values from January 8, 1818; monthly means from January 1749; and yearly means beginning in 1700.

SMOOTHED (OBSERVED AND PREDICTED) SUNSPOT NUMBERS: CYCLES 21, 22 AND 23

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1985	20	20	19	18	18	18	17	17	17	17	17	15	18
1986	14	13	13	14	14	14	14	13	12*	13	15	16	14
1987	18	20	22	24	27	28	31	35	39	44	47	51	32
1988	58	65	71	78	84	94	104	114	121	125	130	138	98
1989	142	145	150	154	157	158	159	158	157	157	158	154	154
1990	151	153	152	149	147	144	141	141	142	142	142	144	146
1991	148	148	147	147	146	145	146	147	145	142	138	132	144
1992	124	115	108	103	100	97	91	84	80	76	74	73	94
1993	71	69	67	64	60	56	55	52	48	45	41	38	56
1994	37	35	34	34	33	31	29	27	27	27	26	26	30
1995	24	23	22	21	19	18	18	17	17	16	15	15	19
							(2)	(3)	(4)	(5)	(5)	(5)	(2)
1996	14	13	12	11	11	10	10	9	9	8	8	8	10
	(7)	(8)	(8)	(8)	(9)	(9)	(10)	(10)	(10)	(10)	(10)	(10)	(9)
1997	8	8	9	9	10	10	11	12	13	13	14	16	11
	(10)	(10)	(9)	(9)	(10)	(12)	(13)	(15)	(16)	(17)	(19)	(22)	(14)

Sep 1986 marks Cycle 21's minimum and the onset of cycle 22, which reached a maximum in July 1989.

◆ SUNSPOT NUMBER PREDICTIONS

For the end of Solar Cycle 21, and the beginning of Cycle 22, the table gives smoothed sunspot numbers up to the one calculated that first uses the most recently measured monthly mean. These smoothed, observed values are based on final, unsmoothed monthly means through June 1995 and on provisional ones thereafter. We compute a smoothed monthly mean by forming the arithmetic average of two sequential 12-month running means of monthly means.

Table entries with numbers in parentheses below them denote predictions by the McNish-Lincoln method. This method estimates future numbers by adding a correction to the mean of all cycles that is proportional to the departure of earlier values of the current cycle from the mean cycle. (See page 9 in the July 1987 supplement to *Solar-Geophysical Data*). We use and predict only smoothed monthly means, because we believe the errors are too great to

estimate any values more precise. In the table above, adding the number in parentheses to the predicted value generates the upper limit of the 90% confidence interval; subtracting the number from the predicted value generates the lower limit. Consider, for example the June 1996 prediction. There exists a 90% chance that in June 1996 the actual smoothed sunspot number will fall somewhere between 1 and 19.

The McNish-Lincoln prediction method generates useful estimates of smoothed, monthly mean sunspot numbers for no more than 12 months ahead. Beyond a year these predictions regress rapidly toward the mean of all 13 cycles used in the computation. Moreover, the method is very sensitive to the date defined as the beginning of the current sunspot cycle, that is, to the date of the most recent sunspot minimum. The new cycle predictions tabulated above are based on the minimum value of 12.3 that occurred in September 1986.

Although every effort has been made to ensure that these data are correct, we can assume no liability for any damages their inaccuracies might cause. The charge for a 1-year subscription to this monthly bulletin in US\$21.00. To become a subscriber, you may either call (303) 497-6346 or write the NATIONAL GEOPHYSICAL DATA CENTER, Solar-Terrestrial Physics Division (E/GC2), 325 Broadway, Boulder, Colorado 80303 USA. Please include with your written order a cheque or money order payable in U.S. currency to the "Department of Commerce, NOAA/NGDC". Payment may also be made through VISA, MasterCard or American Express credit cards.