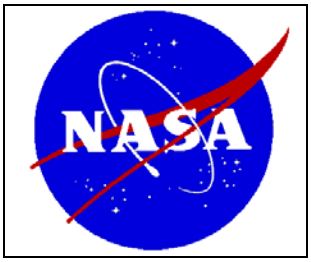

Future Solar Activity Estimates for Use in Prediction of Space Environmental Effects on Spacecraft Orbital Lifetime and Performance

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August 2009

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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 and is the basis for the development of most orbital altitude atmospheric density models in current use for spacecraft orbital lifetime and performance predictions**.**

Marshall Solar Activity Future Estimates (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 with associated statistical confidence bounds, i.e. 95 Percentile, etc.

Observed Data

Generation of the information provided in this report begins each month with the acquisition of recently observed solar activity data. Table 1 (page 6) 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) 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) and the Sunspot Index Data Center site.

The inputs used by the MSAFE model computer 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 8) 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 6).

Future Estimates

Using these smoothed values as inputs, the MSAFE program estimates the intermediate-term (months) and long-term (years) behavior of $\overline{F}_{10.7}$, $\overline{R}$, and $\overline{A}_p$ for up to 132 months into the future, initialized from the cycle 23 maximum. For reports starting with April 2004 and continuing through October 2007, the date of the cycle 23 maximum was determined to be April 2000 indicated by the 13-month smoothed sunspot values. This date was used for $\overline{F}_{10.7}$, $\overline{R}$, and $\overline{A}_p$ predictions. Beginning with the November 2007 report, MSAFE was re-initialized from the cycle 23 maximum using a date determined from a 27-month running mean. This was done to smooth the double peaks observed in the 13-month smoothed values in order to reduce the inconsistency in the dates of cycle maximum for $\overline{F}_{10.7}$, $\overline{R}$. The new date used for cycle 23 maximum of $\overline{F}_{10.7}$, $\overline{R}$ is April 2001. As before, the $\overline{A}_p$ input to the MSAFE program has been initialized at the 13-month smooth sunspot maximum for cycle 23 (April 2000).

The results of the MSAFE model calculations (i.e. the output data) to the maximum of solar cycle 24 are reported in Tables 3, 4 and 5[1]. Table 3 (page 14) contains the statistical estimates of future $\overline{F}_{10.7}$ and $\overline{A}_p$ 5, 50, and 95 Percentile values for the balance of cycle 23 and cycle 24. Table 4 (page19) contains the statistical estimate of future $\overline{R}$ and $\overline{A}_p$ 5, 50, and 95 Percentile values for the balance of cycle 23 and cycle 24. Table 5[1] (page 22) 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. The extended statistical characteristics of cycle 24 beyond the maximum are 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 28) illustrate the inputs and 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 future13-month Zurich smoothed 10.7-cm solar radio flux for solar cycles 23 and 24. Similarly, Figures 3 and 4 (page 29) demonstrate inputs and application of the MSAFE 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 future13-month Zurich smoothed relative sunspot number for solar cycles 23 and 24. Figure 5[1] (page 30) 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

[1] Table 5, Figure 5 and Figure 6 were added in June 2002 on the request of the NASA/JSC Vehicle Integration Performance and Resources (VIPeR) team.

6 is a plot of the statistical estimates of future13-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 5, 50, and 95 Percentile values beyond the maximum are the statistical evaluation of the past 22 cycles and are not influenced by the MSAFE model's performance. Cycle 24 values from the maximum 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 maximum 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 solar cycle period of 11 years (132 months) is assumed for the period of cycle 23 to the maximum of cycle 24 based on the nominal solar cycle period from past records.

Applications

General. The observed and predicted 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 orbital lifetime and performance, e.g. ambient density, ionosphere plasma density, cosmic ray flux, etc. The Marshall Engineering Thermosphere Model [Hickey, 1988a, 1988b], as well as the NASA/MSFC Global Reference Atmospheric Model-1999 Version [Justus et al., 1999], 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) and the Fully Analytical Ionospheric Model (FAIM), and newly emerging cosmic ray models utilize sunspot number (R) inputs. Therefore, the statistical estimates produced by the MSAFE model provide future 13-month smoothed values of the smoothed sunspot number ($\overline{R}$).

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 orbital altitude atmospheric density and 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, etc. 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 envelopes of 95 percentile estimates of future smoothed solar radio flux ($\overline{F}_{10.7}$) and geomagnetic index ($\overline{A}_p$) that are recommended. These estimates permit statistically conservative spacecraft design and mission planning. Critical project considerations such as orbital lifetime predictions should be based on the most current MSAFE model intermediate and long-range statistical estimates of future solar and geophysical data that are consistent with the critical project development and operational decision time points prior to the planned launch of the spacecraft.

Additional Information
Questions on the contents of this report may be addressed to Ron Suggs (ron.suggs@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.M.Suggs@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)**
2005	January	102.2	31.3	24.0
	February	97.2	29.2	11.0
	March	89.9	24.5	12.0
	April	86.0	24.2	11.0
	May	99.5	42.7	19.0
	June	93.7	39.3	12.0
	July	96.5	40.1	14.0
	August	90.5	36.4	14.0
	September	91.1	21.9	20.0
	October	76.6	8.7	8.0
	November	86.2	18.0	8.0
	December	90.7	41.1	9.0
2006	January	83.4	15.3	6.0
	February	76.5	4.9	5.0
	March	75.5	10.6	8.0
	April	89.0	30.2	11.0
	May	80.9	22.2	7.0
	June	76.5	13.9	7.0
	July	75.8	12.2	7.0
	August	79.4	12.9	9.0
	September	77.8	14.5	8.0
	October	74.3	10.4	9.0
	November	86.3	21.5	9.0
	December	84.5	13.6	15.0
2007	January	83.5	16.9	10.0
	February	77.7	10.6	7.0
	March	72.2	4.8	8.0
	April	72.4	3.7	9.0
	May	74.5	11.7	8.0
	June	73.7	12.0	6.0
	July	71.6	10.0	7.0
	August	69.2	6.2	6.0
	September	67.1	2.4	9.0
	October	67.5	0.9	9.0
	November	69.6	1.7	7.0
	December	78.2	10.1	6.0

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

* Preliminary Estimates

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)
2008	January	74.0	3.4	8.0
	February	71.0	2.1	11.0
	March	73.0	9.3	11.0
	April	70.2	2.9	9.0
	May	68.3	2.9	6.0
	June	65.9	3.1	7.0
	July	65.8	0.5	5.0
	August	66.4	0.5	5.0
	September	67.1	1.1	6.0
	October	68.3	2.9	7.0
	November	68.6	4.1	4.0
	December	69.2	0.8	4.0
2009	January	69.8	1.5	4.0
	February	70.1	1.4	5.0
	March	69.2	0.7	5.0
	April	69.7	1.2	4.0
	May	70.5	2.9	4.0
	June	68.6	2.6	4.0
	July	68.2*	3.5*	4.0*

* 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 ($\bar{A}_p$)**
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 ($\overline{F}_{10.7}$)	++Sunspot Numbers ($\overline{R}$)	+++Geomagnetic Index ($\overline{A}_p$)
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	12.3
	February	197.2	114.6	13.1
	March	195.7	113.3	12.2
	April	191.5	110.5	12.5
	May	188.0	108.8	12.7
	June	182.9	106.2	12.9
	July	176.3	102.7	13.7
	August	169.5	98.7	14.2
	September	164.1	94.6	15.0
	October	159.4	90.5	15.6
	November	154.1	85.2	15.8
	December	150.7	82.0	17.1
2003	January	148.0	80.8	18.2
	February	143.6	78.3	18.9
	March	138.3	74.0	19.5
	April	135.0	70.1	20.1
	May	133.1	67.6	22.0
	June	130.2	65.0	21.5
	July	127.2	61.8	22.0
	August	125.2	60.0	22.2
	September	123.7	59.5	21.8
	October	121.8	58.2	21.1
	November	120.1	56.7	20.0
	December	118.0	54.8	18.6
2004	January	116.4	52.0	18.1
	February	115.5	49.3	17.7
	March	114.6	47.1	16.9
	April	112.3	45.6	15.5
	May	109.3	43.8	14.3
	June	107.3	41.6	14.0
	July	106.0	40.2	13.8
	August	105.1	39.2	13.8
	September	103.8	37.5	13.6
	October	102.2	35.9	13.5
	November	101.6	35.3	14.0
	December	101.4	35.2	14.7

* 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 ($\bar{A}_p$)**
2005	January	100.3	34.6	14.1
	February	98.6	33.9	13.9
	March	97.3	33.5	14.6
	April	95.5	31.6	15.1
	May	93.2	28.9	14.4
	June	91.8	28.8	13.6
	July	90.9	29.1	12.8
	August	89.2	27.4	11.8
	September	87.8	25.8	11.4
	October	87.3	25.5	11.3
	November	86.7	24.9	10.8
	December	85.2	23.0	10.1
2006	January	83.6	20.8	9.6
	February	82.3	18.6	9.1
	March	81.2	17.4	8.4
	April	80.6	17.1	7.9
	May	80.5	17.3	7.9
	June	80.2	16.3	8.3
	July	80.0	15.3	8.7
	August	80.1	15.6	8.9
	September	80.0	15.6	8.9
	October	79.1	14.2	8.8
	November	78.2	12.7	8.8
	December	77.8	12.1	8.8
2007	January	77.5	12.0	8.7
	February	76.9	11.6	8.5
	March	76.0	10.8	8.4
	April	75.3	9.9	8.4
	May	74.3	8.7	8.3
	June	73.3	7.7	7.8
	July	72.7	7.0	7.3
	August	72.0	6.1	7.4
	September	71.8	5.9	7.7
	October	71.7	6.1	7.8
	November	71.4	5.7	7.8
	December	70.8	5.0	7.7

* 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 ($\overline{A}_p$)
2008	January	70.0	4.2	7.7
	February	69.8	3.6	7.5
	March	69.7	3.3	7.4
	April	69.8	3.3	7.3
	May	69.8	3.5	7.2
	June	69.2	3.2	7.0
	July	68.8	2.7	6.8
	August	68.6	2.6	6.3
	September	68.4	2.2	5.8
	October	68.2	1.8	5.4
	November	68.3	1.7	5.1
	December	68.5	1.7	4.9
2009	January	68.7*	1.8*	4.7*
	February			
	March			
	April			
	May			
	June			
	July			
	August			
	September			
	October			
	November			
	December			
2010	January			
	February			
	March			
	April			
	May			
	June			
	July			
	August			
	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%
2009.0833	FEB	70.2	68.9	68.3	5.4	4.7	4.2
2009.1667	MAR	71.8	69.0	67.0	5.4	4.9	4.2
2009.2500	APR	73.7	69.5	66.0	5.6	4.9	3.9
2009.3333	MAY	75.5	70.3	65.7	5.7	4.9	3.8
2009.4167	JUN	77.1	71.5	65.7	6.7	5.4	4.0
2009.5000	JUL	80.5	73.0	66.5	7.8	5.8	4.1
2009.5833	AUG	84.6	74.3	67.2	9.2	6.3	4.2
2009.6667	SEP	90.1	75.9	67.1	10.3	7.0	4.8
2009.7500	OCT	96.6	77.9	67.7	11.6	8.0	5.4
2009.8333	NOV	103.2	80.4	68.5	12.0	8.8	6.0
2009.9167	DEC	108.9	82.4	68.7	11.9	9.3	6.4
2010.0000	JAN	113.6	84.0	68.4	12.1	9.6	6.5
2010.0833	FEB	119.0	85.9	69.1	12.8	9.9	6.4
2010.1667	MAR	126.4	88.4	70.0	13.5	10.1	6.2
2010.2500	APR	134.1	91.0	70.1	14.1	10.4	6.1
2010.3333	MAY	141.3	93.4	70.5	14.7	10.6	6.2
2010.4167	JUN	150.5	96.3	70.7	15.4	10.7	6.2
2010.5000	JUL	157.0	100.9	72.8	15.7	10.7	5.9
2010.5833	AUG	163.4	105.5	74.9	16.0	10.9	6.1
2010.6667	SEP	169.7	110.0	76.9	16.5	11.2	6.4
2010.7500	OCT	176.0	114.5	79.0	17.0	11.5	6.8
2010.8333	NOV	182.2	118.9	80.9	17.4	11.8	7.2
2010.9167	DEC	188.2	123.2	82.9	17.9	12.1	7.5
2011.0000	JAN	194.0	127.3	84.8	18.3	12.4	7.9
2011.0833	FEB	199.6	131.3	86.6	18.7	12.7	8.2
2011.1667	MAR	205.0	135.2	88.3	19.1	12.9	8.6
2011.2500	APR	210.2	138.9	90.0	19.5	13.2	8.9
2011.3333	MAY	215.0	142.3	91.5	19.9	13.4	9.2
2011.4167	JUN	219.5	145.5	93.0	20.2	13.7	9.5
2011.5000	JUL	223.7	148.5	94.3	20.6	13.9	9.7
2011.5833	AUG	227.5	151.2	95.6	20.9	14.1	10.0
2011.6667	SEP	230.8	153.6	96.6	21.1	14.3	10.2
2011.7500	OCT	233.8	155.7	97.6	21.3	14.4	10.3
2011.8333	NOV	236.2	157.5	98.4	21.5	14.5	10.5
2011.9167	DEC	238.2	158.9	99.0	21.7	14.6	10.6
2012.0000	JAN	239.6	159.9	99.5	21.8	14.7	10.7
2012.0833	FEB	240.5	160.5	99.8	21.9	14.8	10.8
2012.1667	MAR	240.8	160.8	99.9	21.9	14.8	10.8
2012.2500	APR	237.9	159.6	98.5	20.6	14.9	11.5
2012.3333	MAY	233.7	157.8	97.8	20.2	15.0	11.8
2012.4167	JUN	229.9	156.0	96.7	19.7	15.1	11.7
2012.5000	JUL	228.6	154.7	95.4	19.4	15.3	11.9
2012.5833	AUG	228.6	153.6	93.8	19.2	15.6	12.1
2012.6667	SEP	227.1	152.7	92.6	19.0	15.7	11.6
2012.7500	OCT	225.2	151.7	91.8	19.0	15.7	10.9
2012.8333	NOV	224.4	150.4	91.2	18.9	15.7	10.8
2012.9167	DEC	223.6	148.9	90.3	19.0	15.7	10.8
2013.0000	JAN	222.8	147.2	89.3	19.2	15.8	10.8
2013.0833	FEB	221.6	145.3	88.6	19.8	15.9	10.8
2013.1667	MAR	217.7	143.4	87.7	20.4	16.1	10.9

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%
2013.2500	APR	214.3	141.8	86.2	21.4	16.3	10.8
2013.3333	MAY	211.4	140.6	85.4	21.9	16.5	10.7
2013.4167	JUN	207.1	139.5	84.9	21.6	16.6	10.6
2013.5000	JUL	206.7	138.5	84.0	21.3	16.4	10.3
2013.5833	AUG	206.0	137.4	82.7	21.8	16.5	10.3
2013.6667	SEP	203.8	135.6	81.3	23.1	16.7	10.4
2013.7500	OCT	200.3	133.6	80.4	23.3	16.9	10.9
2013.8333	NOV	196.2	131.5	79.8	22.7	17.0	11.7
2013.9167	DEC	191.2	129.6	79.1	22.6	17.0	11.8
2014.0000	JAN	185.0	127.8	78.4	22.7	16.9	11.9
2014.0833	FEB	179.1	126.3	77.5	23.2	17.1	12.0
2014.1667	MAR	178.4	125.2	76.5	23.9	17.3	12.1
2014.2500	APR	177.7	123.7	75.5	23.9	17.2	12.5
2014.3333	MAY	175.3	121.6	74.6	23.9	17.1	13.3
2014.4167	JUN	171.4	119.5	73.6	23.3	17.0	13.7
2014.5000	JUL	166.1	117.5	72.7	21.6	16.8	13.3
2014.5833	AUG	161.9	115.9	72.3	21.8	16.6	12.8
2014.6667	SEP	160.4	114.4	72.0	21.8	16.4	12.7
2014.7500	OCT	159.3	112.9	71.6	21.5	16.4	12.5
2014.8333	NOV	157.5	111.4	71.4	21.1	16.4	12.4
2014.9167	DEC	154.7	109.9	71.5	20.5	16.4	12.2
2015.0000	JAN	150.5	108.3	71.4	19.9	16.1	11.9
2015.0833	FEB	144.9	106.7	71.2	20.1	16.0	11.9
2015.1667	MAR	138.7	104.8	70.9	21.6	15.9	11.7
2015.2500	APR	132.9	103.0	70.7	23.2	15.8	11.7
2015.3333	MAY	128.3	101.4	70.5	24.0	15.8	11.5
2015.4167	JUN	124.5	99.9	70.7	25.1	15.7	11.3
2015.5000	JUL	121.4	98.7	71.1	25.8	15.7	11.3
2015.5833	AUG	119.3	97.7	71.2	25.0	15.6	10.8
2015.6667	SEP	119.4	96.7	71.4	25.0	15.6	10.3
2015.7500	OCT	119.0	95.6	71.2	24.1	15.7	10.7
2015.8333	NOV	117.9	94.3	70.7	22.2	15.7	10.8
2015.9167	DEC	117.2	93.0	70.3	21.4	15.6	10.8
2016.0000	JAN	116.2	91.9	69.9	21.7	15.8	11.0
2016.0833	FEB	116.4	91.1	69.6	22.4	16.0	11.2
2016.1667	MAR	116.7	90.2	69.2	22.6	16.0	11.2
2016.2500	APR	116.8	89.2	69.0	22.5	16.1	11.0
2016.3333	MAY	116.6	88.2	68.7	22.7	16.3	11.0
2016.4167	JUN	115.9	87.1	68.2	22.9	16.6	11.3
2016.5000	JUL	114.8	86.1	68.0	23.4	16.8	11.2
2016.5833	AUG	113.1	85.1	67.8	24.1	16.9	11.2
2016.6667	SEP	109.9	84.2	67.7	24.8	17.0	11.8
2016.7500	OCT	104.9	83.2	67.6	25.4	16.9	12.2
2016.8333	NOV	99.4	82.3	67.6	25.6	16.7	12.1
2016.9167	DEC	98.8	81.3	67.5	25.4	16.4	12.0
2017.0000	JAN	99.6	80.6	67.3	24.7	16.0	12.2
2017.0833	FEB	100.2	80.0	67.2	23.6	15.6	12.3
2017.1667	MAR	98.7	79.4	67.2	22.8	15.2	12.2
2017.2500	APR	95.8	78.8	67.2	22.4	14.9	11.8
2017.3333	MAY	93.0	78.2	67.2	21.9	14.6	11.2

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%
2017.4167	JUN	91.3	77.8	67.1	21.6	14.2	10.7
2017.5000	JUL	91.5	77.2	67.1	20.9	13.8	10.0
2017.5833	AUG	91.4	76.6	67.0	20.0	13.4	9.4
2017.6667	SEP	90.9	76.0	67.0	18.7	13.1	9.0
2017.7500	OCT	90.4	75.6	67.0	18.2	12.8	8.5
2017.8333	NOV	89.7	75.1	67.0	18.7	12.6	8.0
2017.9167	DEC	88.8	74.7	67.1	18.7	12.5	7.8
2018.0000	JAN	88.1	74.4	67.3	18.4	12.4	7.4
2018.0833	FEB	87.2	74.0	67.4	18.4	12.2	7.0
2018.1667	MAR	85.9	73.7	67.5	18.8	12.1	6.6
2018.2500	APR	84.4	73.2	67.6	18.9	12.0	6.5
2018.3333	MAY	82.3	72.7	67.7	18.8	12.0	6.4
2018.4167	JUN	80.0	72.3	67.7	18.4	11.9	6.6
2018.5000	JUL	77.7	71.9	68.0	17.5	11.8	6.9
2018.5833	AUG	76.9	71.7	68.0	16.5	11.7	7.2
2018.6667	SEP	76.5	71.5	68.0	16.3	11.6	7.4
2018.7500	OCT	75.8	71.4	68.0	16.6	11.6	7.5
2018.8333	NOV	76.0	71.3	67.9	16.9	11.6	7.5
2018.9167	DEC	76.0	71.2	67.9	17.2	11.6	7.7
2019.0000	JAN	76.3	71.2	67.7	17.3	11.6	7.7
2019.0833	FEB	76.8	71.3	67.6	17.7	11.5	7.6
2019.1667	MAR	77.8	71.5	67.7	18.0	11.4	7.6
2019.2500	APR	79.5	71.9	67.6	18.2	11.4	7.6
2019.3333	MAY	81.5	72.3	67.6	18.1	11.3	7.6
2019.4167	JUN	83.2	72.6	67.7	17.8	11.2	7.5
2019.5000	JUL	85.4	73.2	67.9	17.3	11.1	7.5
2019.5833	AUG	88.2	74.0	68.1	16.3	11.0	7.5
2019.6667	SEP	91.0	74.9	68.5	15.5	10.9	7.5
2019.7500	OCT	93.8	75.8	68.6	16.1	10.8	7.7
2019.8333	NOV	96.7	76.9	68.8	16.3	10.8	7.7
2019.9167	DEC	100.7	78.4	69.1	16.6	10.9	7.8
2020.0000	JAN	105.5	80.0	69.3	16.7	11.0	7.7
2020.0833	FEB	111.4	81.8	69.6	16.8	11.1	7.7
2020.1667	MAR	116.6	83.6	70.2	17.1	11.1	7.8
2020.2500	APR	120.6	85.6	71.1	17.3	11.1	8.0
2020.3333	MAY	123.8	87.7	71.8	17.3	11.2	8.3
2020.4167	JUN	126.5	89.8	72.5	17.4	11.5	8.6
2020.5000	JUL	130.1	92.1	73.7	17.6	11.7	9.0
2020.5833	AUG	133.5	94.4	74.2	17.5	12.0	8.8
2020.6667	SEP	136.2	96.7	74.5	16.9	12.2	8.7
2020.7500	OCT	141.6	99.5	74.8	16.2	12.4	8.9
2020.8333	NOV	147.9	102.3	75.1	16.0	12.5	9.0
2020.9167	DEC	153.4	104.8	75.3	16.0	12.7	9.0
2021.0000	JAN	157.1	107.3	75.2	16.1	12.9	8.8
2021.0833	FEB	159.2	109.6	75.2	16.7	13.0	8.4
2021.1667	MAR	162.0	111.9	75.3	17.1	13.0	8.2
2021.2500	APR	165.3	114.5	75.7	17.5	13.1	8.2
2021.3333	MAY	172.5	117.4	76.1	18.2	13.2	8.1
2021.4167	JUN	181.4	120.5	76.6	18.5	13.2	7.9
2021.5000	JUL	188.0	123.1	77.5	18.5	13.1	7.8

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%
2021.5833	AUG	191.8	125.3	78.3	18.7	13.1	7.9
2021.6667	SEP	194.8	127.4	78.6	19.0	13.2	8.1
2021.7500	OCT	197.7	129.3	79.6	18.6	13.3	8.6
2021.8333	NOV	201.4	131.0	80.8	17.8	13.3	9.2
2021.9167	DEC	206.7	132.7	82.2	18.1	13.4	9.6
2022.0000	JAN	211.5	134.8	84.1	18.9	13.5	10.1
2022.0833	FEB	214.4	137.2	85.4	19.1	13.6	10.1
2022.1667	MAR	218.4	139.6	86.3	19.5	13.9	10.3
2022.2500	APR	223.8	142.2	88.1	20.5	14.1	10.4
2022.3333	MAY	227.1	144.8	90.0	20.2	14.1	10.6
2022.4167	JUN	228.9	146.9	91.1	20.4	14.1	10.2
2022.5000	JUL	230.4	148.9	93.3	20.7	14.1	10.2
2022.5833	AUG	231.8	150.9	95.7	21.1	14.2	9.9
2022.6667	SEP	234.4	152.8	97.5	21.4	14.2	9.8
2022.7500	OCT	237.7	154.7	98.7	21.4	14.4	10.5
2022.8333	NOV	239.4	156.3	98.8	21.6	14.5	10.9
2022.9167	DEC	238.3	157.5	98.2	21.9	14.7	10.9
2023.0000	JAN	237.2	158.9	97.8	22.4	14.9	11.0
2023.0833	FEB	238.5	160.7	99.1	22.9	15.1	11.2

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%
2009.0833	FEB	3.0	2.1	1.4	5.4	4.7	4.2
2009.1667	MAR	5.8	2.5	0.3	5.4	4.9	4.2
2009.2500	APR	8.4	3.5	0.0	5.6	4.9	3.9
2009.3333	MAY	10.4	4.7	0.0	5.7	4.9	3.8
2009.4167	JUN	15.4	6.3	0.0	6.7	5.4	4.0
2009.5000	JUL	19.7	8.1	0.0	7.8	5.8	4.1
2009.5833	AUG	24.2	9.9	0.0	9.2	6.3	4.2
2009.6667	SEP	31.4	12.5	0.9	10.3	7.0	4.8
2009.7500	OCT	39.9	15.9	2.9	11.6	8.0	5.4
2009.8333	NOV	48.5	19.4	4.7	12.0	8.8	6.0
2009.9167	DEC	56.2	22.3	5.2	11.9	9.3	6.4
2010.0000	JAN	63.0	24.7	5.1	12.1	9.6	6.5
2010.0833	FEB	70.9	27.4	4.8	12.8	9.9	6.4
2010.1667	MAR	80.7	30.2	4.5	13.5	10.1	6.2
2010.2500	APR	90.2	32.9	4.3	14.1	10.4	6.1
2010.3333	MAY	97.9	35.5	4.6	14.7	10.6	6.2
2010.4167	JUN	105.9	38.9	5.2	15.4	10.7	6.2
2010.5000	JUL	112.3	44.2	8.3	15.7	10.7	5.9
2010.5833	AUG	118.6	49.4	11.4	16.0	10.9	6.1
2010.6667	SEP	124.9	54.6	14.5	16.5	11.2	6.4
2010.7500	OCT	131.0	59.7	17.5	17.0	11.5	6.8
2010.8333	NOV	137.1	64.7	20.5	17.4	11.8	7.2
2010.9167	DEC	143.0	69.6	23.4	17.9	12.1	7.5
2011.0000	JAN	148.8	74.4	26.2	18.3	12.4	7.9
2011.0833	FEB	154.3	79.0	28.9	18.7	12.7	8.2
2011.1667	MAR	159.6	83.4	31.5	19.1	12.9	8.6
2011.2500	APR	164.7	87.6	34.0	19.5	13.2	8.9
2011.3333	MAY	169.4	91.5	36.3	19.9	13.4	9.2
2011.4167	JUN	173.9	95.2	38.5	20.2	13.7	9.5
2011.5000	JUL	178.0	98.6	40.5	20.6	13.9	9.7
2011.5833	AUG	181.7	101.7	42.3	20.9	14.1	10.0
2011.6667	SEP	185.0	104.5	43.9	21.1	14.3	10.2
2011.7500	OCT	187.9	106.9	45.4	21.3	14.4	10.3
2011.8333	NOV	190.3	108.9	46.6	21.5	14.5	10.5
2011.9167	DEC	192.3	110.5	47.5	21.7	14.6	10.6
2012.0000	JAN	193.7	111.7	48.2	21.8	14.7	10.7
2012.0833	FEB	194.6	112.4	48.6	21.9	14.8	10.8
2012.1667	MAR	194.9	112.6	48.8	21.9	14.8	10.8
2012.2500	APR	190.7	111.7	47.2	20.6	14.9	11.5
2012.3333	MAY	185.3	109.8	46.2	20.2	15.0	11.8
2012.4167	JUN	181.3	107.7	45.1	19.7	15.1	11.7
2012.5000	JUL	180.3	106.1	43.5	19.4	15.3	11.9
2012.5833	AUG	180.1	104.9	41.5	19.2	15.6	12.1
2012.6667	SEP	178.8	103.9	40.1	19.0	15.7	11.6
2012.7500	OCT	176.6	102.7	39.1	19.0	15.7	10.9
2012.8333	NOV	175.4	101.6	38.3	18.9	15.7	10.8
2012.9167	DEC	174.6	100.2	37.1	19.0	15.7	10.8
2013.0000	JAN	172.9	98.5	35.9	19.2	15.8	10.8
2013.0833	FEB	171.8	96.7	35.1	19.8	15.9	10.8

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%
2013.1667	MAR	169.2	95.0	33.8	20.4	16.1	10.9
2013.2500	APR	164.9	93.4	32.0	21.4	16.3	10.8
2013.3333	MAY	161.5	92.2	30.8	21.9	16.5	10.7
2013.4167	JUN	157.3	91.1	30.4	21.6	16.6	10.6
2013.5000	JUL	153.1	89.9	29.1	21.3	16.4	10.3
2013.5833	AUG	149.3	88.6	27.2	21.8	16.5	10.3
2013.6667	SEP	146.5	86.9	25.5	23.1	16.7	10.4
2013.7500	OCT	145.1	85.0	24.2	23.3	16.9	10.9
2013.8333	NOV	142.6	82.8	23.3	22.7	17.0	11.7
2013.9167	DEC	139.5	80.6	22.3	22.6	17.0	11.8
2014.0000	JAN	134.9	78.5	21.1	22.7	16.9	11.9
2014.0833	FEB	132.1	76.6	19.8	23.2	17.1	12.0
2014.1667	MAR	132.2	75.0	18.3	23.9	17.3	12.1
2014.2500	APR	133.2	73.4	16.7	23.9	17.2	12.5
2014.3333	MAY	132.3	71.5	15.2	23.9	17.1	13.3
2014.4167	JUN	128.8	69.3	13.5	23.3	17.0	13.7
2014.5000	JUL	123.2	67.0	11.9	21.6	16.8	13.3
2014.5833	AUG	118.8	65.3	11.1	21.8	16.6	12.8
2014.6667	SEP	116.4	63.8	10.6	21.8	16.4	12.7
2014.7500	OCT	115.3	62.2	9.7	21.5	16.4	12.5
2014.8333	NOV	113.1	60.8	9.3	21.1	16.4	12.4
2014.9167	DEC	110.6	59.5	9.4	20.5	16.4	12.2
2015.0000	JAN	106.6	57.9	9.4	19.9	16.1	11.9
2015.0833	FEB	100.7	56.0	8.9	20.1	16.0	11.9
2015.1667	MAR	94.5	54.0	8.6	21.6	15.9	11.7
2015.2500	APR	88.4	52.2	8.2	23.2	15.8	11.7
2015.3333	MAY	83.4	50.4	8.0	24.0	15.8	11.5
2015.4167	JUN	79.8	48.4	8.5	25.1	15.7	11.3
2015.5000	JUL	76.6	46.7	9.1	25.8	15.7	11.3
2015.5833	AUG	73.3	45.5	9.5	25.0	15.6	10.8
2015.6667	SEP	71.2	44.2	9.7	25.0	15.6	10.3
2015.7500	OCT	71.4	43.1	9.3	24.1	15.7	10.7
2015.8333	NOV	71.6	41.6	8.5	22.2	15.7	10.8
2015.9167	DEC	70.0	39.9	7.7	21.4	15.6	10.8
2016.0000	JAN	68.6	38.5	7.0	21.7	15.8	11.0
2016.0833	FEB	68.8	37.4	6.2	22.4	16.0	11.2
2016.1667	MAR	68.7	36.2	5.5	22.6	16.0	11.2
2016.2500	APR	68.2	35.0	5.0	22.5	16.1	11.0
2016.3333	MAY	67.4	33.6	4.3	22.7	16.3	11.0
2016.4167	JUN	65.8	32.0	3.2	22.9	16.6	11.3
2016.5000	JUL	63.7	30.7	2.5	23.4	16.8	11.2
2016.5833	AUG	61.1	29.5	2.0	24.1	16.9	11.2
2016.6667	SEP	56.9	28.4	1.8	24.8	17.0	11.8
2016.7500	OCT	51.2	27.3	1.8	25.4	16.9	12.2
2016.8333	NOV	46.9	26.1	1.6	25.6	16.7	12.1
2016.9167	DEC	46.8	24.9	1.2	25.4	16.4	12.0
2017.0000	JAN	47.3	23.9	0.8	24.7	16.0	12.2
2017.0833	FEB	48.4	23.1	0.6	23.6	15.6	12.3
2017.1667	MAR	48.9	22.3	0.6	22.8	15.2	12.2

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%
2017.2500	APR	47.1	21.5	0.6	22.4	14.9	11.8
2017.3333	MAY	43.6	20.8	0.5	21.9	14.6	11.2
2017.4167	JUN	40.7	19.9	0.3	21.6	14.2	10.7
2017.5000	JUL	39.0	19.1	0.2	20.9	13.8	10.0
2017.5833	AUG	38.6	18.2	0.1	20.0	13.4	9.4
2017.6667	SEP	38.0	17.3	0.0	18.7	13.1	9.0
2017.7500	OCT	37.4	16.5	0.0	18.2	12.8	8.5
2017.8333	NOV	36.5	15.7	0.0	18.7	12.6	8.0
2017.9167	DEC	35.4	15.0	0.3	18.7	12.5	7.8
2018.0000	JAN	34.4	14.4	0.8	18.4	12.4	7.4
2018.0833	FEB	33.3	13.8	1.0	18.4	12.2	7.0
2018.1667	MAR	31.7	13.0	1.3	18.8	12.1	6.6
2018.2500	APR	29.6	12.3	1.5	18.9	12.0	6.5
2018.3333	MAY	26.9	11.5	1.7	18.8	12.0	6.4
2018.4167	JUN	23.6	10.8	2.0	18.4	11.9	6.6
2018.5000	JUL	20.3	10.2	2.5	17.5	11.8	6.9
2018.5833	AUG	19.7	9.7	2.6	16.5	11.7	7.2
2018.6667	SEP	19.1	9.3	2.6	16.3	11.6	7.4
2018.7500	OCT	18.1	8.9	2.6	16.6	11.6	7.5
2018.8333	NOV	17.0	8.7	2.4	16.9	11.6	7.5
2018.9167	DEC	16.0	8.6	2.3	17.2	11.6	7.7
2019.0000	JAN	15.4	8.6	1.9	17.3	11.6	7.7
2019.0833	FEB	14.5	8.7	1.8	17.7	11.5	7.6
2019.1667	MAR	15.4	9.0	1.8	18.0	11.4	7.6
2019.2500	APR	16.5	9.4	1.8	18.2	11.4	7.6
2019.3333	MAY	18.0	9.6	1.7	18.1	11.3	7.6
2019.4167	JUN	20.0	10.0	1.7	17.8	11.2	7.5
2019.5000	JUL	22.2	10.7	2.4	17.3	11.1	7.5
2019.5833	AUG	24.5	11.8	3.0	16.3	11.0	7.5
2019.6667	SEP	27.7	13.0	3.8	15.5	10.9	7.5
2019.7500	OCT	30.9	14.3	4.0	16.1	10.8	7.7
2019.8333	NOV	34.2	15.9	4.5	16.3	10.8	7.7
2019.9167	DEC	38.3	17.8	5.2	16.6	10.9	7.8
2020.0000	JAN	43.1	19.7	5.8	16.7	11.0	7.7
2020.0833	FEB	47.9	21.7	6.2	16.8	11.1	7.7
2020.1667	MAR	52.1	23.9	7.4	17.1	11.1	7.8
2020.2500	APR	55.4	26.5	9.2	17.3	11.1	8.0
2020.3333	MAY	58.8	29.4	10.5	17.3	11.2	8.3
2020.4167	JUN	62.6	32.4	11.8	17.4	11.5	8.6
2020.5000	JUL	65.9	35.3	14.0	17.6	11.7	9.0
2020.5833	AUG	68.4	38.0	14.7	17.5	12.0	8.8
2020.6667	SEP	70.8	40.8	15.2	16.9	12.2	8.7
2020.7500	OCT	73.1	44.1	15.7	16.2	12.4	8.9
2020.8333	NOV	78.8	47.4	16.2	16.0	12.5	9.0
2020.9167	DEC	85.1	50.4	16.4	16.0	12.7	9.0
2021.0000	JAN	92.8	53.6	16.3	16.1	12.9	8.8
2021.0833	FEB	102.4	56.5	16.1	16.7	13.0	8.4
2021.1667	MAR	111.8	59.2	16.2	17.1	13.0	8.2
2021.2500	APR	119.9	62.3	16.8	17.5	13.1	8.2

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%
2021.3333	MAY	127.9	65.5	17.2	18.2	13.2	8.1
2021.4167	JUN	136.4	68.9	17.9	18.5	13.2	7.9
2021.5000	JUL	143.1	71.8	19.3	18.5	13.1	7.8
2021.5833	AUG	146.6	74.4	20.7	18.7	13.1	7.9
2021.6667	SEP	149.9	76.5	21.1	19.0	13.2	8.1
2021.7500	OCT	154.1	78.7	22.6	18.6	13.3	8.6
2021.8333	NOV	158.4	80.9	24.4	17.8	13.3	9.2
2021.9167	DEC	163.8	83.2	26.5	18.1	13.4	9.6
2022.0000	JAN	168.2	85.7	29.0	18.9	13.5	10.1
2022.0833	FEB	169.7	88.0	30.9	19.1	13.6	10.1
2022.1667	MAR	172.7	90.3	32.1	19.5	13.9	10.3
2022.2500	APR	178.2	93.0	34.4	20.5	14.1	10.4
2022.3333	MAY	182.2	95.8	36.7	20.2	14.1	10.6
2022.4167	JUN	184.8	98.2	38.2	20.4	14.1	10.2
2022.5000	JUL	187.6	100.5	40.9	20.7	14.1	10.2
2022.5833	AUG	189.9	102.8	43.9	21.1	14.2	9.9
2022.6667	SEP	192.1	105.0	45.9	21.4	14.2	9.8
2022.7500	OCT	193.6	106.7	47.3	21.4	14.4	10.5
2022.8333	NOV	194.3	108.3	47.5	21.6	14.5	10.9
2022.9167	DEC	193.6	109.6	46.7	21.9	14.7	10.9
2023.0000	JAN	192.7	110.9	46.3	22.4	14.9	11.0
2023.0833	FEB	194.4	112.7	47.8	22.9	15.1	11.2

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%
2009.0833	FEB	69.1	68.9	68.3	5.4	4.7	4.2
2009.1667	MAR	69.4	69.0	67.0	5.4	4.9	4.2
2009.2500	APR	70.2	69.5	66.0	5.6	4.9	3.9
2009.3333	MAY	71.7	70.3	65.7	5.7	4.9	3.8
2009.4167	JUN	74.0	71.5	65.7	6.7	5.4	4.0
2009.5000	JUL	75.9	73.0	66.5	7.8	5.8	4.1
2009.5833	AUG	77.2	74.3	67.2	9.2	6.3	4.2
2009.6667	SEP	78.7	75.9	67.1	10.3	7.0	4.8
2009.7500	OCT	81.3	77.9	67.7	11.6	8.0	5.4
2009.8333	NOV	83.8	80.4	68.5	12.0	8.8	6.0
2009.9167	DEC	86.6	82.4	68.7	11.9	9.3	6.4
2010.0000	JAN	89.4	84.0	68.4	12.1	9.6	6.5
2010.0833	FEB	93.7	85.9	69.1	12.8	9.9	6.4
2010.1667	MAR	96.9	88.4	70.0	13.5	10.1	6.2
2010.2500	APR	99.1	91.0	70.1	14.1	10.4	6.1
2010.3333	MAY	101.2	93.4	70.5	14.7	10.6	6.2
2010.4167	JUN	103.3	96.3	70.7	15.4	10.7	6.2
2010.5000	JUL	109.8	100.9	72.8	15.7	10.7	5.9
2010.5833	AUG	116.2	105.5	74.9	16.0	10.9	6.1
2010.6667	SEP	122.6	110.0	76.9	16.5	11.2	6.4
2010.7500	OCT	128.9	114.5	79.0	17.0	11.5	6.8
2010.8333	NOV	135.0	118.9	80.9	17.4	11.8	7.2
2010.9167	DEC	141.1	123.2	82.9	17.9	12.1	7.5
2011.0000	JAN	146.9	127.3	84.8	18.3	12.4	7.9
2011.0833	FEB	152.5	131.3	86.6	18.7	12.7	8.2
2011.1667	MAR	158.0	135.2	88.3	19.1	12.9	8.6
2011.2500	APR	163.1	138.9	90.0	19.5	13.2	8.9
2011.3333	MAY	167.9	142.3	91.5	19.9	13.4	9.2
2011.4167	JUN	172.5	145.5	93.0	20.2	13.7	9.5
2011.5000	JUL	176.6	148.5	94.3	20.6	13.9	9.7
2011.5833	AUG	180.4	151.2	95.6	20.9	14.1	10.0
2011.6667	SEP	183.8	153.6	96.6	21.1	14.3	10.2
2011.7500	OCT	186.8	155.7	97.6	21.3	14.4	10.3
2011.8333	NOV	189.2	157.5	98.4	21.5	14.5	10.5
2011.9167	DEC	191.2	158.9	99.0	21.7	14.6	10.6
2012.0000	JAN	192.7	159.9	99.5	21.8	14.7	10.7
2012.0833	FEB	193.5	160.5	99.8	21.9	14.8	10.8
2012.1667	MAR	193.9	160.8	99.9	21.9	14.8	10.8
2012.2500	APR	192.9	159.6	98.5	20.6	14.9	11.5
2012.3333	MAY	191.7	157.8	97.8	20.2	15.0	11.8
2012.4167	JUN	188.2	156.0	96.7	19.7	15.1	11.7
2012.5000	JUL	184.1	154.7	95.4	19.4	15.3	11.9
2012.5833	AUG	180.2	153.6	93.8	19.2	15.6	12.1
2012.6667	SEP	178.7	152.7	92.6	19.0	15.7	11.6
2012.7500	OCT	177.3	151.7	91.8	19.0	15.7	10.9
2012.8333	NOV	176.9	150.4	91.2	18.9	15.7	10.8
2012.9167	DEC	175.2	148.9	90.3	19.0	15.7	10.8
2013.0000	JAN	170.9	147.2	89.3	19.2	15.8	10.8
2013.0833	FEB	167.1	145.3	88.6	19.8	15.9	10.8
2013.1667	MAR	165.8	143.4	87.7	20.4	16.1	10.9
2013.2500	APR	163.6	141.8	86.2	21.4	16.3	10.8
2013.3333	MAY	160.6	140.6	85.4	21.9	16.5	10.7
2013.4167	JUN	159.8	139.5	84.9	21.6	16.6	10.6
2013.5000	JUL	158.8	138.5	84.0	21.3	16.4	10.3
2013.5833	AUG	156.3	137.4	82.7	21.8	16.5	10.3
2013.6667	SEP	153.6	135.6	81.3	23.1	16.7	10.4

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%
2013.7500	OCT	152.4	133.6	80.4	23.3	16.9	10.9
2013.8333	NOV	151.6	131.5	79.8	22.7	17.0	11.7
2013.9167	DEC	151.1	129.6	79.1	22.6	17.0	11.8
2014.0000	JAN	149.3	127.8	78.4	22.7	16.9	11.9
2014.0833	FEB	146.2	126.3	77.5	23.2	17.1	12.0
2014.1667	MAR	144.8	125.2	76.5	23.9	17.3	12.1
2014.2500	APR	144.9	123.7	75.5	23.9	17.2	12.5
2014.3333	MAY	143.0	121.6	74.6	23.9	17.1	13.3
2014.4167	JUN	139.7	119.5	73.6	23.3	17.0	13.7
2014.5000	JUL	135.8	117.5	72.7	21.6	16.8	13.3
2014.5833	AUG	135.2	115.9	72.3	21.8	16.6	12.8
2014.6667	SEP	134.7	114.4	72.0	21.8	16.4	12.7
2014.7500	OCT	132.8	112.9	71.6	21.5	16.4	12.5
2014.8333	NOV	130.1	111.4	71.4	21.1	16.4	12.4
2014.9167	DEC	128.2	109.9	71.5	20.5	16.4	12.2
2015.0000	JAN	126.8	108.3	71.4	19.9	16.1	11.9
2015.0833	FEB	124.8	106.7	71.2	20.1	16.0	11.9
2015.1667	MAR	122.0	104.8	70.9	21.6	15.9	11.7
2015.2500	APR	119.8	103.0	70.7	23.2	15.8	11.7
2015.3333	MAY	116.8	101.4	70.5	24.0	15.8	11.5
2015.4167	JUN	115.1	99.9	70.7	25.1	15.7	11.3
2015.5000	JUL	113.4	98.7	71.1	25.8	15.7	11.3
2015.5833	AUG	111.9	97.7	71.2	25.0	15.6	10.8
2015.6667	SEP	111.3	96.7	71.4	25.0	15.6	10.3
2015.7500	OCT	110.5	95.6	71.2	24.1	15.7	10.7
2015.8333	NOV	109.2	94.3	70.7	22.2	15.7	10.8
2015.9167	DEC	107.4	93.0	70.3	21.4	15.6	10.8
2016.0000	JAN	106.7	91.9	69.9	21.7	15.8	11.0
2016.0833	FEB	106.3	91.1	69.6	22.4	16.0	11.2
2016.1667	MAR	103.9	90.2	69.2	22.6	16.0	11.2
2016.2500	APR	100.8	89.2	69.0	22.5	16.1	11.0
2016.3333	MAY	98.4	88.2	68.7	22.7	16.3	11.0
2016.4167	JUN	98.2	87.1	68.2	22.9	16.6	11.3
2016.5000	JUL	97.5	86.1	68.0	23.4	16.8	11.2
2016.5833	AUG	96.1	85.1	67.8	24.1	16.9	11.2
2016.6667	SEP	93.2	84.2	67.7	24.8	17.0	11.8
2016.7500	OCT	91.8	83.2	67.6	25.4	16.9	12.2
2016.8333	NOV	90.3	82.3	67.6	25.6	16.7	12.1
2016.9167	DEC	89.3	81.3	67.5	25.4	16.4	12.0
2017.0000	JAN	88.5	80.6	67.3	24.7	16.0	12.2
2017.0833	FEB	88.7	80.0	67.2	23.6	15.6	12.3
2017.1667	MAR	88.6	79.4	67.2	22.8	15.2	12.2
2017.2500	APR	87.2	78.8	67.2	22.4	14.9	11.8
2017.3333	MAY	85.8	78.2	67.2	21.9	14.6	11.2
2017.4167	JUN	85.0	77.8	67.1	21.6	14.2	10.7
2017.5000	JUL	84.0	77.2	67.1	20.9	13.8	10.0
2017.5833	AUG	83.1	76.6	67.0	20.0	13.4	9.4
2017.6667	SEP	81.7	76.0	67.0	18.7	13.1	9.0
2017.7500	OCT	80.4	75.6	67.0	18.2	12.8	8.5
2017.8333	NOV	79.2	75.1	67.0	18.7	12.6	8.0
2017.9167	DEC	78.5	74.7	67.1	18.7	12.5	7.8
2018.0000	JAN	78.1	74.4	67.3	18.4	12.4	7.4
2018.0833	FEB	77.5	74.0	67.4	18.4	12.2	7.0
2018.1667	MAR	76.7	73.7	67.5	18.8	12.1	6.6
2018.2500	APR	76.0	73.2	67.6	18.9	12.0	6.5
2018.3333	MAY	75.2	72.7	67.7	18.8	12.0	6.4
2018.4167	JUN	74.3	72.3	67.7	18.4	11.9	6.6
2018.5000	JUL	73.8	71.9	68.0	17.5	11.8	6.9
2018.5833	AUG	73.6	71.7	68.0	16.5	11.7	7.2
2018.6667	SEP	73.6	71.5	68.0	16.3	11.6	7.4

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%
2018.7500	OCT	73.0	71.4	68.0	16.6	11.6	7.5
2018.8333	NOV	73.2	71.3	67.9	16.9	11.6	7.5
2018.9167	DEC	73.4	71.2	67.9	17.2	11.6	7.7
2019.0000	JAN	73.4	71.2	67.7	17.3	11.6	7.7
2019.0833	FEB	73.2	71.3	67.6	17.7	11.5	7.6
2019.1667	MAR	73.6	71.5	67.7	18.0	11.4	7.6
2019.2500	APR	74.0	71.9	67.6	18.2	11.4	7.6
2019.3333	MAY	74.8	72.3	67.6	18.1	11.3	7.6
2019.4167	JUN	75.5	72.6	67.7	17.8	11.2	7.5
2019.5000	JUL	76.4	73.2	67.9	17.3	11.1	7.5
2019.5833	AUG	77.5	74.0	68.1	16.3	11.0	7.5
2019.6667	SEP	78.8	74.9	68.5	15.5	10.9	7.5
2019.7500	OCT	80.1	75.8	68.6	16.1	10.8	7.7
2019.8333	NOV	81.4	76.9	68.8	16.3	10.8	7.7
2019.9167	DEC	82.8	78.4	69.1	16.6	10.9	7.8
2020.0000	JAN	84.6	80.0	69.3	16.7	11.0	7.7
2020.0833	FEB	87.1	81.8	69.6	16.8	11.1	7.7
2020.1667	MAR	89.6	83.6	70.2	17.1	11.1	7.8
2020.2500	APR	91.9	85.6	71.1	17.3	11.1	8.0
2020.3333	MAY	95.1	87.7	71.8	17.3	11.2	8.3
2020.4167	JUN	97.7	89.8	72.5	17.4	11.5	8.6
2020.5000	JUL	101.0	92.1	73.7	17.6	11.7	9.0
2020.5833	AUG	106.6	94.4	74.2	17.5	12.0	8.8
2020.6667	SEP	109.0	96.7	74.5	16.9	12.2	8.7
2020.7500	OCT	111.9	99.5	74.8	16.2	12.4	8.9
2020.8333	NOV	116.4	102.3	75.1	16.0	12.5	9.0
2020.9167	DEC	121.0	104.8	75.3	16.0	12.7	9.0
2021.0000	JAN	125.4	107.3	75.2	16.1	12.9	8.8
2021.0833	FEB	129.9	109.6	75.2	16.7	13.0	8.4
2021.1667	MAR	134.5	111.9	75.3	17.1	13.0	8.2
2021.2500	APR	139.7	114.5	75.7	17.5	13.1	8.2
2021.3333	MAY	144.5	117.4	76.1	18.2	13.2	8.1
2021.4167	JUN	147.3	120.5	76.6	18.5	13.2	7.9
2021.5000	JUL	149.3	123.1	77.5	18.5	13.1	7.8
2021.5833	AUG	150.4	125.3	78.3	18.7	13.1	7.9
2021.6667	SEP	151.2	127.4	78.6	19.0	13.2	8.1
2021.7500	OCT	151.5	129.3	79.6	18.6	13.3	8.6
2021.8333	NOV	153.9	131.0	80.8	17.8	13.3	9.2
2021.9167	DEC	156.4	132.7	82.2	18.1	13.4	9.6
2022.0000	JAN	160.0	134.8	84.1	18.9	13.5	10.1
2022.0833	FEB	163.9	137.2	85.4	19.1	13.6	10.1
2022.1667	MAR	167.9	139.6	86.3	19.5	13.9	10.3
2022.2500	APR	171.2	142.2	88.1	20.5	14.1	10.4
2022.3333	MAY	174.1	144.8	90.0	20.2	14.1	10.6
2022.4167	JUN	176.5	146.9	91.1	20.4	14.1	10.2
2022.5000	JUL	178.1	148.9	93.3	20.7	14.1	10.2
2022.5833	AUG	178.7	150.9	95.7	21.1	14.2	9.9
2022.6667	SEP	181.8	152.8	97.5	21.4	14.2	9.8
2022.7500	OCT	184.2	154.7	98.7	21.4	14.4	10.5
2022.8333	NOV	187.0	156.3	98.8	21.6	14.5	10.9
2022.9167	DEC	189.7	157.5	98.2	21.9	14.7	10.9
2023.0000	JAN	191.8	158.9	97.8	22.4	14.9	11.0
2023.0833	FEB	192.7	160.7	99.1	22.9	15.1	11.2

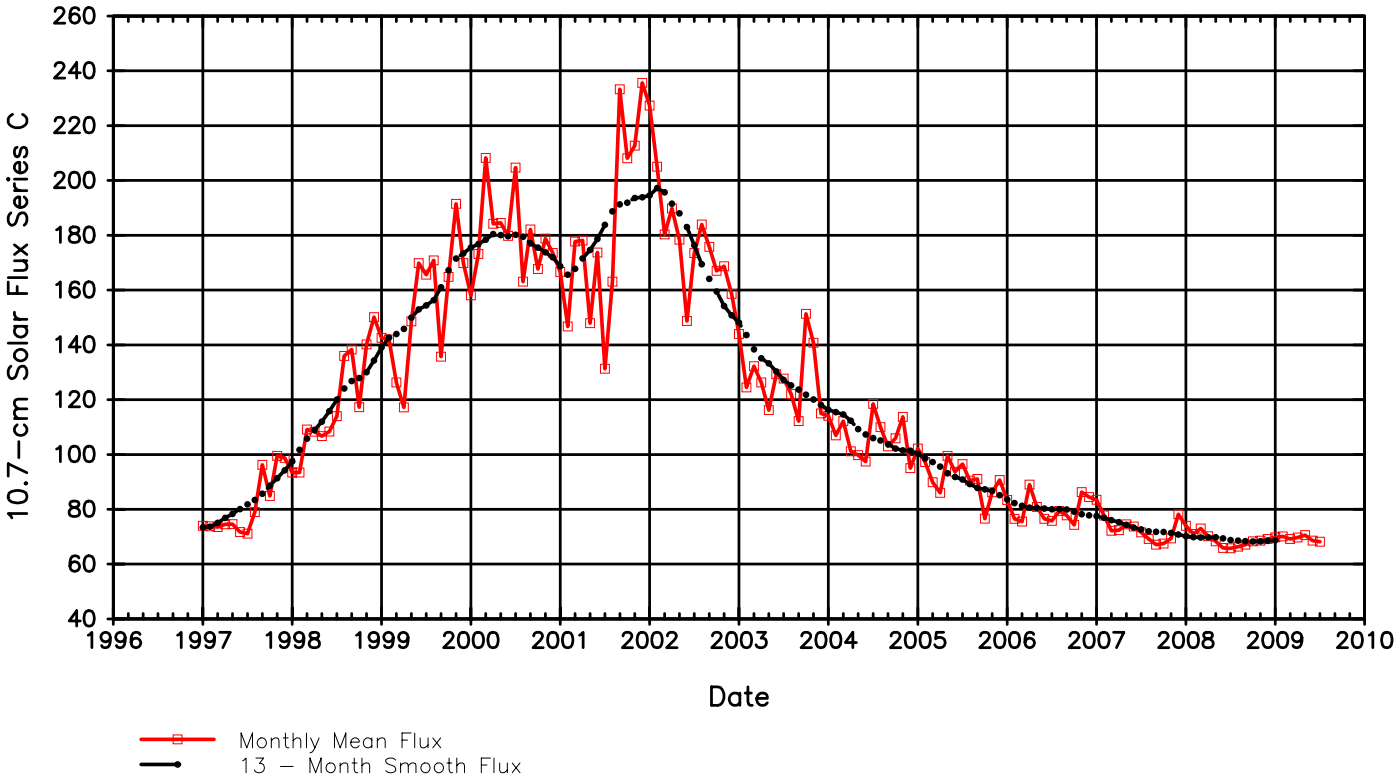

Figure 1. Plot of Recent Monthly Mean and 13-Month Smoothed Solar Flux

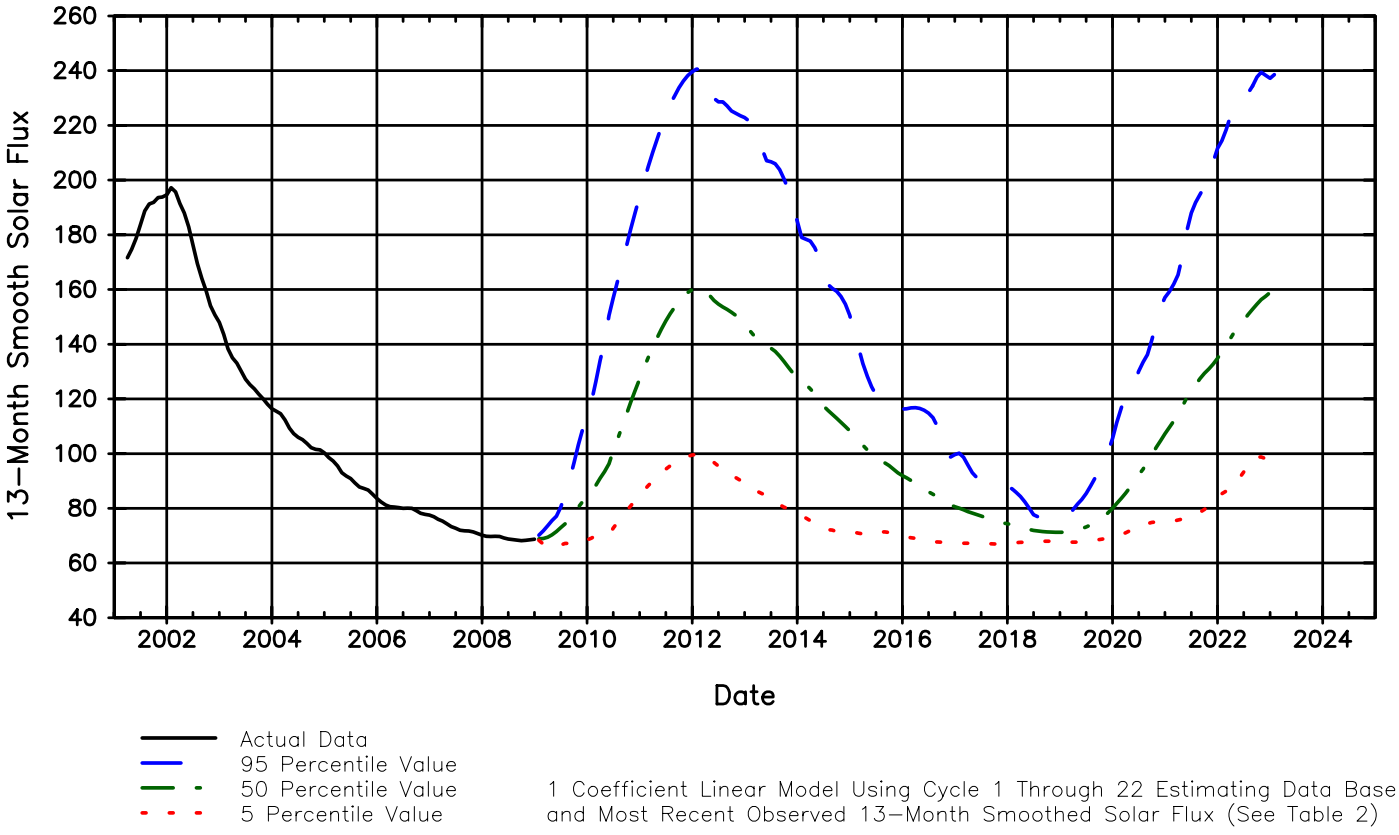

Figure 2. Estimate of 13-Month Smoothed Solar Flux For Cycle 23* and Cycle 24

* Program initialized from Cycle 23 smoothed maximum

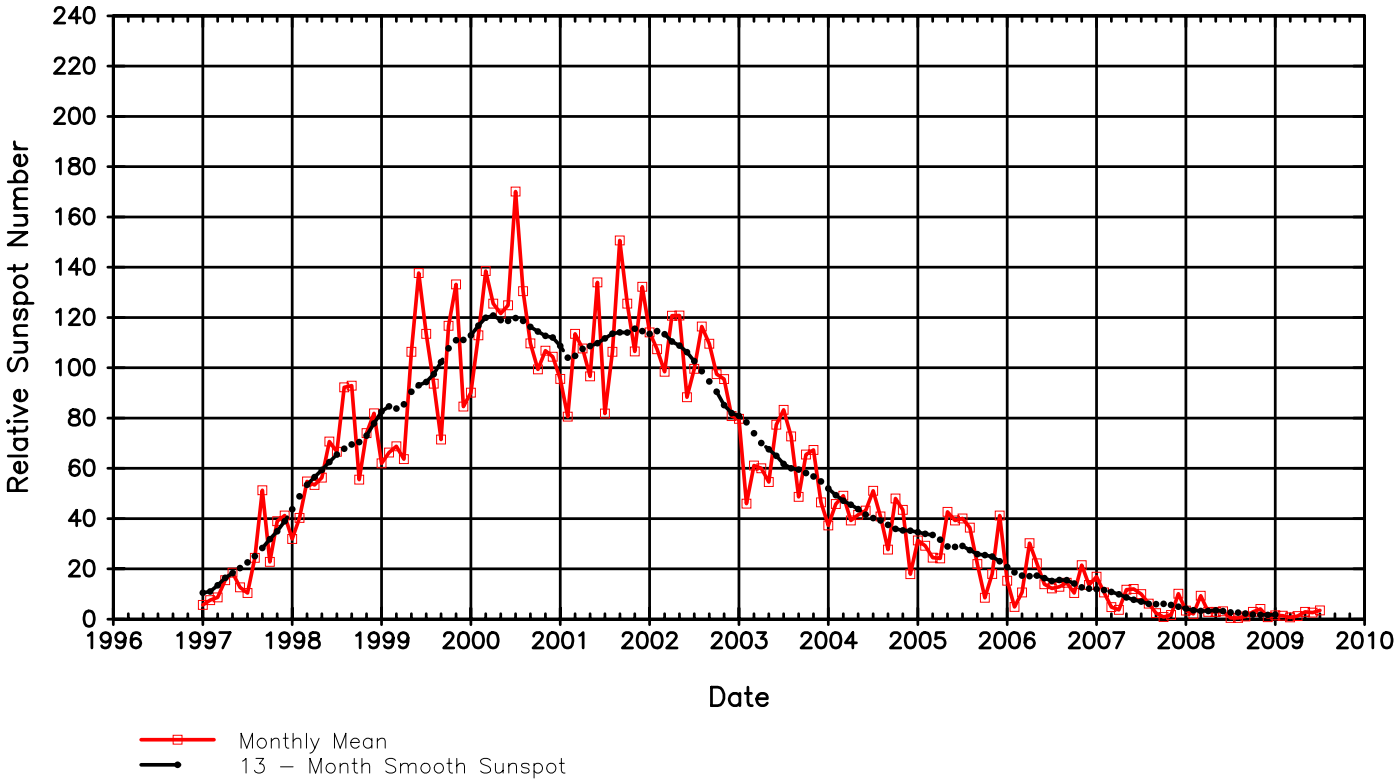

Figure 3. Plot of Recent Monthly Mean and 13-Month Smoothed Relative Sunspot Number

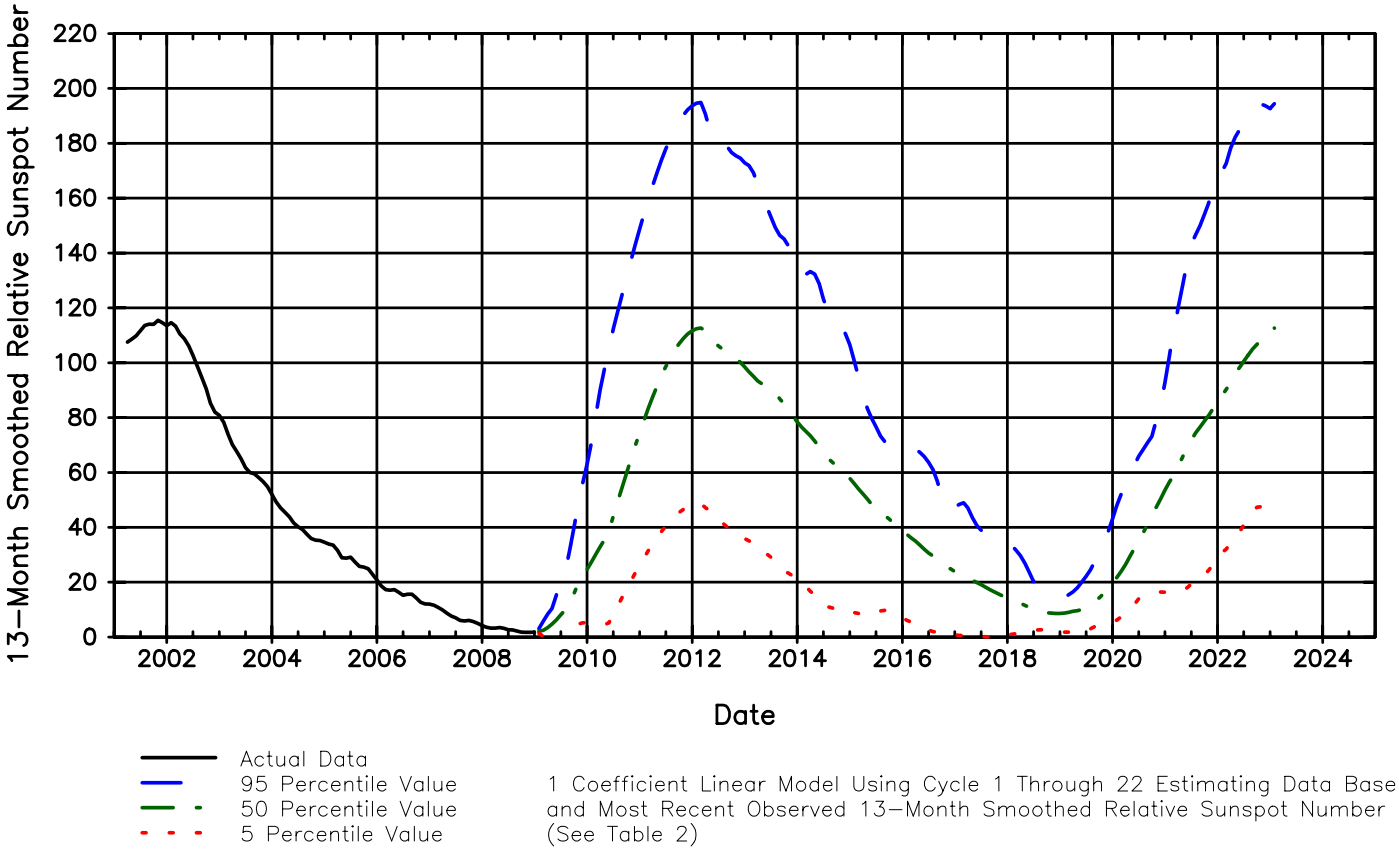

Figure 4. Estimate of 13-Month Smoothed Sunspot Number For Cycle 23* and Cycle 24

* Program initialized from Cycle 23 smoothed maximum

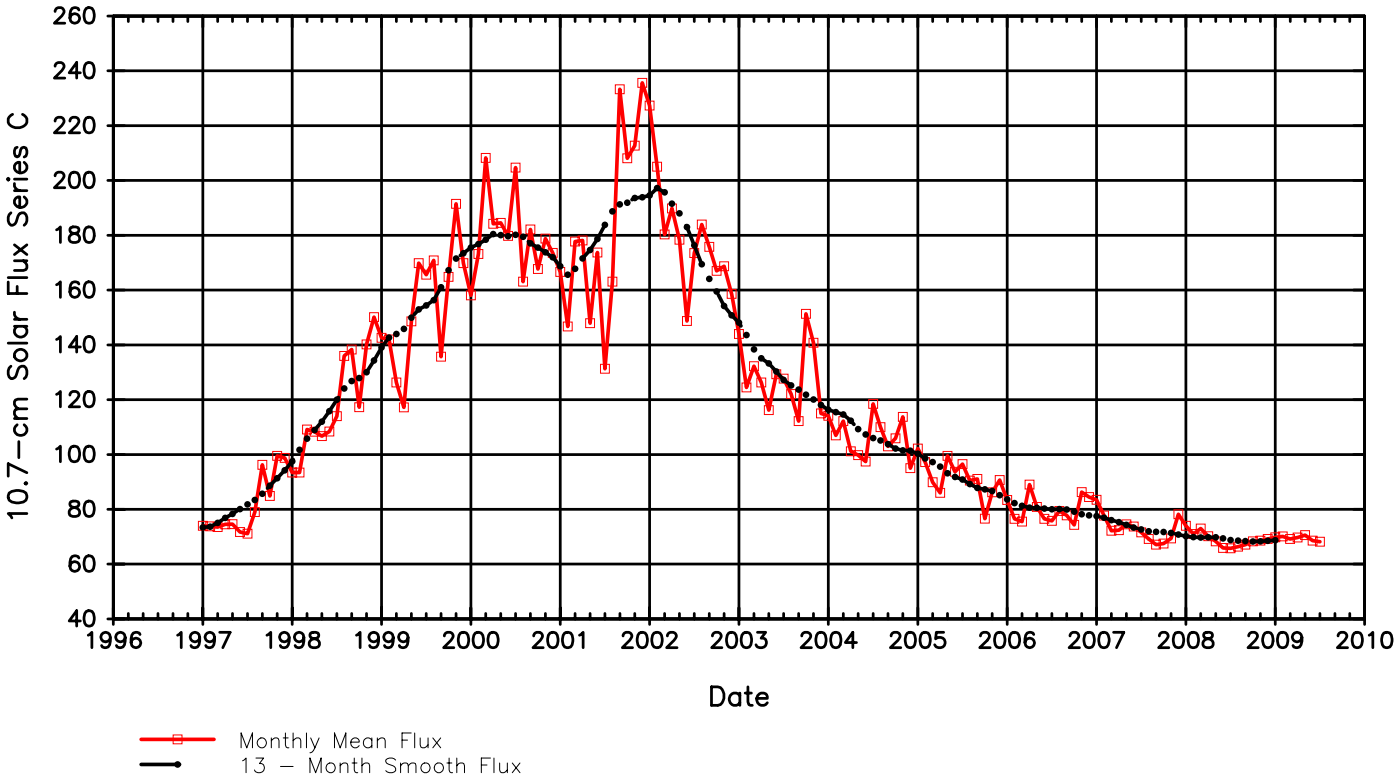

Figure 5. Plot of Recent Monthly Mean and 13-Month Smoothed Solar Flux

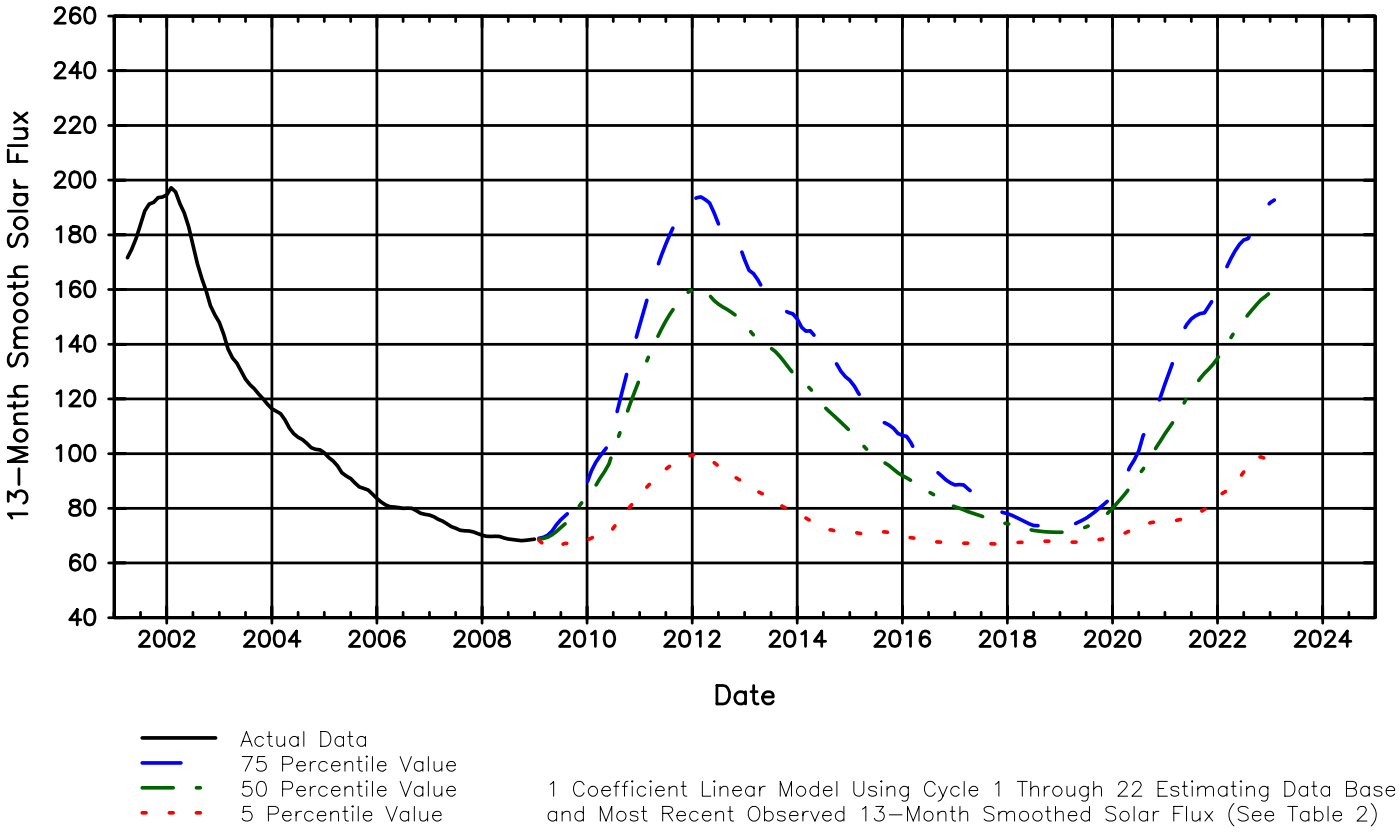

Figure 6. Estimate of 75th Percentile 13-Month Smoothed Solar Flux For Cycle 23* and Cycle 24

* Program initialized from Cycle 23 smoothed maximum