16th IAA SYMPOSIUM ON SPACE DEBRIS (A6)
Orbit Determination and Propagation (9)

Author: Mr. Changyong HE
RMIT University (Royal Melbourne Institute of Technology), Australia, changy.he@gmail.com

Dr. Yang Yang
RMIT University (Royal Melbourne Institute of Technology), Australia, yiyinfeixiong@gmail.com
Dr. Brett Carter
RMIT University, Australia, brett.carter@rmit.edu.au
Dr. Haibing Ruan
University of Science and Technology of China, China, rhb@ustc.edu.cn
Dr. Florent Deleflie
Observatoire de Paris, France, florent.deleflie@obspm.fr
Prof. Jiuhou Lei
University of Science and Technology of China, China, leijh@ustc.edu.cn
Prof. Kefei Zhang
RMIT University, Australia, Australia, kefei.zhang@rmit.edu.au

IMPACT OF VARIATIONS IN THERMOSPHERIC MASS DENSITY ON THE ORBIT PROPAGATION OF LOW EARTH ORBIT SATELLITES

Abstract

Thermospheric mass density (TMD) contains complicated and non-linear temporal and spatial variations caused by external forcing (e.g., solar and geomagnetic activities) and internal forcing (thermosphere-ionosphere coupling). With the help of an increasing number of TMD estimates from the low Earth orbit (LEO) satellites, more TMD variations have been recognised and quantified in space physics and upper atmosphere studies. Whilst the quantitative impact of these variations on the orbit propagation (OP) for LEO objects is still unknown. The present study will identify the impact of different TMD variations on the orbital dynamics for LEO targets and hence help to further improve the performance of OP-oriented empirical TMD models.

Comparative simulation of OP is carried out with or without different TMD variations in Table 1 such as temporal (annual, semi-annual, solar cycles, solar rotation, storm time, etc.) and spatial variations (latitudinal and longitudinal variations). The equatorial mass density anomaly (EMA) is a two-cell structure, peaking at mid-latitudes and having a trough near the equator. The midnight density maximum (MDM) refers to the density maximum near the equator at midnight. These two variations are good examples which can be observed by LEO satellites and may have observable impact on LEO dynamics. Their mechanisms have been well-investigated and can be simulated by the physical atmospheric model, e.g., Thermosphere Ionosphere Electrodynamics General Circulation Model (TIEGCM). The other variations are simulated by the empirical model, i.e., NRLMSISE00. Note that all of the aforementioned variations are not strictly grouped by tempo-spatial variability since many of them (e.g., the EMA and MDM) are featured in both time and space. The difference between the predicted orbit of LEO satellites is presented and reveals the impact of these TMD variations on the orbital dynamics in LEO. Some recommendations for the TMD modelling are also formulated.

	Magnitude(%)	Time/Period	Latitude(°)
Annual	5–35	all	all
Semi-annual	5–25	all	all
Solar cycle	20–100	11 yrs	all
Solar rotation	0–5	27 days	all
Storms	up to 100	hourly	all
Latitudinal	20–40	all	all
Longitudinal	0–10	all	all
MDM	20–30	local summer (23–01 LT)	$[-10, 10]$
EMA	1–6	10–20 LT	$[-40, 40]$

Table 1: Variations in TMD at 200–800 km (MDM: midnight density maximum; EMA: equatorial mass density anomaly).