# SOLAR INDICES BULLETIN

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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 $10^{-22}$ $J/m^2 Hz sec$.

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 ±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.

JANUARY 1999 PRELIMINARY SUNSPOT NUMBERS AND SOLAR RADIO FLUX

| Day | Sunspot Number Intl | Obs Flux Pentic (2800) | Solar Flux Adjusted to 1 Astronomical Unit LEAR (15400) | LEAR (8800) | LEAR (4995) | Pentic (2800) | LEAR (2695) | LEAR (1415) | LEAR (610) | LEAR (410) | LEAR (245) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | 57 | 163 | 608 | 309 | 207 | 161 | 163 | 120 | 86 | 55 | 22 |
| 02 | 68 | 156 | --- | 310 | 205 | 155 | 156 | 117 | 85 | --- | 22 |
| 03 | 58 | 145 | 563 | 291 | 182 | 150 | 145 | 114 | --- | 57 | 24 |
| 04 | 60 | 145 | 563 | 291 | 182 | 142 | 145 | 114 | 85 | 57 | 24 |
| 05 | 64 | 134 | 539 | 277 | 167 | 132 | 134 | 107 | 78 | 54 | 25 |
| 06 | 48 | 125 | 549 | 279 | 158 | 122 | 125 | 101 | 77 | 53 | 24 |
| 07 | 64 | 115 | 547 | 290 | 155 | 111 | 115 | 96 | 61 | 39 | 15 |
| 08 | 51 | 115 | 544 | 287 | 148 | 112 | 115 | 94 | 66 | 45 | 18 |
| 09 | 47 | 108 | 538 | 283 | 147 | 111 | 108 | 88 | 65 | 44 | 19 |
| 10 | 46 | 110 | 544 | 288 | 149 | 106 | 110 | 87 | 65 | 44 | 19 |
| 11 | 32 | 105 | 535 | 285 | 144 | 108 | 105 | 85 | 65 | 44 | 17 |
| 12 | 38 | 102 | 533 | 294 | 148 | 109 | 102 | 84 | 64 | 43 | 16 |
| 13 | 41 | 107 | 534 | 306 | 149 | 115 | 107 | 83 | 64 | 43 | 16 |
| 14 | 65 | 117 | 541 | 310 | 162 | 132 | 117 | 88 | 65 | 42 | 15 |
| 15 | 83 | 131 | 536 | 326 | 182 | 138 | 131 | 95 | 68 | 44 | 15 |
| 16 | 90 | 139 | 534 | 294 | 170 | 154 | 139 | 99 | 67 | 44 | 15 |
| 17 | 93 | 149 | 544 | --- | 187 | 156 | 149 | 109 | 70 | 44 | 16 |
| 18 | 111 | 165 | 560 | 353 | 197 | 166 | 165 | 118 | 79 | 52 | 18 |
| 19 | 121 | 163 | 554 | 354 | 197 | 170 | 163 | 121 | 80 | 56 | 22 |
| 20 | 120 | 164 | 554 | 312 | 198 | 166 | 164 | 126 | 84 | 53 | 23 |
| 21 | 114 | 186 | 566 | 366 | 226 | 169 | 186 | 134 | 84 | 51 | 19 |
| 22 | 108 | 168 | 561 | 340 | 203 | 172 | 168 | 132 | 87 | 62 | 31 |
| 23 | 87 | 160 | 561 | 308 | 194 | 161 | 160 | 125 | --- | 55 | 23 |
| 24 | 68 | 158 | 563 | 337 | 202 | 157 | 158 | 126 | 84 | 60 | --- |
| 25 | 31 | 145 | --- | 303 | 177 | 134 | 145 | 119 | 84 | 57 | 27 |
| 26 | 30 | 124 | --- | 316 | 169 | 129 | 124 | 112 | 84 | 67 | 44 |
| 27 | 35 | 118 | --- | 279 | 151 | 121 | 118 | 106 | 79 | 52 | 27 |
| 28 | 28 | 117 | --- | 281 | 149 | 115 | 117 | 102 | --- | --- | --- |
| 29 | 24 | 117 | 551 | 273 | 144 | 114 | 117 | 95 | 73 | 47 | 20 |
| 30 | 22 | --- | --- | --- | --- | 114 | --- | --- | --- | --- | --- |
| 31 | 30 | 113 | --- | --- | 153 | 112 | 113 | 91 | 71 | 48 | 19 |
| Mean | 62 | 135 | 551 | 305 | 173 | 136 | 135 | 106 | 75 | 50 | 21 |

DEC 1998 FINAL FLUX

| Observed Pentic (2800) | Adjusted Pentic (2800) |
|---|---|
| 162.7 | 158.2 |
| 151.7 | 147.4 |
| 153.1 | 148.7 |
| 148.2 | 144.0 |
| 142.4 | 138.3 |
| 142.3 | 138.1 |
| 153.2 | 148.7 |
| 162.0 | 157.1 |
| 153.9 | 149.3 |
| 133.8 | 129.8 |
| 143.1 | 138.8 |
| 143.3 | 138.9 |
| 144.2 | 139.7 |
| 144.4 | 139.9 |
| 141.6 | 137.2 |
| 140.5 | 136.1 |
| 146.1 | 141.5 |
| 154.7 | 149.8 |
| 138.0 | 133.6 |
| 134.7 | 130.4 |
| 135.3 | 130.9 |
| 128.8 | 124.6 |
| 139.8 | 135.2 |
| 139.4 | 134.9 |
| 144.4 | 139.6 |
| 144.9 | 140.2 |
| 166.8 | 161.4 |
| 184.4 | 178.3 |
| 182.8 | 176.8 |
| 179.0 | 173.1 |
| 174.6 | 168.8 |
| 150.1 | 145.5 |

## ♦ 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 August 1998 data combine observations from 41 stations. http://www.oma.be/KSB-ORB/SIDC/index.html.

## ♦ 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 22 AND 23

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 | 17 | 15 | 13 | 12 | 11 | 11 | 17 |
| 1996 | 10 | 10 | 10 | 9 | 8* | 9 | 8 | 8 | 8 | 9** | 10 | 10 | 9 |
| 1997 | 10 | 11 | 14 | 17 | 18 | 20 | 23 | 25 | 28 | 32 | 35 | 39 | 23 |
| 1998 | 44 | 49 | 53 | 57 | 59 | 62 | 65 | 72 | 78 | 84 | 88 | 93 | 67 |
| | | | | | | | | (3) | (5) | (7) | (10) | (13) | (3) |
| 1999 | 97 | 100 | 104 | 109 | 113 | 117 | 121 | 123 | 126 | 129 | 132 | 134 | 117 |
| | (16) | (17) | (16) | (14) | (14) | (16) | (20) | (24) | (27) | (30) | (33) | (35) | (22) |
| 2000 | 134 | 135 | 136 | 136 | 125 | 134 | 134 | 133 | 133 | 131 | 130 | 128 | 132 |
| | (38) | (40) | (42) | (43) | (43) | (43) | (41) | (41) | (42) | (42) | (43) | (43) | (42) |

*May 1996 marks Cycle 22's mathematical minimum.
**October 1996 marks the consensus Cycle 22 minimum which NGDC is now using.

## ♦ SUNSPOT NUMBER PREDICTIONS

For the end of Solar Cycle 22, and the beginning of Cycle 23, 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 1998 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 1999 prediction. There exists a 90% chance that in July 1999 the actual smoothed sunspot number will fall somewhere between 101 and 141.

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 consensus minimum value of 8.8 that occurred in October 1996. For solar maximum discussions, visit http://www.sec.noaa.gov.