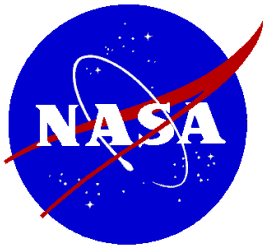


Future Solar Activity Estimates for Use in Prediction of Space Environmental Effects On Spacecraft

Harold C. Euler Jr
George C. Marshall Space Flight Center
Huntsville, Alabama
and
Steven W. Smith
Computer Sciences Corporation
Huntsville, Alabama

APPROVAL:

Original Signed By
Robert M. Suggs
for

Lowell E. Primm, Jr.
Group Lead
Environments Group

National Aeronautics and Space Administration
Marshall Space Flight Center • Huntsville, Alabama 35812

Engineering Directorate
Engineering Systems Department
Environments Group

April 2000

Future Solar Activity Estimates for Use in Prediction of Space Environmental Effects On Spacecraft

Introduction

The main sources of uncertainty in spacecraft orbital lifetime prediction are estimated future solar radio flux and geomagnetic activity, modeled atmospheric density, and the ballistic factor. The major source of uncertainty in models estimating future atmospheric density at orbital altitude is the solar extreme ultraviolet heat input values. The observed 10.7-cm solar radio flux (not adjusted to 1 AU) is used as a proxy for this most significant input, which is not otherwise available.

MSAFE Model

Because no generally accepted physical solar model is available to accurately predict future solar activity, the NASA Marshall Space Flight Center (MSFC) developed a 13-month Zurich smoothed solar radio flux ($\overline{F}_{10.7}$) and geomagnetic ($\overline{A}_p$) index intermediate (months) and long-range (years) statistical estimation technique [Niehuss *et al.*, 1996; Vaughan *et al.*, 1999]. The technique is also applicable to the 13-month smoothed sunspot number ($\overline{R}$). The 13-month Zurich smoothing technique is a running average with a 13-month kernal size and the first and thirteenth months given half the weight of the others. This technique was developed by the Swiss Federal Observatory, Zurich, Switzerland [Waldmeier, 1961].

The primary reason for developing the MSFC Solar Activity Future Estimation (MSAFE) model, and for issuing intermediate and long-range solar radio flux and geomagnetic index future estimates, is the need for updated inputs to the upper atmosphere (thermosphere) density models used for spacecraft orbital lifetime predictions and performance requirement analyses [Dreher and Lyons, 1990]. Mission analysis and planning for future spacecraft launches and on-orbit operations require estimates of orbital lifetimes, altitudes, inclinations, and eccentricities as well as various space environment parameters important to selection of materials and parts and equipment design.

The MSFC Solar Activity Future Estimation (MSAFE) linear regression program is a modified McNish-Lincoln model [McNish and Lincoln, 1949; Boykin and Richards, 1966] based on the Lagrangian least-squares statistical technique of Holland and Vaughan [1984]. A detailed explanation of the MSAFE model, its computer program, and modifications that took place in 1995 and 1996 is given by Niehuss et al. [1996], copies of which are available on request. This model is built to provide the capability to provide monthly updates of future $\overline{F}_{10.7}$, $\overline{R}$, and $\overline{A}_p$ estimates.

Observed Data

Generation of the information provided in this report begins each month with the acquisition of recently observed data. Table 1 (page 5) contains recent monthly mean observed 10.7 cm solar radio flux, sunspot number, and planetary geomagnetic index values. The information in this table is based upon data from the National Research Council of Canada for the Series C 10.7-cm solar radio flux ($F_{10.7}$) data, the Sunspot Index Data Center Brussels, Belgium for the monthly mean relative sunspot number (R), and the Institute for Geophysics in Gottingen, Germany for

the monthly mean geomagnetic index (A_p) data as received from the U. S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) via their National Geophysical Data Center (NGDC) FTP site. When there is insufficient data at the NGDC site to provide information through the most recently completed month, preliminary values are calculated using daily values from the NOAA Space Environment Center (SEC) gopher site and the Sunspot Index Data Center site.

The computer programs inputs used by the MSAFE program are databases comprising Lagrangian interpolated $\overline{F}_{10.7}$ (cycles 1 through 22 converted and observed), $\overline{R}$ (cycles 1 through 22 observed), and $\overline{A}_p$ (cycles 13 through 22 converted and observed) and the smoothed values for cycle 23. Table 2 (page 6) presents 13-month Zurich smoothed values for Cycle 22 and 23 of the observed 10.7 cm solar radio flux, sunspot number, and planetary geomagnetic index values assigned at the midpoint calculated from monthly values in Table 1 (page 5).

Future Estimates

Using these smoothed values as inputs, the program estimates the intermediate-term (months) and long-term (years) behavior of these parameters for up to 132 months into the future, initialized from the cycle 23 minimum. The cycle 23 minimum has been confirmed as May 1996 for both the $\overline{F}_{10.7}$ and $\overline{R}$. The cycle 23 minimum $\overline{A}_p$ occurred in August 1997. Once the cycle 23 maximum has been established from observed $\overline{F}_{10.7}$, $\overline{R}$, and $\overline{A}_p$ data, the MSAFE program will be re-initialized at the maximum for cycle 23. The results of the MSAFE model calculations (i.e. the output data) are reported in Tables 3 and 4. Table 3 (page 11) contains the statistical estimates of $\overline{F}_{10.7}$ and $\overline{A}_p$ values for the balance of cycle 23 and cycle 24. Table 4 (page15) contains the statistical estimate of $\overline{R}$ and $\overline{A}_p$ values for the balance of cycle 23 and cycle 24. Information on the characteristics of cycle 24 is included to permit use of the information in long range spacecraft programs planning and analysis.

The computer program's input and output data are also depicted in graphical form. Figures 1 and 2 (page 19) illustrate the application of the MSAFE model to the 10.7-cm solar radio flux. Figure 1 is a plot of monthly mean and 13-month Zurich smoothed observed 10.7-cm solar radio flux for solar cycles 22 and 23. Figure 2 is a plot of the statistical estimates of 13-month Zurich smoothed 10.7-cm solar radio flux for solar cycles 23 and 24. Similarly, Figures 3 and 4 (page 20) demonstrate application of the algorithm to sunspot number. Figure 3 is a plot of the monthly mean and 13-month Zurich smoothed observed sunspot number for solar cycles 22 and 23. Figure 4 is a plot of the statistical estimates of 13-month Zurich smoothed relative sunspot number for solar cycles 23 and 24.

It should be noted that the cycle 24 values are the statistical evaluation of the past 22 cycles and are not influenced by the MSAFE model's performance. Cycle 24 values are estimated using statistics for cycles 1 through 22 for $\overline{F}_{10.7}$ and $\overline{R}$, and statistics for cycles 13 through 22 are used for $\overline{A}_p$. The 50 percentile values in Tables 3 and 4 and in Figures 3 and 4, at and beyond minimum of cycle 24, are computed arithmetic means and are given with 95 percentile and 5 percentile values. Since the planetary geomagnetic data are only available for solar cycles 13 through 22 to produce the statistics, the small sample size requires that the 95 percentile and 5 percentile values for the $\overline{A}_p$ are only approximations. The mean cycle period of 11 years (132 months) is assumed for cycle 24.

Applications

General. The solar activity information presented in this report is provided as input data for atmospheric and space environment models to ensure compatibility between calculations made for prediction of environmental effects on spacecraft, e.g. ambient density, ionospheric plasma density, cosmic ray flux, etc. The Marshall Engineering Thermosphere Model [Hickey, 1988a, 1988b], as well as the NASA/MSFC Global Reference Atmospheric Model-1995 Version [Justus et al., 1995], were developed on the basis of inputs of the daily 10.7-cm solar radio flux ($F_{10.7}$) and the 3-hourly planetary geomagnetic index (a_p) to compute atmospheric density. Some ionosphere models, such as the International Reference Ionosphere (IRI) [Bilitza et al., 1993] and the Fully Analytical Ionospheric Model (FAIM) [Anderson et al., 1989], and newly emerging cosmic ray models [Nymmik et al., 1996] utilize sunspot number (R) inputs. However, the statistical estimates produced by the MSAFE model provide future 13-month smoothed values of these parameters rather than the daily and 3-hourly values used in development of the models.

Changes of thermospheric and ionospheric density associated with short-term (days) variations in $F_{10.7}$, R, and a_p, required as inputs to the thermospheric and ionospheric models, are not represented by the 13-month Zurich smoothed statistical estimates of these parameters as provided by the MSAFE model and reported in this document. Future estimates of this dynamic component of the solar activity cannot be made with any acceptable degree of statistical confidence using existing techniques, so estimates from the MSAFE model represent the best information available for computing future space environment parameters. Representative data sets, based on past $F_{10.7}$, R, and a_p values, may be utilized to compute the effects of the dynamic component on the ambient densities at orbital altitudes.

Design Requirements. Design requirements for solar activity and associated values of atmospheric space environment parameters are specified in the appropriate spacecraft and space vehicle project design requirements documentation. These documents should be consulted for this information. For spacecraft projects requiring minimum risk design for lifetime orbital altitude(s), re-boost activities, and control capability, the 95 percentile estimates of future smoothed solar radio flux and geomagnetic index are recommended. These estimates permit statistically conservative spacecraft design and mission planning. Critical considerations such as orbital lifetime predictions should be based on the most current intermediate and long-range statistical estimates of future solar and geophysical data consistent with the critical project development decision time points prior to planned launch of the spacecraft.

Additional Information

Questions on the contents of this report may be addressed to Harold Euler at (256) 544-2282 or via e-mail to harold.euler@msfc.nasa.gov.

References

Anderson, D.N., J.M. Forbes, and M. Codrescu, A Fully Analytical, Low- and Middle-Latitude Ionosphere Model, *J. Geophys. Res.*, **94**, 1520, 1989.

Bilitza, D., K. Rawer, L. Bosy, and T. Gulyaeva, International Reference Ionosphere - Past, Present, Future, *Adv. Space Res.*, **13**, (3)3-(3)23, 1993.

Boykin, E. P. and T. J. Richards, Application of the Lincoln McNish Technique to the Prediction of the Remainder of the Twentieth Sunspot Cycle, Technical Memorandum 54/30-89, Lockheed Missiles and Space Company, Huntsville, Alabama, 1966.

Dreher, P. E. and A. T. Lyons, Long-Term Orbital Lifetime Predictions, NASA Technical Paper 3058, NASA Marshall Space Flight Center, Huntsville, Alabama (1990).

Hickey, M. P., The NASA Marshall Engineering Thermosphere Model, NASA CR-179359, 1988a.

Hickey, M. P., An Improvement in the Integration Procedure Used in the NASA Marshall Engineering Thermosphere Model, NASA CR-179389, 1988b.

Holland, R. L. and W. W. Vaughan, Lagrangian Least-Squares Prediction of Solar radio flux ($F_{10.7}$), *J. Geophys. Res.*, **89**, 11-16, 1984.

Justus, C. G., W. R. Jeffries III, S. P. Yung and D. L. Johnson, "The NASA/MSFC Global Reference Atmosphere Model – 1995 Version (GRAM-95)". NASA TM4715, August 1995.

McNish, A. G. and J. V. Lincoln, Prediction of Sunspot Numbers, *Trans. Am. Geophys. Union*, **30**, 673, 1949.

Niehuss, K.O., H.C. Euler, and W.W. Vaughan, Statistical Technique for Intermediate and Long-Range Estimation of 13-Month Smoothed Solar radio flux and Geomagnetic Index, NASA TM-4759, 1996.

Nymmik, R.A., M.I. Panasyuk, and A.A. Suslov, Galactic Cosmic Ray Flux Simulation and Prediction, *Adv. Space Res.*, **17**, (2)19-(2)30, 1996.

Vaughan, W.W., J.K. Owens, K.O. Niehuss, and M.A. Shea, The NASA Marshall Solar Activity Model for Use in Predicting Satellite Lifetime, *Adv. Space Res.*, **23**, (4)715-(4)719, 1999.

Waldmeier, M., *The Sunspot Activity in the Years 1610-1960*. Zurich Schulthess and Company, Switzerland, 1961.

TABLE 1: RECENT MONTHLY MEAN SOLAR ACTIVITY VALUES

Year	Month	Solar Flux ($F_{10.7}$ (Series C))	Relative Sunspot Numbers (R)	Geomagnetic Index (A_P)
1998	January	93.4	31.9	8
	February	93.4	40.3	8
	March	109.1	54.8	13
	April	108.3	53.4	10
	May	106.7	56.3	18
	June	108.4	70.7	10
	July	114.0	66.6	11
	August	136.0	92.2	18
	September	138.3	92.9	13
	October	117.3	55.5	13
	November	140.2	74.0	16
	December	150.1	81.9	8
1999	January	142.6	62.0	10
	February	142.0	66.3	12
	March	126.3	68.8	14
	April	117.2	63.7	12
	May	148.6	106.4	8
	June	169.8	137.7	7
	July	165.6	113.5	10
	August	170.8	93.7	15
	September	135.7	71.5	19
	October	164.8	116.4	19
	November	191.5	132.7	14
	December	169.8	86.4	10
2000	January	159.0	90.2*	13
	February	173.2	112.3*	13*
	March	208.2*	138.2*	9*
	April			
	May			
	June			
	July			
	August			
	September			
	October			
	November			
	December			

Solar flux in units of 10^4 JANSKY (where one JANSKY equals 10^{-26} W m^{-2} Hz^{-1} Bandwidth)

* Preliminary Estimates

TABLE 2: 13-MONTH ZURICH SMOOTHED VALUES				
Year	**Month**	**+10.7-cm Solar Flux ($\bar{F}_{10.7}$)**	**++Sunspot Numbers ($\bar{R}$)**	**+++Geomagnetic Index ($\bar{A}_p$)**
1987	January	76.3	17.6	10.0
	February	77.8	19.6	10.2
	March	79.4	22.1	10.4
	April	80.8	24.4	10.7
	May	82.4	26.5	10.9
	June	84.3	28.4	11.0
	July	86.7	31.2	11.2
	August	89.6	34.8	11.6
	September	92.7	39.0	12.0
	October	96.0	43.5	12.5
	November	98.7	46.7	13.1
	December	102.4	51.3	13.4
1988	January	107.8	58.2	13.5
	February	113.3	64.6	13.3
	March	118.8	71.3	12.9
	April	124.5	77.5	12.5
	May	129.8	83.8	12.3
	June	136.5	93.7	12.4
	July	146.2	104.3	12.8
	August	156.4	113.7	13.1
	September	165.0	121.2	14.2
	October	171.6	125.3	15.6
	November	177.5	130.4	16.1
	December	184.8	137.6	16.5
1989	January	190.2	142.0	16.7
	February	194.0	145.0	17.0
	March	199.7	149.7	17.6
	April	204.4	153.5	18.2
	May	209.3	156.9	18.8
	June	213.1	158.4	19.2
	July	212.6	158.5	19.1
	August	209.7	157.7	19.2
	September	207.2	156.6	18.8
	October	206.3	157.4	18.2
	November	206.1	157.5	18.4
	December	203.3	153.5	18.4

* Preliminary Estimates

TABLE 2 : 13-MONTH ZURICH SMOOTHED VALUES				
Year	**Month**	**+10.7-cm Solar Flux ($\bar{F}_{10.7}$)**	**++Sunspot Numbers ($\bar{R}$)**	**+++Geomagnetic Index ($\bar{A}_p$)**
1990	January	200.3	150.6	18.6
	February	200.5	152.9	18.8
	March	198.7	152.0	18.6
	April	195.6	149.3	18.2
	May	192.4	147.0	17.6
	June	189.9	143.8	16.8
	July	190.4	140.6	16.2
	August	193.9	140.5	15.4
	September	198.3	142.1	15.0
	October	200.6	142.1	14.8
	November	201.2	141.7	14.4
	December	202.7	143.9	15.7
1991	January	205.5	147.6	17.4
	February	206.3	147.6	18.4
	March	205.9	146.6	19.1
	April	206.8	146.5	20.0
	May	207.1	145.5	21.7
	June	207.4	145.2	23.0
	July	207.7	146.3	23.6
	August	206.8	146.6	24.7
	September	203.9	144.9	25.0
	October	199.7	141.7	24.2
	November	195.4	138.1	24.1
	December	188.9	131.7	23.0
1992	January	181.8	123.7	21.1
	February	174.8	115.4	19.8
	March	168.5	108.2	19.4
	April	162.9	103.3	18.9
	May	158.9	100.3	17.5
	June	154.3	97.1	16.6
	July	146.7	90.7	16.6
	August	138.9	84.0	16.1
	September	133.8	79.5	15.9
	October	130.5	76.4	16.7
	November	128.2	74.4	16.6
	December	127.4	73.2	16.1

* Preliminary Estimates

TABLE 2: 13-MONTH ZURICH SMOOTHED VALUES				
Year	**Month**	**+10.7-cm Solar Flux ($\bar{F}_{10.7}$)**	**++Sunspot Numbers ($\bar{R}$)**	**+++Geomagnetic Index ($\bar{A}_p$)**
1993	January	125.7	71.4	16.0
	February	123.1	69.3	15.9
	March	120.7	66.6	15.3
	April	118.1	63.6	14.9
	May	114.8	59.9	14.9
	June	111.3	56.1	15.0
	July	109.6	54.7	14.9
	August	107.6	52.3	15.4
	September	103.9	48.4	16.0
	October	100.4	44.9	16.4
	November	97.5	41.2	17.4
	December	94.8	38.4	18.1
1994	January	92.7	36.6	18.2
	February	91.2	34.8	18.1
	March	90.2	34.1	17.8
	April	89.3	33.7	18.0
	May	88.1	32.5	18.3
	June	86.7	30.8	18.2
	July	84.5	28.5	18.1
	August	82.5	26.8	17.5
	September	81.7	26.6	16.5
	October	81.4	26.5	15.5
	November	81.2	26.2	14.7
	December	81.0	25.6	14.3
1995	January	80.6	24.2	14.0
	February	80.2	23.0	14.0
	March	79.9	22.1	14.0
	April	79.2	20.6	13.8
	May	78.5	19.2	13.4
	June	77.7	18.2	13.0
	July	76.9	17.0	12.6
	August	76.0	15.4	12.2
	September	74.8	13.4	11.8
	October	73.8	12.1	11.5
	November	73.2	11.4	10.8
	December	72.8	10.8	10.0

* Preliminary Estimates

TABLE 2: 13-MONTH ZURICH SMOOTHED VALUES				
Year	**Month**	**+10.7-cm Solar Flux ($\overline{F}_{10.7}$)**	**++Sunspot Numbers ($\overline{R}$)**	**+++Geomagnetic Index ($\overline{A}_p$)**
1996	January	72.4	10.4	9.7
	February	72.2	10.1	9.7
	March	72.1	9.7	9.8
	April	71.6	8.4	9.7
	May	71.4	8.0	9.5
	June	71.8	8.5	9.4
	July	72.0	8.4	9.3
	August	72.1	8.3	9.4
	September	72.3	8.4	9.3
	October	72.6	8.8	9.1
	November	73.0	9.8	9.1
	December	73.3	10.4	9.2
1997	January	73.4	10.5	9.3
	February	73.7	11.0	9.2
	March	75.1	13.5	8.9
	April	76.8	16.5	8.6
	May	78.4	18.3	8.6
	June	80.1	20.3	8.6
	July	81.8	22.6	8.5
	August	83.4	25.0	8.3
	September	85.7	28.3	8.4
	October	88.6	31.8	8.6
	November	91.3	35.0	9.0
	December	94.2	39.0	9.5
1998	January	97.5	43.7	9.9
	February	101.7	48.9	10.5
	March	105.8	53.4	11.1
	April	108.9	56.5	11.3
	May	112.0	59.4	11.6
	June	115.8	62.5	12.0
	July	120.0	65.5	12.2
	August	124.1	67.8	12.5
	September	126.8	69.5	12.7
	October	127.9	70.5	12.8
	November	130.0	73.0	12.5
	December	134.3	77.9	12.0

* Preliminary Estimates

TABLE 2: 13-MONTH ZURICH SMOOTHED VALUES				
Year	**Month**	**+10.7-cm Solar Flux ($\bar{F}_{10.7}$)**	**++Sunspot Numbers ($\bar{R}$)**	**+++Geomagnetic Index ($\bar{A}_p$)**
1999	January	139.0	82.6	11.8
	February	142.6	84.6	11.6
	March	144.0	83.8	11.8
	April	145.8	85.5	12.2
	May	149.9	90.4	12.4
	June	152.9	93.1	12.4
	July	154.4	94.4*	12.6
	August	156.4*	97.5*	12.8*
	September	161.1*	102.3*	12.6*
	October			
	November			
	December			

NOTES:
+ computed and assigned at the mid-point from the National Research Council of Canada, Ottawa and Penticton Series C observed monthly values as received from the National Geophysical Data Center ftp site
++ computed and assigned at the mid-point from the Sunspot Index Data Center Brussels, Belgium observed monthly values as received from the National Geophysical Data Center ftp site
+++ computed and assigned at the mid-point from Institute for Geophysics in Gottingen, Germany observed monthly values as received from the National Geophysical Data Center ftp site

* Preliminary Estimates

TABLE 3 ESTIMATES OF 13-MONTH SMOOTHED $F_{10.7}$* AND A_p FOR BALANCE OF CYCLE 23 AND CYCLE 24

TIME		10.7-CM SOLAR FLUX ($\bar{F}_{10.7}$) PERCENTILE			GEOMAGNETIC INDEX ($\bar{A}_p$) PERCENTILE		
		95.0%	50%	5.0%	95.0%	50%	5.0%
1999.7507	OCT	168.5	162.5	158.8	13.7	12.7	12.0
1999.8340	NOV	173.9	163.3	156.6	14.2	13.0	11.8
1999.9173	DEC	180.8	164.1	154.6	15.2	13.2	11.7
2000.0007	JAN	185.4	164.4	151.5	16.1	13.6	11.8
2000.0840	FEB	188.8	164.5	147.8	16.5	14.0	11.8
2000.1673	MAR	191.7	164.6	144.5	16.4	14.3	11.5
2000.2507	APR	193.9	164.4	141.5	16.1	14.3	11.2
2000.3340	MAY	198.3	164.2	139.2	16.2	14.3	10.8
2000.4173	JUN	199.3	163.1	138.3	16.7	14.4	10.6
2000.5007	JUL	195.1	161.3	137.4	17.4	14.6	10.2
2000.5840	AUG	190.8	159.7	134.3	17.6	14.7	9.8
2000.6673	SEP	190.1	158.6	130.9	17.3	14.6	9.0
2000.7507	OCT	191.3	158.2	129.3	17.4	14.4	8.3
2000.8340	NOV	191.7	158.0	129.5	17.8	14.4	8.3
2000.9173	DEC	191.7	157.7	128.9	18.2	14.4	8.3
2001.0007	JAN	190.7	157.1	128.9	18.9	14.3	7.9
2001.0840	FEB	188.5	156.5	126.7	18.9	14.1	7.6
2001.1673	MAR	184.4	155.8	123.0	18.4	13.9	7.8
2001.2507	APR	179.4	155.4	120.8	18.2	13.9	8.2
2001.3340	MAY	176.8	155.1	119.1	18.0	13.9	8.7
2001.4173	JUN	179.1	154.2	117.3	17.7	13.8	9.0
2001.5007	JUL	181.1	153.0	116.0	17.7	13.8	9.2
2001.5840	AUG	182.2	151.2	113.4	17.4	13.8	9.3
2001.6673	SEP	181.9	149.5	111.7	16.9	14.0	9.5
2001.7507	OCT	181.6	148.2	110.2	17.4	14.3	10.3
2001.8340	NOV	182.2	147.0	109.1	17.6	14.4	10.6
2001.9173	DEC	183.3	145.5	108.2	17.3	14.2	10.3
2002.0007	JAN	183.1	143.5	107.4	17.7	14.3	10.7
2002.0840	FEB	180.5	141.2	106.6	19.1	14.6	11.1
2002.1673	MAR	178.2	139.4	104.5	20.3	14.9	11.3
2002.2507	APR	177.8	137.8	102.8	20.9	15.1	11.5
2002.3340	MAY	176.8	136.1	101.0	21.9	15.3	11.7
2002.4173	JUN	174.5	134.1	98.1	22.3	15.5	11.6
2002.5007	JUL	171.3	132.1	95.2	21.7	15.5	11.7
2002.5840	AUG	167.5	130.6	93.9	21.8	15.5	11.6
2002.6673	SEP	163.9	129.2	93.6	21.1	15.5	11.4
2002.7507	OCT	162.0	127.9	93.5	19.3	15.5	11.3
2002.8340	NOV	160.7	126.5	93.3	19.1	15.6	11.3
2002.9173	DEC	157.3	124.4	92.6	19.5	15.7	11.4
2003.0007	JAN	152.1	122.0	91.7	19.8	15.7	11.5
2003.0840	FEB	147.2	119.9	90.6	19.8	15.7	11.2
2003.1673	MAR	144.7	117.7	89.0	19.9	15.5	11.1
2003.2507	APR	143.3	115.5	86.5	19.4	15.4	11.2
2003.3340	MAY	141.4	113.6	84.7	19.3	15.6	11.2
2003.4173	JUN	138.9	112.1	84.1	20.0	15.8	11.3
2003.5007	JUL	136.4	110.4	83.5	19.9	15.9	11.4
2003.5840	AUG	133.6	108.6	82.5	19.7	16.1	11.3
2003.6673	SEP	131.3	106.9	80.7	19.7	16.2	11.2
2003.7507	OCT	131.0	105.1	78.1	19.7	16.2	10.9
2003.8340	NOV	129.7	103.3	76.6	20.0	16.3	10.9
2003.9173	DEC	127.3	101.6	75.7	20.5	16.3	11.0
2004.0007	JAN	126.4	100.2	74.6	21.0	16.4	11.7
2004.0840	FEB	125.3	99.1	73.8	21.2	16.7	12.2
2004.1673	MAR	123.1	98.0	73.3	20.8	17.0	12.3
2004.2507	APR	121.1	97.2	73.2	20.9	16.9	12.3
2004.3340	MAY	119.7	96.2	72.7	21.8	16.8	12.3
2004.4173	JUN	119.0	95.0	71.9	22.2	16.7	12.5
2004.5007	JUL	117.8	93.6	71.3	22.0	16.6	13.3

* Program Initialized from established Cycle 23 smoothed 10.7-cm solar flux minimum

TABLE 3 ESTIMATES OF 13-MONTH SMOOTHED $F_{10.7}$* AND A_p FOR BALANCE OF CYCLE 23 AND CYCLE 24

TIME		10.7-CM SOLAR FLUX ($\bar{F}_{10.7}$) PERCENTILE			GEOMAGNETIC INDEX ($\bar{A}_p$) PERCENTILE		
		95.0%	50%	5.0%	95.0%	50%	5.0%
2004.5840	AUG	115.4	92.4	70.9	21.9	16.8	12.8
2004.6673	SEP	112.0	91.0	70.9	22.3	16.9	12.5
2004.7507	OCT	108.6	89.6	71.1	22.0	16.8	12.5
2004.8340	NOV	105.5	88.5	71.3	21.9	16.6	12.0
2004.9173	DEC	104.6	87.7	71.3	22.1	16.3	11.6
2005.0007	JAN	103.2	86.8	71.2	22.1	15.9	10.9
2005.0840	FEB	101.8	85.6	71.4	22.5	15.6	9.8
2005.1673	MAR	100.2	84.8	71.2	22.9	15.3	8.7
2005.2507	APR	98.6	83.9	71.0	23.2	15.1	8.4
2005.3340	MAY	97.1	83.0	70.7	23.5	15.1	8.2
2005.4173	JUN	95.5	82.1	70.5	23.6	15.1	7.9
2005.5007	JUL	94.0	81.3	70.2	23.4	14.9	7.9
2005.5840	AUG	92.4	80.4	70.0	22.9	14.8	8.1
2005.6673	SEP	90.9	79.6	69.8	22.1	14.7	8.4
2005.7507	OCT	89.5	78.8	69.5	21.3	14.6	8.9
2005.8340	NOV	88.0	78.0	69.3	21.1	14.7	9.1
2005.9173	DEC	86.7	77.2	69.1	20.8	14.9	9.2
2006.0007	JAN	85.3	76.5	68.9	20.8	15.1	9.7
2006.0840	FEB	84.0	75.8	68.7	20.6	15.3	10.2
2006.1673	MAR	82.8	75.1	68.5	20.1	15.3	10.5
2006.2507	APR	81.6	74.4	68.3	20.0	15.2	10.7
2006.3340	MAY	80.4	73.8	68.1	20.2	15.0	11.2
2006.4173	JUN	79.4	73.2	68.0	20.2	14.8	11.9
2006.5007	JUL	78.4	72.7	67.8	19.9	14.7	11.7
2006.5840	AUG	77.5	72.1	67.7	19.4	14.6	11.6
2006.6673	SEP	76.6	71.7	67.5	18.9	14.7	11.4
2006.7507	OCT	75.9	71.3	67.4	18.1	14.8	11.3
2006.8340	NOV	75.2	70.9	67.3	18.1	14.8	10.7
2006.9173	DEC	74.6	70.6	67.2	18.0	14.6	10.4
2007.0007	JAN	74.1	70.3	67.1	17.9	14.5	10.3
2007.0840	FEB	73.7	70.1	67.1	17.5	14.4	10.3
2007.1673	MAR	73.5	69.9	67.0	17.2	14.3	10.5
2007.2507	APR	73.3	69.8	67.0	16.6	13.9	10.2
2007.3340	MAY	73.2	69.8	67.0	16.1	13.4	9.9
2007.4173	JUN	73.4	69.9	67.1	15.6	12.9	9.6
2007.5007	JUL	74.0	70.3	67.3	15.1	12.5	9.2
2007.5840	AUG	74.8	70.7	67.4	14.6	12.1	9.0
2007.6673	SEP	75.7	71.0	67.5	14.1	11.6	8.7
2007.7507	OCT	76.7	71.5	67.6	13.6	11.2	8.4
2007.8340	NOV	78.3	72.0	67.9	13.2	10.8	8.1
2007.9173	DEC	79.6	72.7	68.1	12.8	10.5	7.9
2008.0007	JAN	81.1	73.3	68.2	12.4	10.2	7.7
2008.0840	FEB	83.4	74.2	68.2	12.1	9.9	7.5
2008.1673	MAR	86.5	75.1	68.3	11.8	9.6	7.3
2008.2507	APR	91.3	76.3	68.3	11.6	9.4	7.2
2008.3340	MAY	95.8	77.7	68.3	11.4	9.2	7.1
2008.4173	JUN	99.3	79.1	68.6	11.2	9.1	7.0
2008.5007	JUL	104.6	80.8	68.6	11.1	9.0	6.9
2008.5840	AUG	110.7	82.8	68.7	11.1	9.0	6.9
2008.6673	SEP	116.6	84.9	68.9	11.3	9.1	6.9
2008.7507	OCT	124.0	87.2	68.9	11.6	9.3	7.1
2008.8340	NOV	132.5	89.6	69.0	11.7	9.4	7.4
2008.9173	DEC	139.0	92.2	69.4	11.9	9.5	7.5
2009.0007	JAN	143.6	95.0	69.8	12.0	9.6	7.5
2009.0840	FEB	147.9	97.8	70.1	12.1	9.6	7.3
2009.1673	MAR	152.2	100.6	70.8	12.2	9.7	7.2
2009.2507	APR	157.0	103.3	71.2	12.6	9.8	7.0
2009.3340	MAY	162.1	106.3	71.4	12.9	10.1	6.9

* Program Initialized from established Cycle 23 smoothed 10.7-cm solar flux minimum

TABLE 3 ESTIMATES OF 13-MONTH SMOOTHED $F_{10.7}$* AND A_p FOR BALANCE OF CYCLE 23 AND CYCLE 24

TIME		10.7-CM SOLAR FLUX ($\bar{F}_{10.7}$) PERCENTILE			GEOMAGNETIC INDEX ($\bar{A}_p$) PERCENTILE		
		95.0%	50%	5.0%	95.0%	50%	5.0%
2009.4173	JUN	167.2	109.5	72.1	13.3	10.5	7.1
2009.5007	JUL	171.5	112.8	72.7	13.8	10.8	7.5
2009.5840	AUG	177.3	115.9	73.3	14.6	11.1	7.8
2009.6673	SEP	185.2	119.0	74.0	15.8	11.4	7.6
2009.7507	OCT	190.2	122.2	74.3	16.2	11.6	7.6
2009.8340	NOV	192.8	125.1	74.6	16.4	11.7	7.5
2009.9173	DEC	195.4	127.5	75.0	16.9	11.9	7.5
2010.0007	JAN	198.3	129.7	75.3	18.1	12.2	7.5
2010.0840	FEB	202.9	131.9	75.5	19.0	12.6	7.6
2010.1673	MAR	209.1	134.3	75.5	19.2	12.8	7.6
2010.2507	APR	213.2	136.8	75.1	19.3	13.0	7.7
2010.3340	MAY	215.9	139.1	74.9	19.1	13.2	7.6
2010.4173	JUN	220.4	141.2	75.2	18.7	13.3	7.6
2010.5007	JUL	225.0	143.1	75.5	18.6	13.3	7.7
2010.5840	AUG	227.3	144.9	76.3	19.0	13.5	7.9
2010.6673	SEP	228.4	146.5	77.5	18.9	13.6	8.1
2010.7507	OCT	230.3	147.9	78.2	17.9	13.6	8.5
2010.8340	NOV	232.4	148.8	79.1	18.0	13.8	8.6
2010.9173	DEC	235.4	149.7	80.7	18.6	14.1	8.6
2011.0007	JAN	238.7	150.1	82.6	19.2	14.3	8.9
2011.0840	FEB	240.3	150.5	84.7	19.7	14.8	9.3
2011.1673	MAR	238.7	150.8	85.9	20.4	15.1	9.5
2011.2507	APR	236.9	151.0	86.9	20.4	15.2	9.5
2011.3340	MAY	238.1	151.2	88.8	20.4	15.2	9.7
2011.4173	JUN	238.7	150.6	90.2	20.6	15.2	9.9
2011.5007	JUL	236.3	149.2	92.2	20.9	15.4	10.4
2011.5840	AUG	232.9	148.1	93.5	21.3	15.4	11.0
2011.6673	SEP	229.2	147.5	94.0	21.3	15.3	11.6
2011.7507	OCT	227.4	147.4	95.3	21.5	15.1	11.2
2011.8340	NOV	227.8	147.4	95.6	21.7	15.1	11.1
2011.9173	DEC	227.9	147.1	95.2	22.1	15.1	10.6
2012.0007	JAN	226.5	146.7	95.3	22.9	15.0	10.1
2012.0840	FEB	224.8	146.3	96.8	22.6	14.7	9.8
2012.1673	MAR	224.3	145.7	97.5	21.4	14.4	10.0
2012.2507	APR	224.2	145.2	97.1	20.7	14.3	10.0
2012.3340	MAY	223.6	144.8	96.3	20.1	14.2	10.2
2012.4173	JUN	222.6	144.0	96.3	19.7	14.1	10.5
2012.5007	JUL	220.3	143.0	96.8	19.6	14.1	10.5
2012.5840	AUG	216.8	141.4	95.9	19.4	14.1	10.4
2012.6673	SEP	213.9	139.8	95.4	19.2	14.4	10.4
2012.7507	OCT	211.1	138.6	96.2	19.0	14.7	10.4
2012.8340	NOV	207.5	137.6	97.2	19.0	14.9	10.2
2012.9173	DEC	206.6	136.3	96.2	19.5	14.8	9.8
2013.0007	JAN	204.5	134.6	94.6	20.5	14.9	10.1
2013.0840	FEB	201.1	132.8	93.9	22.1	15.3	10.6
2013.1673	MAR	197.5	131.4	93.6	23.5	15.6	10.6
2013.2507	APR	195.2	130.3	91.9	24.1	15.8	10.8
2013.3340	MAY	193.4	128.9	88.5	25.3	16.1	10.9
2013.4173	JUN	189.6	127.1	87.7	25.8	16.3	11.1
2013.5007	JUL	185.1	125.5	88.8	25.0	16.3	11.4
2013.5840	AUG	180.7	124.2	88.3	24.9	16.3	11.6
2013.6673	SEP	176.8	123.1	87.0	24.1	16.2	11.7
2013.7507	OCT	174.6	122.0	86.0	22.2	16.1	11.7
2013.8340	NOV	172.7	120.8	85.7	22.5	16.2	11.9
2013.9173	DEC	168.6	119.2	84.8	23.2	16.3	11.7
2014.0007	JAN	162.0	117.2	83.5	23.3	16.3	10.9
2014.0840	FEB	156.1	115.4	82.5	22.8	16.1	10.6
2014.1673	MAR	152.5	113.5	81.9	22.1	15.9	10.7

* Program Initialized from established Cycle 23 smoothed 10.7-cm solar flux minimum

TABLE 3 ESTIMATES OF 13-MONTH SMOOTHED $F_{10.7}$* AND A_p FOR BALANCE OF CYCLE 23 AND CYCLE 24

TIME		10.7-CM SOLAR FLUX ($\bar{F}_{10.7}$) PERCENTILE			GEOMAGNETIC INDEX ($\bar{A}_p$) PERCENTILE		
		95.0%	50%	5.0%	95.0%	50%	5.0%
2014.2507	APR	150.3	111.5	81.9	22.0	15.9	10.7
2014.3340	MAY	148.0	109.8	81.6	22.9	16.1	10.6
2014.4173	JUN	145.1	108.3	80.4	23.8	16.4	10.7
2014.5007	JUL	142.0	106.9	80.5	24.0	16.6	10.7
2014.5840	AUG	138.4	105.4	80.2	24.0	16.8	10.6
2014.6673	SEP	134.5	103.9	79.5	24.0	16.9	10.5
2014.7507	OCT	130.1	102.4	79.0	23.6	16.9	10.2
2014.8340	NOV	124.1	100.8	78.2	22.7	16.9	10.3
2014.9173	DEC	119.1	99.3	77.1	22.9	16.8	10.5
2015.0007	JAN	118.2	98.0	75.4	23.1	16.9	11.3
2015.0840	FEB	118.7	96.9	74.3	23.2	17.2	11.8
2015.1673	MAR	119.3	95.9	73.6	22.6	17.3	11.9
2015.2507	APR	119.6	95.0	72.8	21.6	17.3	12.1
2015.3340	MAY	118.8	94.0	71.8	21.3	17.1	12.2
2015.4173	JUN	117.4	92.9	71.3	21.8	16.9	12.4
2015.5007	JUL	116.0	91.8	70.8	21.8	16.7	13.2
2015.5840	AUG	113.9	90.7	70.4	22.2	16.8	13.0
2015.6673	SEP	110.2	89.5	70.3	22.6	16.9	12.7
2015.7507	OCT	105.1	88.3	70.4	22.4	16.9	13.0
2015.8340	NOV	102.7	87.3	70.2	22.4	16.7	12.7
2015.9173	DEC	101.7	86.6	70.1	22.8	16.5	12.4
2016.0007	JAN	100.2	85.8	70.2	23.0	16.1	12.0
2016.0840	FEB	98.1	84.7	70.1	23.6	15.8	11.1
2016.1673	MAR	96.3	83.6	70.3	24.2	15.6	10.4
2016.2507	APR	94.5	82.5	69.8	25.0	15.5	10.5
2016.3340	MAY	93.4	81.8	69.6	25.5	15.5	10.6
2016.4173	JUN	92.1	81.0	69.4	25.7	15.5	10.5
2016.5007	JUL	91.7	80.3	69.3	25.6	15.4	10.6
2016.5840	AUG	91.1	79.5	69.0	25.0	15.3	10.9
2016.6673	SEP	90.5	78.8	68.7	24.1	15.1	11.0
2016.7507	OCT	89.8	78.1	68.4	23.1	14.9	11.2
2016.8340	NOV	88.9	77.5	68.3	22.6	15.0	11.1
2016.9173	DEC	88.0	77.0	68.3	22.2	15.2	11.0
2017.0007	JAN	87.1	76.4	68.2	21.9	15.4	11.1
2017.0840	FEB	85.8	75.9	68.0	21.5	15.5	11.3
2017.1673	MAR	84.4	75.4	67.7	20.8	15.5	11.4
2017.2507	APR	82.3	74.8	67.5	20.0	15.3	11.4
2017.3340	MAY	79.9	74.2	67.6	20.1	15.1	11.7
2017.4173	JUN	78.4	73.5	67.4	20.2	14.9	11.9
2017.5007	JUL	77.5	72.9	67.3	19.9	14.7	11.6
2017.5840	AUG	77.0	72.4	67.2	19.5	14.6	11.5
2017.6673	SEP	76.9	72.0	67.2	19.0	14.6	11.1
2017.7507	OCT	76.7	71.6	67.2	18.3	14.6	10.6
2017.8340	NOV	76.5	71.3	67.1	17.3	14.5	9.8
2017.9173	DEC	76.2	71.0	67.1	17.4	14.4	9.4
2018.0007	JAN	75.2	70.7	67.0	17.5	14.3	9.3
2018.0840	FEB	74.2	70.4	67.0	17.6	14.2	9.3
2018.1673	MAR	74.0	70.1	67.0	17.6	14.1	9.3

* Program Initialized from established Cycle 23 smoothed 10.7-cm solar flux minimum

TABLE 4 ESTIMATES OF 13-MONTH SMOOTHED R* AND A_p FOR BALANCE OF CYCLE 23 AND CYCLE 24

TIME		SUNSPOT NUMBER ($\overline{R}$) PERCENTILE			GEOMAGNETIC INDEX ($\overline{A}_p$) PERCENTILE		
		95.0%	50%	5.0%	95.0%	50%	5.0%
1999.7507	OCT	110.3	104.3	100.1	13.7	12.7	12.0
1999.8340	NOV	116.1	105.6	97.8	14.2	13.0	11.8
1999.9173	DEC	123.3	106.5	95.3	15.2	13.2	11.7
2000.0007	JAN	128.1	106.6	92.6	16.1	13.6	11.8
2000.0840	FEB	131.7	106.8	89.1	16.5	14.0	11.8
2000.1673	MAR	135.3	107.6	85.4	16.4	14.3	11.5
2000.2507	APR	138.0	108.2	82.3	16.1	14.3	11.2
2000.3340	MAY	143.3	108.6	80.2	16.2	14.3	10.8
2000.4173	JUN	144.7	108.0	79.4	16.7	14.4	10.6
2000.5007	JUL	140.7	106.5	78.8	17.4	14.6	10.2
2000.5840	AUG	136.7	105.0	76.1	17.6	14.7	9.8
2000.6673	SEP	137.0	104.0	73.1	17.3	14.6	9.0
2000.7507	OCT	137.6	103.7	72.0	17.4	14.4	8.3
2000.8340	NOV	138.1	103.3	72.5	17.8	14.4	8.3
2000.9173	DEC	137.9	102.7	72.1	18.2	14.4	8.3
2001.0007	JAN	136.8	102.0	72.5	18.9	14.3	7.9
2001.0840	FEB	134.6	101.4	70.2	18.9	14.1	7.6
2001.1673	MAR	130.5	100.8	66.2	18.4	13.9	7.8
2001.2507	APR	125.1	100.1	64.0	18.2	13.9	8.2
2001.3340	MAY	121.6	99.2	62.2	18.0	13.9	8.7
2001.4173	JUN	119.7	98.1	60.7	17.7	13.8	9.0
2001.5007	JUL	117.2	96.9	59.3	17.7	13.8	9.2
2001.5840	AUG	114.3	95.1	56.7	17.4	13.8	9.3
2001.6673	SEP	114.0	93.3	54.9	16.9	14.0	9.5
2001.7507	OCT	114.1	91.8	53.5	17.4	14.3	10.3
2001.8340	NOV	113.9	90.6	52.5	17.6	14.4	10.6
2001.9173	DEC	114.6	89.1	51.8	17.3	14.2	10.3
2002.0007	JAN	114.9	87.3	51.5	17.7	14.3	10.7
2002.0840	FEB	117.1	85.7	50.9	19.1	14.6	11.1
2002.1673	MAR	118.0	84.4	49.3	20.3	14.9	11.3
2002.2507	APR	116.4	82.9	47.9	20.9	15.1	11.5
2002.3340	MAY	115.4	81.3	45.8	21.9	15.3	11.7
2002.4173	JUN	115.9	79.5	42.3	22.3	15.5	11.6
2002.5007	JUL	114.0	77.7	39.2	21.7	15.5	11.7
2002.5840	AUG	111.1	76.2	37.9	21.8	15.5	11.6
2002.6673	SEP	107.6	75.0	37.6	21.1	15.5	11.4
2002.7507	OCT	103.8	73.7	37.7	19.3	15.5	11.3
2002.8340	NOV	101.0	72.3	37.4	19.1	15.6	11.3
2002.9173	DEC	99.6	70.5	36.1	19.5	15.7	11.4
2003.0007	JAN	97.3	68.5	34.0	19.8	15.7	11.5
2003.0840	FEB	92.2	66.4	32.2	19.8	15.7	11.2
2003.1673	MAR	89.6	64.0	31.0	19.9	15.5	11.1
2003.2507	APR	87.7	61.7	30.0	19.4	15.4	11.2
2003.3340	MAY	85.3	59.9	27.6	19.3	15.6	11.2
2003.4173	JUN	83.0	58.4	26.8	20.0	15.8	11.3
2003.5007	JUL	81.5	56.9	26.1	19.9	15.9	11.4
2003.5840	AUG	81.5	55.2	25.0	19.7	16.1	11.3
2003.6673	SEP	81.4	53.5	22.7	19.7	16.2	11.2
2003.7507	OCT	81.3	51.7	19.3	19.7	16.2	10.9
2003.8340	NOV	80.7	49.9	17.2	20.0	16.3	10.9
2003.9173	DEC	78.2	47.9	15.9	20.5	16.3	11.0
2004.0007	JAN	77.2	46.2	14.3	21.0	16.4	11.7
2004.0840	FEB	76.0	44.9	13.1	21.2	16.7	12.2
2004.1673	MAR	73.5	43.7	12.3	20.8	17.0	12.3
2004.2507	APR	71.2	42.6	12.0	20.9	16.9	12.3
2004.3340	MAY	69.7	41.2	11.1	21.8	16.8	12.3
2004.4173	JUN	68.9	39.6	9.9	22.2	16.7	12.5
2004.5007	JUL	67.6	38.1	9.0	22.0	16.6	13.3

* Program Initialized from established Cycle 23 smoothed sunspot minimum

TABLE 4 ESTIMATES OF 13-MONTH SMOOTHED R* AND A_p FOR BALANCE OF CYCLE 23 AND CYCLE 24

TIME		SUNSPOT NUMBER ($\overline{R}$) PERCENTILE			GEOMAGNETIC INDEX ($\overline{A}_p$) PERCENTILE		
		95.0%	50%	5.0%	95.0%	50%	5.0%
2004.5840	AUG	64.8	36.7	8.4	21.9	16.8	12.8
2004.6673	SEP	61.5	35.3	8.3	22.3	16.9	12.5
2004.7507	OCT	58.2	33.8	8.5	22.0	16.8	12.5
2004.8340	NOV	55.0	32.6	8.9	21.9	16.6	12.0
2004.9173	DEC	54.0	31.7	8.8	22.1	16.3	11.6
2005.0007	JAN	52.6	30.7	8.6	22.1	15.9	10.9
2005.0840	FEB	51.2	29.4	9.0	22.5	15.6	9.8
2005.1673	MAR	49.0	27.9	9.0	22.9	15.3	8.7
2005.2507	APR	46.3	26.6	8.1	23.2	15.1	8.4
2005.3340	MAY	45.5	25.7	8.4	23.5	15.1	8.2
2005.4173	JUN	43.6	24.8	8.6	23.6	15.1	7.9
2005.5007	JUL	41.1	23.8	8.3	23.4	14.9	7.9
2005.5840	AUG	39.7	22.9	7.9	22.9	14.8	8.1
2005.6673	SEP	39.1	22.0	7.5	22.1	14.7	8.4
2005.7507	OCT	37.1	20.8	7.0	21.3	14.6	8.9
2005.8340	NOV	35.1	19.6	6.4	21.1	14.7	9.1
2005.9173	DEC	33.1	18.4	5.8	20.8	14.9	9.2
2006.0007	JAN	31.2	17.2	5.3	20.8	15.1	9.7
2006.0840	FEB	29.3	16.1	4.8	20.6	15.3	10.2
2006.1673	MAR	27.4	15.0	4.2	20.1	15.3	10.5
2006.2507	APR	25.6	13.9	3.7	20.0	15.2	10.7
2006.3340	MAY	23.9	12.9	3.3	20.2	15.0	11.2
2006.4173	JUN	22.2	11.9	2.8	20.2	14.8	11.9
2006.5007	JUL	20.7	11.0	2.4	19.9	14.7	11.7
2006.5840	AUG	19.2	10.1	2.0	19.4	14.6	11.6
2006.6673	SEP	17.9	9.3	1.6	18.9	14.7	11.4
2006.7507	OCT	16.6	8.6	1.2	18.1	14.8	11.3
2006.8340	NOV	15.5	7.9	.9	18.1	14.8	10.7
2006.9173	DEC	14.6	7.3	.7	18.0	14.6	10.4
2007.0007	JAN	13.8	6.9	.4	17.9	14.5	10.3
2007.0840	FEB	13.1	6.5	.3	17.5	14.4	10.3
2007.1673	MAR	12.7	6.2	.1	17.2	14.3	10.5
2007.2507	APR	12.4	6.0	.0	16.6	13.9	10.2
2007.3340	MAY	12.3	6.0	.0	16.1	13.4	9.9
2007.4173	JUN	12.9	6.3	.4	15.6	12.9	9.6
2007.5007	JUL	14.3	6.9	.7	15.1	12.5	9.2
2007.5840	AUG	15.5	7.6	1.0	14.6	12.1	9.0
2007.6673	SEP	16.7	8.2	1.5	14.1	11.6	8.7
2007.7507	OCT	18.1	9.0	1.7	13.6	11.2	8.4
2007.8340	NOV	20.6	9.9	2.2	13.2	10.8	8.1
2007.9173	DEC	22.9	10.9	2.7	12.8	10.5	7.9
2008.0007	JAN	25.0	12.0	2.9	12.4	10.2	7.7
2008.0840	FEB	28.3	13.2	3.1	12.1	9.9	7.5
2008.1673	MAR	32.2	14.6	3.3	11.8	9.6	7.3
2008.2507	APR	38.3	16.3	3.3	11.6	9.4	7.2
2008.3340	MAY	43.7	18.3	3.3	11.4	9.2	7.1
2008.4173	JUN	47.9	20.4	4.0	11.2	9.1	7.0
2008.5007	JUL	53.9	22.6	4.2	11.1	9.0	6.9
2008.5840	AUG	60.9	25.0	4.3	11.1	9.0	6.9
2008.6673	SEP	67.5	27.6	4.8	11.3	9.1	6.9
2008.7507	OCT	75.1	30.2	4.6	11.6	9.3	7.1
2008.8340	NOV	83.9	33.0	4.8	11.7	9.4	7.4
2008.9173	DEC	90.9	36.3	5.6	11.9	9.5	7.5
2009.0007	JAN	96.0	39.9	6.6	12.0	9.6	7.5
2009.0840	FEB	100.8	43.5	7.3	12.1	9.6	7.3
2009.1673	MAR	105.5	46.9	8.6	12.2	9.7	7.2
2009.2507	APR	110.7	50.3	9.5	12.6	9.8	7.0
2009.3340	MAY	116.4	53.7	9.6	12.9	10.1	6.9

* Program Initialized from established Cycle 23 smoothed sunspot minimum

TABLE 4 ESTIMATES OF 13-MONTH SMOOTHED R* AND A_p FOR BALANCE OF CYCLE 23 AND CYCLE 24

TIME		SUNSPOT NUMBER ($\overline{R}$) PERCENTILE			GEOMAGNETIC INDEX ($\overline{A}_p$) PERCENTILE		
		95.0%	50%	5.0%	95.0%	50%	5.0%
2009.4173	JUN	121.8	57.4	11.1	13.3	10.5	7.1
2009.5007	JUL	126.2	61.0	12.2	13.8	10.8	7.5
2009.5840	AUG	134.2	64.5	13.2	14.6	11.1	7.8
2009.6673	SEP	141.9	67.7	14.4	15.8	11.4	7.6
2009.7507	OCT	146.6	71.2	14.9	16.2	11.6	7.6
2009.8340	NOV	148.6	74.6	15.4	16.4	11.7	7.5
2009.9173	DEC	151.8	77.4	16.0	16.9	11.9	7.5
2010.0007	JAN	155.5	79.8	16.4	18.1	12.2	7.5
2010.0840	FEB	159.3	81.9	16.7	19.0	12.6	7.6
2010.1673	MAR	164.8	84.2	16.6	19.2	12.8	7.6
2010.2507	APR	168.2	86.5	16.1	19.3	13.0	7.7
2010.3340	MAY	169.9	88.9	15.7	19.1	13.2	7.6
2010.4173	JUN	173.9	91.1	16.1	18.7	13.3	7.6
2010.5007	JUL	178.8	93.2	16.6	18.6	13.3	7.7
2010.5840	AUG	181.8	95.2	17.7	19.0	13.5	7.9
2010.6673	SEP	183.9	97.4	19.5	18.9	13.6	8.1
2010.7507	OCT	186.7	99.4	20.7	17.9	13.6	8.5
2010.8340	NOV	189.2	100.7	22.0	18.0	13.8	8.6
2010.9173	DEC	191.5	101.6	24.3	18.6	14.1	8.6
2011.0007	JAN	192.9	101.8	27.0	19.2	14.3	8.9
2011.0840	FEB	194.3	102.2	29.8	19.7	14.8	9.3
2011.1673	MAR	194.4	103.0	31.5	20.4	15.1	9.5
2011.2507	APR	193.8	103.6	32.8	20.4	15.2	9.5
2011.3340	MAY	195.2	104.2	35.3	20.4	15.2	9.7
2011.4173	JUN	195.8	103.7	37.1	20.6	15.2	9.9
2011.5007	JUL	192.6	102.3	39.5	20.9	15.4	10.4
2011.5840	AUG	188.0	101.0	41.2	21.3	15.4	11.0
2011.6673	SEP	183.4	100.2	41.9	21.3	15.3	11.6
2011.7507	OCT	181.2	100.0	43.4	21.5	15.1	11.2
2011.8340	NOV	180.5	99.8	43.7	21.7	15.1	11.1
2011.9173	DEC	179.4	99.1	43.2	22.1	15.1	10.6
2012.0007	JAN	178.2	98.5	43.3	22.9	15.0	10.1
2012.0840	FEB	176.8	98.0	45.1	22.6	14.7	9.8
2012.1673	MAR	176.1	97.4	46.0	21.4	14.4	10.0
2012.2507	APR	175.0	96.8	45.4	20.7	14.3	10.0
2012.3340	MAY	173.8	95.9	44.6	20.1	14.2	10.2
2012.4173	JUN	172.1	94.9	44.5	19.7	14.1	10.5
2012.5007	JUL	169.5	93.7	45.1	19.6	14.1	10.5
2012.5840	AUG	165.3	92.0	44.1	19.4	14.1	10.4
2012.6673	SEP	162.0	90.2	43.4	19.2	14.4	10.4
2012.7507	OCT	158.7	88.8	44.4	19.0	14.7	10.4
2012.8340	NOV	154.4	87.7	45.5	19.0	14.9	10.2
2012.9173	DEC	150.8	86.3	44.5	19.5	14.8	9.8
2013.0007	JAN	146.5	84.6	42.5	20.5	14.9	10.1
2013.0840	FEB	142.9	83.1	41.6	22.1	15.3	10.6
2013.1673	MAR	142.2	81.9	41.3	23.5	15.6	10.6
2013.2507	APR	138.9	80.6	39.2	24.1	15.8	10.8
2013.3340	MAY	136.8	79.1	34.9	25.3	16.1	10.9
2013.4173	JUN	135.9	77.3	33.9	25.8	16.3	11.1
2013.5007	JUL	132.9	75.6	35.4	25.0	16.3	11.4
2013.5840	AUG	129.3	74.2	34.8	24.9	16.3	11.6
2013.6673	SEP	125.3	73.1	33.1	24.1	16.2	11.7
2013.7507	OCT	121.0	71.9	31.9	22.2	16.1	11.7
2013.8340	NOV	117.5	70.5	31.3	22.5	16.2	11.9
2013.9173	DEC	115.3	68.8	30.2	23.2	16.3	11.7
2014.0007	JAN	111.4	66.9	28.4	23.3	16.3	10.9
2014.0840	FEB	104.9	64.9	27.0	22.8	16.1	10.6
2014.1673	MAR	98.0	62.6	26.2	22.1	15.9	10.7

* Program Initialized from established Cycle 23 smoothed sunspot minimum

TABLE 4 ESTIMATES OF 13-MONTH SMOOTHED R* AND A_p FOR BALANCE OF CYCLE 23 AND CYCLE 24

TIME		SUNSPOT NUMBER ($\overline{R}$) PERCENTILE			GEOMAGNETIC INDEX ($\overline{A}_p$) PERCENTILE		
		95.0%	50%	5.0%	95.0%	50%	5.0%
2014.2507	APR	94.1	60.4	26.3	22.0	15.9	10.7
2014.3340	MAY	93.1	58.6	25.8	22.9	16.1	10.6
2014.4173	JUN	92.2	57.1	24.2	23.8	16.4	10.7
2014.5007	JUL	89.9	55.6	24.3	24.0	16.6	10.7
2014.5840	AUG	87.6	54.1	23.9	24.0	16.8	10.6
2014.6673	SEP	83.8	52.4	22.9	24.0	16.9	10.5
2014.7507	OCT	80.3	50.7	22.1	23.6	16.9	10.2
2014.8340	NOV	76.6	49.0	20.9	22.7	16.9	10.3
2014.9173	DEC	71.1	47.1	19.3	22.9	16.8	10.5
2015.0007	JAN	69.8	45.4	16.8	23.1	16.9	11.3
2015.0840	FEB	70.3	44.2	14.9	23.2	17.2	11.8
2015.1673	MAR	69.9	42.9	13.8	22.6	17.3	11.9
2015.2507	APR	69.7	41.8	12.3	21.6	17.3	12.1
2015.3340	MAY	68.9	40.4	10.5	21.3	17.1	12.2
2015.4173	JUN	66.9	38.9	9.5	21.8	16.9	12.4
2015.5007	JUL	64.3	37.4	8.7	21.8	16.7	13.2
2015.5840	AUG	61.0	36.1	7.8	22.2	16.8	13.0
2015.6673	SEP	56.5	34.7	7.6	22.6	16.9	12.7
2015.7507	OCT	52.1	33.3	7.7	22.4	16.9	13.0
2015.8340	NOV	48.9	32.1	7.4	22.4	16.7	12.7
2015.9173	DEC	49.9	31.3	7.2	22.8	16.5	12.4
2016.0007	JAN	49.1	30.3	7.3	23.0	16.1	12.0
2016.0840	FEB	46.6	29.0	7.2	23.6	15.8	11.1
2016.1673	MAR	44.5	27.6	7.7	24.2	15.6	10.4
2016.2507	APR	42.4	26.3	6.6	25.0	15.5	10.5
2016.3340	MAY	41.1	25.4	6.2	25.5	15.5	10.6
2016.4173	JUN	39.5	24.4	5.8	25.7	15.5	10.5
2016.5007	JUL	38.9	23.5	5.4	25.6	15.4	10.6
2016.5840	AUG	38.3	22.5	4.9	25.0	15.3	10.9
2016.6673	SEP	37.9	21.6	4.3	24.1	15.1	11.0
2016.7507	OCT	37.1	20.6	3.5	23.1	14.9	11.2
2016.8340	NOV	36.1	19.7	3.4	22.6	15.0	11.1
2016.9173	DEC	34.9	19.0	3.3	22.2	15.2	11.0
2017.0007	JAN	33.5	18.1	3.1	21.9	15.4	11.1
2017.0840	FEB	31.8	17.1	2.5	21.5	15.5	11.3
2017.1673	MAR	29.9	16.2	1.9	20.8	15.5	11.4
2017.2507	APR	27.1	15.3	1.4	20.0	15.3	11.4
2017.3340	MAY	24.6	14.3	1.4	20.1	15.1	11.7
2017.4173	JUN	22.2	13.1	1.2	20.2	14.9	11.9
2017.5007	JUL	20.3	12.0	.8	19.9	14.7	11.6
2017.5840	AUG	19.2	11.1	.5	19.5	14.6	11.5
2017.6673	SEP	19.0	10.3	.4	19.0	14.6	11.1
2017.7507	OCT	18.6	9.5	.4	18.3	14.6	10.6
2017.8340	NOV	18.2	8.8	.3	17.3	14.5	9.8
2017.9173	DEC	16.8	8.3	.2	17.4	14.4	9.4
2018.0007	JAN	15.9	7.8	.1	17.5	14.3	9.3
2018.0840	FEB	15.9	7.3	.0	17.6	14.2	9.3
2018.1673	MAR	15.1	6.8	.0	17.6	14.1	9.3

* Program Initialized from established Cycle 23 smoothed sunspot minimum

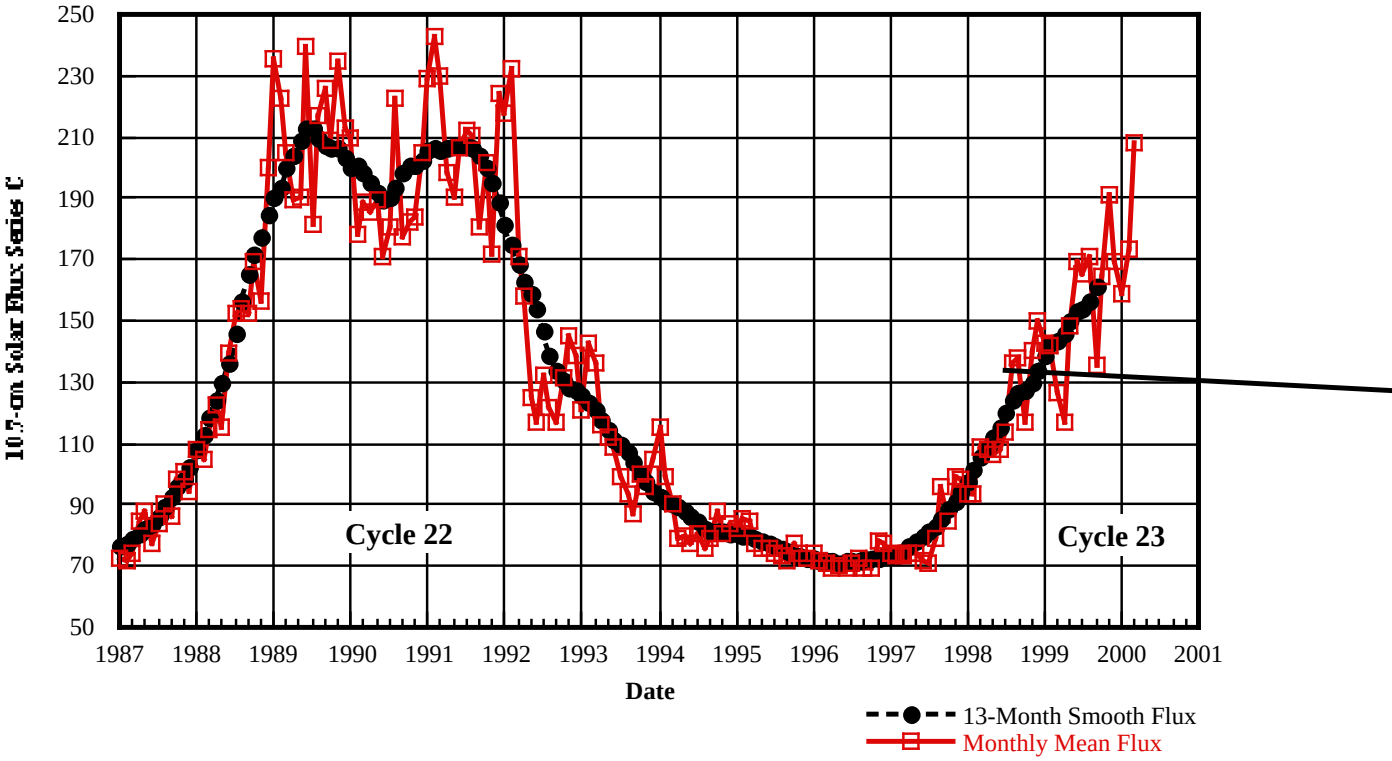
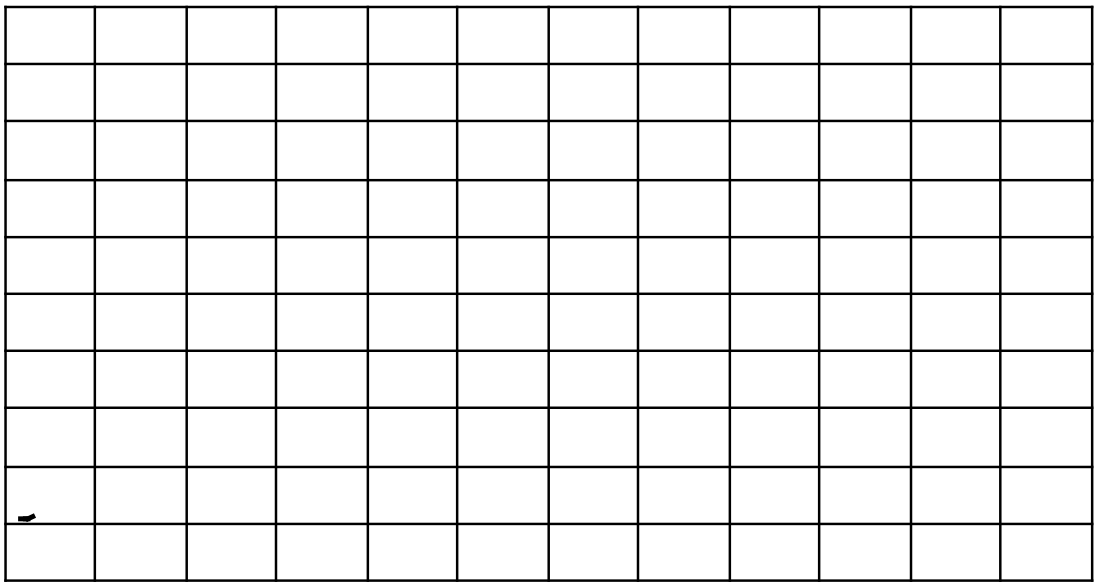


Figure 1. Plot of Recent Monthly Mean and 13-Month Smoothed Solar Flux



* Program Initialized from Cycle 23 May 1996 smoothed minimum