Analysis of Density Perturbations in Relation to Solar X-flare Events Isolated from Coronal Mass Ejections

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ABSTRACT

The purpose of this work is to explore the impact of isolated solar flare events on the density of the ionosphere, at an altitude of ~500km, through the use of GRACE and CHAMP satellites. The study shows that the disturbances on the order of a 200% increase can be reached considering X-flares isolated from other geomagnetic activity. The flare events of December 5-6th 2006 are shown, with the results from simulation showing orbit effects on high- and GRACE-like- area-to-mass-ratio (AMR) objects.

INTRODUCTION

Investigating the effects of solar flares without the influence of coronal mass ejections (CMEs) is important to because of the time-scale at which they perturb the Earth's atmosphere – reaching the Earth within minutes of eruption on the Sun. CMEs, however, will impact the Earth up to a few days after their initial eruption. With the increasing amount of space debris populating orbits around Earth, it is crucial to develop accurate models of the Earth's atmosphere. This includes the perturbations to the density caused by flares, which can induce an increased drag force on objects that could result in collisions from changes to the attitude and position of orbiting objects.

OBJECTIVES

1. Determine, if any, the effect of X-class solar flare events on the neutral density of the Earth's atmosphere isolated from CMEs.
2. Investigate the effects on orbits of differing area-to-mass ratio objects due to the density perturbations from flares.

RESULTS

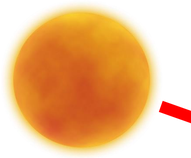
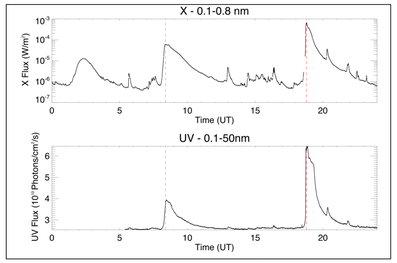


Figure 2 (below): X-ray and UV measurements over December 6th. Note the two peaks, the smaller corresponding to an M6.0 flare and the larger with the X6.5 flare.



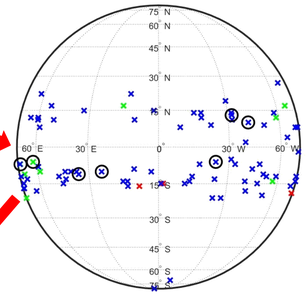


Figure 1 (above): Plot of all X-flare events with available location data from 2002-2017 on the Solar disk. **Red denotes X strength >=10**, **Green denotes 10>X >=5**, and **Blue X <5**

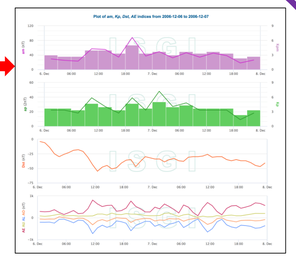


Figure 3 (right): Plot of am, Kp, Dst, and AE indices for December 6th-7th 2006

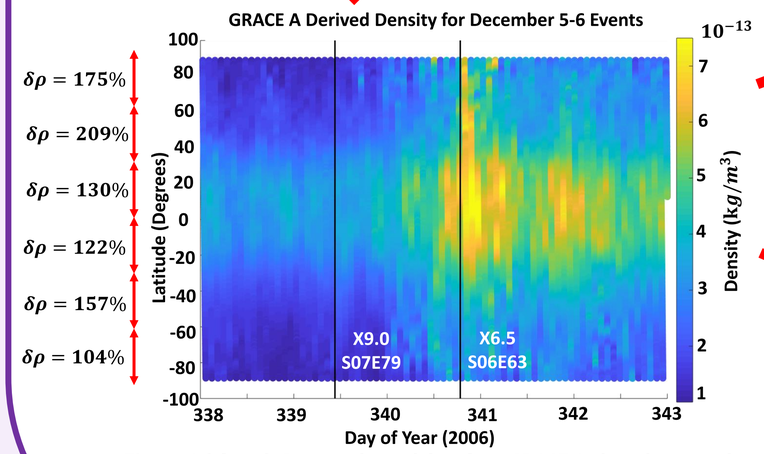


Figure 4 (above): Density-derived data from GRACE A plotted against the latitude and time during a solar day (07:00:00 LT – 19:00:00 LT). Black lines denote X-flares peak times, labelled by flare strength and origin of eruption on solar disk. $\delta\rho$ denotes the max percent change in density compared to a quiet day over the low (0-30), mid (30-60) and high (>60) latitude range.

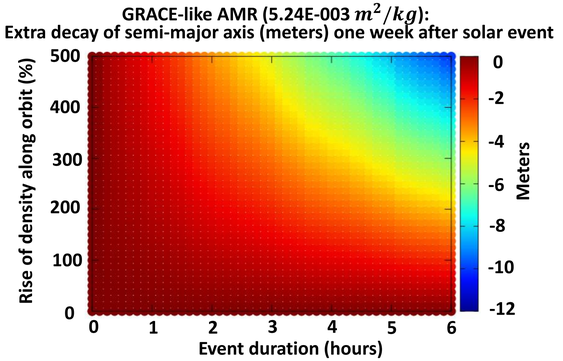


Figure 5 (above): Decay of semi-major axis on object, one week after solar event. GRACE-like-AMR (top), high-AMR (bottom).

METHODOLOGY

1. A list of X-class flares from 2002-2017 was compiled [1], and cross-referenced with all halo CMEs and ICMEs (Figure 1)
2. Density datasets from [2] were investigated during the dates at which X-flares occurred with no CME and plotted (Figure 4).
3. Density increase and duration of perturbation are added as parameters into simulation for high- and GRACE-like- AMR objects at GRACE-like orbit to investigate changes to satellite attitude.

CONCLUSIONS

1. X-Class solar flares are strong enough to cause a significant increase to the neutral density of the Earth's atmosphere.
2. The X9.0 flare on December 5th, 2006, did not cause a density increase to the ionosphere, likely due to its location on the solar limb.
3. Flares can effect the decay of the semi-major axis of high- and GRACE-like AMR objects which could effect mission lifetime.
4. Current atmospheric models need to consider short-term events with the consideration from disruptions due to X-rays to improve model accuracy.

REFERENCES

[1]: NOAA GOES Satellite data. [Online]. Available: https://satdat.ngdc.noaa.gov/sem/goes/data/full/

[2] Mehta, P.M., Walker, A.C., Suttonm E.K., Godinez, H.C., 2017. New density estimates derived using accelerometers on board the CHAMP and GRACE satellites. Space Weather 15, 558-576. doi:10.1002/2016SW001562.

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