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Atmospheric Drag Perturbation On Weather Satellite At Two Different Geomagnetic Fields Conditions

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Abstract. *This study analyzes the effect of atmospheric drag perturbation at two different magnetic index A_P (active and severe storm) conditions, on the motion of NOAA 15 weather satellite, the Celestial Mechanics software results were plotted with the assistance of the MATLAB program. From the results it is noticed that for short period of time the effect of atmospheric suppression disturbance at different geomagnetic activity had the same effect on the orbital elements and orbital motion components , for a long period there is a slight variation in the effect of the perturbation at two different geomagnetic activities, which can be seen in the orbit's inclination as well as its size and shape. The results demonstrated that motion components were significantly impacted by geomagnetic activity over relatively extended time scales.*

Keywords: *perturbations, orbital elements, atmospheric drag, Geomagnetic index, celestial mechanics*

Introduction :

Noaa15 Weather satellite developed to improve Weather, Ocean, and Environmental prediction by delivering more precise data, real time photographs and better monitoring of solar activity and space weather [1].And monitoring the locations of groundwater [2]. Noaa15 Weather satellite like other types of satellite has sixth orbital elements (semi major axis, inclination, eccentricity, ascending node, argument of perigee, mean anomaly), these elements effected by atmospheric drag perturbation which is an atmospheric force that acts in opposition to an object's relative motion. If a satellite's orbit is low enough, the force of Earth's atmosphere will affect it, which could slow down the satellite's speed [3, 4]. Magnetic lenses design that has remote sensing feature such as the satellite has a role in collection , accuracy and analysis of information [5]. In this study, atmospheric drag perturbation's impact on weather orbital components at two different geomagnetic fields was taken, while the geomagnetic field is the magnetic field that surrounds the earth, as the earth rotates around itself, large electrical currents will rise as a result of the presence of metal that prevent iron or nickel or cooper in the core of earth , thus, a magnetic field is created . The lines of this field are vertical in the

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north and south pole and flow into the magnetic south pole, its intensity and density at the poles are twice what it is at the equator [6,7], and it is approximately (62,000) at the poles and (24,000) at the equator, and the geomagnetic field reverses its direction every (70,000) years as the poles flip, meaning that the hemisphere the northern hemisphere of the earth will be the magnetic north, and the southern hemisphere of the earth will be the magnetic south. In another (70,000) years it will turn again and be as it was, and the magnetic field will show through changing geomagnetic parameters many changes that causes it to be affected by solar activity. This terrestrial magnetism controls a large area surrounding the earth's atmosphere and is above ionosphere and is called the magnetosphere. This region surrounds astronomical bodies just as it does on Earth [8]. The magnetosphere is sometimes called magnetic specification, and this phenomenon occurs because of the intense heat in the sun's atmosphere that leads to the formation of plasma, which is gas. Which contains charged atoms, mostly electrons and protons, and this solar plasma flows radially through space at high speed, pulling the solar magnetic field with it. The electrified atoms and the solar magnetic field that pull them together along its length is called the solar wind, as it reaches the Earth in 2 to 3 days. The diameter of the Earth pulls the dark outer side of the magnetosphere to perhaps thousands of times the radius of the Earth, which is the tail of the magnetosphere. This interrelation between the Earth's magnetic field and solar activity through the magnetosphere layer is known as global geomagnetic coefficients (A_P)[9]. The large short-term increases in upper atmosphere temperature and density can be produced by the solar wind and Earth's magnetic field during geomagnetic storms, which can alter satellite orbits and increase drag on satellites. Long-term changes in upper atmospheric temperature and density are caused by the solar cycle. causing perturbations to the orbital elements [10]. Damages can be caused from exposure or using ionizing rays [11]. Perturbations are deviation from a normal, idealized, or unperturbed motion [12]. The main goal in this study is to analyzes the effect of atmospheric drag perturbation on the motion of weather satellite (NOAA 15) at two different conditions of geomagnetic fields (active and severe conditions) , To determine the extent of variations in the satellite's movement under the influence of atmospheric perturbation under both of the mentioned.

Theoretical Foundation :

1- Atmospheric drag perturbation

A force applied to an object flowing through a fluid that is directed toward the relative fluid flow is called drag. Drag tends to slow an object down by acting in the opposite direction of its motion. Consider running against a strong wind as an example, and feeling

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the drag push you back in the direction of relative fluid flow. Both spacecraft and objects in flight experience the same force. Spacecraft in low Earth orbit (LEO), which is generally defined as an orbit below an altitude of about 2,000 kilometers, are significantly affected by drag. The air resistance in the layers of the atmosphere where satellites in low Earth orbit travel is still strong enough to create drags and pull them closer to the Earth, even though the air density there is far lower than it is near the surface.

When the Sun is active, satellites experience an increase in drag force. Low-density air layers at LEO altitudes rise and are replaced by higher-density air layers that were previously at lower altitudes when the Sun adds more energy to the atmosphere. The spacecraft now travels through the layer of increased density and encounters a greater drag force as a result. Satellites in low Earth orbit (LEO) must raise their orbits roughly four times a year to compensate for atmospheric drag when the Sun is quiet. During the 11-year solar cycle, when solar activity is at its peak, satellites may need to be repositioned every two to three weeks in order to stay in orbit [13]. The increase in atmospheric density seen as a satellite (the black diamond) passes through at 400 km altitude on May 15, 2005, during the occurrence of a significant magnetic storm. The Kg/m3 value for atmospheric density is provided. The satellite will eventually come into closer proximity to denser air as the magnetic storm intensifies, which is expected to occur at approximately 06:00 Universal Time. The atmospheric density gradually returns to the quiet conditions as the storm moves out [14].

2. Perturbation Equations

The perturbation equations is clarified by the following equations [15]:

$$\begin{aligned}
\dot{a} &= \sqrt{\frac{p}{\mu}}\frac{2a}{1-e^2}\left\{e\sin\,vR' + \frac{p}{r}S'\right\}\\
\dot{e} &= \sqrt{\frac{p}{\mu}}\{\sin\,vR' + (\cos\,v + \cos\,E)S'\}\\
\dot{T}_0 &= -\frac{1-e^2}{n^2ae}\left\{\left(\cos\,v - 2e\frac{r}{p}\right)R' - \left(1+\frac{r}{p}\right)\sin\,vS'\right\} - \frac{3}{2a}(t-T_0)\dot{a}\\
\frac{di}{dt} &= \frac{r\cos\,u}{na^2\sqrt{1-e^2}}W'\\
\dot{\Omega} &= \frac{r\sin\,u}{na^2\sqrt{1-e^2}\sin\,i}W'\\
\dot{\omega} &= \frac{1}{e}\sqrt{\frac{p}{\mu}}\left\{-\cos vR' + \left(1+\frac{r}{p}\right)\sin vS'\right\} - \cos i\,\dot{\Omega}
\end{aligned} \tag{1}$$

$$\sigma_0 \overset{\text{def}}{=} n\,(t_0 - T_0) \quad (2)$$

$$\dot{\sigma}_0 = \frac{1-e^2}{nae}\{(\cos\nu - 2e\frac{r}{p})R' - (1+\frac{r}{p})\sin\nu S'\} + \frac{3n}{2a}(t-t_0)\,\dot{a} \quad (3)$$

breaking down the perturbing acceleration into three parts: the out-of-plane component W' normal to the orbital plane, the radial component R', and the component S' normal to R' in the orbital plane (pointing roughly in the direction of motion). T_0:The gradients of the time of pericenter passage, And ν: true anomaly ,

E: the eccentric anomaly, The semiparameter,

u : the argument of latitude of the celestial body considered , where :

$$u = \omega + \nu \quad (4) \quad [15].$$

3. Geomagnetic Indices

The magnetic field coefficient shows many changes due to its influence on solar activity. Geomagnetic describes the change in the earth's magnetic field over a specific period of time. Among these coefficients is the coefficient A_P, Which is an indicator of the occurrence of global magnetic activity, or A_p, which is an indicator of local magnetic activity, as the intensity of geomagnetic storms is measured through this coefficient. The coefficient A_p is linear indicator extracted eight times per day, i.e. its value is taken every three hours from magnetic stations near the western Hemisphere at mid or high latitudes. As for geomagnetic activity, it represents natural variations in the geomagnetic field as a result of magnetic storms. In this study two geomagnetic field conditions were taken active and severe storm conditions the magnitudes of index given in table (1)[16].

Table (1) represents the classification of the level of magnetic storms according to Geomagnetic index (2004)[16].

A_p Index	Geomagnetic field conditions
6-9	**Quiet**
12-18	**Unsettled**
22-32	**Active**
39-56	**Manor Storm**
67-94	**Major Storm**
111-154	**Severe Storm**
179-236	**Severe Storm**

The earth's geomagnetic is a vector quantity, it has a magnitude and direction, as it is symbolized by the vector (B). It consists of two components, the horizontal component (H), which is a vector quantity that makes an angle with the magnetic north, symbolized by (D), the declination angle, and the vertical component (Z), which is directed downward. Accordingly, the geomagnetic total field of a given point equals:

$$\sqrt{B = H^2 + Z^2} \quad (5)$$

$$\sqrt{B = X^2 + Y^2 + Z^2}^{\,2} \quad (6)$$

X = H cos D (7)

Y= H sin D (8)

H= B cos I (9)

Z= B sin I (10)

Tan I = Z/H (11)

Tan D = Y/X (12)

Where I : deep angle. [17]

Results and Discussion

Of course, these fundamental truths are used by space agencies that operate artificial Earth satellites. The semi-major axis of a spacecraft must be changed by maneuvers that requires thrusts in the tangential (along-track) direction.

A (more or less) constant perturbing force in an atmospheric drag on a man-made Earth satellite in a circular orbit would be along-track direction. It opposes the motion of the satellite, which causes the semi-major axis to shrink and finally causes the satellite to decay.

As a result, in this study, the study has been done for the atmospheric perturbation on a NOAA 15 (formerly known as NOAA-K), one of NOAA's TIROS series of weather forecasting satellites that NASA provides. The satellite is positioned 807 kilometers above the earth in a sun-synchronous orbit. 98.6° of inclination, 818.7 km of apogee, 803.2 km of perigee, and 7174 km of semimajor axis.

In this study, the celestial mechanics program is employed to ascertain the impacts of atmospheric medication on NOAA 15 under two geomagnetic field conditions: active condition with magnetic index Ap = (22–32) and severe condition with magnetic index A_p = (111–154). The results of the perturbation on the satellite's components are plotted in Figures 1 through 10 using MATLAB 2014b.

the first comprising equations defining the orbital motion's semi-major axis (which defines size), eccentricity (which defines shape), and time of pericenter passage (which defines dynamics), by substituting the mean anomaly relating to the beginning epoch to , the researches provide one choice for the time of pericenter.

the second, which consists of the three Eulerian angles (i, ω, and Ω) and defines the orbital plane and the orientation of the conic section within the orbital plane.

Figure (1 – 3) represents the perturbation effects for one day seems like a rather short time interval corresponds to 16 revolutions. It is noted from the results that the effect of atmospheric suppression disturbance at different geomagnetic activity had the same effect on the orbital elements and in the coordinates of initial osculating Keplerian orbits. In the figures (4 – 6), it was noted that there is a slight variation in the effect of the perturbation at two different geomagnetic activities on the size, the shape and inclination elements when taking its effect over a rather long period of time. While observing that mean anomaly, one of the crucial components that creates the dynamics of motion, is where this effect is most noticeable. Studying Figure 6 revealed that the geomagnetic activities had a considerable impact on these components over relatively long-time scales, representing the change in the components of difference with respect to the initial osculating Keplerian orbit elements.

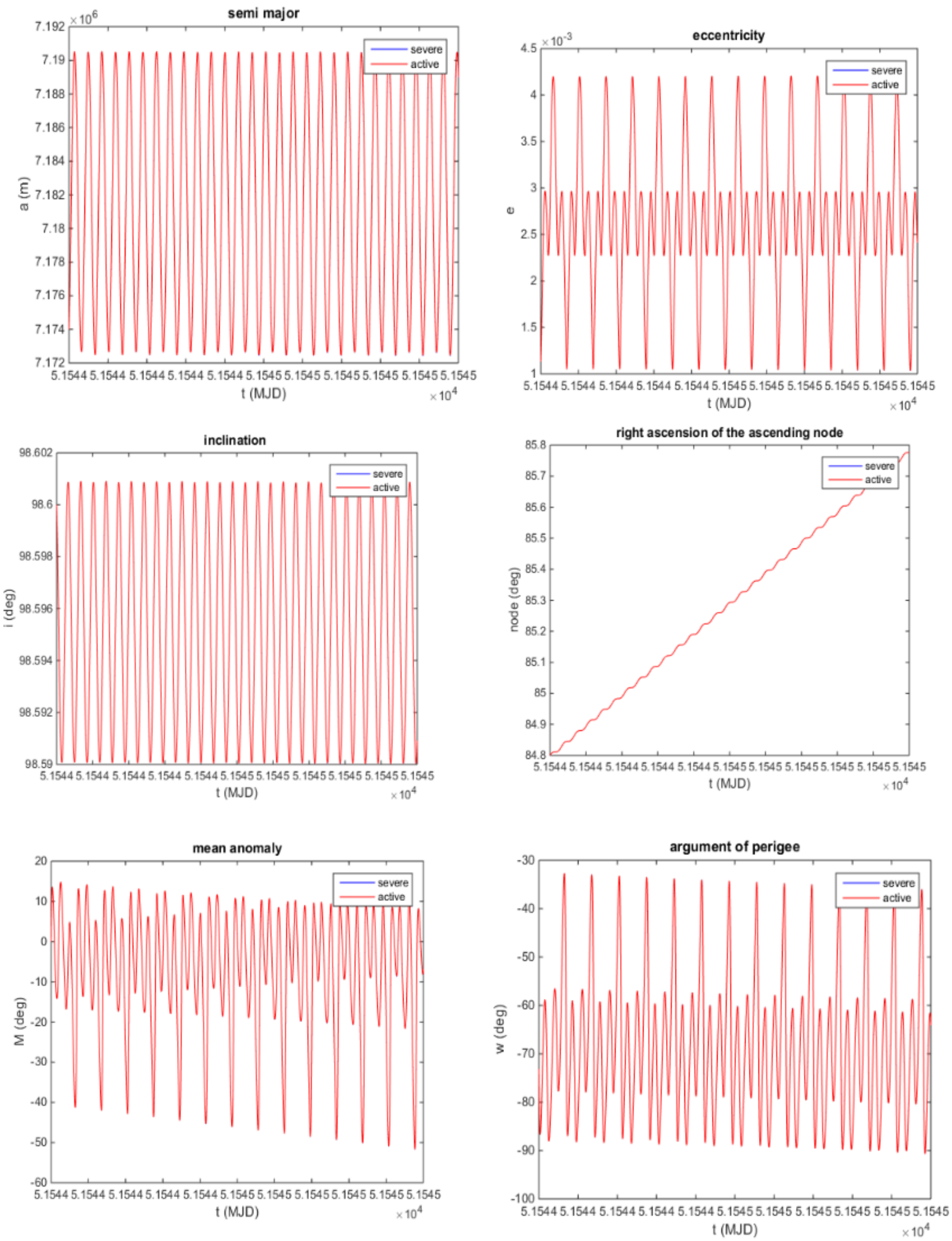
Additionally, the study looks at the effects of atmospheric disturbance over the course of a whole year and provids the satellite a long amount of time with nearly 6,000 revolutions. Figure 7 indicates the significant differences in major axis and mean anomaly at two different geomagnetic conditions.

Figure 8 demonstrates the variance in the components of radial acceleration. As seen in figure 9, different magnetic index values have varied effects on the radial and along track components of difference with respect to initial oscillating Keplerian orbits.

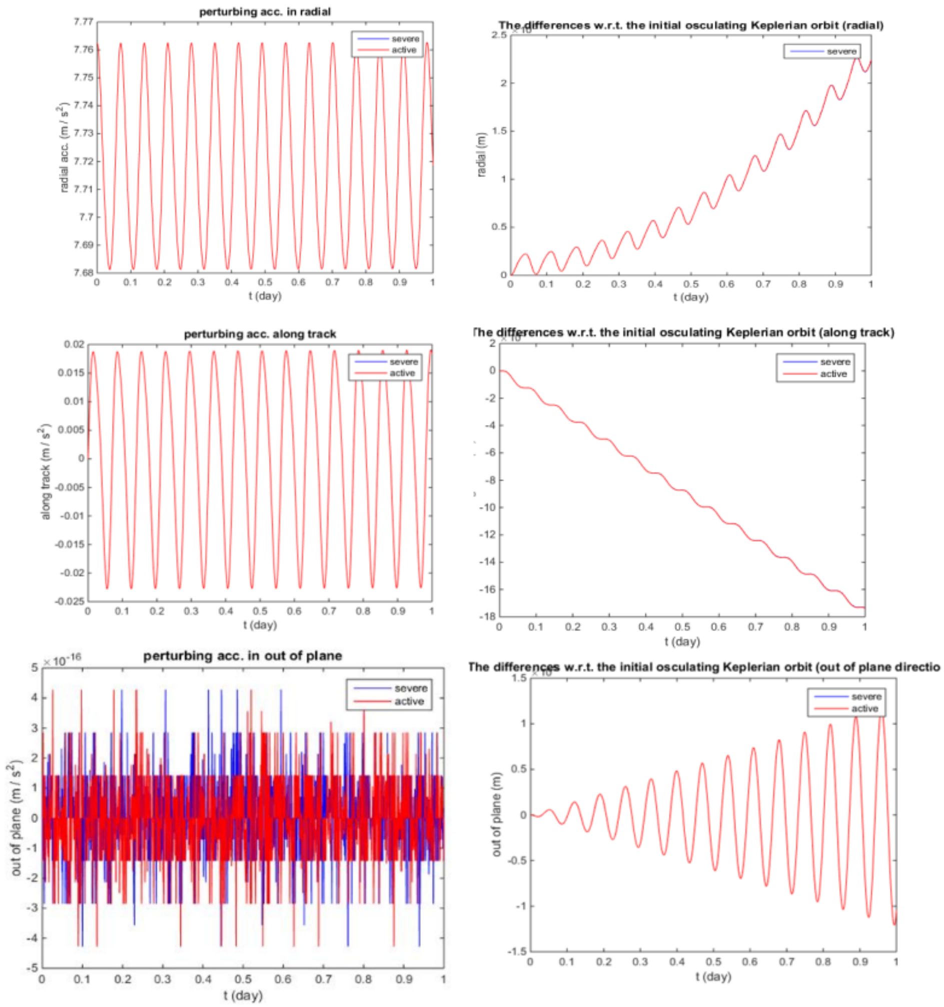
Conclusion:

The study of atmospheric perturbation over the low orbit satellites is of great importance in celestial mechanics due to the great influence of the orbit of these satellites by the geomagnetic activity of the atmosphere.

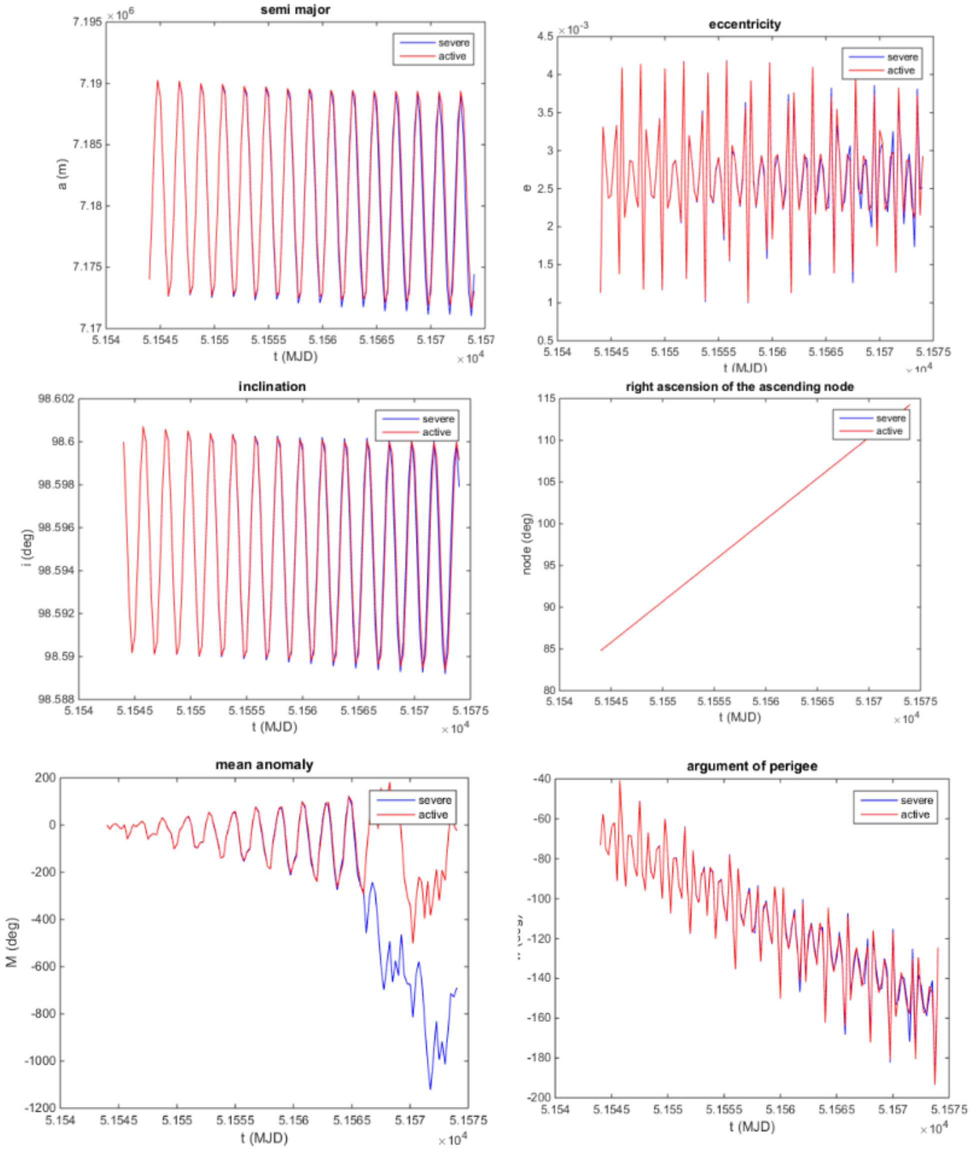
After analyzing the data, it became clear that the influence of the drug perturbation on the satellites occurs over long periods of time, and that due to the more revolutions a satellite makes while in orbit, the more affected it is, the amount of time the satellite spends in orbit and the geomagnetic activity of the atmosphere



both directly correlate to a satellite's susceptibility to perturbation.


perturbing acc. in radial
radial acc. (m / s^2)
t (day)
severe
active
The differences w.r.t. the initial osculating Keplerian orbit (radial)
radial (m)
perturbing acc. along track
along track (m / s^2)
The differences w.r.t. the initial osculating Keplerian orbit (along track)
perturbing acc. in out of plane
out of plane (m / s^2)
The differences w.r.t. the initial osculating Keplerian orbit (out of plane directio
out of plane (m)

Fig(1) orbital elements for NOAA 15 satellite under atmospheric perturbation in two solar condition (active and severe storm solar condition



Fig(4) orbital elements for NOAA 15 satellite under atmospheric perturbation in two solar condition (active and severe storm solar condition for 30 days

Figure (2) acceleration component for NOAA for one day

Figure (3) the difference w.r.t. the initial osculating Keplerian orbit for one day

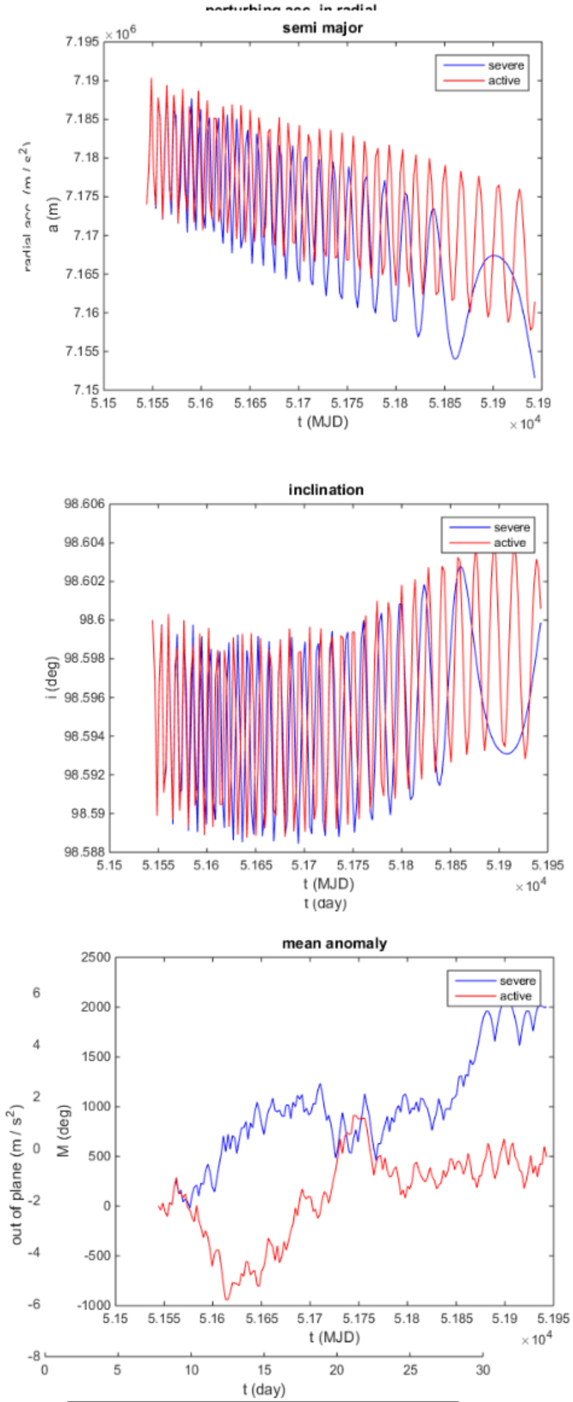


Figure (5) acceleration component for NOAA for 30 days

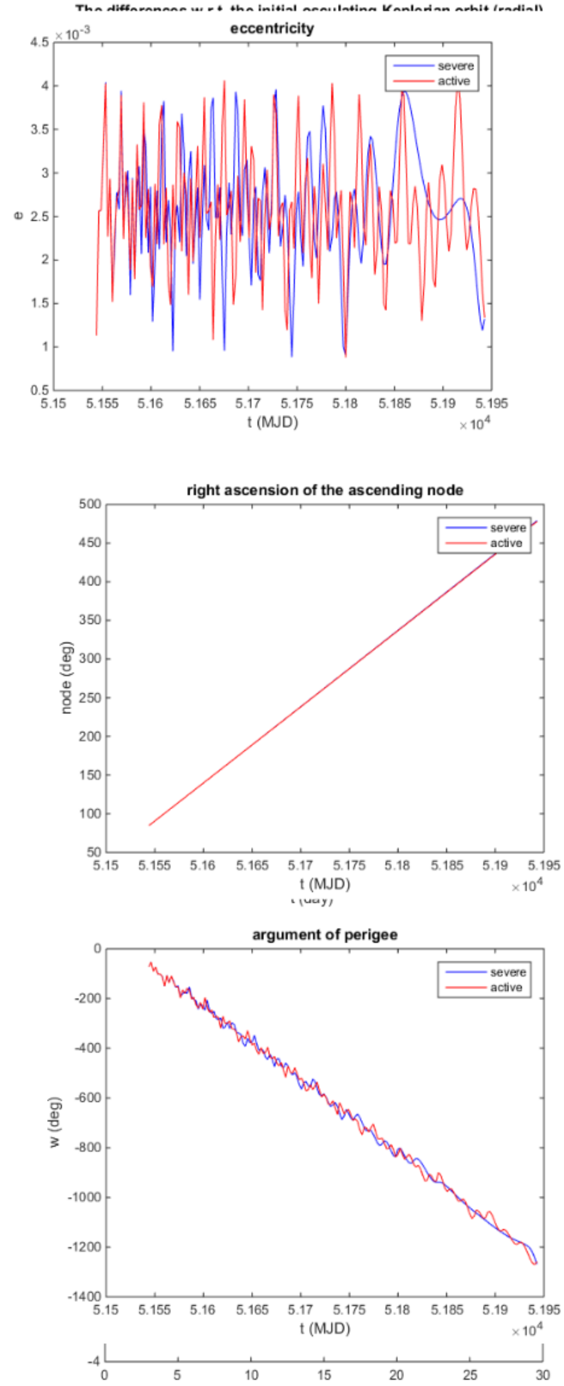


Figure (6) the difference w.r.t. the initial osculating Keplerian orbit for 30 days

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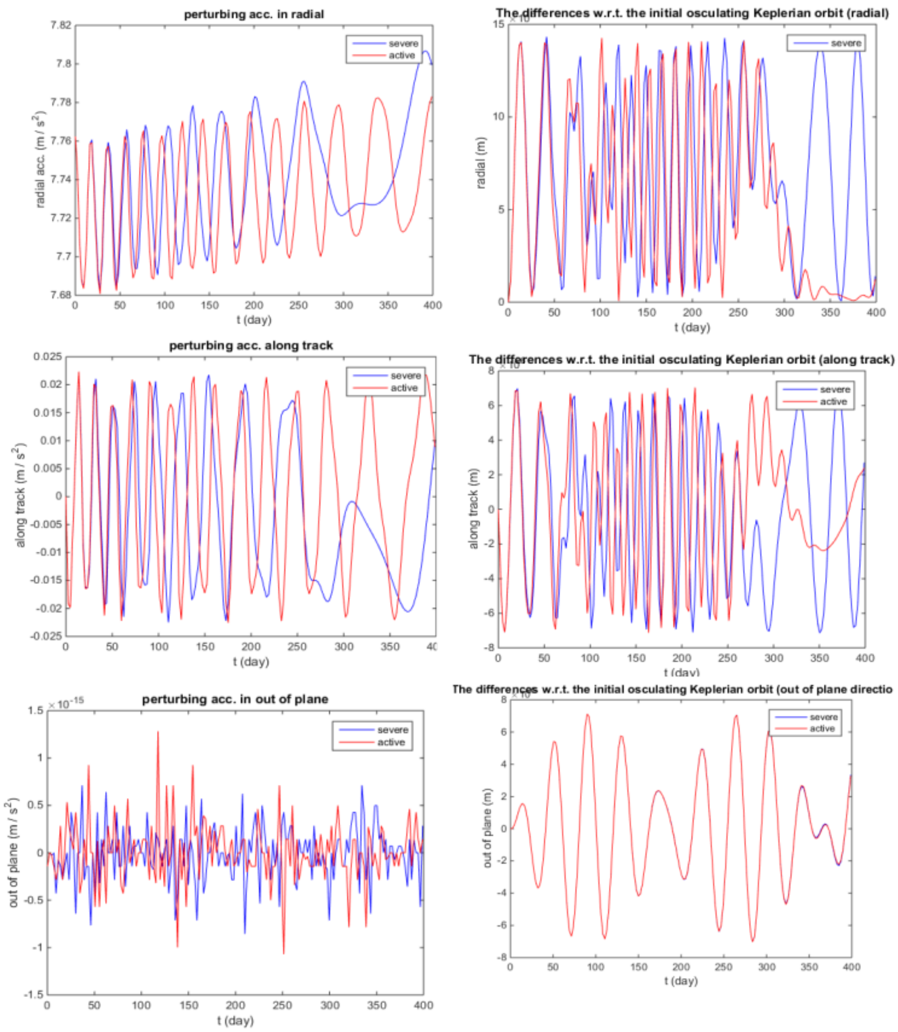
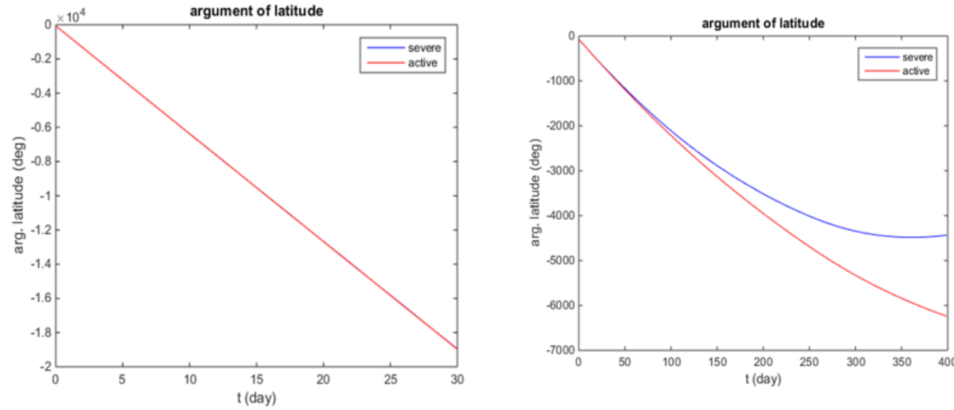
Fig(7) orb



ital elements for NOAA 15 satellite under atmospheric perturbation in two solar condition (active and severe storm solar condition for 400 days

Figure (10) argument of latitude for NOAA 15 under the perturbation at two different geomagnetic conditions for 30 and 400 days in



References

Abdel Rahman, M. F. (2004). The effect of solar disturbance on communications in the city of Baghdad (Master's thesis). University of Baghdad.

Al-Gburi, M. R., & Al-Tamimi, O. S. (2023). Groundwater risk mapping model using GIS of Al-Khassa upstream sub-basin, Kirkuk, Iraq. *Iraqi Geological Journal*, *56*(IE), 131-141.

Ali, R. S., & Hussein, M. A. (2023). Optimizing the effectiveness of magnetic lenses by utilizing the Electron Optical Design (EOD) software. *Engineering, Technology & Applied Science Research, 13*(6), 11980-11984.

Al-Sawad, A., Zaki, W. H. A., & Kareem, M. N. (2022). Third body perturbation effect on Low Earth Orbit Satellite (GEOS-17). *NeuroQuantology, 20*(4), 318-324.

Al-Ubaidi, N. M. R. (2003). The accuracy of ionospheric models with ionosonde observation for Iraq (PhD thesis). Baghdad University.

Beutler, G. (2005). *Methods of celestial mechanics, Volume 1*. Springer-Verlag Berlin Heidelberg.

Figure (8) acceleration component for NOAA for 400 days

Figure (9) the difference w.r.t. the initial osculating Keplerian orbit for 400 days

Bhatnagar, V. P., & Mitra, A. P. (1966, March). An upper atmospheric model for solar minimum conditions. *Journal of the Atmospheric Sciences, 23*(2), 233-244.

Codrescu, M. V., Negrea, C., Fedrizzi, M., FullerRowell, T. J., Dobin, A., Jakowsky, N., ... Maruyama, N. (2012). A real-time run of the coupled thermosphere ionosphere plasmasphere electrodynamics (CTIPe) model. *Space Weather, 10*, S02001. https://doi.org/10.1029/2011SW000736

Garovilano, A. K., & Fobes, J. M. (1983). Solar-terrestrial physics. Reidal Publishing Company.

Hasan, N. O., Zaki, W. H. A., & Izzet, A. K. (2021). The effect of atmospheric drag force on the elements of low Earth orbital satellite at minimum solar activity. *NeuroQuantology, 19*(9), 24-37.

Izzet, A. K., Hamwdi, M. J., & Jasim, A. T. (2022). Analytical study on Low Orbits Satellites. *Iraqi Journal of Science, 61*(2), 453-461.

Karim, L. M., Zaki, W. H. A., & Hasan, N. O. (2010). The effect of sunspot cycle (23) on the earth's magnetic field over Iraq. *Journal of College of Education, 1*(3), 1-2011.

Mohammed, H. M., & Al-Jumaily, H. A. (2023, December). Geochemical and environmental evaluation of the copper element in the surface soil and its health effects in selected areas of Kirkuk Governorate. *IOP Conference Series: Earth and Environmental Science, 1262*(8), 082050.

NASA Earth Observatory. (n.d.). *Achieving and maintaining orbit*. Retrieved from https://earthobservatory.nasa.gov/features/OrbitsCatalog

Taqi, A. H., Ghalib, A. M., & Mohammed, S. I. (2022). Shielding properties of glass containing Li2O, K2O, Na2O, PbO and B2O3 by Geant 4, XCOM and experimental data. *Jordan Journal of Physics, 15*(4), 331-341.

Vampola, A. K. (2000). Electron drift echoes in inner magnetosphere. *Geophysical Research Letters, 27*(7), 915-918.

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