Publication of the Department of Astronomy — Beograd, No.16, 1988.

UDC 523 OSP

# MODEL OF THE UPPER TOTAL DENSITY DISTRIBUTION $TD_{88}$

*L. Sehnal*

Observatory Ondřejov, Ondřejov, Czechoslovakia

*Received May 15, 1988*

*Summary.* A model of thermospheric density distribution and variations is presented. Its properties depend on geometrical (height, latitude, local time) as well as physical (solar flux, geomagnetic index) parameters. Fundamental data were taken mostly from model DTM and partially from observations. The model is especially designed to serve the studies of the artificial satellite dynamic studies.

*L. Sehnal,* MODEL TOTALNE GUSTINE VISOKE ATMOSFERE $TD_{88}$ Dobijen je model raspodele gustine termosfere. Osnovni podaci su uglavnom uzeti iz modela DTM, a delom iz posmatranja. Karakteriše ga zavisnost od geometrijskih i fizičkih parametara.

## 1. INTRODUCTION

Analytical computation of drag effects requires a good knowledge of the upper atmosphere distribution. On the other side, the necessity of analytically tractable formulas contradict the demands of a high accuracy. As a result, the motion of an artificial satellite is described well just within one revolution where the density at perigee is supposed to be constant and well defined by thermospheric models.

The model TD, published in 1986 (Sehnal and Pospišilova, 1986), enables the analytical integration of the equation of motion over one revolution; then, the resulting equations giving the increments of the orbital elements are functions of the parameters defining the state of the atmosphere - without the necessary knowledge of the density at perigee.

The prove of the possibility of an analytical determination of the satellite's orbital changes was made by Y. E. Helali (1987) and especially by S. Šegan (1987).

However, the whole theory suffers an insufficiency of the definition range of the original TD thermospheric model. The new model $TD_{88}$ is well defined within the height range of 150-750 km height over the oblate Earth. It was 200-500 with the old TD. The range in solar activity given by the $F_{10.7}$ cm index is (60-220) and geomagnetic index can vary within (0-10).

The accuracy assesment of the $TD_{88}$ model was cheked by the determination of the average deviation from the model DTM (Barlier et al., 1977). The density values were computed at constant heights from 20000 randomly chosen sets of parameters. Fig.1 shows the average deviations in case of the present $TD_{88}$ and the "old" TD as well.

## 2. MATHEMATICAL FORMULATION

The model formulation expresses the density distribution on a specific surface of a constant altitude (over an oblate Earth) by seven additive terms. Each term has its own height dependence given by a series of exponential functions.

Solar and geomagnetic effects are characterized by general multiplicative factors and moreover, the individual terms contain special factors depending on mean solar flux. The terms describe:

1. the average density,
2. the individual mean solar flux dependence,
3. the north-south assymetry,
4. the annual and
5. the semiannual variations,
6. the diurnal and
7. the semidiurnal changes. The density $\rho$ is described by the expression

$$\rho = k_0 f_0 f_x \sum_{n=1}^{7} h_n g_n. \tag{1}$$

There is

$$f_x = 1 + a_1(F_x - F_b),$$

$$f_0 = a_2 + f_m,$$

$$k_0 = 1 + a_3(K_p - 3),$$

and

$$f_m = \frac{F_b - 60}{160},$$

The height dependence is described by the $h_n$ terms,

$$h_n = K_{n0} + \sum_{j=1}^{3} K_{nj} e^{\frac{(120-h)}{2^{3j}}}.$$

Functions $g_n$ are given by:

$g_1 = 1$,
$g_2 = \frac{f_m}{2} + a_4$,
$g_3 = \sin(d - p_3)\sin\varphi$,
$g_4 = (a_5 f_m + 1)\sin(d - p_4)$ ,
$g_5 = (a_6 f_m + 1)\sin 2(d - p_5)$,
$g_6 = (a_7 f_m + 1)\sin(t - p_6)\cos\varphi$,
$g_7 = (a_8 f_m + 1)\sin 2(t - p_7)\cos^2\varphi$. The simbols used are:
$K_{n,j}$–numerical constants, Table 1,
$p_n$–phases, Table 2,
$a_i$–numerical constants, Table 3,
$F_x$ - solar flux measured on 10.7 cm, for day-1,
$F_b$ - solar flux averaged over three solar rotations,
$K_p$ - geomagnetic $K_p$ index 3 hours before local time,
$h$–altitude in $km$,
$d$–day count in the year,
$\varphi$–latitude,
$t$–local time.
Numerical constants are summarized in the following tables:

Table **T1**: CONSTANTS $K_{n,j}$

| $n$ | $j=0$ | 1 | 2 | 3 |
|---|---|---|---|---|
| 1 | 2.96815E-15 | 7.66373E-09 | 1.65738E-10 | 3.87086E-11 |
| 2 | 2.81456E-14 | -4.40149E-9 | 3.34283E-10 | 9.35229E-11 |
| 3 | -1.23300E-14 | 1.18107E-10 | -1.47817E-10 | -1.51755E-12 |
| 4 | -1.14892E-17 | -1.59664E-11 | -6.46708E-12 | -2.04955E-12 |
| 5 | -39.00645E-17 | -24.07553E-11 | -13.98567E-11 | -30.59493E-13 |
| 6 | 7.42439E-15 | 6.43785E-11 | 1.36185E-10 | 3.51700E-11 |
| 7 | -3.41594E-16 | 7.44666E-12 | 4.54160E-12 | 2.07975E-12 |

Table **T2**: PHASES $p_n$

| $n$ | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|
| $p_n$ | 263 | -263 | -29.41 | 8.0913 | 10.0813 |

Table T3: CONSTANTS $a_i$

| $i$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| $a_i$ | 0.007 | 0.2875 | 0.04762 | 0.0471 | 7.0 | 7.0 | 0.3333 | 15.0 |

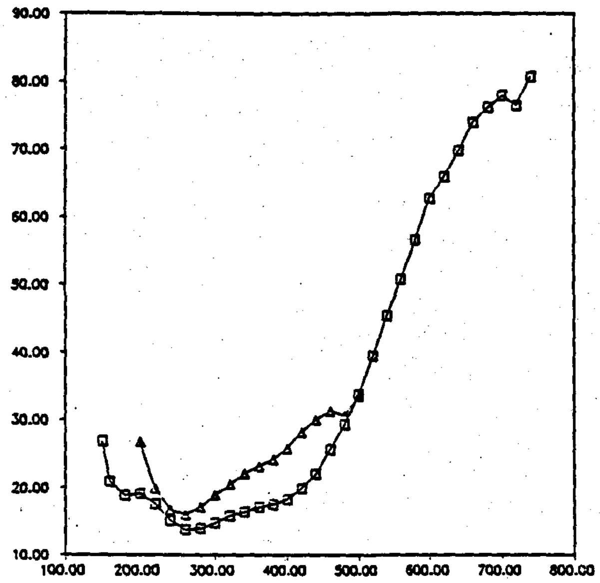


*Fig. 1* Changes of total density with height; Δ–old model , ◇–new model.

This work is part of the research project supported by the Fund for Scientific Research of the S. R. Srbia.

R E F E R E N C E S

Barlier, F., Berger C., Falin J. L., Kockarts G., Thullier G.: 1977, *Ann. Geophys.*, **34**, 1, 9.

Helali, Y. E.: 1987, *Bull. Astr. Inst.Czech.*, **38**, 6, 329.

Sehnal, L.: 1986, *Adv. in Space Res.*, **7**, 10, 203.

Sehnal, L.: 1986, *Bull. Astr. Inst.Czech.*, preprint, 41.

Šegan, S.: 1987, *Pub. Dept. Astron.*, **15**, 5.