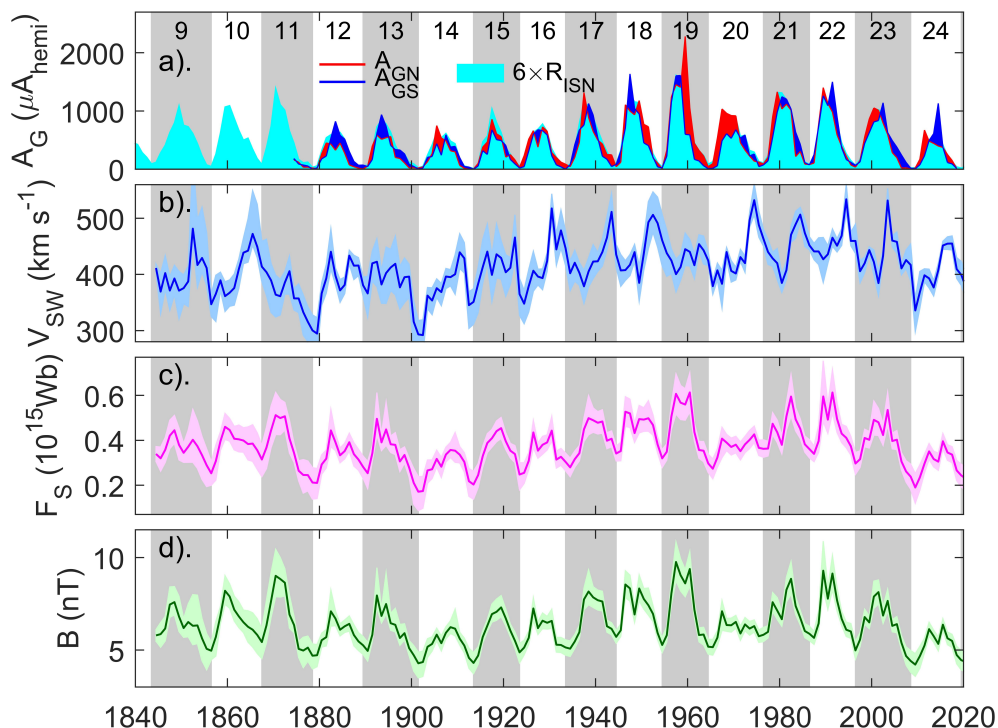


# Supplementary Material

## 1 SUPPLEMENTARY DATA

Application of historic datasets to understanding Open Solar Flux and the 20th-century Grand Solar Maximum. 1. Geomagnetic, ionospheric, spacecraft and sunspot observations by Mike Lockwood, Mathew J. Owens, Luke A. Barnard, Chris J. Scott, Anna Frost, Bingkun Yu, and Yutian Chi

### 1.1 Figures



**Figure S1.** Time series of reconstructions with  $\pm 2\sigma$  uncertainty bands: (b). the solar wind speed,  $V_{SW}$ ; (c). the open solar flux,  $F_S$  and (d). the IMF,  $B$ ; Panel (a) shows sunspot data from comparison. The red and blue show the hemispheric sunspot areas and the filled cyan area shows the International Sunspot number ( $6 \times R_{ISN}$ ). Gray and white vertical bands mark odd and even numbered sunspot cycles. The time series data for  $V_{SW}$ ,  $F_S$  and  $B$  (with uncertainties) are given in **Data Tables** (Tables S2-S7) below.

### 1.2 Tables

Table S1 gives the results of the tests of all correlations cited in the paper (either used in derivations or as tests). The  $p$ -values of the null hypothesis that there is no correlation (allowing for persistence of the data series) are exceptionally low. The  $p$ -values that the residuals are not normally distributed and are not homoskedastic are also generally low, but some do show potential departures, making the regression less reliable and that correlation a source of error in the fit ensemble. The bottom 3 lines are the tests of the final results of the reconstructions.

Tables S2 to S7 give the reconstruction time series and Tables S8 and S9 give the observations from near-Earth space, both as annual means.

**Table S1.** Test metrics of Correlation coefficients  $r$  given in the main text for fitter polynomial of order  $P$ . These are: the number of samples,  $n_r$ ; the effective number of independent samples allowing for the persistence of the two data series,  $n_e$ ; the p-value of the null hypothesis that there is no correlation, allowing for the persistence of the two data series,  $p_r$ ; the root mean square fit residual as a percentage of the mean value,  $\Delta_{rms}(\%)$ ; the p-value for the null hypothesis that the residuals are not normally distributed, derived from a chi-squared test,  $p_{norm}$ ; and the p-value that the fit is not fully homoskedastic (i.e. that the fit residuals have some variation with the fitted value),  $p_{het}$ . The fits to IMF, SW velocity and OSF ( $B'$ ,  $V'_{SW}$  and  $F'_S$ ) are subscripted A for the  $aa_H - IDV$  pairing, B for the  $aa_H - IDV(1d)$  pairing, C for the  $IHV - IDV$  pairing, and D for the  $IHV - IDV(1d)$  pairing. Values subscripted E are for the optimum fits for the full ensemble.

Index	Index	Dates	$P$	$r$	$n_r$	$n_e$	$p_r$	$\Delta_{rms}(\%)$	$p_{norm}$	$p_{het}$
$aa_{HN}$	$aa_{HS}$	1868 – 2020	1	0.983	153	24.4	$< 10^{-20}$	6.58	0.002	0.181
$aa_{HN}$	$k_{NGK}$	1970 – 2020	1	0.978	51	9.1	$2.31 \times 10^{-6}$	6.17	0.260	0.014
$aa_{HN}$	$k_{NGK}$	1970 – 2020	2	0.983	51	9.7	$3.12 \times 10^{-7}$	5.46	0.360	0.020
$aa_{HN}$	$ap$	1970 – 2020	1	0.984	51	10.1	$4.03 \times 10^{-7}$	6.12	0.092	0.148
$aa_{HN}$	$ap$	1970 – 2020	2	0.984	51	9.9	$4.83 \times 10^{-7}$	6.14	0.240	0.102
$IHV$	$aa_H$	1868 – 2020	1	0.977	131	22.6	$1.33 \times 10^{-15}$	6.28	0.545	0.044
$IDV(1d)$	$IDV$	1844 – 2016	1	0.987	168	26.1	$4.91 \times 10^{-12}$	11.18	$8.67 \times 10^{-8}$	0.017
$IDV(1d)$	$IDV$	1844 – 2016	2	0.988	168	26.5	$3.10 \times 10^{-12}$	11.16	$3.71 \times 10^{-8}$	0.016
$IDV(1d)$	$IDV(NGK)$	1970 – 2020	1	0.948	51	10.7	$6.74 \times 10^{-6}$	10.21	0.149	0.011
$IDV(1d)$	$IDV(NGK)$	1970 – 2020	2	0.950	51	9.2	$6.73 \times 10^{-6}$	10.21	0.002	$9.41 \times 10^{-8}$
$IDV(1d)$	$IDV(TUC)$	1970 – 2020	1	0.948	51	10.7	$6.74 \times 10^{-6}$	10.21	0.149	0.011
$aa_H$	$BV_{SW}^{1.76}$	1964 – 2020	1	0.968	57	12.4	$7.23 \times 10^{-8}$	6.88	0.031	0.045
$IDV(1d)$	$BV_{SW}^{-0.05}$	1964 – 2020	1	0.915	57	8.8	$3.44 \times 10^{-4}$	7.69	0.272	0.020
$IDV$	$BV_{SW}^{-0.08}$	1964 – 2016	1	0.919	53	7.7	$8.30 \times 10^{-4}$	7.20	0.256	0.003
$IHV$	$BV_{SW}^{1.68}$	1964 – 2010	1	0.955	47	11.6	$1.15 \times 10^{-6}$	7.62	0.036	0.222
$[V'_{SW}]_A$	$V_{SW}$	1964 – 2016	1	0.905	53	19.9	$2.33 \times 10^{-8}$	3.90	0.111	0.008
$[V'_{SW}]_B$	$V_{SW}$	1964 – 2020	1	0.879	57	21.1	$6.99 \times 10^{-8}$	4.58	0.348	0.008
$[V'_{SW}]_C$	$V_{SW}$	1964 – 2010	1	0.858	47	17.7	$3.41 \times 10^{-6}$	4.91	0.357	0.020
$[V'_{SW}]_D$	$V_{SW}$	1964 – 2010	1	0.826	47	17.9	$1.28 \times 10^{-5}$	5.80	0.101	$7.45 \times 10^{-4}$
$[B']_A$	$B$	1964 – 2016	1	0.925	49	7.7	$6.52 \times 10^{-4}$	7.03	0.237	0.003
$[B']_B$	$B$	1964 – 2020	1	0.921	57	8.6	$3.18 \times 10^{-4}$	7.53	0.169	0.021
$[B']_C$	$B$	1964 – 2010	1	0.926	49	7.6	$7.97 \times 10^{-4}$	6.99	0.277	0.005
$[B']_D$	$B$	1964 – 2010	1	0.914	49	8.2	$6.17 \times 10^{-4}$	7.58	0.082	0.051
$[F'_S]_A$	$F_S$	1964 – 2016	1	0.884	53	7.9	$1.80 \times 10^{-3}$	10.94	0.003	0.089
$[F'_S]_B$	$F_S$	1964 – 2020	1	0.880	57	8.7	$1.10 \times 10^{-3}$	11.25	0.115	0.200
$[F'_S]_C$	$F_S$	1964 – 2010	1	0.895	47	8.0	$1.30 \times 10^{-3}$	10.41	0.010	0.143
$[F'_S]_D$	$F_S$	1964 – 2010	1	0.891	47	8.0	$1.50 \times 10^{-3}$	10.65	0.088	0.303
$\langle R_{ISN} \rangle_{smo}$	$\langle R_{GC} \rangle_{smo}$	1950 – 2010	1	0.996	61	6.5	$2.50 \times 10^{-6}$	6.39	0.026	0.001
$[B']_E$	$B$	1964 – 2019	1	0.926	56	8.6	$2.53 \times 10^{-4}$	7.11	0.176	0.110
$[V'_{SW}]_E$	$V_{SW}$	1964 – 2019	1	0.880	56	20.1	$1.45 \times 10^{-7}$	4.48	0.227	0.245
$[F'_S]_E$	$F_S$	1964 – 2019	1	0.883	51	9.1	$7.59 \times 10^{-4}$	10.98	0.088	0.218

**Table S2. Data Table.** Reconstructed IMF, solar wind speed and Open solar flux data series derived in the paper. The minimum, optimum and maximum values are given where the maximum and minimum values define the  $\pm 2\sigma$  uncertainty band of an ensemble of 4 million values.

1	2	3	4	5	6	7	8	9	10
date	IMF $B_{min}$ (nT)	IMF $B$ (nT)	IMF $B_{max}$ (nT)	SW $V_{min}$ (kms <sup>-1</sup> )	SW $V$ (kms <sup>-1</sup> )	SW $V_{max}$ (kms <sup>-1</sup> )	OSF $[F_S]_{min}$ (10 <sup>14</sup> Wb)	OSF $F_S$ (10 <sup>14</sup> Wb)	OSF $[F_S]_{max}$ (10 <sup>14</sup> Wb)
1844.5	5.480	5.792	6.104	404.0	411.5	418.3	2.804	3.137	3.467
1845.5	5.142	5.849	6.474	330.8	369.9	402.5	2.428	2.995	3.496
1846.5	5.489	6.161	6.819	374.0	402.6	433.7	2.757	3.315	3.862
1847.5	6.762	7.450	8.404	336.5	371.7	396.8	3.265	3.844	4.531
1848.5	6.890	7.581	8.421	364.2	393.1	416.7	3.465	4.047	4.706
1849.5	5.982	6.791	7.884	321.3	371.7	405.8	2.826	3.498	4.240
1850.5	5.678	6.179	6.684	348.2	376.0	399.6	2.776	3.202	3.611
1851.5	5.717	6.515	7.493	342.9	387.6	415.1	2.736	3.428	4.171
1852.5	5.311	6.331	8.019	458.5	480.5	608.2	2.698	3.696	5.042
1853.5	5.354	6.340	7.977	376.7	416.5	497.2	2.466	3.450	4.571
1854.5	4.433	5.643	6.708	403.2	428.9	519.1	2.039	3.115	3.939
1855.5	3.945	5.074	5.894	379.8	411.2	474.3	1.789	2.738	3.462
1856.5	4.466	4.955	5.438	325.6	347.3	365.3	1.901	2.433	2.945
1857.5	4.674	5.708	6.547	316.4	365.6	398.8	2.047	2.890	3.601
1858.5	6.428	6.861	7.351	371.6	389.7	404.2	3.233	3.637	4.057
1859.5	7.448	8.185	9.002	334.6	361.9	387.6	3.612	4.173	4.766
1860.5	7.245	7.881	8.562	343.8	367.9	390.8	3.558	4.054	4.568
1861.5	6.557	7.168	7.905	345.7	376.3	401.2	3.232	3.728	4.274
1862.5	6.211	6.821	7.615	375.4	409.4	427.6	3.152	3.709	4.343
1863.5	5.953	6.510	7.164	418.8	438.5	464.5	3.148	3.666	4.235
1864.5	5.433	6.267	7.137	421.4	441.9	498.6	2.827	3.534	4.296
1865.5	5.181	6.118	7.029	451.2	471.5	548.3	2.764	3.555	4.392
1866.5	4.826	5.829	6.706	429.2	448.8	524.3	2.456	3.303	4.074
1867.5	4.545	5.436	6.159	386.5	413.6	458.8	2.189	2.953	3.592
1868.5	5.398	6.336	7.693	362.6	403.9	462.7	2.461	3.398	4.302
1869.5	6.761	7.643	9.174	332.5	389.6	419.8	3.274	4.042	5.120
1870.5	7.861	8.988	10.419	324.8	364.6	399.1	3.751	4.608	5.620
1871.5	7.842	8.818	9.977	328.4	361.8	392.3	3.759	4.500	5.326
1872.5	7.912	8.630	9.383	365.3	385.9	405.5	3.961	4.569	5.186
1873.5	6.184	6.920	7.963	364.7	405.8	433.0	3.091	3.741	4.546

Table S3. Data Table (continued).

1	2	3	4	5	6	7	8	9	10
date	IMF $B_{min}$ ( $nT$ )	IMF $B$ ( $nT$ )	IMF $B_{max}$ ( $nT$ )	SW $V_{min}$ ( $kms^{-1}$ )	SW $V$ ( $kms^{-1}$ )	SW $V_{max}$ ( $kms^{-1}$ )	OSF $[F_S]_{min}$ ( $10^{14}Wb$ )	OSF $F_S$ ( $10^{14}Wb$ )	OSF $[F_S]_{max}$ ( $10^{14}Wb$ )
1874.5	5.916	6.340	6.798	336.9	357.8	375.5	2.777	3.191	3.603
1875.5	4.594	5.055	5.471	332.2	357.6	383.6	2.080	2.529	2.971
1876.5	4.042	4.965	5.687	292.1	333.2	363.8	1.563	2.368	3.054
1877.5	4.386	5.118	5.743	280.9	316.1	343.1	1.661	2.364	2.990
1878.5	3.963	4.680	5.313	264.8	301.0	328.7	1.346	2.084	2.747
1879.5	4.082	4.703	5.281	259.9	295.3	323.6	1.374	2.069	2.704
1880.5	5.154	5.525	5.902	345.3	366.7	385.4	2.325	2.759	3.186
1881.5	5.218	5.693	6.113	366.9	393.3	417.9	2.566	2.978	3.365
1882.5	6.292	7.093	8.238	409.0	440.4	481.1	3.310	4.032	4.962
1883.5	6.316	6.698	7.110	382.2	398.0	411.5	3.219	3.588	3.961
1884.5	5.756	6.090	6.414	350.7	372.0	391.3	2.768	3.102	3.429
1885.5	5.945	6.278	6.620	365.9	381.6	395.7	2.913	3.259	3.605
1886.5	6.029	6.422	6.847	418.4	433.3	443.0	3.203	3.593	3.990
1887.5	5.233	5.817	6.375	390.8	415.5	434.0	2.618	3.148	3.653
1888.5	4.977	5.472	5.946	397.7	415.8	429.9	2.472	2.945	3.401
1889.5	4.761	5.256	5.735	361.2	380.8	395.3	2.168	2.671	3.151
1890.5	4.406	4.950	5.413	324.5	366.4	397.3	1.752	2.435	2.961
1891.5	5.458	5.823	6.230	388.0	419.8	441.7	2.827	3.172	3.517
1892.5	7.282	7.946	9.454	378.3	422.8	463.8	3.732	4.463	5.632
1893.5	6.461	6.838	7.223	348.9	382.4	407.2	3.215	3.583	3.950
1894.5	6.919	7.479	9.163	348.7	402.8	449.1	3.356	4.065	5.278
1895.5	6.068	6.450	6.987	371.4	412.5	445.0	3.150	3.515	3.885
1896.5	5.980	6.364	7.256	363.8	419.1	468.3	3.064	3.493	4.035
1897.5	5.245	5.644	6.377	338.7	377.4	415.1	2.426	2.873	3.394
1898.5	5.536	5.909	6.416	350.1	395.3	429.4	2.751	3.114	3.474
1899.5	4.695	5.105	5.513	359.0	396.2	418.3	2.226	2.649	3.066
1900.5	3.853	4.714	5.232	266.3	316.3	352.8	1.123	2.074	2.713
1901.5	3.484	4.271	4.873	251.9	293.9	318.7	0.904	1.743	2.412
1902.5	3.558	4.339	4.928	258.7	292.6	319.9	1.004	1.767	2.413
1903.5	4.596	5.170	5.612	339.1	362.6	377.1	1.966	2.537	3.002

Table S4. Data Table (continued).

1	2	3	4	5	6	7	8	9	10
date	IMF $B_{min}$ (nT)	IMF $B$ (nT)	IMF $B_{max}$ (nT)	SW $V_{min}$ (kms <sup>-1</sup> )	SW $V$ (kms <sup>-1</sup> )	SW $V_{max}$ (kms <sup>-1</sup> )	OSF $[F_S]_{min}$ (10 <sup>14</sup> Wb)	OSF $F_S$ (10 <sup>14</sup> Wb)	OSF $[F_S]_{max}$ (10 <sup>14</sup> Wb)
1904.5	4.935	5.322	5.708	328.8	354.0	376.6	2.170	2.582	2.998
1905.5	5.492	5.828	6.176	359.4	375.8	392.4	2.606	2.968	3.355
1906.5	4.949	5.365	5.759	344.7	368.9	384.3	2.201	2.677	3.092
1907.5	5.608	5.933	6.258	375.0	396.4	410.8	2.804	3.132	3.460
1908.5	5.892	6.234	6.583	379.8	395.4	408.8	2.966	3.302	3.638
1909.5	5.763	6.150	7.198	365.0	400.7	435.4	2.758	3.274	4.083
1910.5	5.279	5.624	5.969	410.4	439.2	472.1	2.765	3.131	3.488
1911.5	4.845	5.249	5.651	402.3	428.6	456.4	2.408	2.861	3.271
1912.5	4.008	4.571	5.091	304.3	345.6	369.7	1.462	2.137	2.700
1913.5	3.716	4.299	4.865	311.6	351.4	375.0	1.361	2.013	2.602
1914.5	4.226	4.699	5.172	331.8	383.5	412.9	1.812	2.364	2.876
1915.5	5.373	5.706	6.046	384.7	412.9	462.3	2.594	3.074	3.510
1916.5	6.000	6.323	6.658	419.4	440.5	489.7	3.144	3.566	3.980
1917.5	6.505	6.938	7.483	352.0	399.5	434.4	3.342	3.737	4.129
1918.5	6.609	7.070	7.761	393.9	435.8	490.0	3.535	4.004	4.461
1919.5	6.808	7.307	7.945	391.6	429.4	460.0	3.657	4.116	4.592
1920.5	6.311	6.713	7.213	361.3	404.1	435.3	3.259	3.629	3.994
1921.5	5.716	6.056	6.404	382.1	411.8	430.3	2.951	3.277	3.601
1922.5	5.111	5.514	5.978	426.6	465.4	505.9	2.779	3.156	3.530
1923.5	4.301	4.872	5.352	327.3	365.3	393.1	1.707	2.387	2.913
1924.5	4.728	5.124	5.524	312.7	348.4	372.2	1.975	2.448	2.894
1925.5	5.299	5.656	6.019	333.5	379.6	409.2	2.512	2.894	3.264
1926.5	6.580	7.249	7.811	370.2	406.7	441.1	3.266	3.955	4.478
1927.5	5.840	6.181	6.529	381.4	396.4	409.5	2.939	3.276	3.615
1928.5	6.155	6.584	7.000	373.0	393.6	410.1	3.075	3.495	3.869
1929.5	6.137	6.477	6.822	405.8	423.8	438.6	3.250	3.585	3.917
1930.5	6.196	6.596	7.221	494.3	516.8	542.8	3.578	4.033	4.659
1931.5	4.898	5.297	5.695	416.1	444.3	472.1	2.572	2.947	3.321
1932.5	4.879	5.288	5.697	446.0	477.8	514.1	2.676	3.054	3.426
1933.5	4.731	5.149	5.562	415.7	446.4	477.3	2.468	2.863	3.252

Table S5. **Data Table** (continued).

1	2	3	4	5	6	7	8	9	10
date	IMF $B_{min}$ (nT)	IMF $B$ (nT)	IMF $B_{max}$ (nT)	SW $V_{min}$ (kms <sup>-1</sup> )	SW $V$ (kms <sup>-1</sup> )	SW $V_{max}$ (kms <sup>-1</sup> )	OSF $[F_S]_{min}$ (10 <sup>14</sup> Wb)	OSF $F_S$ (10 <sup>14</sup> Wb)	OSF $[F_S]_{max}$ (10 <sup>14</sup> Wb)
1934.5	4.656	5.076	5.492	371.1	402.1	424.0	2.241	2.655	3.067
1935.5	5.089	5.465	5.840	388.1	420.8	443.0	2.601	2.961	3.321
1936.5	5.612	5.964	6.341	380.7	403.1	421.3	2.841	3.182	3.522
1937.5	7.164	7.728	8.336	348.7	379.1	408.0	3.532	4.068	4.571
1938.5	7.442	8.158	9.321	377.9	405.5	429.8	3.750	4.485	5.484
1939.5	7.303	7.851	8.425	392.6	422.9	453.1	3.875	4.410	4.956
1940.5	7.165	7.695	8.243	405.4	423.4	439.3	3.820	4.317	4.809
1941.5	7.122	7.631	8.185	414.6	439.8	463.1	3.843	4.366	4.887
1942.5	5.974	6.299	6.627	443.5	465.2	502.6	3.297	3.653	4.011
1943.5	5.848	6.167	6.495	483.1	510.5	543.4	3.377	3.730	4.078
1944.5	5.374	5.720	6.065	412.2	435.4	453.2	2.839	3.174	3.507
1945.5	5.736	6.070	6.413	378.9	407.1	435.5	2.831	3.264	3.649
1946.5	7.824	8.539	9.278	389.5	407.9	424.7	4.071	4.726	5.392
1947.5	7.640	8.329	9.046	397.9	417.4	435.7	4.042	4.663	5.296
1948.5	6.508	6.930	7.397	422.3	439.6	453.3	3.524	3.934	4.365
1949.5	7.650	8.320	9.043	352.9	385.3	416.6	3.837	4.449	5.054
1950.5	7.219	7.767	8.330	407.6	436.8	465.3	3.915	4.436	4.963
1951.5	6.903	7.437	8.368	445.5	492.5	529.2	3.917	4.492	5.267
1952.5	6.558	6.974	7.427	474.3	505.4	546.2	3.794	4.243	4.691
1953.5	5.581	5.941	6.346	448.1	490.7	537.0	3.149	3.517	3.867
1954.5	4.878	5.285	5.692	414.6	460.3	506.5	2.589	2.995	3.385
1955.5	5.433	5.808	6.287	396.4	437.7	478.6	2.870	3.237	3.594
1956.5	7.436	8.064	8.719	401.6	424.8	445.4	3.982	4.549	5.122
1957.5	8.745	9.755	10.835	369.1	400.7	427.4	4.498	5.389	6.276
1958.5	8.191	9.041	9.924	389.9	413.4	436.0	4.313	5.063	5.829
1959.5	7.888	8.610	9.357	415.6	444.8	473.5	4.303	4.999	5.698
1960.5	8.471	9.384	10.325	415.0	440.2	462.4	4.585	5.448	6.317
1961.5	6.740	7.176	7.622	392.7	416.5	436.1	3.567	3.968	4.370
1962.5	5.454	5.820	6.211	439.9	453.6	470.3	2.937	3.305	3.687
1963.5	5.280	5.849	6.241	418.1	442.6	468.0	2.790	3.277	3.685

Table S6. Data Table (continued).

1	2	3	4	5	6	7	8	9	10
date	IMF $B_{min}$ (nT)	IMF $B$ (nT)	IMF $B_{max}$ (nT)	SW $V_{min}$ (kms <sup>-1</sup> )	SW $V$ (kms <sup>-1</sup> )	SW $V_{max}$ (kms <sup>-1</sup> )	OSF $[F_S]_{min}$ (10 <sup>14</sup> Wb)	OSF $F_S$ (10 <sup>14</sup> Wb)	OSF $[F_S]_{max}$ (10 <sup>14</sup> Wb)
1964.5	4.780	5.185	5.588	415.4	424.6	440.1	2.401	2.805	3.213
1965.5	4.723	5.153	5.572	364.9	379.3	390.5	2.160	2.603	3.036
1966.5	5.239	5.673	6.053	390.2	407.3	420.1	2.591	3.027	3.407
1967.5	6.060	7.094	7.670	340.7	383.5	407.5	2.877	3.723	4.225
1968.5	6.023	6.358	6.720	425.9	439.6	447.6	3.227	3.581	3.942
1969.5	5.971	6.340	6.725	386.4	406.4	424.8	3.056	3.414	3.809
1970.5	6.177	6.520	6.871	390.3	401.8	413.0	3.137	3.499	3.871
1971.5	5.534	5.898	6.299	422.9	430.7	444.6	2.874	3.262	3.669
1972.5	6.039	6.390	6.762	403.8	420.0	432.9	3.146	3.513	3.867
1973.5	5.821	6.178	6.563	483.8	496.2	510.3	3.300	3.688	4.107
1974.5	5.996	6.317	6.652	504.8	531.2	560.3	3.530	3.896	4.259
1975.5	5.430	5.762	6.106	465.6	487.4	512.3	3.046	3.389	3.732
1976.5	5.467	5.836	6.237	450.2	463.2	480.3	2.975	3.351	3.748
1977.5	5.658	5.989	6.319	417.6	439.8	461.7	3.029	3.357	3.684
1978.5	7.086	7.590	8.111	414.6	428.6	439.7	3.787	4.281	4.774
1979.5	6.658	7.135	7.835	390.9	420.1	446.4	3.506	3.963	4.500
1980.5	6.279	6.661	7.059	368.3	385.1	401.0	3.092	3.493	3.902
1981.5	7.596	8.251	8.927	391.3	407.9	423.5	3.949	4.555	5.175
1982.5	8.028	8.862	9.795	456.6	470.4	485.4	4.427	5.298	6.269
1983.5	6.944	7.404	7.906	464.0	488.7	511.9	3.938	4.454	4.970
1984.5	6.377	6.762	7.160	491.7	505.8	518.7	3.672	4.103	4.549
1985.5	5.681	6.040	6.445	449.3	473.4	497.9	3.167	3.519	3.885
1986.5	5.520	5.888	6.296	443.3	451.4	466.8	2.948	3.338	3.757
1987.5	5.314	5.666	6.019	426.0	440.8	455.2	2.816	3.161	3.506
1988.5	6.052	6.447	7.135	417.4	440.8	465.2	3.135	3.638	4.340
1989.5	8.277	9.287	10.882	386.0	427.1	466.0	4.180	5.296	6.884
1990.5	7.206	7.781	8.389	419.9	435.8	451.3	3.831	4.435	5.090
1991.5	8.253	9.146	10.108	449.8	465.2	480.7	4.529	5.449	6.445
1992.5	7.116	7.694	8.379	439.8	451.0	463.5	3.862	4.461	5.157
1993.5	6.339	6.703	7.102	451.2	468.4	480.8	3.521	3.918	4.327

Table S7. **Data Table** (continued).

1	2	3	4	5	6	7	8	9	10
date	IMF $B_{min}$ ( $nT$ )	IMF $B$ ( $nT$ )	IMF $B_{max}$ ( $nT$ )	SW $V_{min}$ ( $kms^{-1}$ )	SW $V$ ( $kms^{-1}$ )	SW $V_{max}$ ( $kms^{-1}$ )	OSF $[F_S]_{min}$ ( $10^{14}Wb$ )	OSF $F_S$ ( $10^{14}Wb$ )	OSF $[F_S]_{max}$ ( $10^{14}Wb$ )
1994.5	5.755	6.121	6.531	509.7	532.8	559.5	3.326	3.767	4.276
1995.5	5.645	6.013	6.443	450.7	459.3	475.0	3.053	3.447	3.885
1996.5	4.521	4.991	5.466	437.0	459.3	489.2	2.320	2.803	3.296
1997.5	5.194	5.568	5.951	385.1	405.8	424.7	2.595	2.959	3.327
1998.5	6.396	6.787	7.212	403.1	419.9	430.9	3.358	3.749	4.141
1999.5	6.164	6.502	6.850	434.5	443.2	448.9	3.320	3.685	4.057
2000.5	7.249	7.890	8.728	399.2	422.4	443.7	3.750	4.425	5.264
2001.5	7.486	8.122	8.778	362.6	384.9	406.0	3.745	4.329	4.946
2002.5	6.444	6.867	7.364	421.9	433.0	444.3	3.405	3.862	4.373
2003.5	7.126	7.683	8.305	516.2	530.8	552.3	4.124	4.805	5.583
2004.5	5.996	6.319	6.660	448.7	459.9	468.8	3.291	3.641	3.995
2005.5	5.946	6.413	6.822	436.8	457.6	475.2	3.250	3.689	4.098
2006.5	5.017	5.394	5.776	399.2	410.7	419.2	2.490	2.875	3.262
2007.5	4.193	4.686	5.176	410.1	425.4	443.4	2.030	2.505	2.983
2008.5	3.807	4.417	4.981	388.4	416.7	453.9	1.755	2.312	2.866
2009.5	3.574	4.207	4.799	299.0	336.3	357.4	1.205	1.902	2.519
2010.5	4.020	4.673	5.201	340.3	368.8	405.6	1.715	2.282	2.839
2011.5	4.854	5.243	5.642	386.9	398.6	410.2	2.390	2.796	3.209
2012.5	5.741	6.126	6.497	376.1	393.3	409.6	2.902	3.256	3.602
2013.5	5.423	5.754	6.078	361.7	376.7	389.2	2.646	2.997	3.343
2014.5	4.960	5.336	5.708	395.8	407.5	419.4	2.518	2.901	3.279
2015.5	6.050	6.373	6.693	444.5	451.5	459.1	3.309	3.654	3.997
2016.5	5.295	5.638	5.979	444.5	454.8	467.0	2.893	3.241	3.585
2017.5	5.139	5.496	5.850	443.5	455.0	468.6	2.801	3.159	3.513
2018.5	4.259	4.735	5.201	392.8	409.5	430.0	2.124	2.577	3.026
2019.5	3.922	4.453	4.974	380.4	399.3	423.0	1.881	2.390	2.886
2020.5	3.819	4.365	4.901	357.9	377.0	400.0	1.739	2.269	2.786



**Table S8. Data Table** Annual means of spacecraft data: the IMF field strength,  $B$ , the solar wind speed  $V_{SW}$  and the OSF, computed using excess flux allowance from strahl electrons (see text for details),  $F_S$

1	2	3	4
date	IMF, $B(nT)$	$V_{SW}(kms^{-1})$	OSF, $F_S(10^{14}Wb)$
1964.5	5.118	419.8	NaN
1965.5	5.058	419.8	NaN
1966.5	6.347	429.7	NaN
1967.5	6.358	428.1	3.619
1968.5	6.189	468.0	3.450
1969.5	6.052	420.0	3.177
1970.5	6.350	421.6	NaN
1971.5	6.000	440.8	NaN
1972.5	6.381	403.1	NaN
1973.5	6.358	484.8	NaN
1974.5	6.623	525.2	4.241
1975.5	5.829	485.5	3.505
1976.5	5.476	445.4	3.203
1977.5	5.882	413.3	3.242
1978.5	7.134	428.0	3.600
1979.5	7.594	417.3	3.871
1980.5	6.988	390.5	3.729
1981.5	7.832	424.8	4.696
1982.5	8.815	466.6	5.891
1983.5	7.955	472.6	4.531
1984.5	7.978	476.5	5.190
1985.5	5.845	466.4	3.611
1986.5	5.760	452.8	3.507
1987.5	6.072	429.1	3.386
1988.5	7.304	429.4	3.844
1989.5	8.239	451.3	4.604

Table S9. **Data Table** (spacecraft data, continued).

1	2	3	4
date	IMF, $B(nT)$	$V_{SW}(kms^{-1})$	OSF, $F_S(10^{14}Wb)$
1990.5	7.314	444.7	4.200
1991.5	9.331	462.7	5.571
1992.5	8.337	429.8	4.573
1993.5	6.588	448.4	3.813
1994.5	6.136	527.1	3.621
1995.5	5.726	428.5	3.243
1996.5	5.112	422.5	3.297
1997.5	5.504	380.7	3.043
1998.5	6.908	410.4	3.680
1999.5	6.896	438.8	3.842
2000.5	7.176	447.8	3.564
2001.5	6.935	425.5	3.317
2002.5	7.639	439.8	4.533
2003.5	7.587	543.1	4.942
2004.5	6.520	451.5	3.758
2005.5	6.246	472.0	3.514
2006.5	4.999	430.9	2.664
2007.5	4.468	441.1	2.476
2008.5	4.193	450.6	2.363
2009.5	3.894	364.6	1.733
2010.5	4.702	403.6	2.604
2011.5	5.250	420.8	2.781
2012.5	5.706	408.4	2.468
2013.5	5.180	397.0	2.284
2014.5	6.090	398.3	3.402
2015.5	6.679	437.4	4.034
2016.5	6.047	446.5	3.646
2017.5	5.251	454.6	3.260
2018.5	4.658	411.6	2.689
2019.5	4.504	397.6	2.672