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

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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, 4 and 5[1]. 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. Table 5[1] (page 19) contains the statistical estimates of 75 Percentile $\overline{F}_{10.7}$ and 95 Percentile $\overline{A}_p$ 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 23) 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 24) 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. Figure 5[1] (page 25) 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 6 is a plot of the statistical estimates of 13-month Zurich smoothed 75 Percentile 10.7-cm solar radio flux 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

[1] Table 5, Figure 5 and Figure 6 added June 2002 as requested by NASA/JSC Vehicle Integration Performance and Resources (VIPeR) team.

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 (harold.euler@msfc.nasa.gov).

Customer Feedback

Marshall Space Flight Center's ISO 9000 process solicits customer feedback on all of our products. Please send an email to Dr. Rob Suggs (Rob.Suggs@msfc.nasa.gov) regarding the clarity and operational usefulness of this estimate.

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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)**
2000	January	158.1	90.1	13
	February	173.2	112.9	15
	March	208.2	138.5	9
	April	184.2	125.5	15
	May	184.5	121.6	15
	June	179.8	124.9	15
	July	204.7	170.1	21
	August	163.1	130.5	16
	September	182.1	109.7	18
	October	167.7	99.4	18
	November	178.8	106.8	17
	December	173.6	104.4	7
2001	January	166.6	95.6	8
	February	146.7	80.6	7
	March	177.7	113.5	20
	April	178.1	107.7	22
	May	147.9	96.6	10
	June	173.7	134.0	10
	July	131.3	81.8	9
	August	163.1	106.4	11
	September	233.8	150.7	13
	October	208.1	125.5	20
	November	212.7	106.5	16
	December	235.6	132.2	9
2002	January	227.3	114.1	8
	February	205.0*	107.4	10
	March	180.3*	98.4	10
	April	189.8*	120.7	17
	May	178.4*	120.8	12
	June	148.7*	88.3	7
	July	173.5*	99.9*	11
	August	183.9*	116.4*	14
	September	175.8*	109.3*	13
	October	167.0*	97.5*	25
	November	168.7*	95.0*	16*
	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 ($\bar{F}_{10.7}$)**	**++Sunspot Numbers ($\bar{R}$)**	**+++Geomagnetic Index ($\bar{A}_p$)**
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	90.5	12.4
	June	152.9	93.1	12.4
	July	154.4	94.3	12.6
	August	156.3	97.5	12.9
	September	161.0	102.3	12.8
	October	167.2	107.8	12.7
	November	171.5	111.0	13.1
	December	173.4	111.1	13.8
2000	January	175.5	112.9	14.5
	February	176.8	116.8	15.0
	March	178.4	119.9	15.0
	April	180.5	120.8	14.9
	May	180.1	119.0	15.0
	June	179.7	118.7	15.0
	July	180.2	119.8	14.7
	August	179.5	118.6	14.2
	September	177.1	116.3	14.2
	October	175.6	114.5	15.0
	November	173.8	112.7	15.1
	December	172.1	112.0	14.7
2001	January	168.7*	108.7	14.0*
	February	165.6*	104.0	13.3*
	March	167.8*	104.8	12.8*
	April	171.6*	107.5	12.5*
	May	174.7*	108.6	12.5*
	June	178.7*	109.8	12.4*
	July	183.8*	111.7	12.4*
	August	188.7*	113.6	13.0*
	September	191.3*	114.1	12.7*
	October	191.9*	114.0	12.1*
	November	193.6*	115.5	12.0*
	December	193.8*	114.6	12.4*

* 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 ($\bar{A}_p$)**
2002	January	194.6*	113.5*	12.7*
	February	197.3*	114.7*	13.1*
	March	195.7*	113.4*	13.4*
	April	191.6*	110.5*	13.5*
	May	188.1*	108.8*	13.5*
	June			
	July			
	August			
	September			
	October			
	November			
	December			
2003	January			
	February			
	March			
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2004	January			
	February			
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	September			
	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%
2002.4173	JUN	183.0	177.9	175.3	14.1	13.6	13.2
2002.5007	JUL	182.5	174.1	169.0	14.7	13.7	12.8
2002.5840	AUG	180.5	171.0	164.3	14.7	13.8	12.5
2002.6673	SEP	179.2	168.1	159.5	15.0	13.9	12.3
2002.7507	OCT	178.4	165.6	155.9	16.1	14.1	12.2
2002.8340	NOV	177.3	162.8	152.8	17.3	14.3	11.9
2002.9173	DEC	172.8	158.4	147.6	18.3	14.5	11.7
2003.0007	JAN	165.3	153.0	140.9	18.5	14.6	11.7
2003.0840	FEB	162.3	148.2	134.9	18.6	14.7	11.4
2003.1673	MAR	160.9	144.6	130.8	18.6	14.7	11.1
2003.2507	APR	159.9	141.5	128.3	18.9	14.6	10.9
2003.3340	MAY	157.8	138.7	126.0	19.7	14.8	10.5
2003.4173	JUN	154.0	136.4	125.0	20.4	15.1	10.1
2003.5007	JUL	148.8	133.6	122.5	20.4	15.3	10.1
2003.5840	AUG	147.8	130.6	118.5	20.8	15.4	10.3
2003.6673	SEP	147.3	128.0	115.6	21.5	15.6	10.3
2003.7507	OCT	146.6	125.3	111.4	21.6	15.7	10.5
2003.8340	NOV	144.5	121.7	106.7	21.6	15.8	11.1
2003.9173	DEC	141.2	118.3	103.0	22.0	16.0	11.2
2004.0007	JAN	139.9	116.5	101.1	22.5	16.3	11.7
2004.0840	FEB	139.0	115.7	100.6	22.8	16.7	12.1
2004.1673	MAR	136.8	114.7	100.2	22.3	17.0	12.2
2004.2507	APR	134.3	113.8	99.7	21.5	17.1	12.2
2004.3340	MAY	132.5	112.5	99.1	21.3	17.1	12.2
2004.4173	JUN	131.3	110.6	97.3	21.8	17.0	12.3
2004.5007	JUL	129.5	108.3	95.0	21.8	17.0	13.0
2004.5840	AUG	126.6	106.0	92.8	22.5	17.2	13.6
2004.6673	SEP	123.1	103.9	91.4	22.9	17.3	13.3
2004.7507	OCT	119.2	101.6	90.1	22.6	17.1	13.3
2004.8340	NOV	115.4	99.8	89.2	22.5	16.8	13.0
2004.9173	DEC	113.5	98.6	88.4	22.8	16.5	12.5
2005.0007	JAN	112.2	97.2	87.4	23.0	16.0	11.9
2005.0840	FEB	109.4	95.1	85.9	23.5	15.8	10.9
2005.1673	MAR	105.9	92.7	84.2	24.1	15.4	9.9
2005.2507	APR	103.6	90.4	81.5	24.7	15.2	9.8
2005.3340	MAY	101.5	88.3	79.4	25.2	15.2	9.7
2005.4173	JUN	99.1	86.7	77.9	25.4	15.2	9.6
2005.5007	JUL	96.9	85.5	76.5	25.4	15.1	9.9
2005.5840	AUG	96.2	84.6	75.5	24.9	15.1	10.4
2005.6673	SEP	95.6	83.9	74.7	24.1	15.1	11.0
2005.7507	OCT	93.9	82.8	74.1	23.2	15.1	11.5
2005.8340	NOV	92.2	81.8	73.6	22.9	15.3	11.5
2005.9173	DEC	90.6	80.7	73.0	22.6	15.6	11.2
2006.0007	JAN	89.0	79.7	72.4	22.4	15.9	11.3
2006.0840	FEB	87.4	78.7	71.9	22.1	16.1	11.6
2006.1673	MAR	85.8	77.7	71.3	21.5	16.1	12.0
2006.2507	APR	84.3	76.8	70.8	20.7	16.0	11.9
2006.3340	MAY	82.9	75.9	70.3	19.6	15.9	12.2
2006.4173	JUN	81.5	75.0	69.9	19.5	15.7	12.4
2006.5007	JUL	80.2	74.2	69.4	19.2	15.5	12.1
2006.5840	AUG	79.0	73.4	69.0	18.8	15.5	12.1
2006.6673	SEP	77.9	72.7	68.6	18.2	15.5	12.2
2006.7507	OCT	76.9	72.1	68.3	17.9	15.6	12.5
2006.8340	NOV	76.0	71.5	67.9	17.9	15.6	13.0
2006.9173	DEC	75.2	71.0	67.7	17.7	15.4	13.0
2007.0007	JAN	74.5	70.6	67.4	17.6	15.2	12.6
2007.0840	FEB	74.0	70.2	67.2	17.8	15.1	12.5
2007.1673	MAR	73.6	70.0	67.1	18.0	15.0	12.7

* 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%
2007.2507	APR	73.3	69.8	67.0	17.4	14.5	12.2
2007.3340	MAY	73.2	69.8	67.0	16.8	14.0	11.7
2007.4173	JUN	73.4	69.9	67.1	16.2	13.4	11.2
2007.5007	JUL	74.0	70.3	67.3	15.6	12.9	10.7
2007.5840	AUG	74.8	70.7	67.4	15.1	12.4	10.2
2007.6673	SEP	75.7	71.0	67.5	14.5	12.0	9.8
2007.7507	OCT	76.7	71.5	67.6	14.0	11.5	9.3
2007.8340	NOV	78.3	72.0	67.9	13.5	11.1	8.9
2007.9173	DEC	79.6	72.7	68.1	13.0	10.7	8.5
2008.0007	JAN	81.1	73.3	68.2	12.6	10.3	8.2
2008.0840	FEB	83.4	74.2	68.2	12.2	10.0	7.9
2008.1673	MAR	86.5	75.1	68.3	11.9	9.7	7.6
2008.2507	APR	91.3	76.3	68.3	11.6	9.5	7.4
2008.3340	MAY	95.8	77.7	68.3	11.4	9.3	7.2
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
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

* 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%
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	207.6	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	16.2	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
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	17.2	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	88.2	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

* 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%
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	18.2	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 ($\bar{R}$) PERCENTILE			GEOMAGNETIC INDEX ($\bar{A}_p$) PERCENTILE		
		95.0%	50%	5.0%	95.0%	50%	5.0%
2002.4173	JUN	111.7	106.3	102.3	14.1	13.6	13.2
2002.5007	JUL	112.3	103.5	95.9	14.7	13.7	12.8
2002.5840	AUG	111.3	101.2	90.5	14.7	13.8	12.5
2002.6673	SEP	111.0	99.2	86.9	15.0	13.9	12.3
2002.7507	OCT	110.8	97.0	84.6	16.1	14.1	12.2
2002.8340	NOV	110.4	94.7	82.6	17.3	14.3	11.9
2002.9173	DEC	107.5	91.9	78.9	18.3	14.5	11.7
2003.0007	JAN	102.4	88.4	74.0	18.5	14.6	11.7
2003.0840	FEB	100.9	84.8	69.6	18.6	14.7	11.4
2003.1673	MAR	99.4	81.2	66.6	18.6	14.7	11.1
2003.2507	APR	98.9	78.3	64.5	18.9	14.6	10.9
2003.3340	MAY	97.4	76.2	62.7	19.7	14.8	10.5
2003.4173	JUN	94.2	74.5	61.5	20.4	15.1	10.1
2003.5007	JUL	90.0	72.4	59.2	20.4	15.3	10.1
2003.5840	AUG	90.3	70.2	55.6	20.8	15.4	10.3
2003.6673	SEP	90.7	68.0	52.8	21.5	15.6	10.3
2003.7507	OCT	90.9	65.7	48.7	21.6	15.7	10.5
2003.8340	NOV	90.1	63.1	44.3	21.6	15.8	11.1
2003.9173	DEC	87.2	60.2	40.8	22.0	16.0	11.2
2004.0007	JAN	85.7	57.9	38.1	22.5	16.3	11.7
2004.0840	FEB	84.5	56.9	36.7	22.8	16.7	12.1
2004.1673	MAR	82.1	55.8	36.1	22.3	17.0	12.2
2004.2507	APR	79.6	54.7	35.5	21.5	17.1	12.2
2004.3340	MAY	77.8	53.3	35.2	21.3	17.1	12.2
2004.4173	JUN	76.7	51.3	33.4	21.8	17.0	12.3
2004.5007	JUL	75.2	49.0	30.9	21.8	17.0	13.0
2004.5840	AUG	72.6	46.9	28.7	22.5	17.2	13.6
2004.6673	SEP	69.5	45.0	27.6	22.9	17.3	13.3
2004.7507	OCT	65.8	43.1	26.8	22.6	17.1	13.3
2004.8340	NOV	62.1	41.5	25.8	22.5	16.8	13.0
2004.9173	DEC	60.3	40.6	25.3	22.8	16.5	12.5
2005.0007	JAN	59.3	39.4	25.1	23.0	16.0	11.9
2005.0840	FEB	56.9	37.7	24.3	23.5	15.8	10.9
2005.1673	MAR	53.7	35.5	23.4	24.1	15.4	9.9
2005.2507	APR	51.8	33.5	20.4	24.7	15.2	9.8
2005.3340	MAY	50.3	31.9	18.7	25.2	15.2	9.7
2005.4173	JUN	48.0	30.5	17.5	25.4	15.2	9.6
2005.5007	JUL	45.0	29.3	16.1	25.4	15.1	9.9
2005.5840	AUG	43.6	28.3	15.1	24.9	15.1	10.4
2005.6673	SEP	42.9	27.4	14.2	24.1	15.1	11.0
2005.7507	OCT	42.1	26.4	13.1	23.2	15.1	11.5
2005.8340	NOV	39.7	24.8	12.1	22.9	15.3	11.5
2005.9173	DEC	37.4	23.2	11.1	22.6	15.6	11.2
2006.0007	JAN	35.1	21.6	10.1	22.4	15.9	11.3
2006.0840	FEB	32.8	20.0	9.1	22.1	16.1	11.6
2006.1673	MAR	30.6	18.5	8.1	21.5	16.1	12.0
2006.2507	APR	28.4	17.0	7.1	20.7	16.0	11.9
2006.3340	MAY	26.4	15.6	6.2	19.6	15.9	12.2
2006.4173	JUN	24.4	14.3	5.3	19.5	15.7	12.4
2006.5007	JUL	22.5	13.0	4.5	19.2	15.5	12.1
2006.5840	AUG	20.7	11.8	3.7	18.8	15.5	12.1
2006.6673	SEP	19.1	10.6	3.0	18.2	15.5	12.2
2006.7507	OCT	17.6	9.6	2.4	17.9	15.6	12.5
2006.8340	NOV	16.3	8.7	1.8	17.9	15.6	13.0
2006.9173	DEC	15.1	7.9	1.3	17.7	15.4	13.0
2007.0007	JAN	14.1	7.2	0.8	17.6	15.2	12.6
2007.0840	FEB	13.3	6.7	0.5	17.8	15.1	12.5

* 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 ($\bar{R}$) PERCENTILE			GEOMAGNETIC INDEX ($\bar{A}_p$) PERCENTILE		
		95.0%	50%	5.0%	95.0%	50%	5.0%
2007.1673	MAR	12.8	6.3	0.2	18.0	15.0	12.7
2007.2507	APR	12.4	6.1	0.1	17.4	14.5	12.2
2007.3340	MAY	12.3	6.0	0.0	16.8	14.0	11.7
2007.4173	JUN	12.9	6.3	0.4	16.2	13.4	11.2
2007.5007	JUL	14.3	6.9	0.7	15.6	12.9	10.7
2007.5840	AUG	15.5	7.6	1.0	15.1	12.4	10.2
2007.6673	SEP	16.7	8.2	1.5	14.5	12.0	9.8
2007.7507	OCT	18.1	9.0	1.7	14.0	11.5	9.3
2007.8340	NOV	20.6	9.9	2.2	13.5	11.1	8.9
2007.9173	DEC	22.9	10.9	2.7	13.0	10.7	8.5
2008.0007	JAN	25.0	12.0	2.9	12.6	10.3	8.2
2008.0840	FEB	28.3	13.2	3.1	12.2	10.0	7.9
2008.1673	MAR	32.2	14.6	3.3	11.9	9.7	7.6
2008.2507	APR	38.3	16.3	3.3	11.6	9.5	7.4
2008.3340	MAY	43.7	18.3	3.3	11.4	9.3	7.2
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	36.2	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
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

* 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 ($\bar{R}$) PERCENTILE			GEOMAGNETIC INDEX ($\bar{A}_p$) PERCENTILE		
		95.0%	50%	5.0%	95.0%	50%	5.0%
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	16.2	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
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	17.2	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	33.2	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

* 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 ($\bar{R}$) PERCENTILE			GEOMAGNETIC INDEX ($\bar{A}_p$) PERCENTILE		
		95.0%	50%	5.0%	95.0%	50%	5.0%
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	0.8	19.9	14.7	11.6
2017.5840	AUG	19.2	11.1	0.5	19.5	14.6	11.5
2017.6673	SEP	19.0	10.3	0.4	19.0	14.6	11.1
2017.7507	OCT	18.6	9.5	0.4	18.2	14.6	10.6
2017.8340	NOV	18.2	8.8	0.3	17.3	14.5	9.8
2017.9173	DEC	16.8	8.3	0.2	17.4	14.4	9.4
2018.0007	JAN	15.9	7.8	0.1	17.5	14.3	9.3
2018.0840	FEB	15.9	7.3	0.0	17.6	14.2	9.3
2018.1673	MAR	15.1	6.8	0.0	17.6	14.1	9.3

* Program Initialized from established Cycle 23 smoothed sunspot minimum

TABLE 5 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		
		75.0%	50%	5.0%	95.0%	50%	5.0%
2002.4173	JUN	178.9	177.9	175.3	14.1	13.6	13.2
2002.5007	JUL	176.2	174.1	169.0	14.7	13.7	12.8
2002.5840	AUG	173.3	171.0	164.3	14.7	13.8	12.5
2002.6673	SEP	170.7	168.1	159.5	15.0	13.9	12.3
2002.7507	OCT	169.6	165.6	155.9	16.1	14.1	12.2
2002.8340	NOV	165.9	162.8	152.8	17.3	14.3	11.9
2002.9173	DEC	161.7	158.4	147.6	18.3	14.5	11.7
2003.0007	JAN	157.0	153.0	140.9	18.5	14.6	11.7
2003.0840	FEB	152.8	148.2	134.9	18.6	14.7	11.4
2003.1673	MAR	149.8	144.6	130.8	18.6	14.7	11.1
2003.2507	APR	147.5	141.5	128.3	18.9	14.6	10.9
2003.3340	MAY	145.5	138.7	126.0	19.7	14.8	10.5
2003.4173	JUN	144.3	136.4	125.0	20.4	15.1	10.1
2003.5007	JUL	141.5	133.6	122.5	20.4	15.3	10.1
2003.5840	AUG	137.9	130.6	118.5	20.8	15.4	10.3
2003.6673	SEP	135.0	128.0	115.6	21.5	15.6	10.3
2003.7507	OCT	132.5	125.3	111.4	21.6	15.7	10.5
2003.8340	NOV	128.8	121.7	106.7	21.6	15.8	11.1
2003.9173	DEC	125.2	118.3	103.0	22.0	16.0	11.2
2004.0007	JAN	122.8	116.5	101.1	22.5	16.3	11.7
2004.0840	FEB	123.1	115.7	100.6	22.8	16.7	12.1
2004.1673	MAR	120.7	114.7	100.2	22.3	17.0	12.2
2004.2507	APR	119.5	113.8	99.7	21.5	17.1	12.2
2004.3340	MAY	119.2	112.5	99.1	21.3	17.1	12.2
2004.4173	JUN	117.0	110.6	97.3	21.8	17.0	12.3
2004.5007	JUL	113.8	108.3	95.0	21.8	17.0	13.0
2004.5840	AUG	112.8	106.0	92.8	22.5	17.2	13.6
2004.6673	SEP	111.2	103.9	91.4	22.9	17.3	13.3
2004.7507	OCT	108.2	101.6	90.1	22.6	17.1	13.3
2004.8340	NOV	106.1	99.8	89.2	22.5	16.8	13.0
2004.9173	DEC	104.7	98.6	88.4	22.8	16.5	12.5
2005.0007	JAN	102.9	97.2	87.4	23.0	16.0	11.9
2005.0840	FEB	101.1	95.1	85.9	23.5	15.8	10.9
2005.1673	MAR	99.4	92.7	84.2	24.1	15.4	9.9
2005.2507	APR	97.7	90.4	81.5	24.7	15.2	9.8
2005.3340	MAY	94.9	88.3	79.4	25.2	15.2	9.7
2005.4173	JUN	92.5	86.7	77.9	25.4	15.2	9.6
2005.5007	JUL	91.4	85.5	76.5	25.4	15.1	9.9
2005.5840	AUG	90.2	84.6	75.5	24.9	15.1	10.4
2005.6673	SEP	88.4	83.9	74.7	24.1	15.1	11.0
2005.7507	OCT	87.2	82.8	74.1	23.2	15.1	11.5
2005.8340	NOV	85.9	81.8	73.6	22.9	15.3	11.5
2005.9173	DEC	84.6	80.7	73.0	22.6	15.6	11.2
2006.0007	JAN	83.4	79.7	72.4	22.4	15.9	11.3
2006.0840	FEB	82.2	78.7	71.9	22.1	16.1	11.6
2006.1673	MAR	81.0	77.7	71.3	21.5	16.1	12.0
2006.2507	APR	79.9	76.8	70.8	20.7	16.0	11.9
2006.3340	MAY	78.8	75.9	70.3	19.6	15.9	12.2
2006.4173	JUN	77.7	75.0	69.9	19.5	15.7	12.4
2006.5007	JUL	76.7	74.2	69.4	19.2	15.5	12.1
2006.5840	AUG	75.8	73.4	69.0	18.8	15.5	12.1
2006.6673	SEP	75.0	72.7	68.6	18.2	15.5	12.2
2006.7507	OCT	74.2	72.1	68.3	17.9	15.6	12.5
2006.8340	NOV	73.5	71.5	67.9	17.9	15.6	13.0
2006.9173	DEC	72.9	71.0	67.7	17.7	15.4	13.0
2007.0007	JAN	72.4	70.6	67.4	17.6	15.2	12.6
2007.0840	FEB	72.0	70.2	67.2	17.8	15.1	12.5
2007.1673	MAR	71.7	70.0	67.1	18.0	15.0	12.7

* Program Initialized from established Cycle 23 smoothed sunspot minimum

TABLE 5 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		
		75.0%	50%	5.0%	95.0%	50%	5.0%
2007.2507	APR	71.5	69.8	67.0	17.4	14.5	12.2
2007.3340	MAY	71.4	69.8	67.0	16.8	14.0	11.7
2007.4173	JUN	71.6	69.9	67.1	16.2	13.4	11.2
2007.5007	JUL	72.2	70.3	67.3	15.6	12.9	10.7
2007.5840	AUG	73.0	70.7	67.4	15.1	12.4	10.2
2007.6673	SEP	73.0	71.0	67.5	14.5	12.0	9.8
2007.7507	OCT	73.1	71.5	67.6	14.0	11.5	9.3
2007.8340	NOV	73.7	72.0	67.9	13.5	11.1	8.9
2007.9173	DEC	74.4	72.7	68.1	13.0	10.7	8.5
2008.0007	JAN	75.5	73.3	68.2	12.6	10.3	8.2
2008.0840	FEB	77.1	74.2	68.2	12.2	10.0	7.9
2008.1673	MAR	78.6	75.1	68.3	11.9	9.7	7.6
2008.2507	APR	80.4	76.3	68.3	11.6	9.5	7.4
2008.3340	MAY	82.8	77.7	68.3	11.4	9.3	7.2
2008.4173	JUN	85.8	79.1	68.6	11.2	9.1	7.0
2008.5007	JUL	88.3	80.8	68.6	11.1	9.0	6.9
2008.5840	AUG	91.6	82.8	68.7	11.1	9.0	6.9
2008.6673	SEP	95.3	84.9	68.9	11.3	9.1	6.9
2008.7507	OCT	98.0	87.2	68.9	11.6	9.3	7.1
2008.8340	NOV	99.9	89.6	69.0	11.7	9.4	7.4
2008.9173	DEC	104.0	92.2	69.4	11.9	9.5	7.5
2009.0007	JAN	107.7	95.0	69.8	12.0	9.6	7.5
2009.0840	FEB	111.6	97.8	70.1	12.1	9.6	7.3
2009.1673	MAR	116.0	100.6	70.8	12.2	9.7	7.2
2009.2507	APR	118.5	103.3	71.2	12.6	9.8	7.0
2009.3340	MAY	119.9	106.3	71.4	12.9	10.1	6.9
2009.4173	JUN	123.2	109.5	72.1	13.3	10.5	7.1
2009.5007	JUL	128.2	112.8	72.7	13.8	10.8	7.5
2009.5840	AUG	132.8	115.9	73.3	14.6	11.1	7.8
2009.6673	SEP	136.2	119.0	74.0	15.8	11.4	7.6
2009.7507	OCT	141.6	122.2	74.3	16.2	11.6	7.6
2009.8340	NOV	148.4	125.1	74.6	16.4	11.7	7.5
2009.9173	DEC	153.1	127.5	75.0	16.9	11.9	7.5
2010.0007	JAN	158.1	129.7	75.3	18.1	12.2	7.5
2010.0840	FEB	163.8	131.9	75.5	19.0	12.6	7.6
2010.1673	MAR	169.7	134.3	75.5	19.2	12.8	7.6
2010.2507	APR	175.0	136.8	75.1	19.3	13.0	7.7
2010.3340	MAY	180.6	139.1	74.9	19.1	13.2	7.6
2010.4173	JUN	183.7	141.2	75.2	18.7	13.3	7.6
2010.5007	JUL	186.3	143.1	75.5	18.6	13.3	7.7
2010.5840	AUG	187.1	144.9	76.3	19.0	13.5	7.9
2010.6673	SEP	186.9	146.5	77.5	18.9	13.6	8.1
2010.7507	OCT	186.1	147.9	78.2	17.9	13.6	8.5
2010.8340	NOV	186.2	148.8	79.1	18.0	13.8	8.6
2010.9173	DEC	188.5	149.7	80.7	18.6	14.1	8.6
2011.0007	JAN	191.5	150.1	82.6	19.2	14.3	8.9
2011.0840	FEB	192.9	150.5	84.7	19.7	14.8	9.3
2011.1673	MAR	193.3	150.8	85.9	20.4	15.1	9.5
2011.2507	APR	193.1	151.0	86.9	20.4	15.2	9.5
2011.3340	MAY	191.2	151.2	88.8	20.4	15.2	9.7
2011.4173	JUN	187.8	150.6	90.2	20.6	15.2	9.9
2011.5007	JUL	183.4	149.2	92.2	20.9	15.4	10.4
2011.5840	AUG	179.2	148.1	93.5	21.3	15.4	11.0
2011.6673	SEP	176.3	147.5	94.0	21.3	15.3	11.6
2011.7507	OCT	174.7	147.4	95.3	21.5	15.1	11.2
2011.8340	NOV	174.3	147.4	95.6	21.7	15.1	11.1
2011.9173	DEC	173.5	147.1	95.2	22.1	15.1	10.6
2012.0007	JAN	171.4	146.7	95.3	22.9	15.0	10.1

* Program Initialized from established Cycle 23 smoothed sunspot minimum

TABLE 5 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		
		75.0%	50%	5.0%	95.0%	50%	5.0%
2012.0840	FEB	169.8	146.3	96.8	22.6	14.7	9.8
2012.1673	MAR	166.5	145.7	97.5	21.4	14.4	10.0
2012.2507	APR	161.9	145.2	97.1	20.7	14.3	10.0
2012.3340	MAY	159.6	144.8	96.3	20.1	14.2	10.2
2012.4173	JUN	157.4	144.0	96.3	19.7	14.1	10.5
2012.5007	JUL	156.1	143.0	96.8	19.6	14.1	10.5
2012.5840	AUG	155.3	141.4	95.9	19.4	14.1	10.4
2012.6673	SEP	154.4	139.8	95.4	19.2	14.4	10.4
2012.7507	OCT	152.7	138.6	96.2	19.0	14.7	10.4
2012.8340	NOV	151.2	137.6	97.2	19.0	14.9	10.2
2012.9173	DEC	149.2	136.3	96.2	19.5	14.8	9.8
2013.0007	JAN	145.8	134.6	94.6	20.5	14.9	10.1
2013.0840	FEB	143.0	132.8	93.9	22.1	15.3	10.6
2013.1673	MAR	140.7	131.4	93.6	23.5	15.6	10.6
2013.2507	APR	137.8	130.3	91.9	24.1	15.8	10.8
2013.3340	MAY	135.9	128.9	88.5	25.3	16.1	10.9
2013.4173	JUN	135.0	127.1	87.7	25.8	16.3	11.1
2013.5007	JUL	135.0	125.5	88.8	25.0	16.3	11.4
2013.5840	AUG	134.2	124.2	88.3	24.9	16.2	11.6
2013.6673	SEP	134.9	123.1	87.0	24.1	16.2	11.7
2013.7507	OCT	134.1	122.0	86.0	22.2	16.1	11.7
2013.8340	NOV	133.2	120.8	85.7	22.5	16.2	11.9
2013.9173	DEC	131.8	119.2	84.8	23.2	16.3	11.7
2014.0007	JAN	130.0	117.2	83.5	23.3	16.3	10.9
2014.0840	FEB	127.6	115.4	82.5	22.8	16.1	10.6
2014.1673	MAR	126.9	113.5	81.9	22.1	15.9	10.7
2014.2507	APR	126.3	111.5	81.9	22.0	15.9	10.7
2014.3340	MAY	124.2	109.8	81.6	22.9	16.1	10.6
2014.4173	JUN	122.6	108.3	80.4	23.8	16.4	10.7
2014.5007	JUL	121.3	106.9	80.5	24.0	16.6	10.7
2014.5840	AUG	118.9	105.4	80.2	24.0	16.8	10.6
2014.6673	SEP	116.5	103.9	79.5	24.0	16.9	10.5
2014.7507	OCT	115.5	102.4	79.0	23.6	16.9	10.2
2014.8340	NOV	114.2	100.8	78.2	22.7	16.9	10.3
2014.9173	DEC	112.1	99.3	77.1	22.9	16.8	10.5
2015.0007	JAN	108.6	98.0	75.4	23.1	16.9	11.3
2015.0840	FEB	106.6	96.9	74.3	23.2	17.2	11.8
2015.1673	MAR	105.3	95.9	73.6	22.6	17.3	11.9
2015.2507	APR	104.5	95.0	72.8	21.6	17.2	12.1
2015.3340	MAY	102.6	94.0	71.8	21.3	17.1	12.2
2015.4173	JUN	100.8	92.9	71.3	21.8	16.9	12.4
2015.5007	JUL	99.3	91.8	70.8	21.8	16.7	13.2
2015.5840	AUG	98.4	90.7	70.4	22.2	16.8	13.0
2015.6673	SEP	98.4	89.5	70.3	22.6	16.9	12.7
2015.7507	OCT	98.1	88.2	70.4	22.4	16.9	13.0
2015.8340	NOV	97.5	87.3	70.2	22.4	16.7	12.7
2015.9173	DEC	96.0	86.6	70.1	22.8	16.5	12.4
2016.0007	JAN	95.0	85.8	70.2	23.0	16.1	12.0
2016.0840	FEB	93.5	84.7	70.1	23.6	15.8	11.1
2016.1673	MAR	91.1	83.6	70.3	24.2	15.6	10.4
2016.2507	APR	89.8	82.5	69.8	25.0	15.5	10.5
2016.3340	MAY	88.4	81.8	69.6	25.5	15.5	10.6
2016.4173	JUN	86.8	81.0	69.4	25.7	15.5	10.5
2016.5007	JUL	86.1	80.3	69.3	25.6	15.4	10.6
2016.5840	AUG	85.4	79.5	69.0	25.0	15.3	10.9
2016.6673	SEP	84.3	78.8	68.7	24.1	15.1	11.0
2016.7507	OCT	83.0	78.1	68.4	23.1	14.9	11.2
2016.8340	NOV	81.9	77.5	68.3	22.6	15.0	11.1

* Program Initialized from established Cycle 23 smoothed sunspot minimum

TABLE 5 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		
		75.0%	50%	5.0%	95.0%	50%	5.0%
2016.9173	DEC	81.3	77.0	68.3	22.2	15.2	11.0
2017.0007	JAN	81.0	76.4	68.2	21.9	15.4	11.1
2017.0840	FEB	80.0	75.9	68.0	21.5	15.5	11.3
2017.1673	MAR	79.5	75.4	67.7	20.8	15.5	11.4
2017.2507	APR	78.2	74.8	67.5	20.0	15.3	11.4
2017.3340	MAY	77.4	74.2	67.6	20.1	15.1	11.7
2017.4173	JUN	76.8	73.5	67.4	20.2	14.9	11.9
2017.5007	JUL	75.9	72.9	67.3	19.9	14.7	11.6
2017.5840	AUG	75.6	72.4	67.2	19.5	14.6	11.5
2017.6673	SEP	74.8	72.0	67.2	19.0	14.6	11.1
2017.7507	OCT	73.7	71.6	67.2	18.2	14.6	10.6
2017.8340	NOV	73.5	71.3	67.1	17.3	14.5	9.8
2017.9173	DEC	72.6	71.0	67.1	17.4	14.4	9.4
2018.0007	JAN	72.4	70.7	67.0	17.5	14.3	9.3
2018.0840	FEB	72.4	70.4	67.0	17.6	14.2	9.3
2018.1673	MAR	72.0	70.1	67.0	17.6	14.1	9.3

* Program Initialized from established Cycle 23 smoothed sunspot minimum

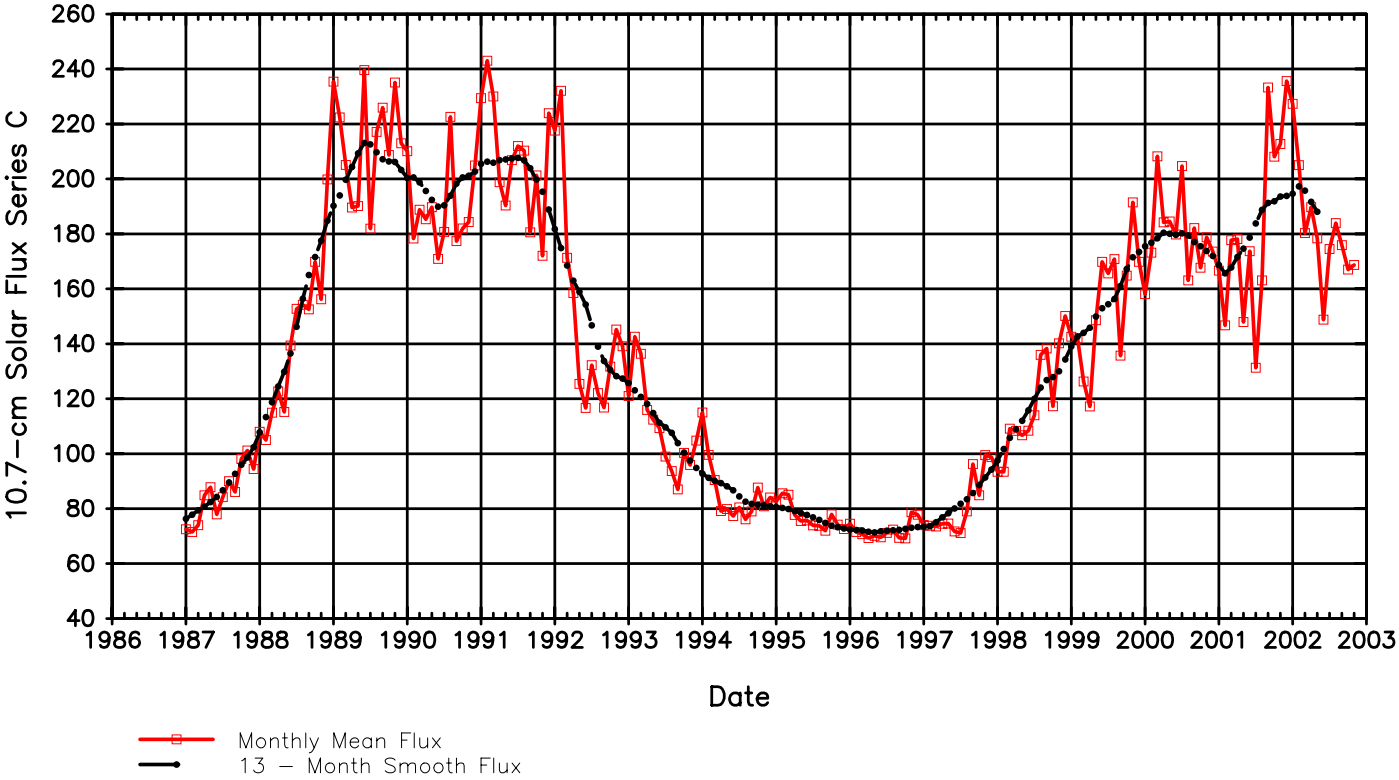

Figure 1. Plot of Recent Monthly Mean and 13-Month Smoothed Solar Flux

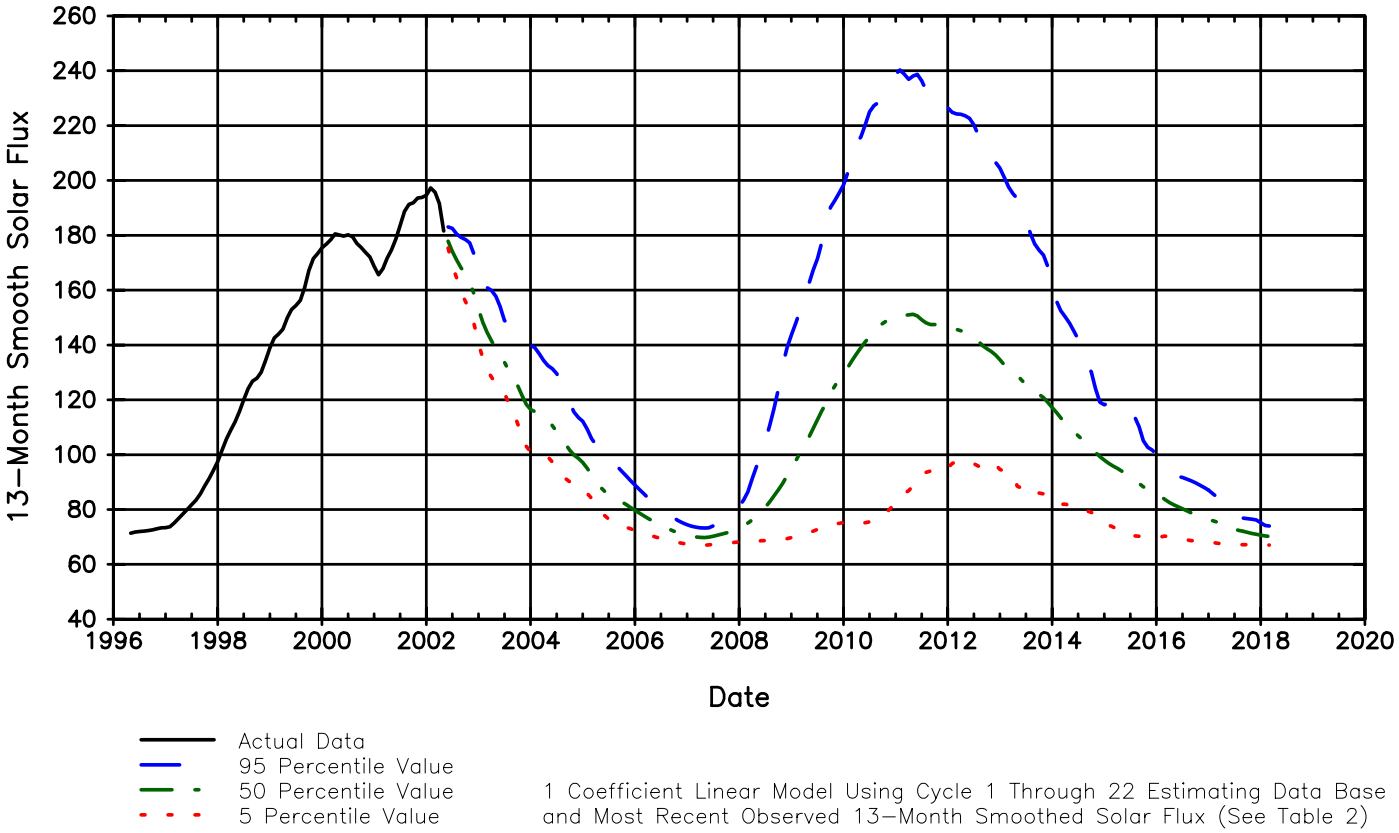

Figure 2. Estimate of 13-Month Smoothed Solar Flux For Cycle 23* and Cycle 24

* Program Initialized from Cycle 23 May 1996 smoothed minimum

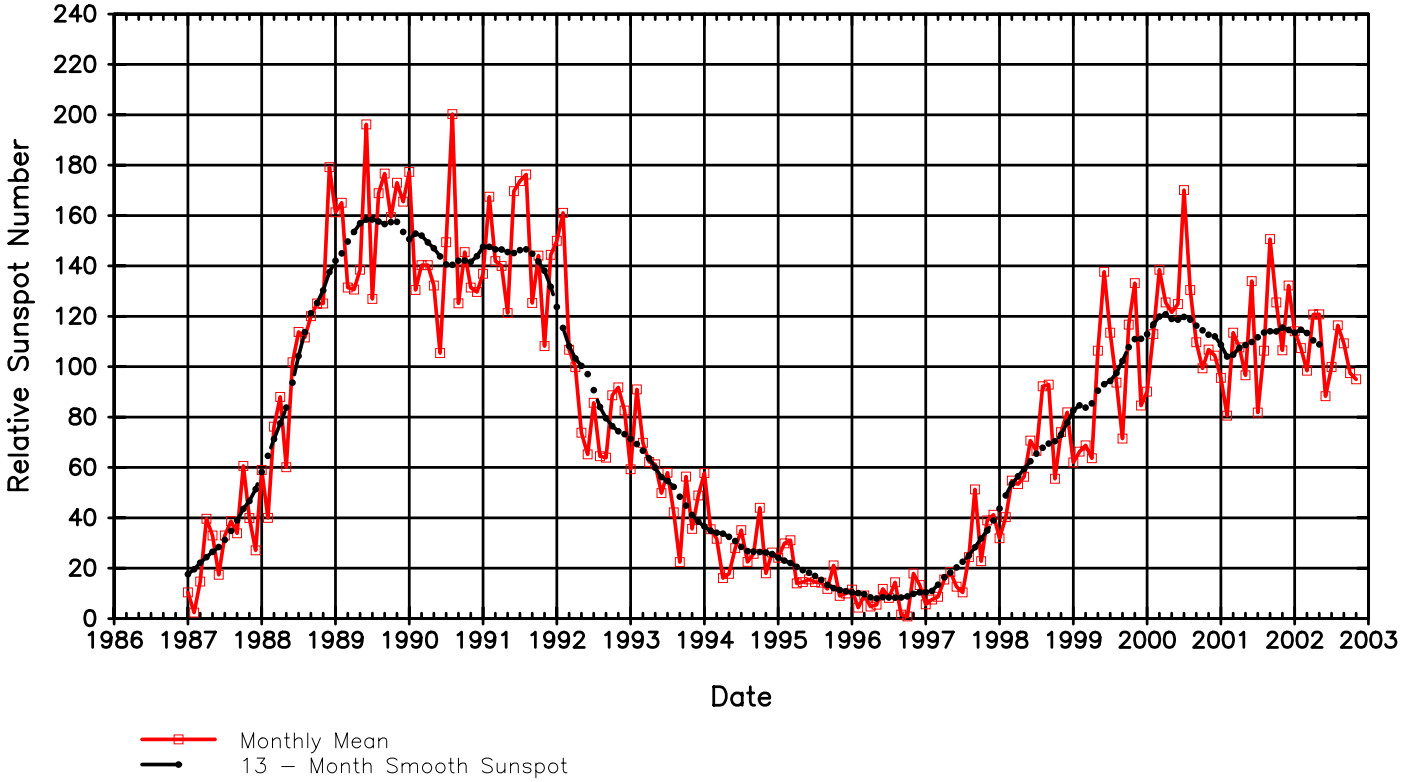

Figure 3. Plot of Recent Monthly Mean and 13-Month Smoothed Relative Sunspot Number

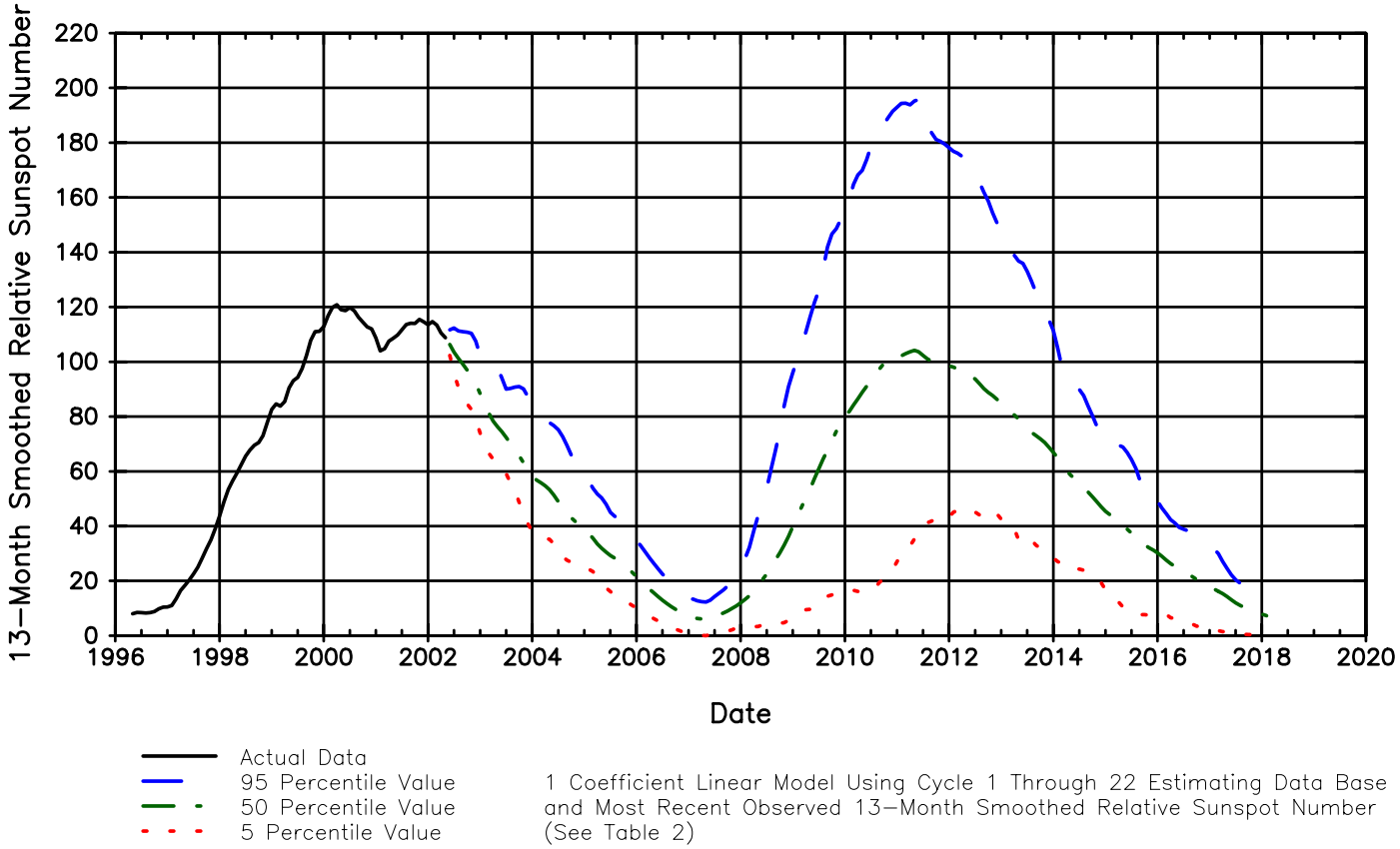

Figure 4. Estimate of 13-Month Smoothed Sunspot Number For Cycle 23* and Cycle 24

* Program Initialized from Cycle 23 May 1996 smoothed minimum

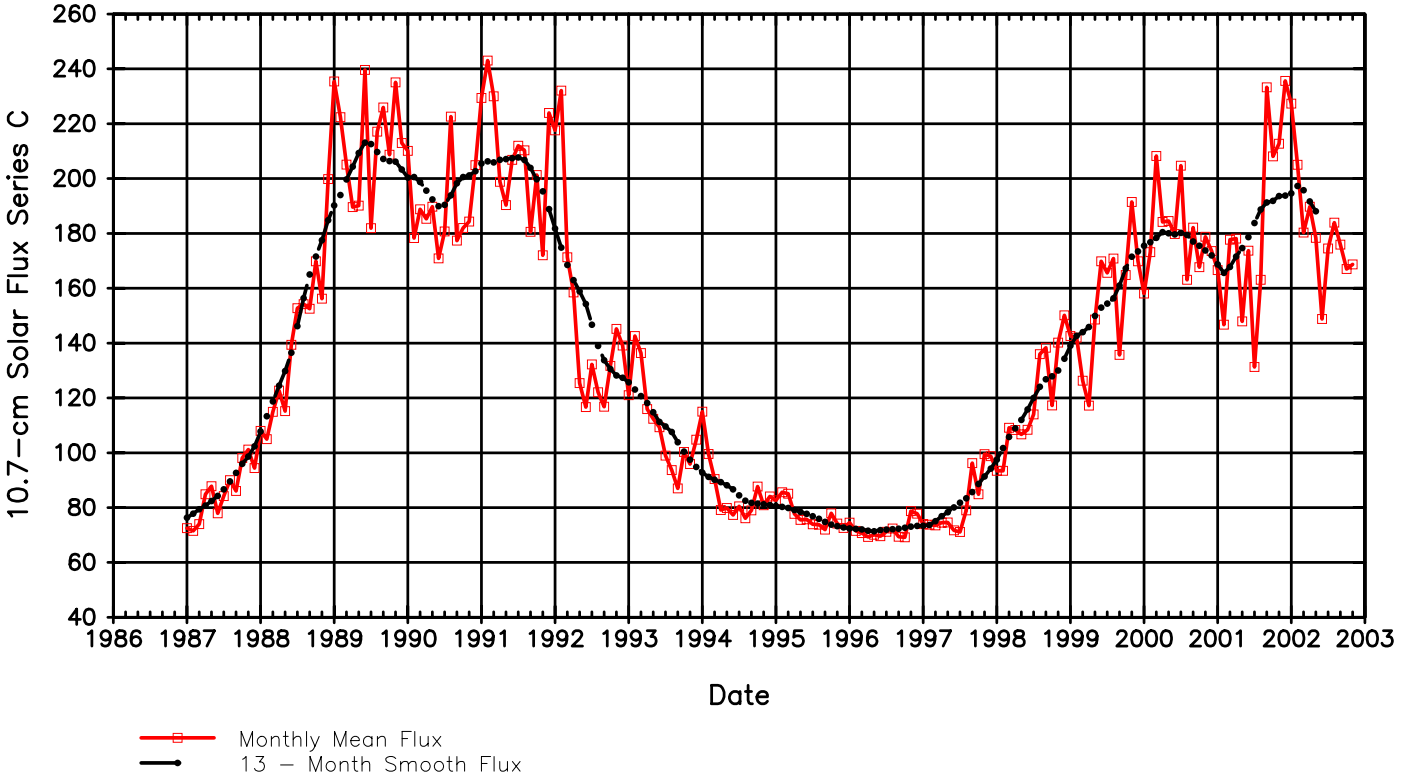

Figure 5. Plot of Recent Monthly Mean and 13-Month Smoothed Solar Flux

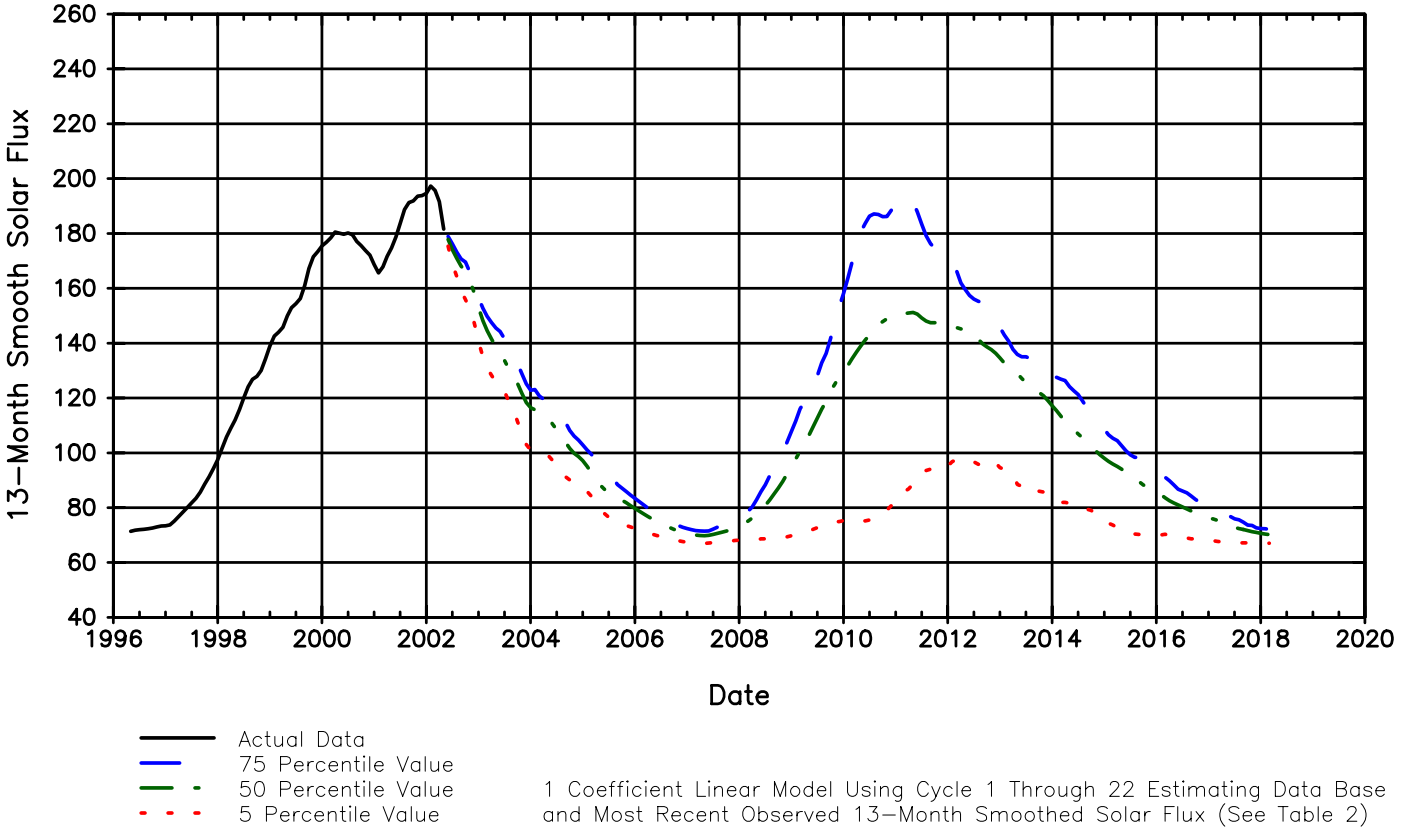

Figure 6. Estimate of 75th Percentile 13-Month Smoothed Solar Flux For Cycle 23* and Cycle 24

* Program Initialized from Cycle 23 May 1996 smoothed minimum