

Satellite Drag

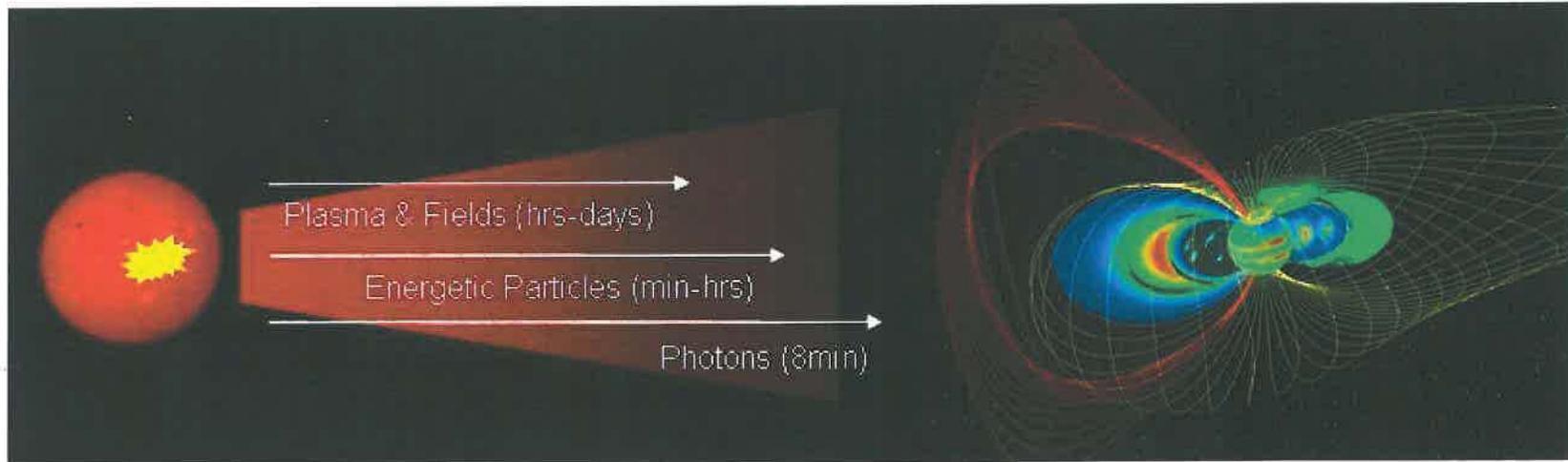
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Contributions from:

Eric Sutton - AFRL

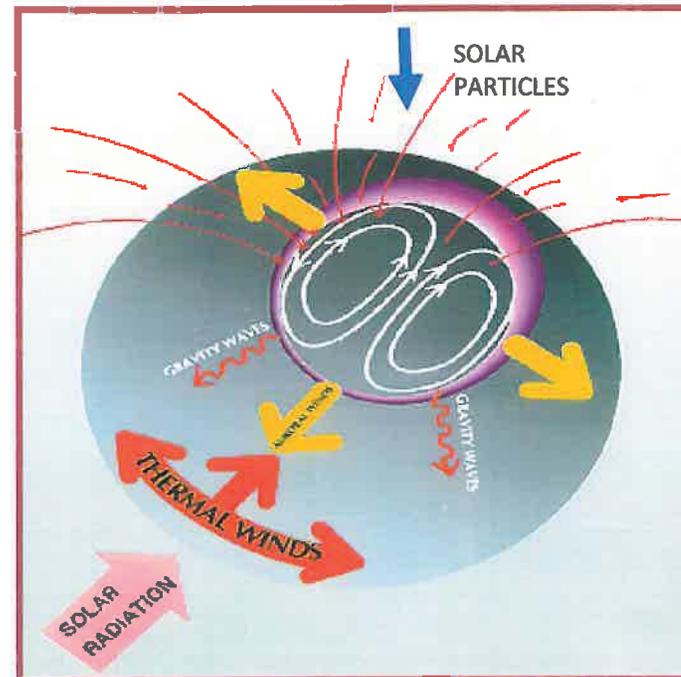
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Sun Drives Neutral Density Variations



Thermosphere Heat Sources

- Solar EUV
- Auroral (Solar Wind)
- Upward Propagating Waves



Orbital Drag Effects on Satellite Orbits

$$a_D = -\frac{1}{2} \left(\frac{C_D A}{m} \right) \rho V^2$$

a_D = aerodynamic drag

ρ = atmospheric density

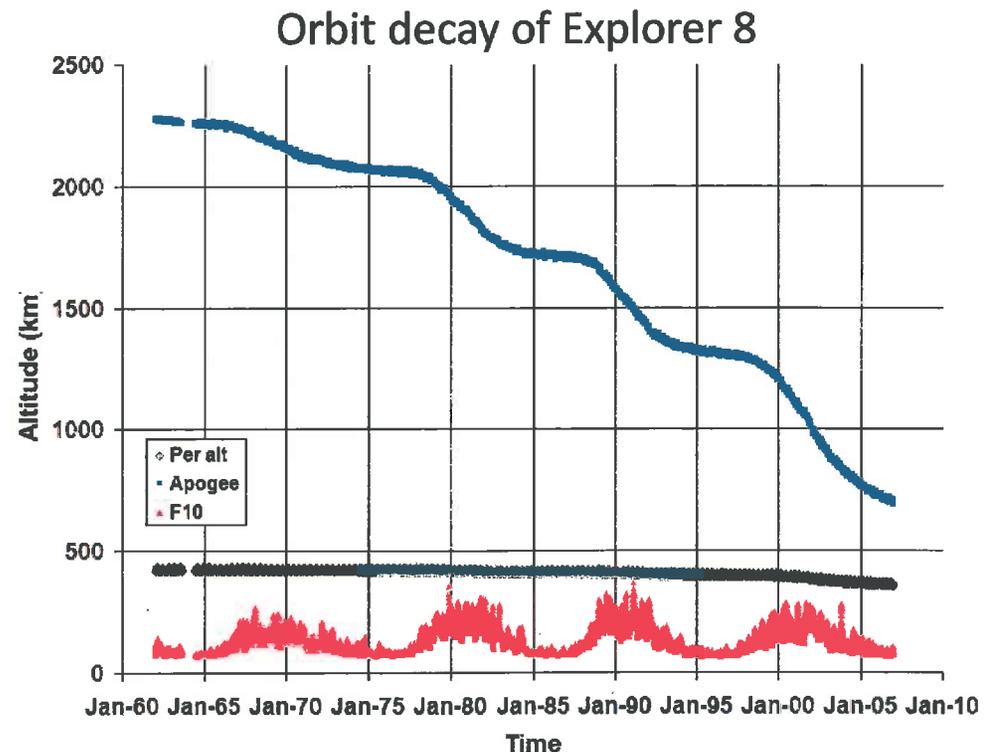
$C_D A/m$ = ballistic coeff. (drag coefficient, area, mass)

V = total atmospheric velocity relative to the satellite velocity

$(V_{\text{sat}} + V_{\text{wind}})$

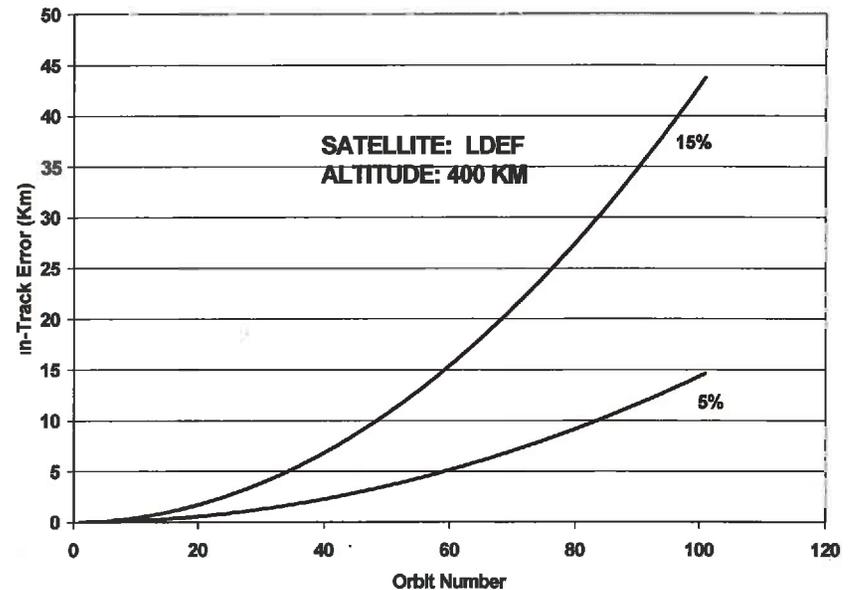
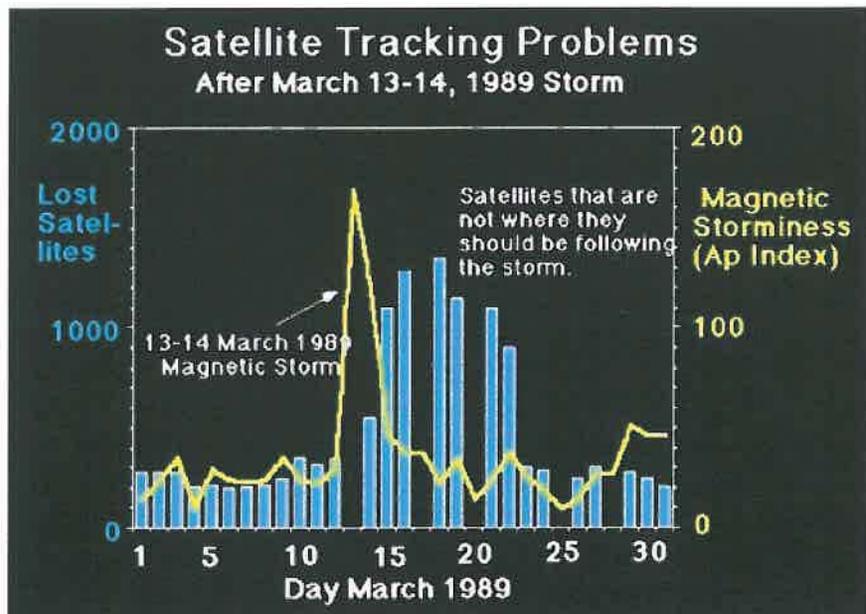
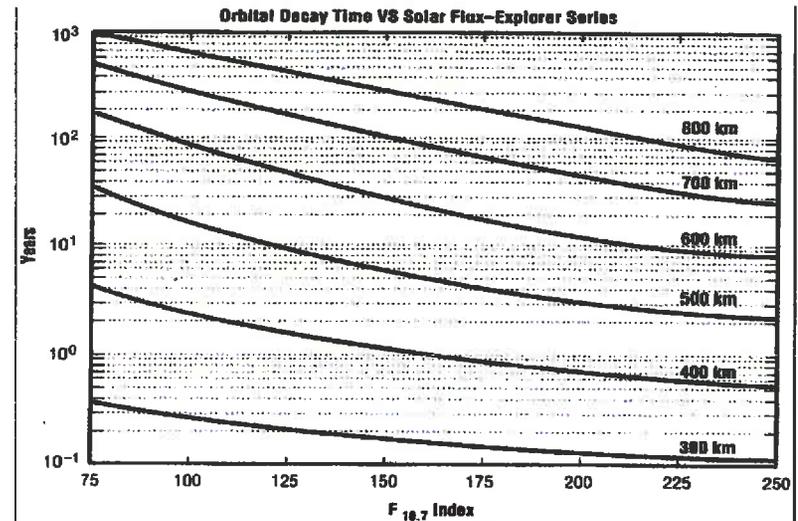
Contributions to Drag variations

- Density is the largest factor – can vary by a factor of 8 and introduce errors by a factor of 3
- Neutral Winds (typically ignored) can introduce error of more than 20%
- Drag Coefficient (typically valued between 2-4) can contribute errors of up to 100%



Selected Satellite Drag Impacts

- Precision orbit determination (catalog, Collision avoidance, reentry)
- Space debris issues
- On-board fuel for orbit maintenance
- Lifetime estimates
- Attitude control system design
- Spacecraft design
- Ionosphere: Comm/Nav

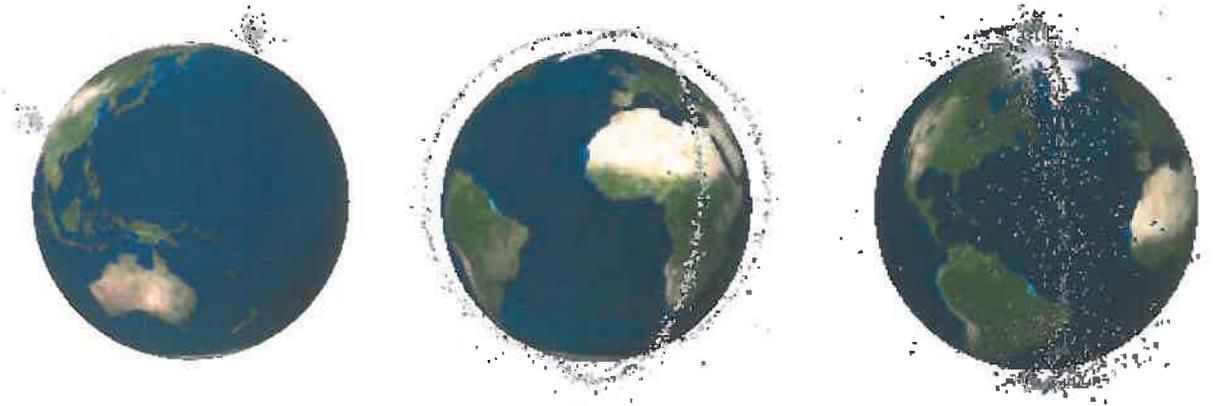


Effects of Collisions and Re-entry

Controlled re-entry of an external tank (ET), discarded by space shuttle



IRIDIUM – COSMOS collision: Debris after 9 min, 10 days, and 6 months



IRIDIUM gets 400 notifications per week for approaches closer than 5 km

Space Station Crew In Near Miss With Space Junk

March 12, 2009

The crew of the international space station survived a close call with space junk Thursday.

The three crew members took refuge for 11 minutes in the Soyuz escape capsule and then were told to go back into the space station. Officials were worried about a possible collision with a small piece of an old spacecraft motor.

The debris was about one-third of an inch in width, said NASA spokesman Josh Byerly. It passed within three miles of the space station.

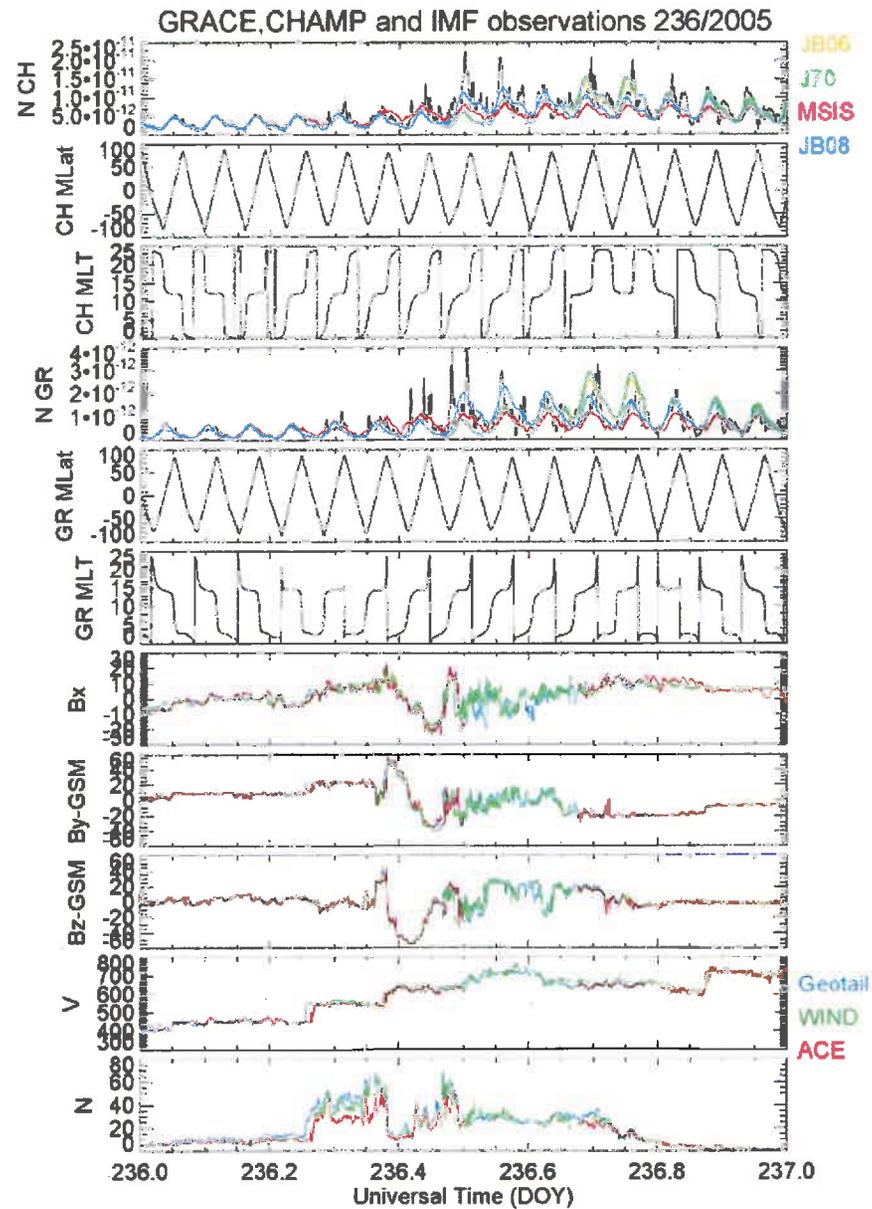
The drama began unfolding with a statement on the NASA Web site expressing concerns about a "minimal" chance that the space station could be hit by debris.

The astronauts aboard the orbiting platform — two Americans and one Russian — retreated to the relative safety of the Soyuz TMA-13 space capsule as a precautionary measure, NASA says.

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With reporting from The Associated Press.

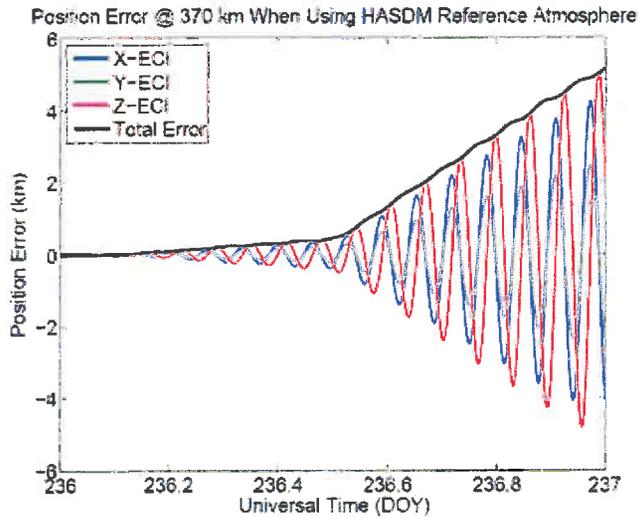
Storm of Aug 24, 2005



Storm of Aug 24, 2005 drag effects

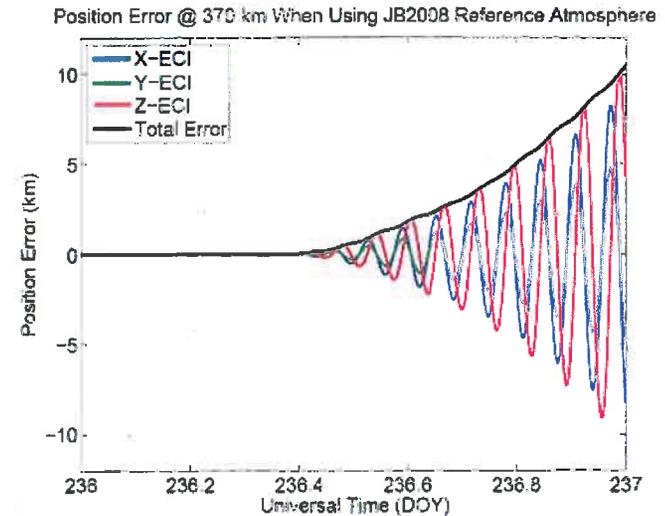
TRACKING ERRORS

HASDM error after 12 hrs

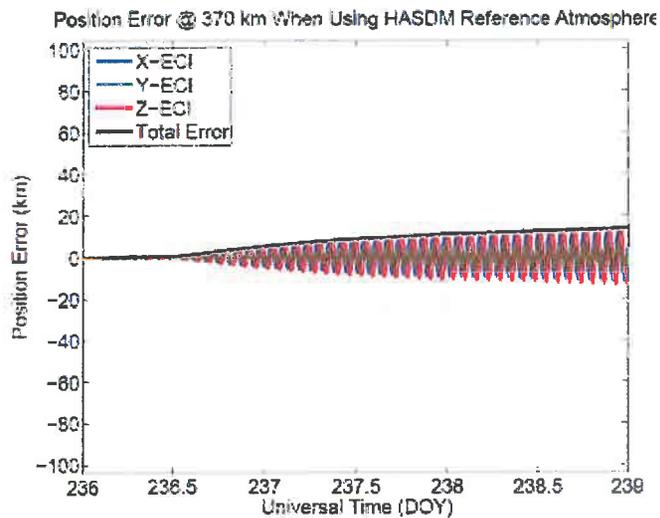


PREDICTION ERRORS

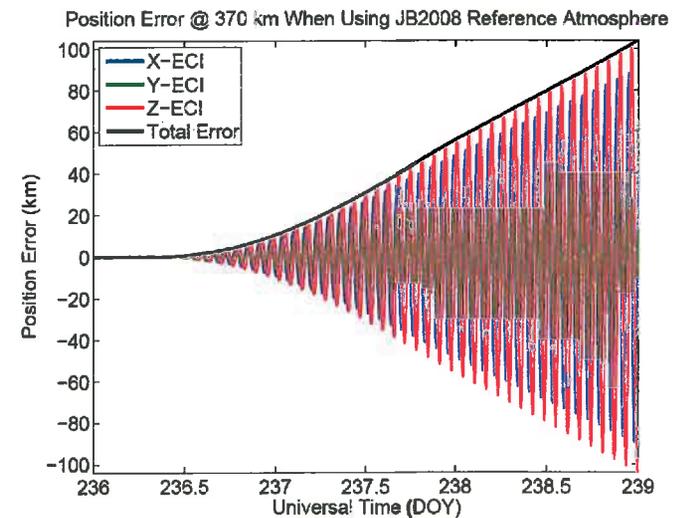
JB08 error after 12 hrs

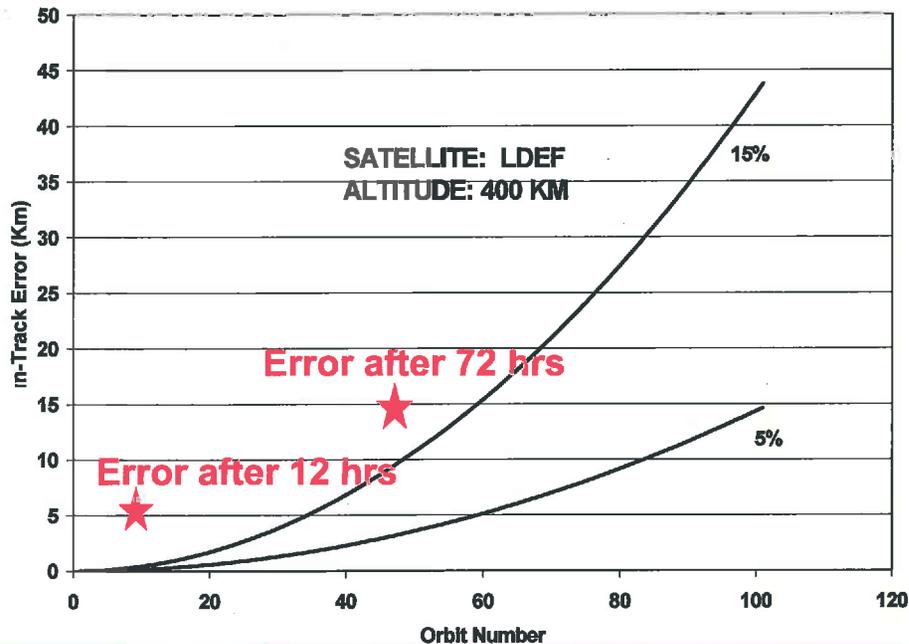


HASDM error after 72 hrs



JB08 error after 72 hrs





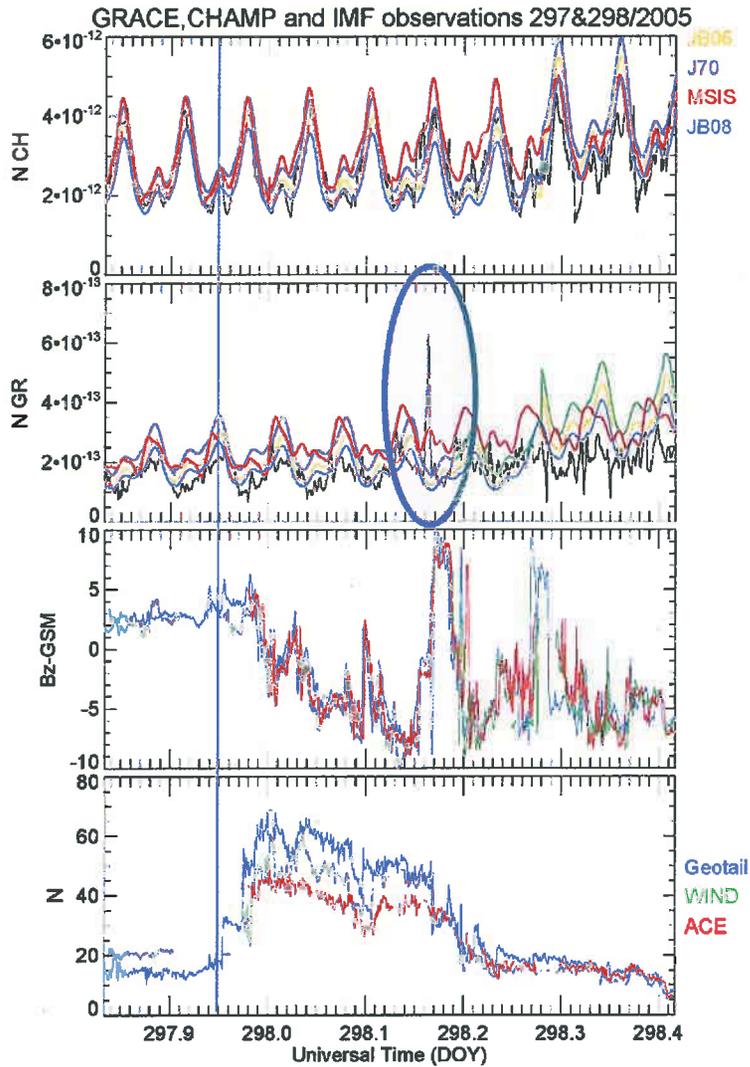
CHAMP and GRACE satellite observations of the neutral density show the enhancements above any modeled density during the storm.

HASDM is the operational model at AFSPC updated every 3 hrs by calibration satellites. During the storm HASDM errors are significant, particularly for objects not tracked regularly.

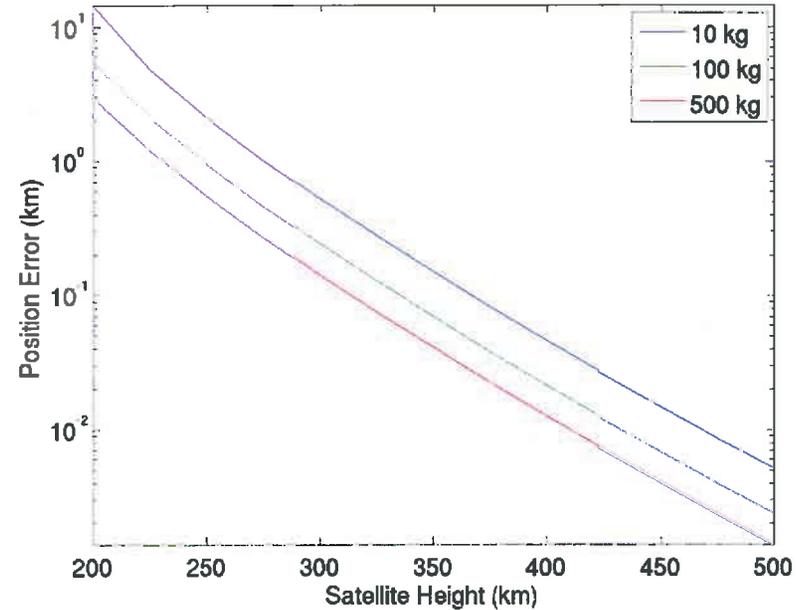
JB08 is the most updated neutral density model at AFSPC used to forecast satellite position. The errors based on JB08 are significantly greater than those based on the HASDM model.

There are significant errors that would affect both tracking and forecast of a satellite position.

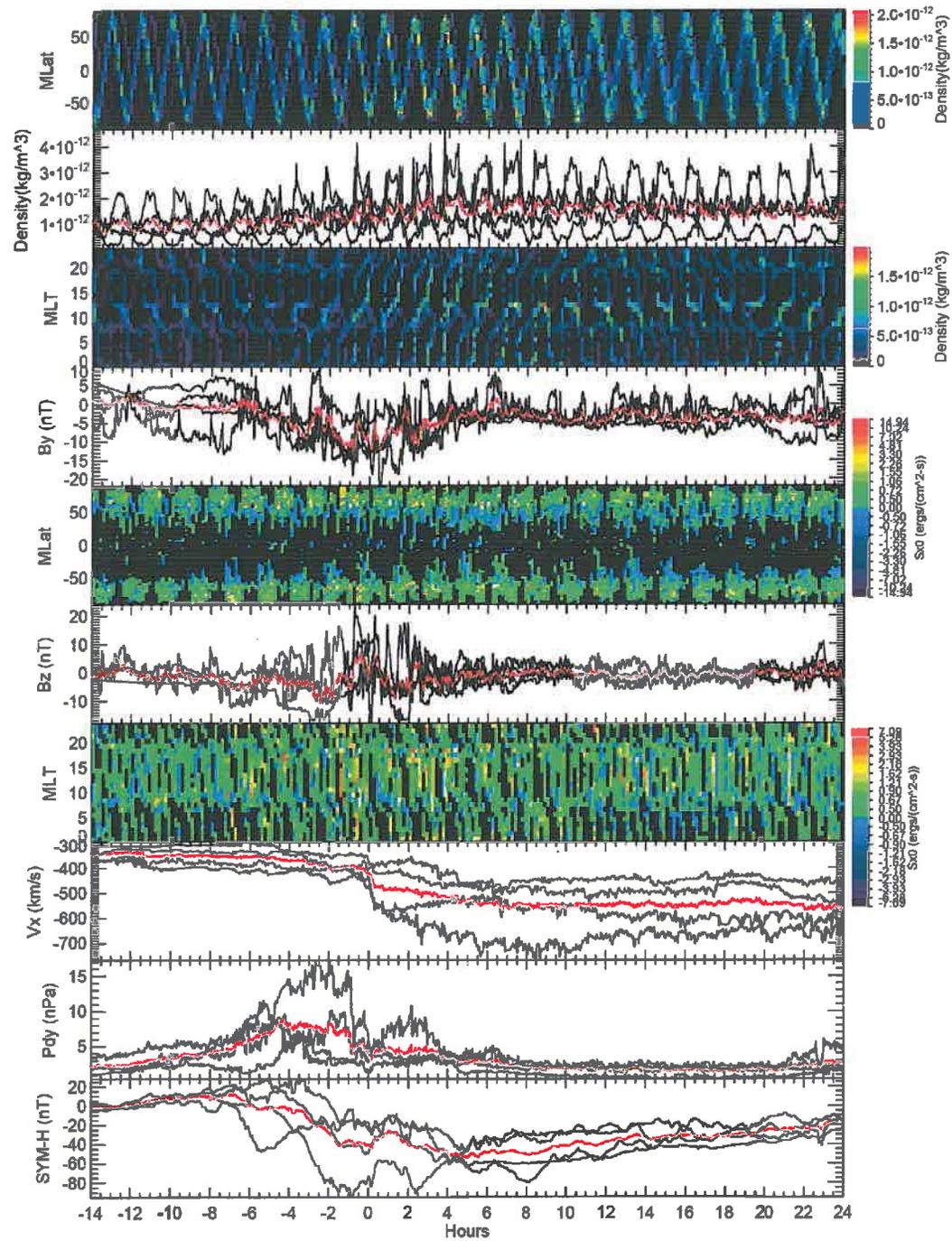
Oct 24-25, 2005



Satellite Position Error 1 Day After Disturbance

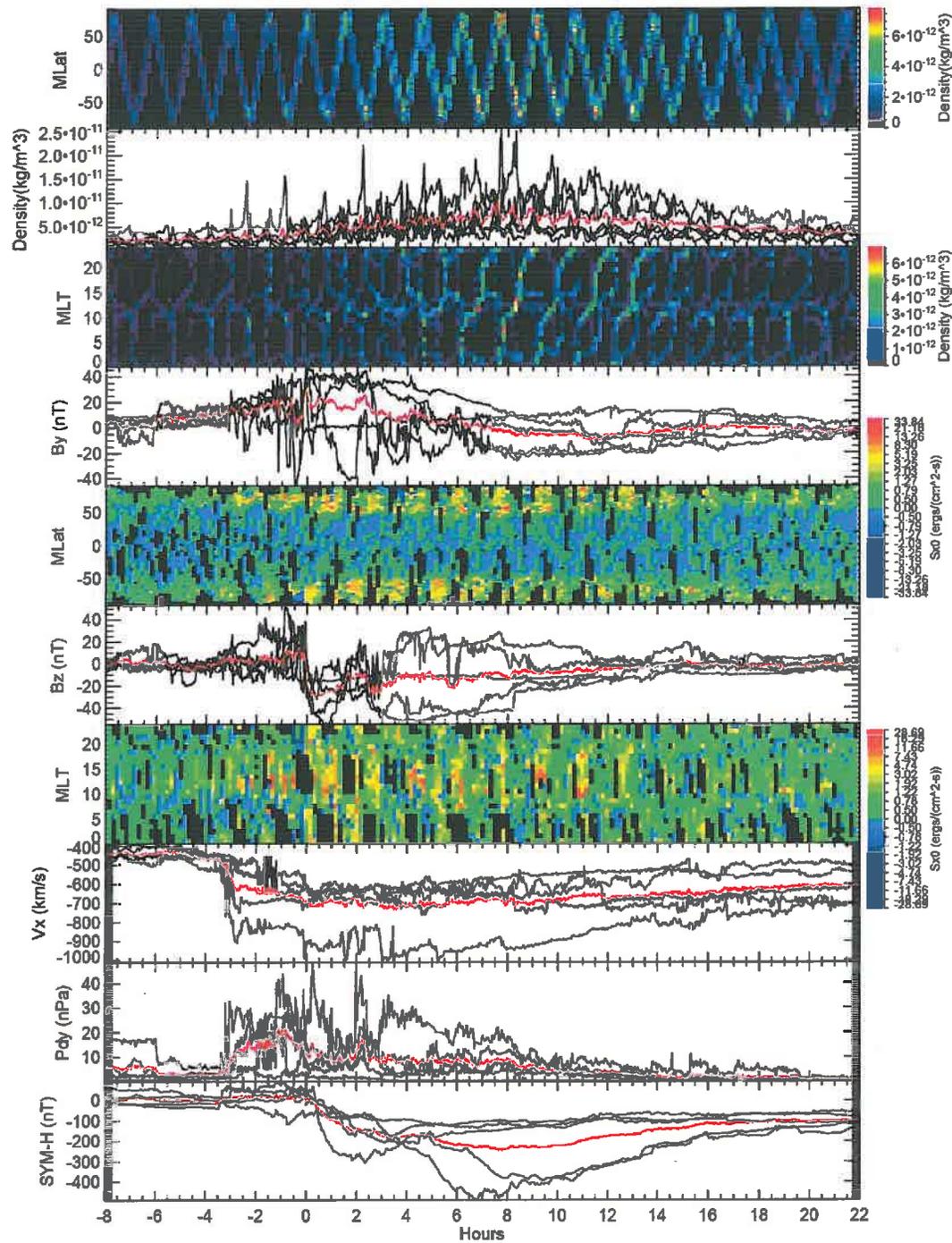


A single passage over the localized density enhancement caused by a moderate substorm can generate measurable in-track error within 24 hrs, particularly for smaller satellites and at lower altitudes.



Superposed Epoch analysis of CIR storms

Superposed Epoch analysis of CME storms



Summary

- It is useful to look at drag effects with the use of non-orbit averaged density values
- Results from HASDM and JB08 should be tested against physics-based models, like CTIPe
- Inputs to physics-based models are currently only empirical. That needs to be remedied