Direct and Indirect Thermospheric Heating Sources for Solar Cycles 21-23

D. J. Knipp[1], W. Kent Tobiska[2] and B. Emery[3]

[1]USAF Academy Department of Physics

[2]Space Weather Technologies

[3]High Altitude Observatory

Space Physics and Atmospheric Research Center (SPARC)

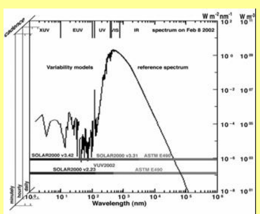
ABSTRACT: We use a trio of empirical models to estimate the relative contributions of solar extreme ultraviolet (EUV) heating, Joule heating and particle heating to the global energy budget of the earth's upper atmosphere over the last three solar cycles. Daily power values are derived from models of three sources. The SOLAR2000 solar irradiance specification model provides estimates of the daily extreme EUV solar power input. Geomagnetic power comes from a combination of satellite-derived particle precipitation power and an empirical model of Joule power derived from hemispherically-integrated estimates of high-latitude heating, which we discuss in this paper. Since 1975 the average daily contributions from the three sources have been: particles ~36 GW, Joule ~95 GW and solar ~464 GW. Joule and particle heating combine to provide more than 22% of the total global upper atmospheric heating and more than one third of the variability in the heating. During solar minimum the variability of the Joule power dominates total variability. During solar maximum the variability in the Joule power is approximately that of the solar power variability. In the top 15 heating events geomagnetic power contributed more than 66% of the total power budget. During all of these events the Joule power alone exceeded solar power. We will briefly discuss our methods of deriving the power estimates. We will also provide quantitative comparisons with the largest storms of the last three solar cycles in terms of total values and temporal profiles of estimated heating.

Acknowledgements: NOAA Space Environment Center, NASA OMNIWEB Danish Meteorological Institute, World Data Center, Kyoto University

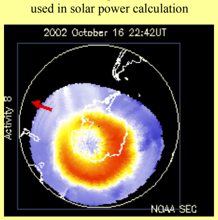
Ref: Knipp et al., Solar Physics, In Press, Oct 2004

Procedure:

- Estimate solar EUV input using daily power estimates from SOLAR2000 Research Grade version 2.22a 1975-2003
- Estimate Joule heating from ground indice proxies 1975-2003 **(see box at top right)**
- Estimate particle heating from NOAA TIROS and DMSP data 1979-2003



•SOLAR2000 Research Grade version 2.22a spectral irradiance used in solar power calculation



•NOAA TIROS southern hemisphere particle data used in particle power calculation

•Uses solar irradiance proxy inputs of F10.7 for coronal emission and the Magnesium II (Mg II) core to wing ratio for chromospheric emission and irradiance measurements from TIMED

•Thermospherically effective irradiances (Wm^{-2}) modeled at 1 nm resolution between 1 and 106 nm at one AU

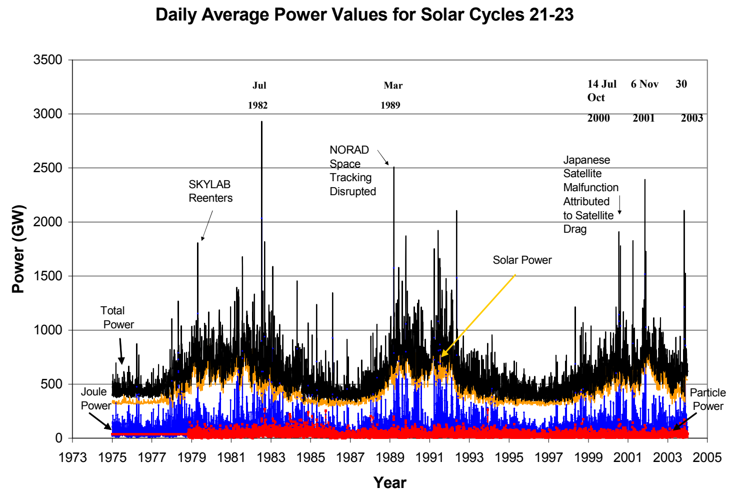
•Model energy deposition is in the 150-200 km range for almost all levels of solar activity, integrated over the dayside

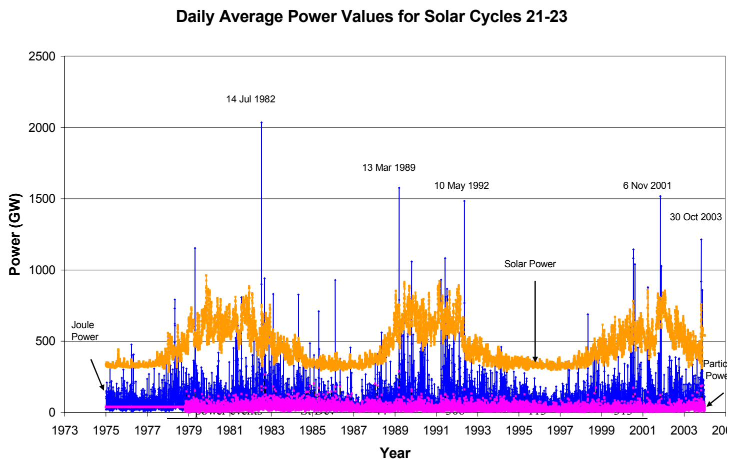
•Electrons from

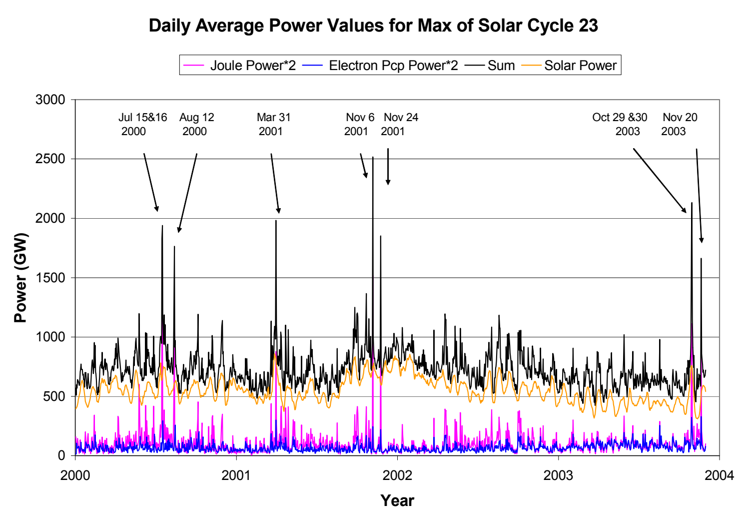
•POES 50 eV - 20 keV,

•DMSP 30 eV- 30 keV

•Low energy ions from POES also included







Joule Power Estimate Procedure

Multiple Linear Regression Fit of Polar Cap Index and Dst hourly values to 13,000+ estimates of integrated hemispheric Joule heating rates from the AMIE procedure

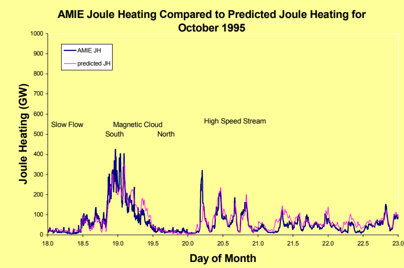


Table 1. Fit Coefficients for Joule Power

Fit Season	Months	Fit Using Absolute Values of PC and Dst	R^2
Annual	Jan-Dec	$JH(GW)=24.89*PC + 3.41*PC^2 +.41*Dst + .0015*Dst^2$	0.76
Winter	21 Oct-20 Feb	$JH(GW)=13.36*PC + 5.08*PC^2 +.47*Dst + .0011*Dst^2$	0.84
Summer	21Apr-20 Aug	$JH(GW)=29.27*PC + 8.18*PC^2 -.04*Dst + .0126*Dst^2$	0.78
Equinox	21Feb-20Apr, 21Aug-20Oct	$JH(GW)=29.14*PC + 2.54*PC^2 +.21*Dst + .0023*Dst^2$	0.74

Power Category:		Particle (GW)	Joule (GW)	Solar (GW)	Total (GW)
Solar Min: 75-77,	Avg	38 (8%)	77 (16%)	359 (76%)	474
83-87, 93-98	St Dev	21	63	46	101
Solar Cycles	Avg	36 (6%)	95 (16%)	464 (78%)	596
21-23	St Dev	24	93	135	190
Solar Max: 78-82,	Avg	35 (5%)	112 (16%)	562 (79%)	710
88-92, 99-03	St Dev	23	111	116	182
Top 5% of	Avg	73 (7%)	331 (30%)	687 (63%)	1090
power events	St Dev	36	226	116	226
Top 1% of	Avg	104 (7%)	638 (45%)	691 (48%)	1433
power events	St Dev	44	306	113	313

Top 15 power events of the last 3 solar cycles

Year	Month/ Day	Particle Pwr (GW)	Joule Pwr (GW)	Solar Pwr (GW)	Total Pwr (GW)	Rank	% Joule Pwr	% Joule + Particle Pwr
1979	25-Apr	152	1154	502	1808	13	64	72
1982	13-Jul	183	900	690	1772	15	51	61
1982	14-Jul	159	2035	739	2932	1	69	75
1982	6-Sep	267	941	609	1817	12	52	66
1989	13-Mar	290	1576	732	2599	2	61	72
1989	21-Oct	147	1059	668	1874	8	56	64
1991	5-Jun	126	1082	717	1924	6	56	63
1992	10-May	162	1484	459	2105	5	71	78
2000	15-Jul	173	1083	652	1909	7	57	66
2000	16-Jul	51	1144	676	1871	9	61	62
2000	12-Aug	129	1040	612	1781	14	58	66
2001	31-Mar	144	878	805	1826	11	48	64
2001	6-Nov	122	1518	754	2394	3	63	74
2003	29-Oct	185	918	760	1863	10	49	59
2003	30-Oct	156	1214	758	2128	4	57	64
	Avg	163	1202	675	2038		59	67

Summary:

Solar wind forcing competes with and at times exceeds solar radiative forcing; thereby adding a significant component of variability to the solar cycle impressed upon the upper atmosphere. When geomagnetic sources are accounted for, the peak upper atmospheric heating events are more extreme than those from solar EUV input only. Further, the solar maxima intervals expand to include broad shoulders of solar wind-driven heating from geomagnetic storms.