ACCURACY ASSESSMENT OF THERMOSPHERIC DENSITY MODELS

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Introduction

The accuracy assessment of the semi-empirical density models:

- Jacchia-Roberts 1971 (JR-71)
- Mass Spectrometer Incoherent Scatter 1986 (MSIS-86)
- Mass Spectrometer Incoherent Scatter Extended 1990 (MSISE-90)
- Thermospheric Density 1988 (TD-88)

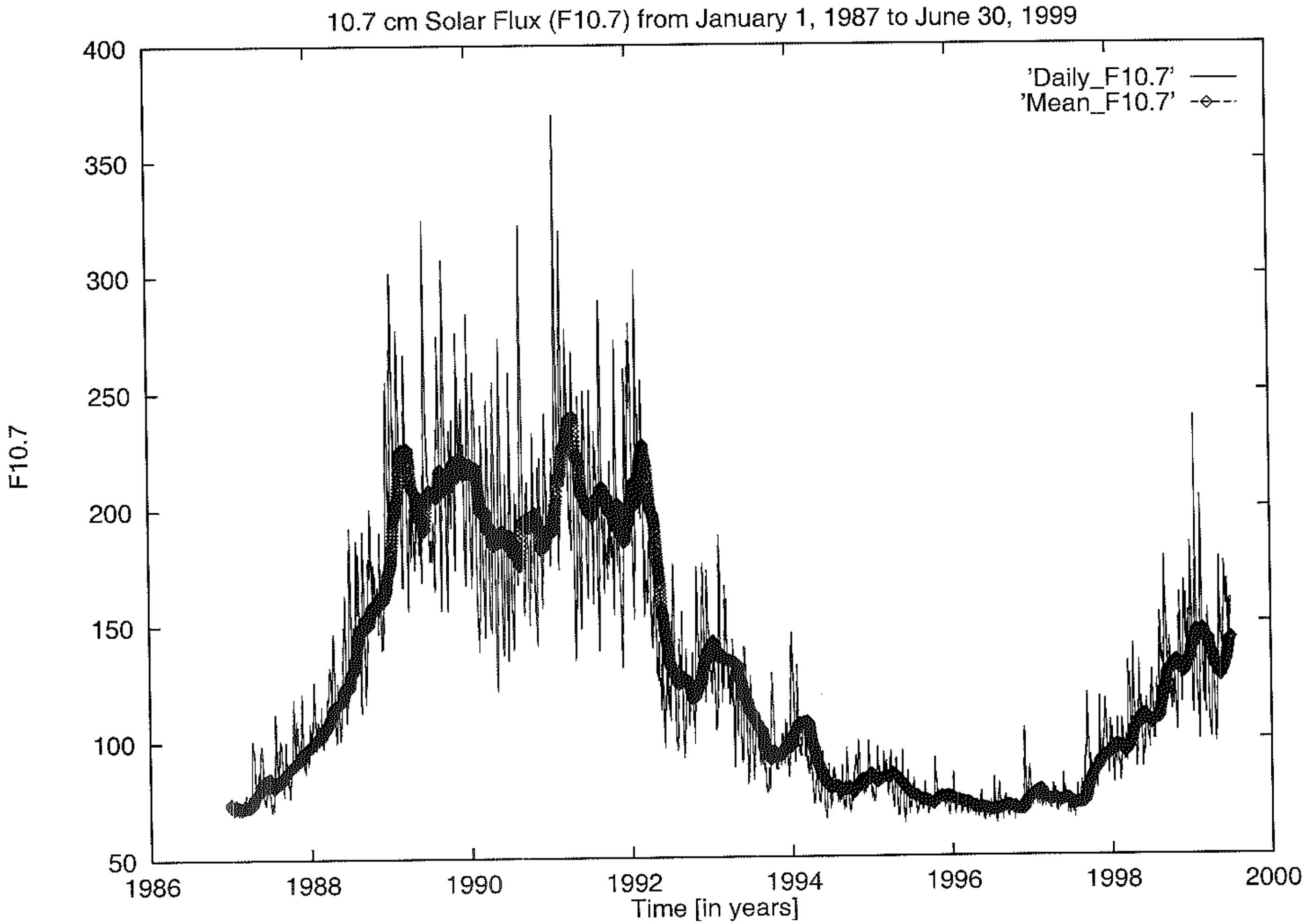
was carried out by analyzing the orbital decay of nine spherical satellites in the 200-1500 km altitude range. The orbital decay data used were distributed over a full solar activity cycle (1987 – 1999).

Satellites

ORBITAL STATE VECTORS CORRESPONDING TO THE FIRST NORAD ELEMENTS SETS USED IN THE ORBITAL DECAY ANALYSIS

SATELLITE NAME	EPOCH yymmdd	hhmmss	SMA [km]	ECC	INC [deg]	RAN [deg]	AP [deg]	MA [deg]	PH [km]	AH [km]
GRIDSPHERE	880425	105609	7204.1	0.00881	87.6	190.0	127.9	233.0	762.5	889.5
AJISAI	880424	024925	7866.9	0.00131	50.0	146.4	34.3	325.7	1478.5	1499.1
STELLA	930928	042027	7176.7	0.00055	98.7	344.3	132.1	227.9	794.7	802.5
ODERACS A	940209	173759	6723.4	0.00080	56.9	188.1	256.6	103.9	339.8	350.6
ODERACS B	940210	162931	6724.7	0.00062	56.9	183.8	254.3	105.6	342.3	350.7
ODERACS E	940211	091627	6726.4	0.00017	56.9	180.7	292.3	67.7	347.1	349.4
ODERACS 2A	950208	100107	6718.9	0.00136	51.6	82.7	354.6	4.3	331.6	349.9
GFZ 1	950420	013725	6767.8	0.00158	51.6	88.8	86.1	274.0	378.9	400.3
STARSHINE	990605	081106	6766.8	0.00103	51.6	257.4	5.5	354.5	381.7	395.7

Solar Activity Conditions



Assessing the Model Accuracy

For each satellite:

- the historical NORAD TLE were processed to obtain the observed time evolution of the mean semi-major axis;
- for each atmospheric density model, a drag coefficient was obtained by fitting the above observed evolution;
- the drag coefficients obtained using the different density models were compared among them and with their theoretical physical values.

Theoretical Physical Drag Coefficients

The theoretical physical drag coefficients of a spherical satellite were found to be:

- Below 400 km: in between 2.07 and 2.40.

- Around 800 km:
  - 2.7-2.8 for low solar activity levels;
  - 2.3-2.4 during high solar activity conditions.

- Around 1500 km:
  - 3.0-3.1 for low solar activity levels;
  - 2.7-2.8 during high solar activity conditions.

Uncertainties of 5% and 15% are assumed below 400 km and above 750 km, respectively.

Results

DIFFERENCES BETWEEN ESTIMATED AND THEORETICAL DRAG COEFFICIENTS

ALTITUDE (KM)	SOLAR ACTIVITY CONDITIONS		
	LOW	MODERATE	HIGH
1500	MSIS-86/90: +62% JR-71: +62% TD-88: N/A		MSIS-86/90: +34% JR-71: +10% TD-88: N/A
750 - 800	MSIS-86/90: +7/+17% JR-71: 0/+9% TD-88: N/A	MSIS-86/90: +6% JR-71: +6% TD-88: N/A	MSIS-86/90: +16% JR-71: −2% TD-88: N/A
350 - 390	MSIS-86/90: 0 JR-71: −4% TD-88: −19%	MSIS-86/90: +15% JR-71: +2% TD-88: −3%	
150 - 350	MSIS-86/90: −11/−19% JR-71: −20/−25% TD-88: −20/−27%	MSIS-86/90: +5% JR-71: +3% TD-88: −11%	

Results

- No model is currently able to accurately compute the atmospheric density at every altitude and solar activity level;
- MSIS-86/90 resulted to be the best models to compute the air density below 400 km, in low solar activity conditions;
- JR-71 was more accurate at greater altitudes and/or solar fluxes;
- TD-88 was reasonably accurate only during periods of moderate solar activity, but was closer, in any case, to the JR-71 results.