

PREDICTIONS OF SOLAR CYCLE 24

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I. PREDICTIONS OF CYCLE 24

Predictions of the magnitude and timing of Cycle 24 are used by a variety of Space Weather groups. It is necessary to have quantitative estimates of the uncertainty of the predictions—in both magnitude and timing. These predictions will help estimate orbital drag and other consequences of Space Weather in solar cycle 24.

The 45 predictions in Table 1 are a combination of personal work, predictions from the refereed literature, and predictions submitted for the Solar Cycle 24 Prediction Panel. The call for predictions was published in several newsletters, including the August, 15, 2006 Solar News. The table is organized by the predicted sunspot maximum and includes the author (listed in the reference list), date, predicted maximum sunspot number (value and date), category of prediction, and a short summary of method. Although F10.7 is used in the atmospheric drag calculations the value of R_z was requested.

The prediction categories were Fun, Precursor, Spectral, Climatology, Recent climatology, Neural network, physics-Based, or other (please specify). The fifth column contains a one-letter abbreviation of the category for each prediction. If the prediction was found during the literature search the category was assigned by the author.

Janssens (2005; 2006) has 11 predictions and was a good check on the coverage of the literature. The group at Lund (<http://www.lund.irf.se/>) also has a prediction page with references but without Cycle 24 numbers derived from their wavelet studies (<http://www.lund.irf.se/rwc/cycle24/>). Their contribution will probably combine wavelet analysis and neural networks. Janssens estimates that Lundstedt will predict low activity ($R_{\max} = 85 \pm 25$) for Cycle 24.

The significance of the difference from the climatological mean can be calculated if an error bar is provided. Defining $R_{\max,ave} = 115$ and $\sigma_0 = 40$ as the climatological mean and standard deviation, created with 23 points. Then the variance of the difference is

$$\sigma_T^2 = (22\sigma_0^2 + \sigma_P^2)/21(1. + 1/23), \quad (1)$$

the t variable is

$$t_{test} = (R_{\max,P} - R_{\max,ave})/\sigma_T, \quad (2)$$

with the number of degrees of freedom (assuming one point in the prediction)

$$n_f = 23 + 1 - 2, \quad (3)$$

the significance of the difference is given by Student's probability distribution function:

$$\text{Pr} = A(t_{test}|n_f). \quad (4)$$

This is plotted in Figure 1.

Table 1: Predictions of Solar Cycle 24

Author and Date		Predicted maximum		Category and Summary	
		R_z	Date		
Horstman	2005	185	2010-2011	C	Projection of last 5 cycles (Johnson SFC)
Thompson	2006	180 ± 32	—	P	
Tsirulnik, <i>et al.</i>	1997	180	2014	S	Modified global minimum analysis
Podladchikova, <i>et al.</i>	2006	152–197	—	P	Integral of sunspot number used as precursor
Dikpati, <i>et al.</i>	2006	155–180	—	B	Modified flux-transport dynamo model calibrated with historical run of sunspot area
Hathaway & Wilson	2006	160 ± 25	—	P	Analysis of aa index
Pesnell	2006	160 ± 54	2010.6	C	Cycle $n + 1 = \text{Cycle } n - 1$
aa_min	2006	148		P	
Maris and Oncica	2006	145	12/2009	N	Neural network forecast
Hathaway, <i>et al.</i>	2004	145 ± 30	2010	P	Fast meridional circulation speed during cycle 22 leads to a strong solar cycle 24
Gholipour, <i>et al.</i>	2005	145	2011-2012	N	Spectral analysis and neuro-fuzzy modeling.
Chopra and Dabas	2006	140	2012.5	P	Disturbed days analysis
modified Feynman	2006	135 ± 20		P	
Kennewell & Patterson	2006	134 ± 50	2011.7	C	Based on average of the last 8 solar cycles
Tritakis <i>et al.</i>	2006	133	2009.5	C	Statistics of $\sqrt{R_z}$
Tlatov	2006	130 ± 15	—	P	Complexity of H α synoptic charts
Nevanlinna	2007	124 ± 30	—	P	Value of aa at solar minimum
Kim, <i>et al.</i>	2004	122 ± 6	11/2010	C	Statistical analysis of cycle parameters
aa_4yr	2006	120 ± 25		P	
Pesnell	2006	120 ± 45	2010.0	C	Cycle $n + 1 = \text{Cycle } n$
Echer, <i>et al.</i>	2004	116 ± 13.2	2012–1013	S	Spectral analysis of R_z
Sello	2006	115 ± 28	2010.5	P	Precursor + nonlinear dynamics
Pesnell	2006	115 ± 40	2011.3	C	Cycle $n + 1 = \bar{n}$
Tlatov	2006	115 ± 15	—	P	Area of high-latitude unipolar regions
Tlatov	2006	115 ± 13	—	P	Large-scale magnetic field, presented at October panel meeting
Prochasta	2006	114 ± 43	—	C	Mean of cycles 1–23.)

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Table 1: (continued)

Author and Date		Predicted maximum		Category and Summary	
		R_z	Date		
de Meyer	2003	110 ± 15	—	S	Transfer function model
Euler and Smith	2006	$110 \frac{196}{49}$	2/2011	C	Modified McNish-Lincoln model (MSAFE)
Hiremath	2007	110 ± 11	2012	S	Autoregressive model
Tlatov	2006	110 ± 10	—	P	Dipole-octupole magnetic moments
Lantos	2006	108 ± 38	2011	C	Skewness of previous cycles separated into even/odd cycles
Kane	1999	105 ± 9	2010-2011	S	Extrapolation of dominant spectral components found by MEM
Pesnell	2006	101 ± 20	2012.5	S	Linear prediction (autoregressive)
Wang, <i>et al.</i>	2002	$83.2 - 119.4$	3/2012	C	Statistical characteristics of solar cycles
Roth	2006	91.9 ± 27.9	1/2011	S	Autoregressive-moving average process
Duhau	2003	87.5 ± 23.5	—	S	Coupling between sunspot maxima and aa minima modulations (wavelet analysis)
Baranovski	2006	80 ± 21	2012	S	Mathematical theory of nonlinear dynamics. Predicts a long cycle lasting 12 years
Schatten	2005	80 ± 30	2012	P	Solar polar field precursor
Choudhuri, <i>et al.</i>	2007	80	—	B	Flux-transport dynamo model
Javariah	2007	74 ± 10	—	P	Statistics of low-latitude sunspot groups
Svalgaard, <i>et al.</i>	2005	70 ± 2	—	P	Polar magnetic field strength at solar minima
Kontor	2006	70 ± 17.5	12/2012	S	Statistical gaussian-based extrapolation
Badalyan, <i>et al.</i>	2001	< 50	2010-2011	P	Statistics of the $\lambda 5303 \text{ \AA}$ coronal line
Clilverd, <i>et al.</i>	2006	42 ± 35	—	C	Atmospheric cosmogenic radiocarbon
Mariş, <i>et al.</i>	2004	low	—	C	Observations of flare energy release during the descending phase of cycle 23 (empirical)

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 Category of prediction: Average Cycle,
 Cycle 24 Prediction details:
- | Cycle parameter | Value |
|-----------------|--------------|
| Start time | 2007.8 ± 0.5 |
| Peak time | 2011.7 ± 1.0 |
| End time | 2018.2 ± 1.5 |
| Peak Value | 134 ± 50 |
- Description of Prediction Technique: The prediction is based on the average of the last 8 solar cycles (Cycles 15 to 23). IPS plans to adjust this average cycle as the new cycle unfolds. To do this, IPS is developing software for manipulating this predicted cycle. The difficulty is ensuring that you are not chasing a short-term variation when making an adjustment to the cycle prediction. Verified 9/24/2006 during construction of this table.
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Table 2: Tlatov's Predictions of the Magnitude of Solar Cycle 24

Index	Name	$R_z(\text{max})$	Comments
Area of high-latitude unipolar regions	Apz(t)	115 ± 15	
Dipole-octupole magnetic moments	A(t)	110 ± 10	
Complexity of H α synoptic charts	K(t)	130 ± 15	
Power of sector structure of the magnetic field	SSPD(t)		Prediction comes one year after minimum
Length of neutral lines	L(t)		Prediction comes after minimum
Declination angle of filaments	P(t)		Prediction comes after minimum
Number of CaII-K bright points at high latitudes	NK		No data after 2002
Large-scale magnetic field		115 ± 13	Presented at October panel meeting
Weighted average		115 ± 7	

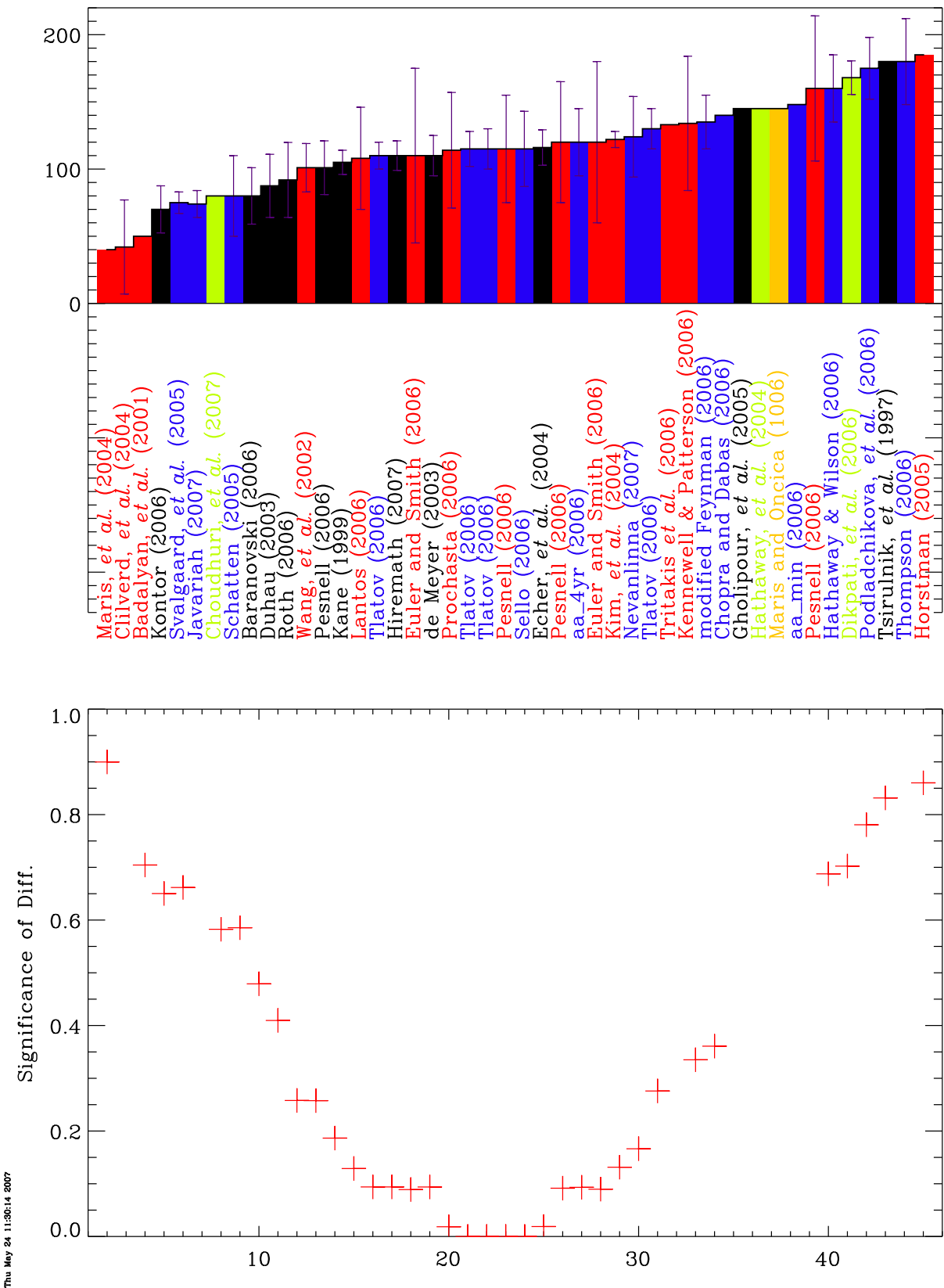


Figure 1: The predictions from Table 1, plotted in order of increasing predicted maximum for Cycle 24. The lower plot is the significance of the difference from the climatological average of 115 ± 40 for those predictions that included an error bar.