

The Impact of Space Weather on GEO Space Debris Orbit Evolution



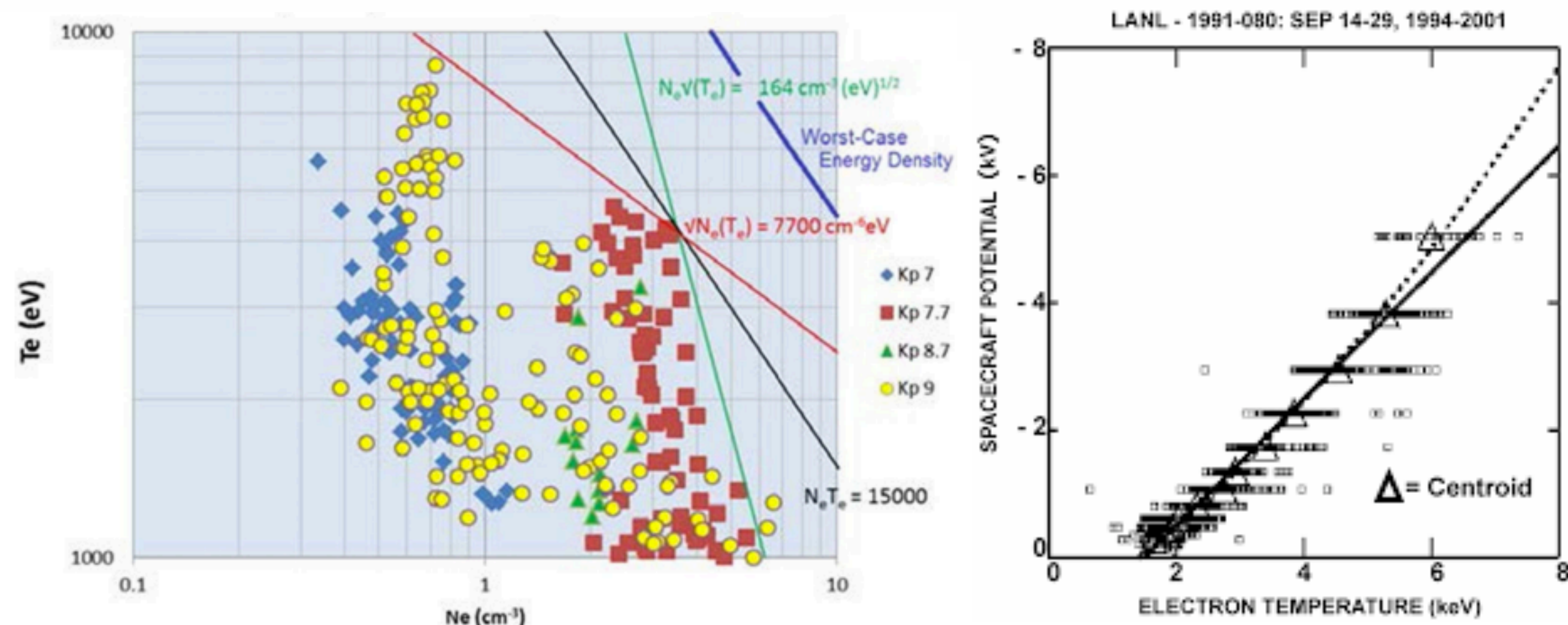
Joseph Hughes and Dr. Hanspeter Schaub
Department of Aerospace Engineering, University of Colorado Boulder

Motivation

Space weather has a well known impact on the orbits of LEO objects by inflating the ionosphere and increasing drag. However, space weather is important for GEO orbits too because of spacecraft charging.

Spacecraft Charging

The space plasma and the sun combine to charge spacecraft to very negative voltages during solar storms. As a rule of thumb, spacecraft can charge to roughly the electron temperature.



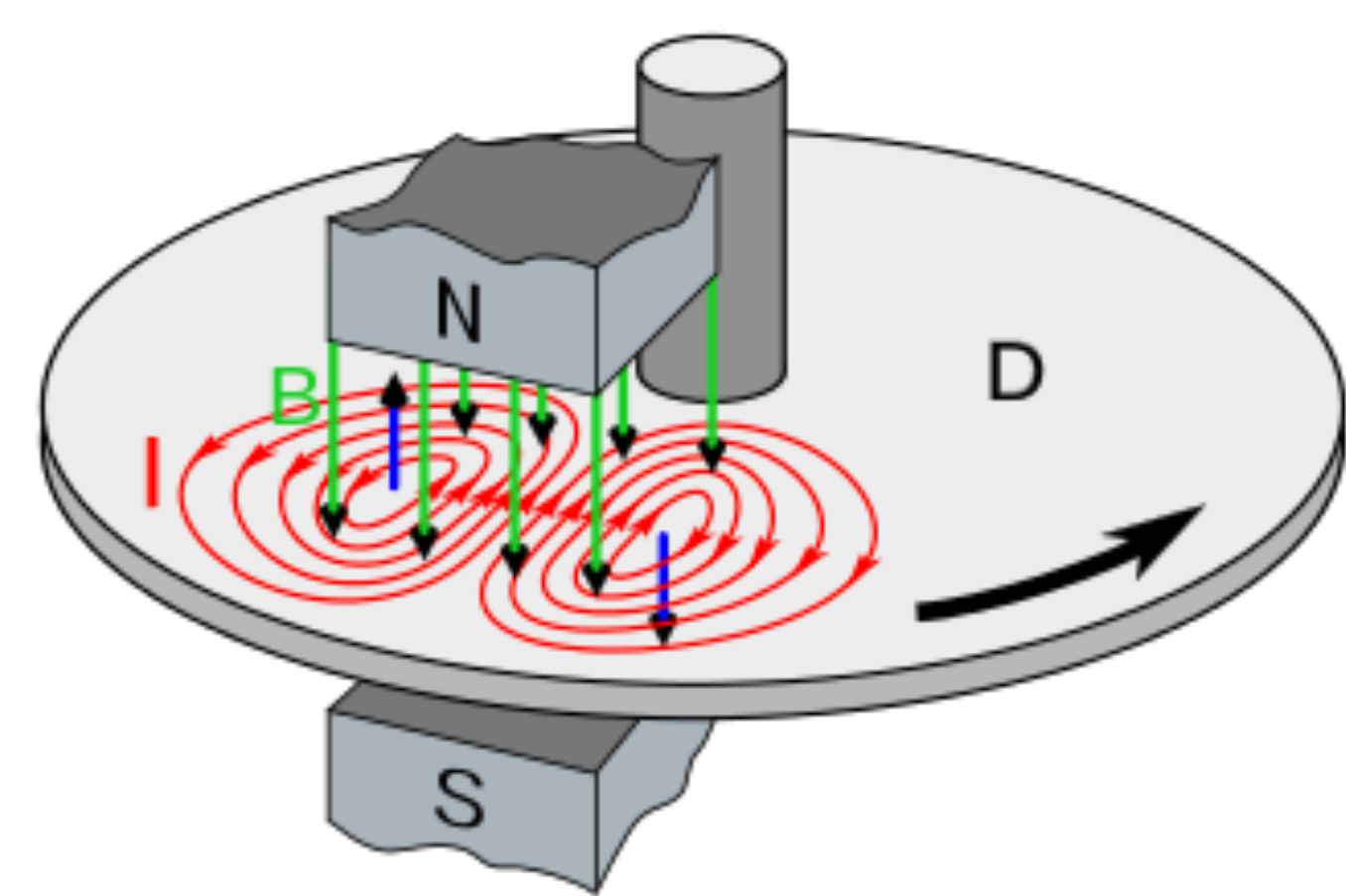
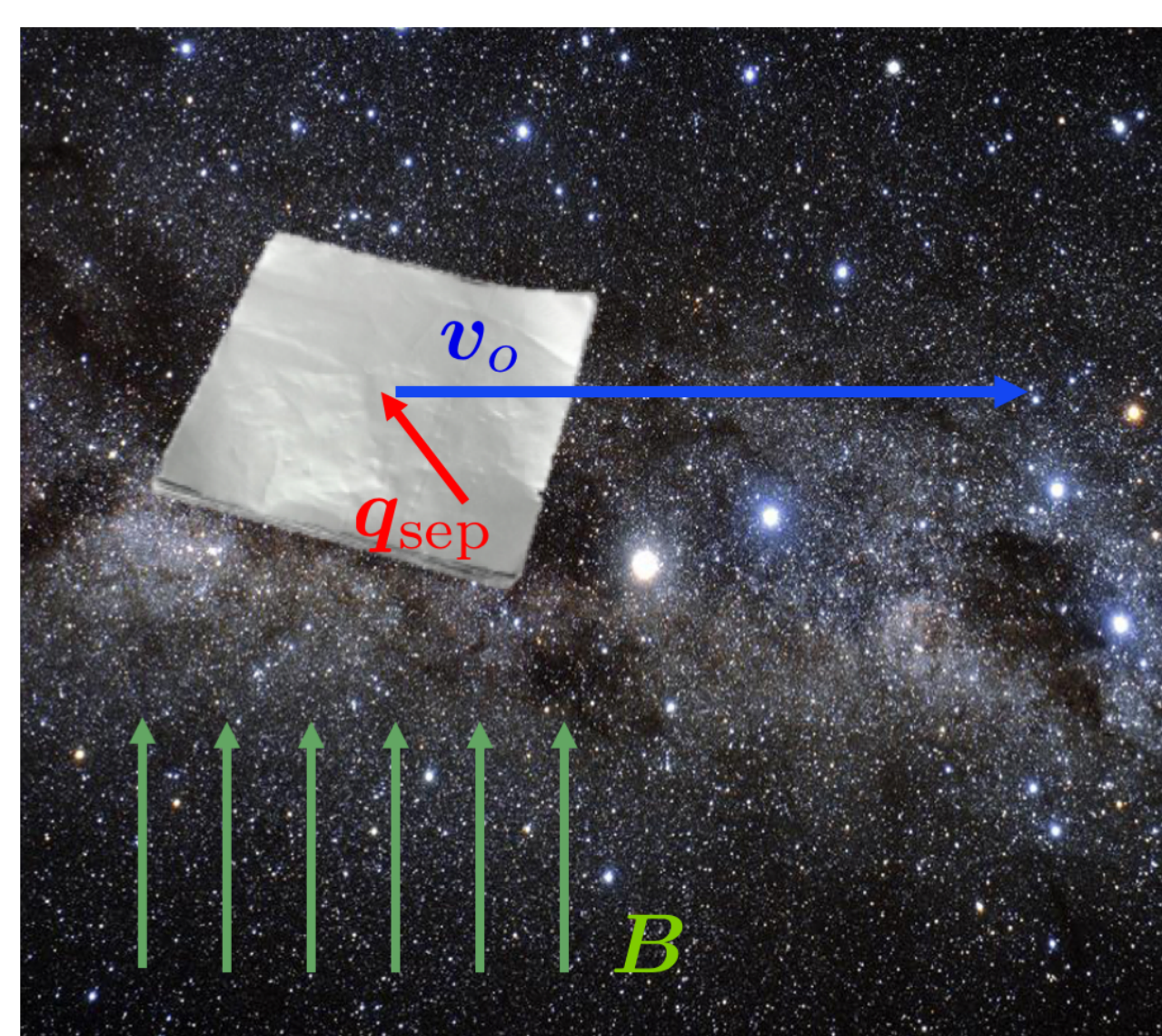
Electromagnetic Dynamics

Charged spacecraft experience a force and torque from their interactions with earth's magnetic field.

$$F = Qv \times B$$

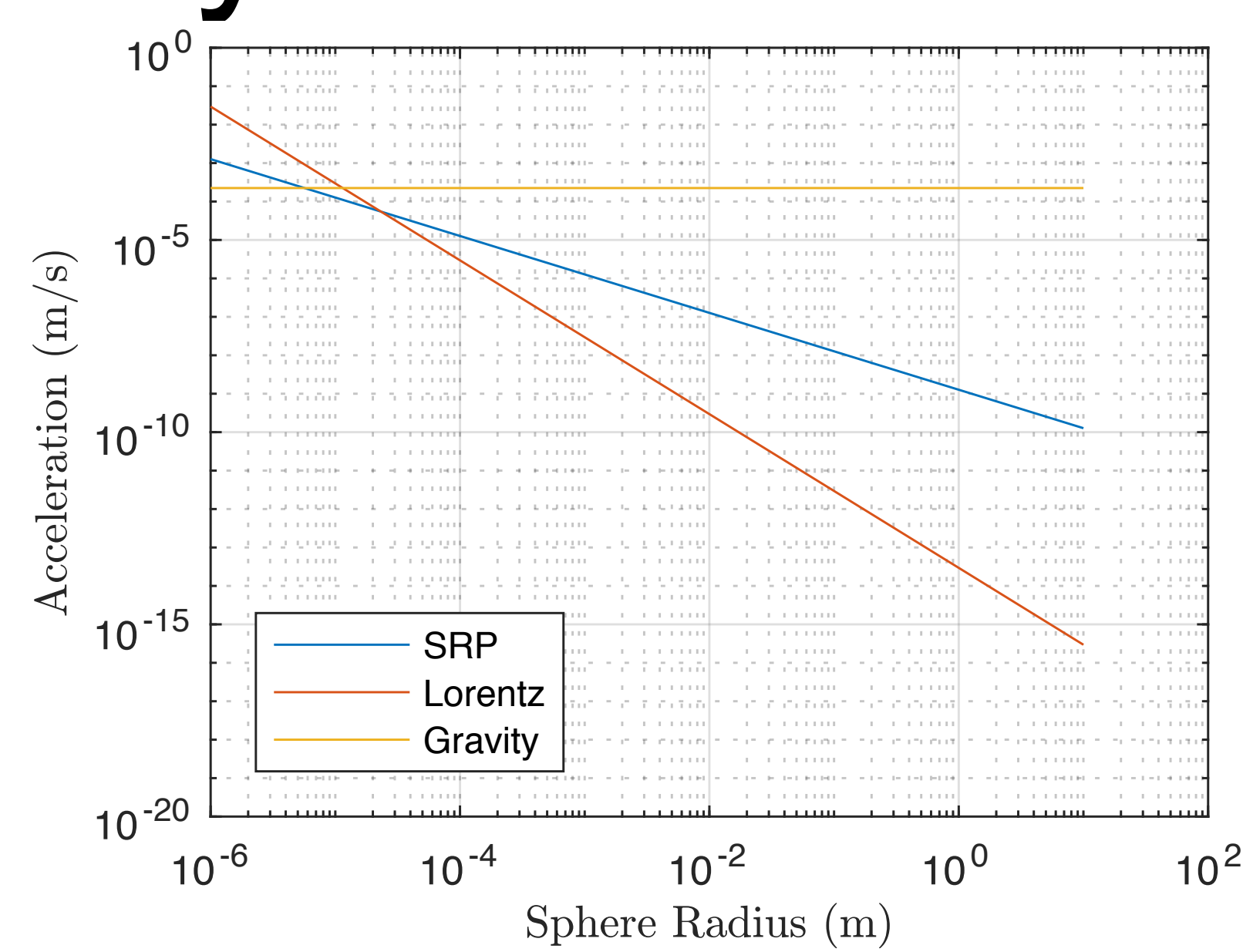
$$L = q \times A$$

$$L = ([M](\omega \times B)) \times B$$



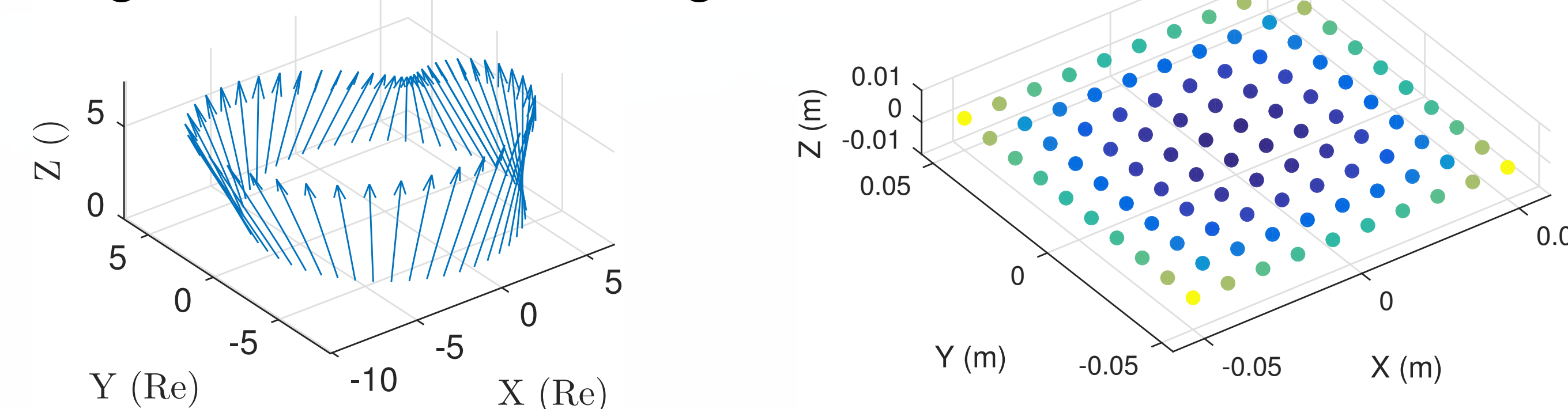
Lorentz Force Only

The Lorentz force will have a miniscule effect on large objects compared to Earth's gravity and SRP. The forces balance at the micron level for 30 kV charging.

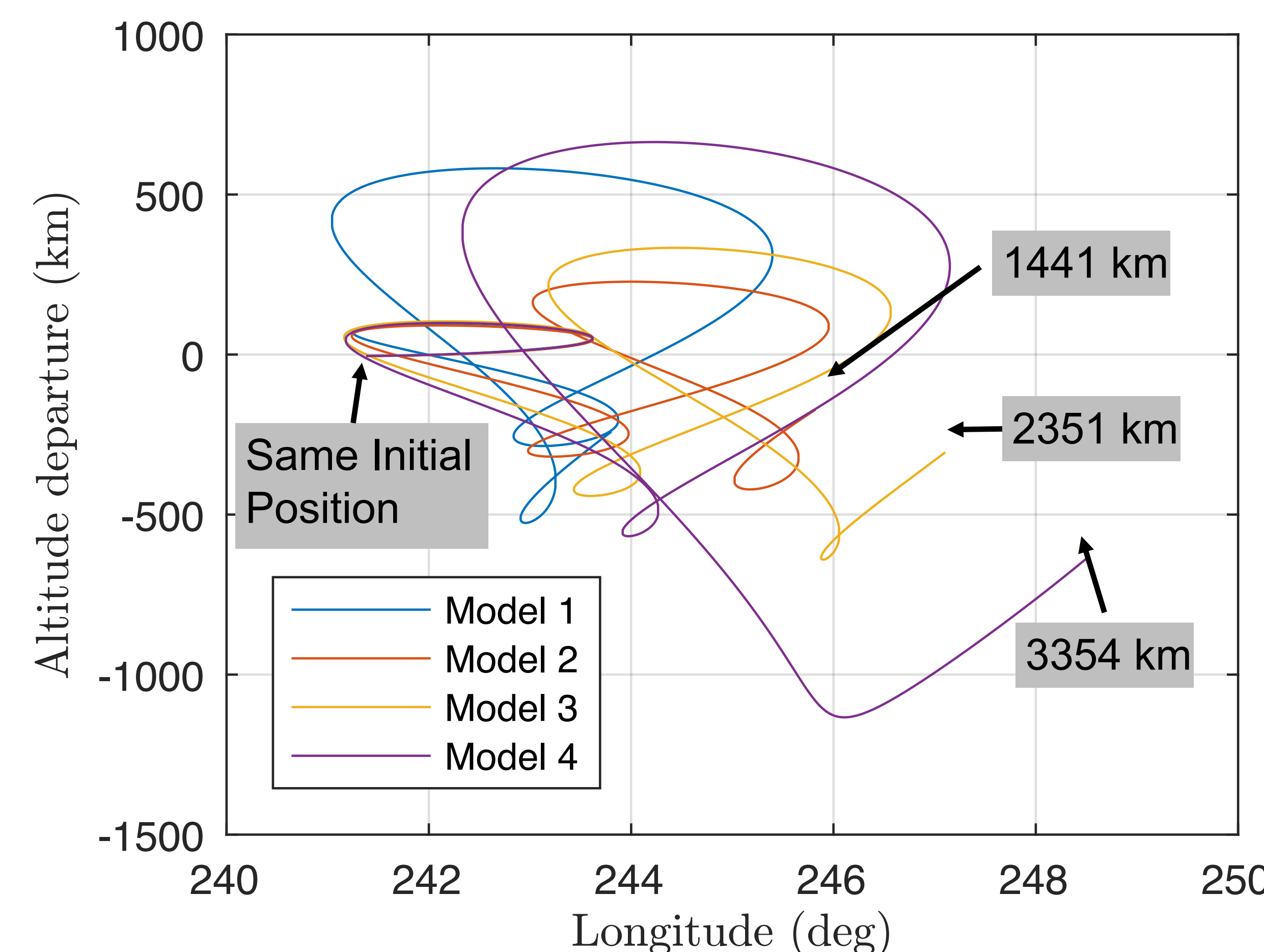


Fully Coupled Propagation

Fully coupled 6DOF model used to investigate electromagnetic perturbations, Tsyangenko model of magnetic field used alongside AFMs

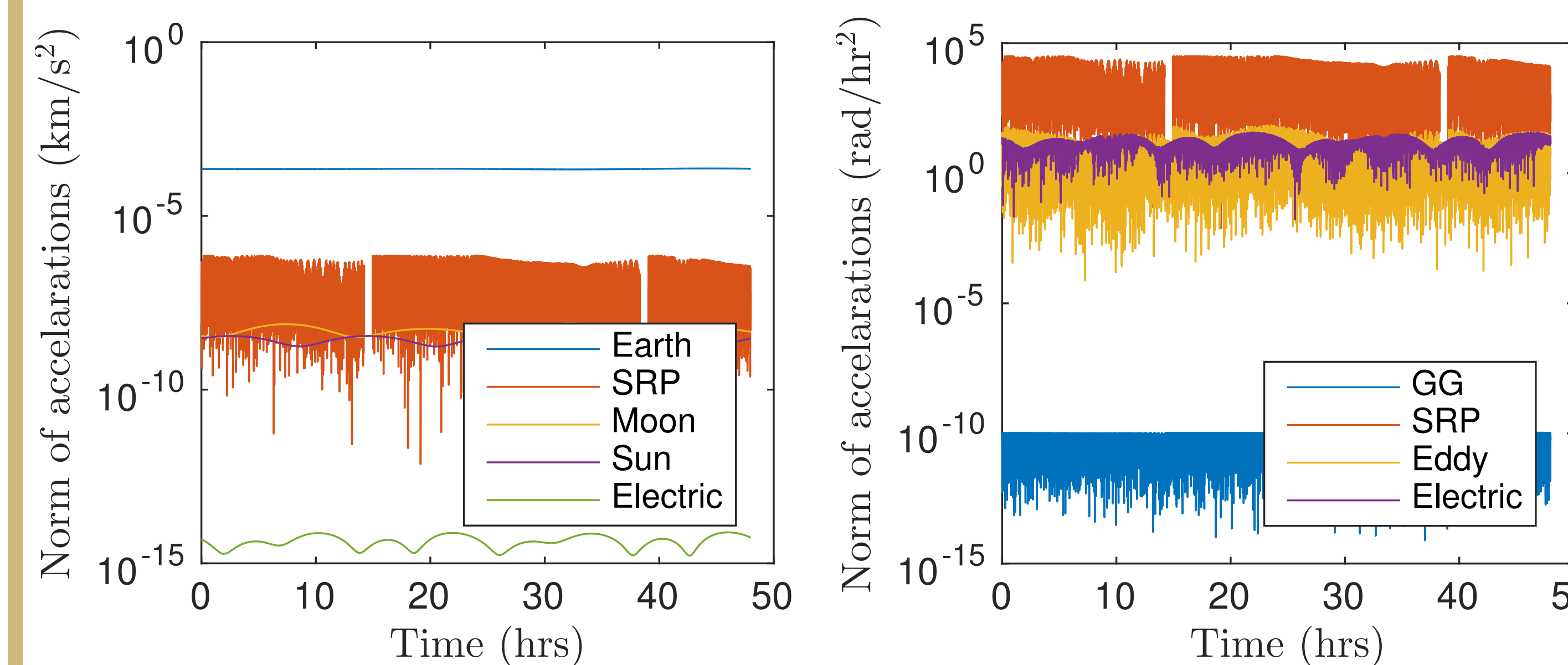


Perturbation	Force	Torque
Earth gravity	Spherical Harmonics up to 4th order	$L = \frac{3\mu}{R_c^3} R_c \times [I] R_c$
Lunar gravity	point-mass gravity	0
Solar gravity	point-mass gravity	0
SRP	Absorptive, specular, and diffuse	$L = r_{sep} \times F_{SRP}$
Electrostatic	$F = Qv \times B$	$L = q_{sep} \times (v \times B)$
Eddy Currents	0	$L = ([M](\omega \times B)) \times B$



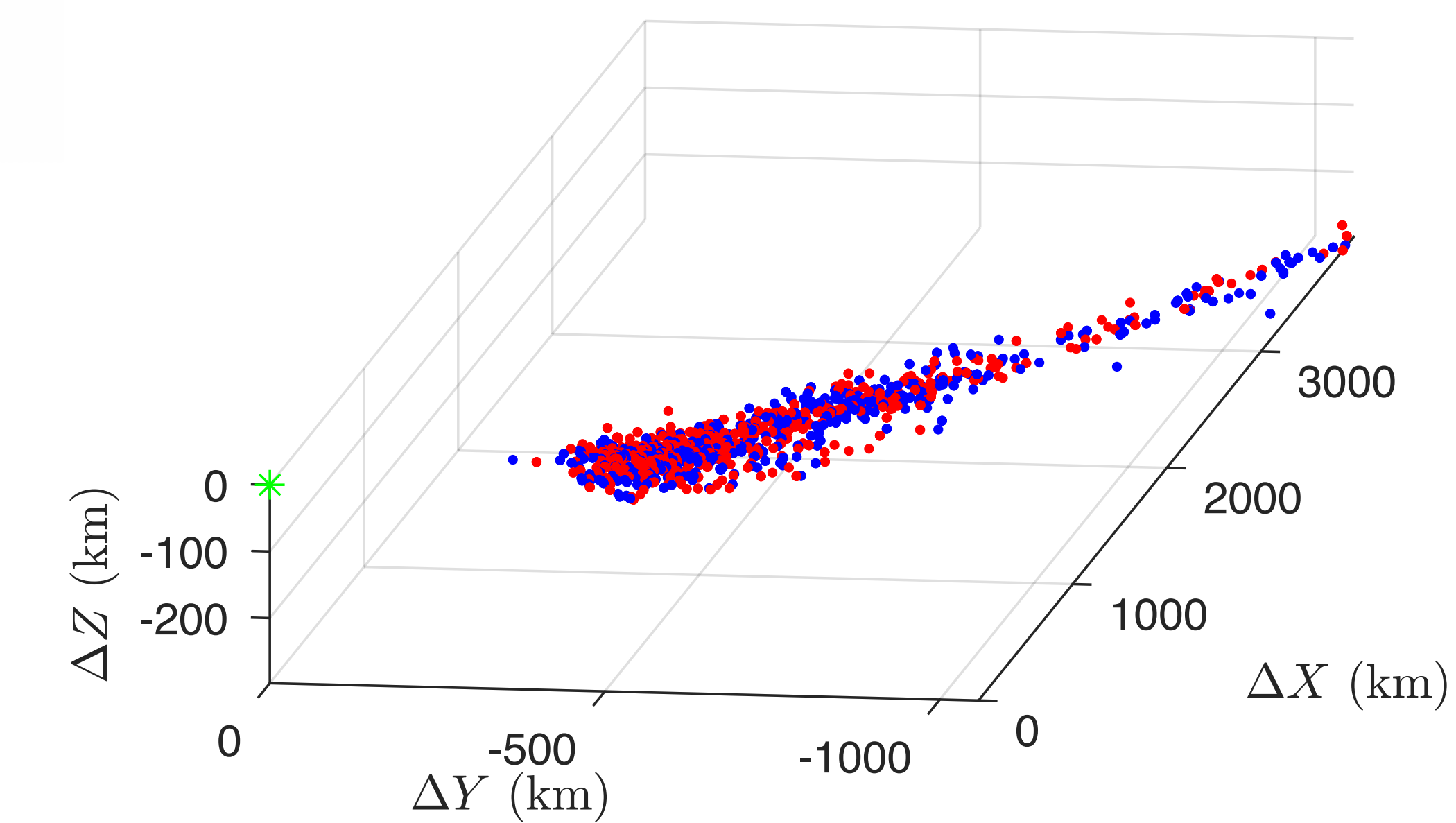
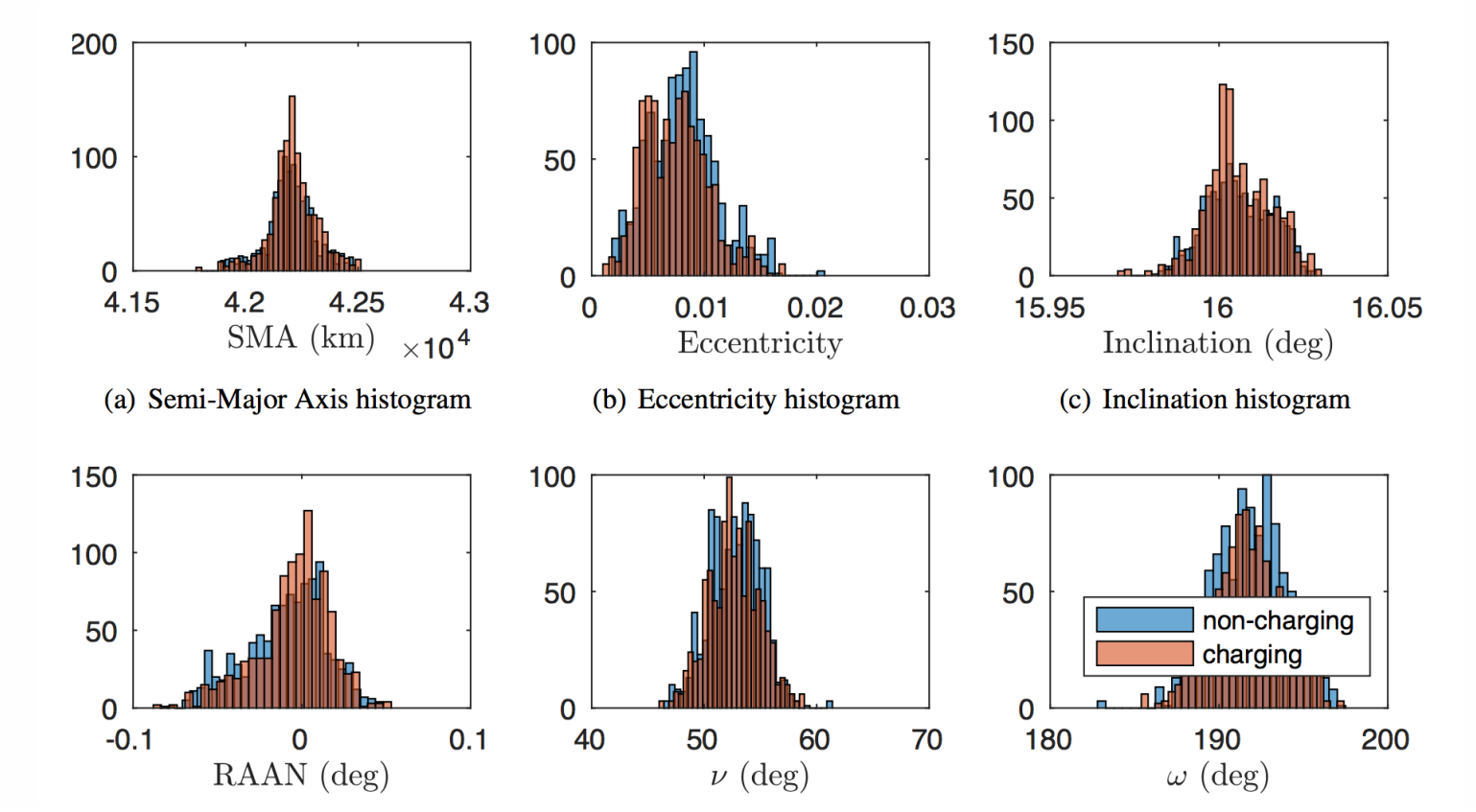
Dynamics history

Linear and rotational accelerations shown over the 2 orbit propagation. The main force is SRP, but it is highly attitude dependent and can be influenced by the torques. The electrostatic and eddy torques change the attitude, which can change the orbit



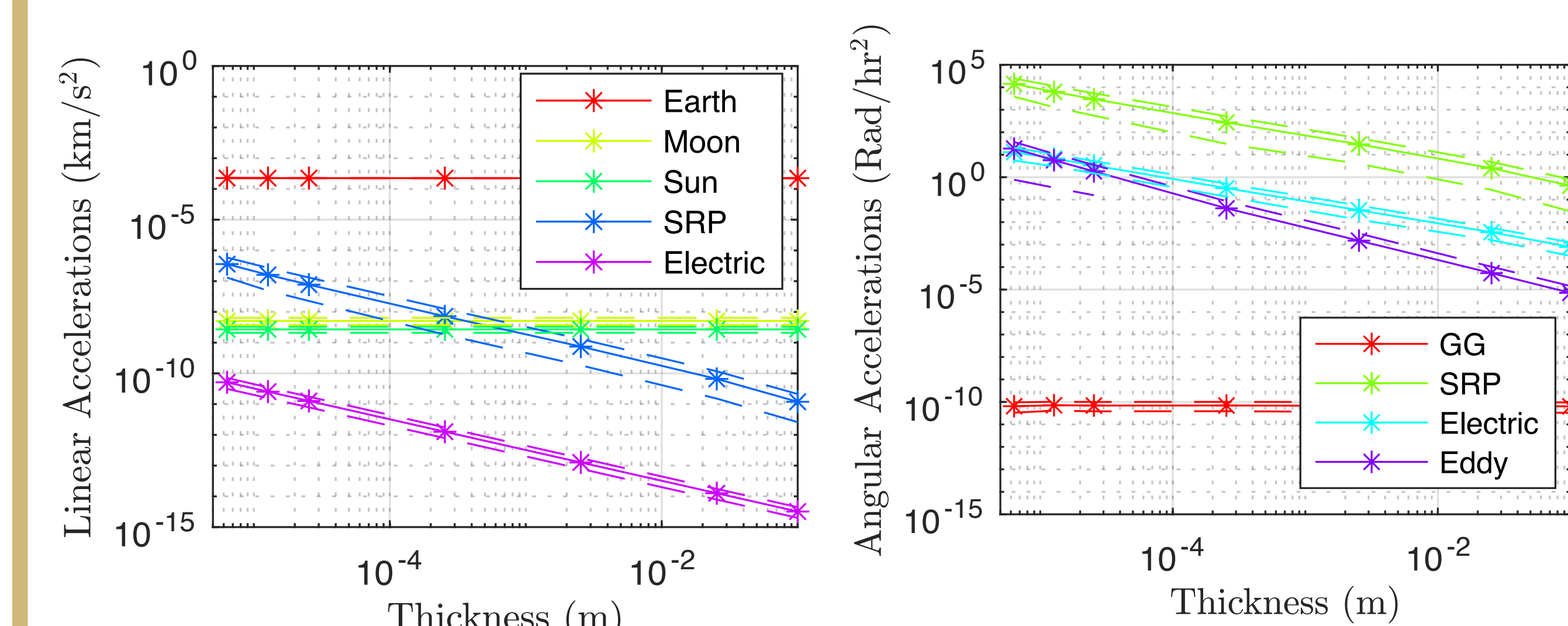
Monte Carlo Analysis

Initial attitude of the flat plate is varied in a Monte Carlo analysis with 1000 runs. Significant (5%) changes in SMA, eccentricity, and RAAN



Object Selection

The objects that will most likely experience significant perturbations are lightweight, HAMR objects with attitude dependent AMR that are not in a stable spin. Objects charged over 1 kV, and having a CM offset of more than 1 mm.



Conclusions

Even at GEO, space weather has a significant impact on the orbits of certain objects. This is due to the Lorentz and Eddy torques which change the attitude with changes the SRP force.

Space weather has a known effect on drag in LEO, and spacecraft charging, but it's effect on GEO orbital dynamics is a new and exciting field.