SPACE ENVIRONMENT TECHNOLOGIES

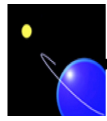*Space Research   Space Operations   Space Standards*
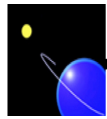
Thermospheric Density Analyses
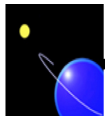
Project HASDM

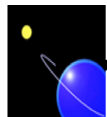**Bruce R Bowman**
W. Kent Tobiska

- HASDM Overview

- HASDM Density Accuracies

- Historical Storm Examples

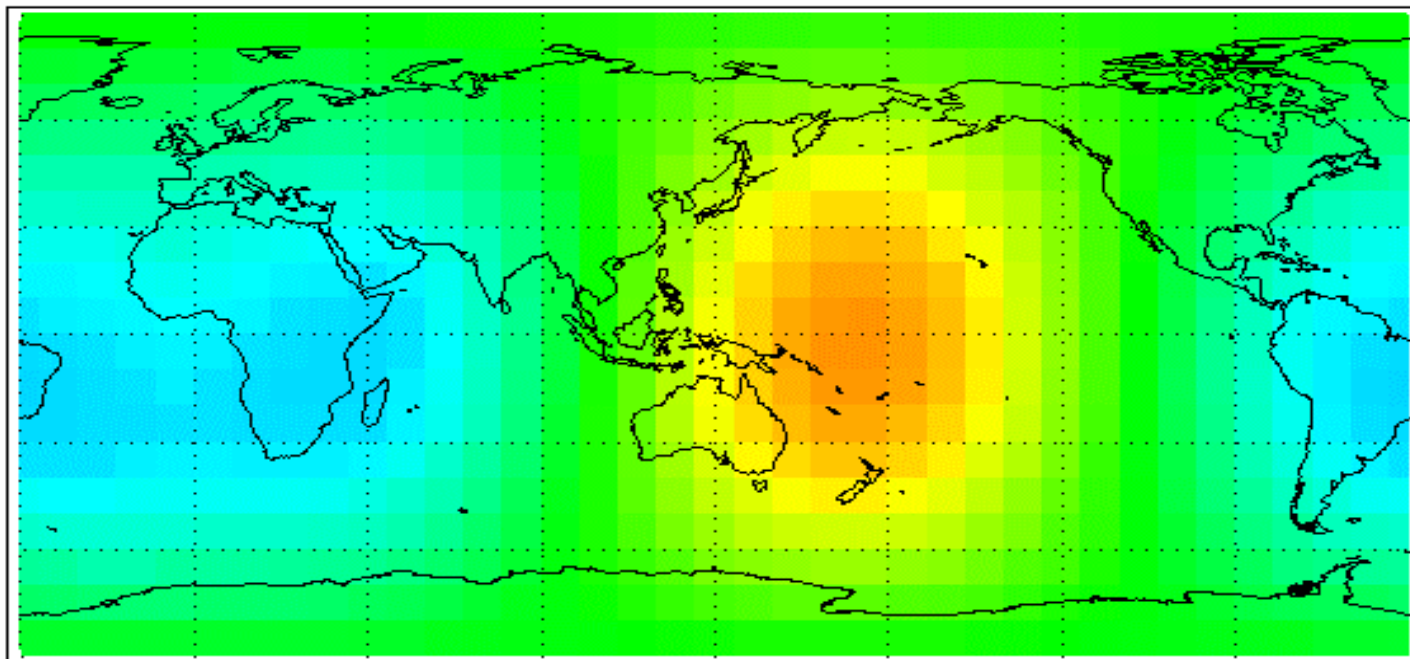- HASDM Density Research Applications

- Storm Movie

- HASDM – Air Force Operational High Accuracy Satellite Drag Model development started in 2000, operational in 2004 - current

- DCA – Dynamic Calibration Atmosphere program using AF Space Surveillance Network observations every orbit from multiple radars

- Produces density corrections every 3 hours using multiple calibration satellites (~80-90) consisting of spheres, R/B, debris at altitudes from 200 to 800 km

- Corrects temperature profiles solving for 9 spherical harmonic coefficients in T_c and 1 global coefficient in T_x

- Currently corrects operational Jacchia-Bowman 2008 density model (JB2008) using new solar indices and Dst index
    - Correction varies with latitude, longitude, altitude, and time

SPACE ENVIRONMENT TECHNOLOGIES

Space Research   Space Operations   Space Standards

HASDM 2012 Calibration Satellites

Height Km: Inclination	190 250	250 300	300 400	400 500	500 550	550 600	600 700	700 800	Total		Deep Space
20-30	2	3	5								5
30-40	5	2	1	1	1						6
40-50		1			3						
50-60	1	1					1				
60-70		1	2	1			1	2			
70-80			4								
80-100			13	14	8	9	4	1			
Total	**8**	**8**	**25**	**16**	**12**	**9**	**6**	**3**	**87**		**11**

Global Density During Quiet Time

HASDM DENSITY FOR 450.0 KM ALT
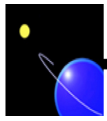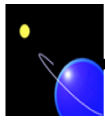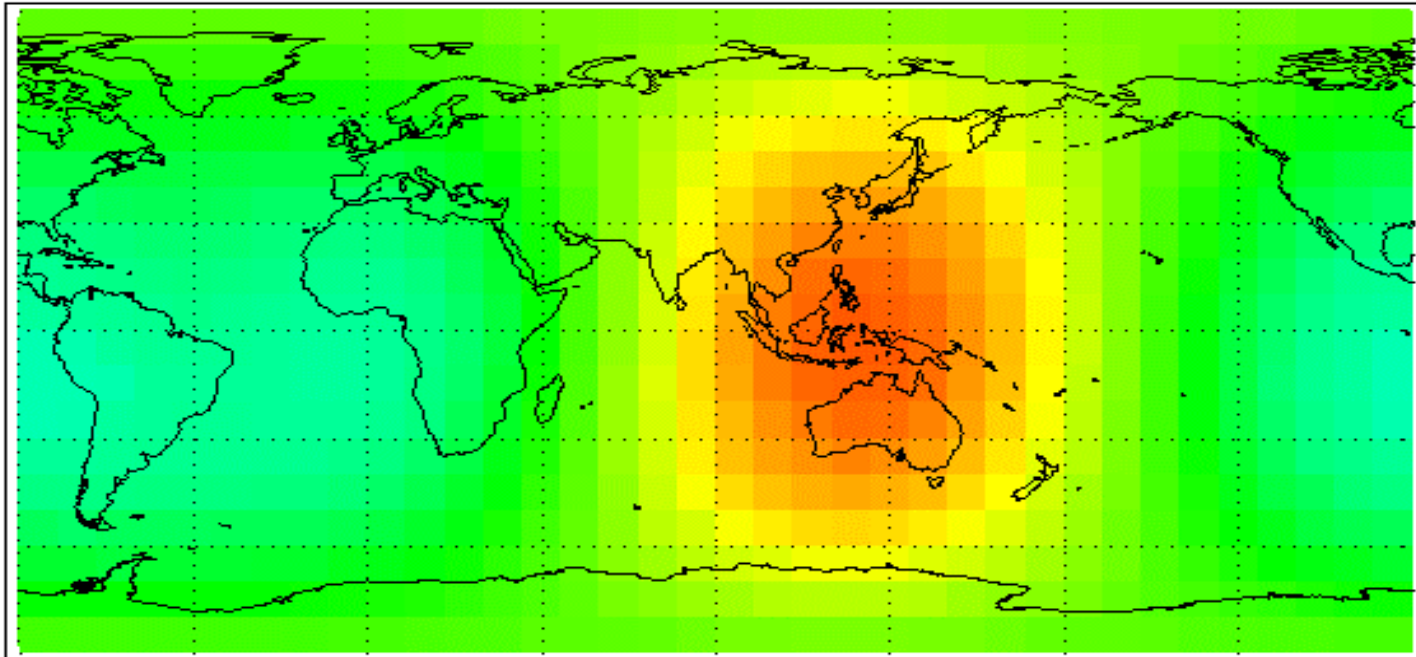
DENSITY (KG/M**3)

10^{-12} 10^{-11}

HASDM DENSITY VALUE IN EACH 10 DEG LAT BY 10 DEG LONG BIN

27 MAR 01 AT 03:00:00 UT

F10.7 = 264   F10.7BAR = 161   ap = 6

Global Density During Minor Storm

HASDM DENSITY FOR 450.0 KM ALT

DENSITY (KG/M**3)

10^{-12} 10^{-11}
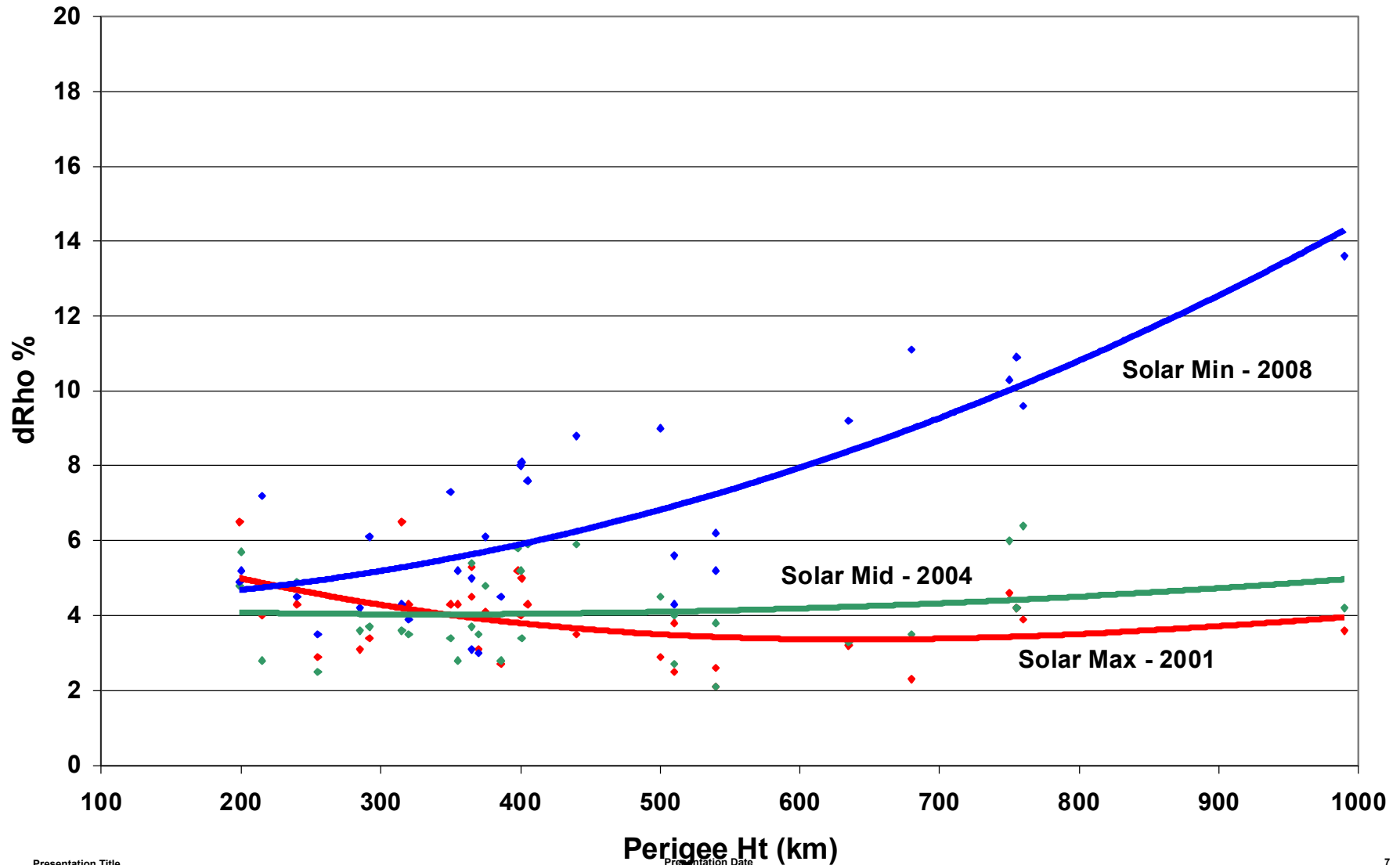
HASDM DENSITY VALUE IN EACH 10 DEG LAT BY 10 DEG LONG BIN
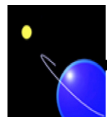
27 MAR 01 AT 06:00:00 UT

F10.7 = 264   F10.7BAR = 161   ap = 22

Density % Error (1 Sigma) HASDM DCA Values

SPACE ENVIRONMENT TECHNOLOGIES
Space Research   Space Operations   Space Standards

HASDM Density Accuracy

Solar Min - 2008

Solar Mid - 2004

Solar Max - 2001
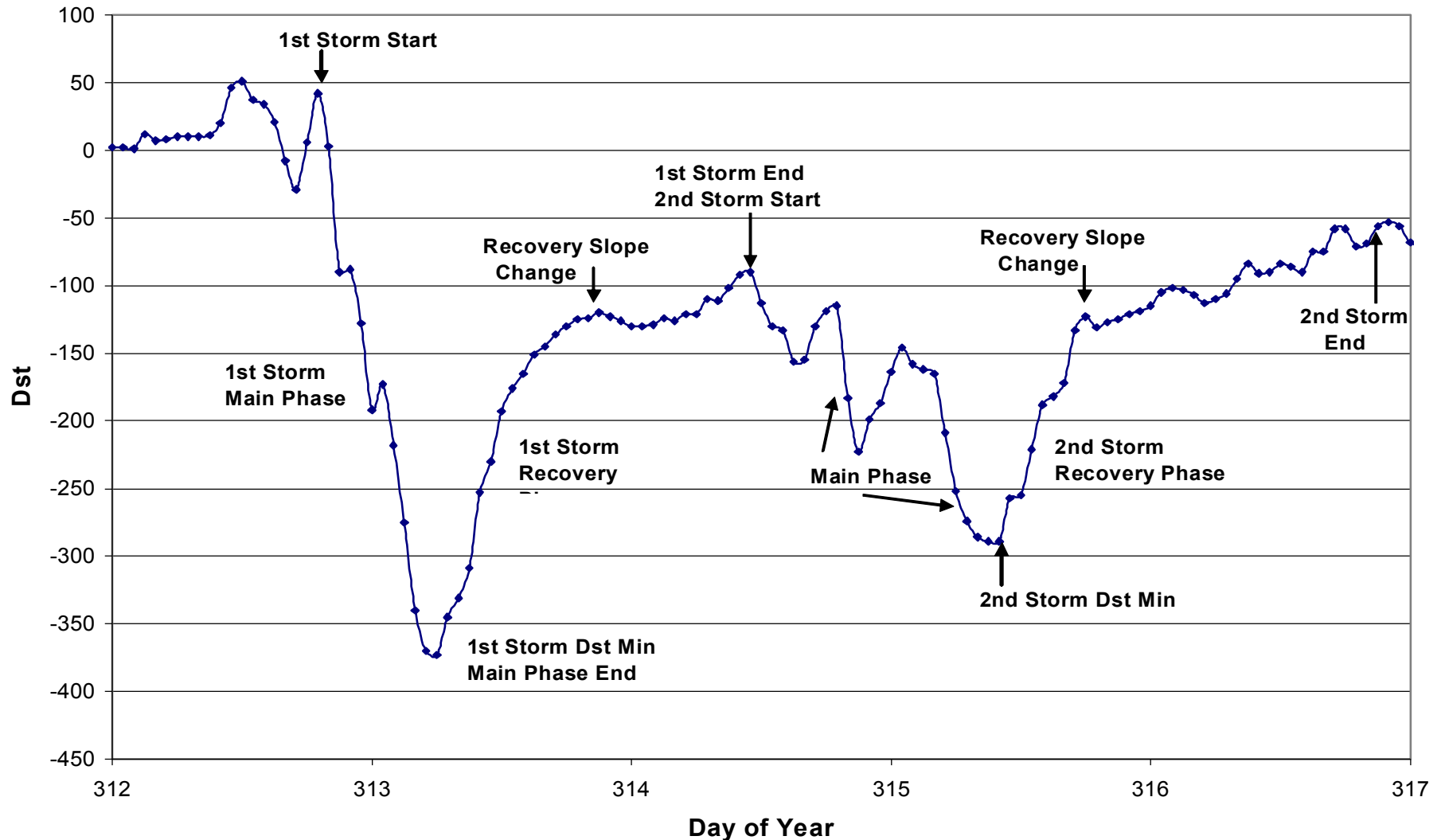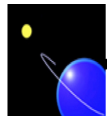
dRho %

Perigee Ht (km)

- All previous empirical models use ap geomagnetic index for storm modeling

- The 3-hour ap is a measure of general magnetic activity over the Earth, and responds primarily to currents flowing in the ionosphere and only secondarily to magnetospheric variations

- The ap index is determined by observatories at high latitudes which can be blind to energy input during large storms (Huang and Burke, 2004)

- The Disturbance Storm Time (Dst) index is primarily used to indicate the strength of the storm-time ring current in the inner magnetosphere

- During the main phase of magnetic storms, the ring current becomes highly energized and produces a southward-directed magnetic field perturbation at low latitudes on the Earth's surface

- The Dst index is determined from hourly measurements of the magnetic field made at four points around the Earth's equator
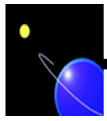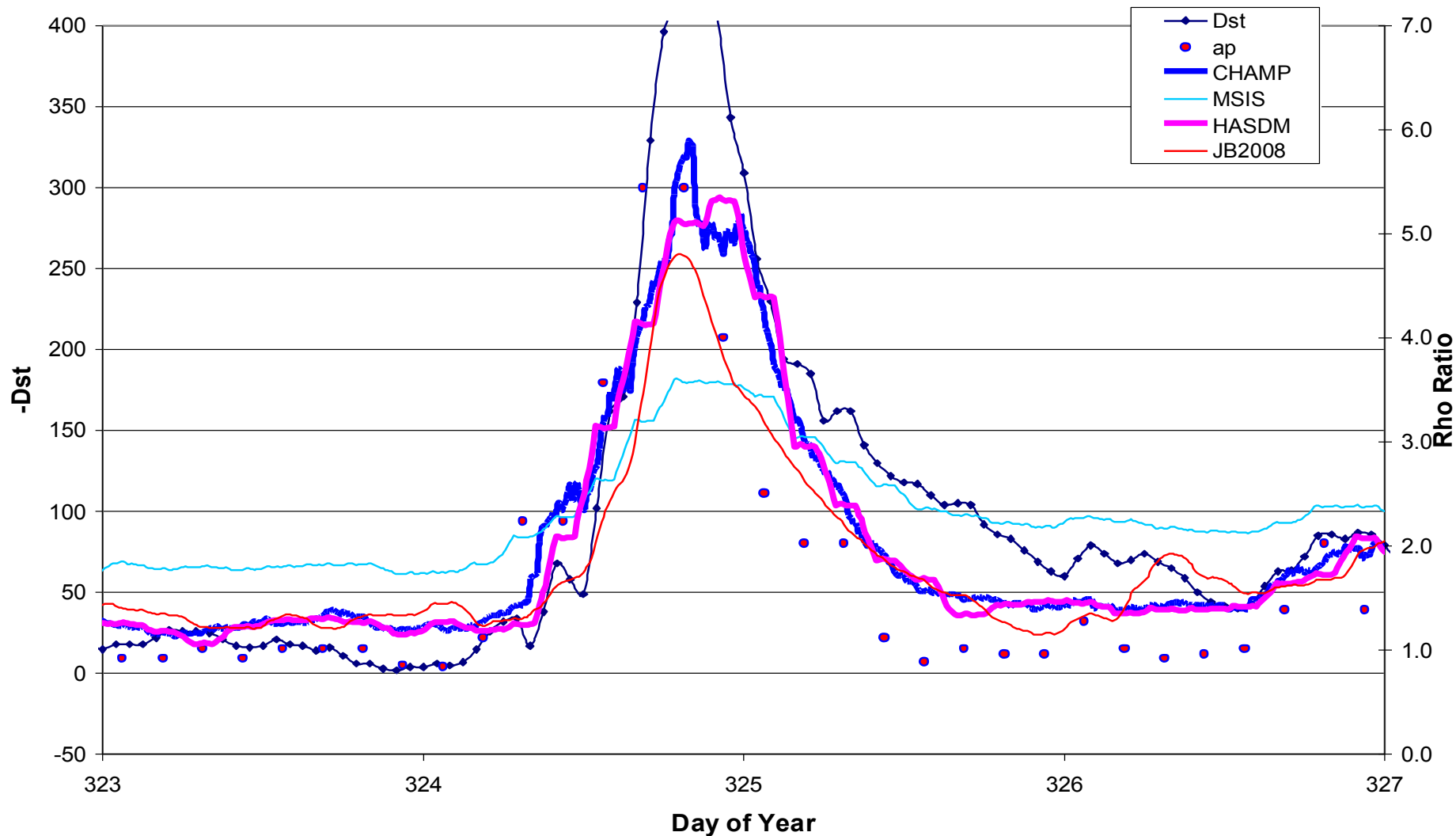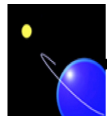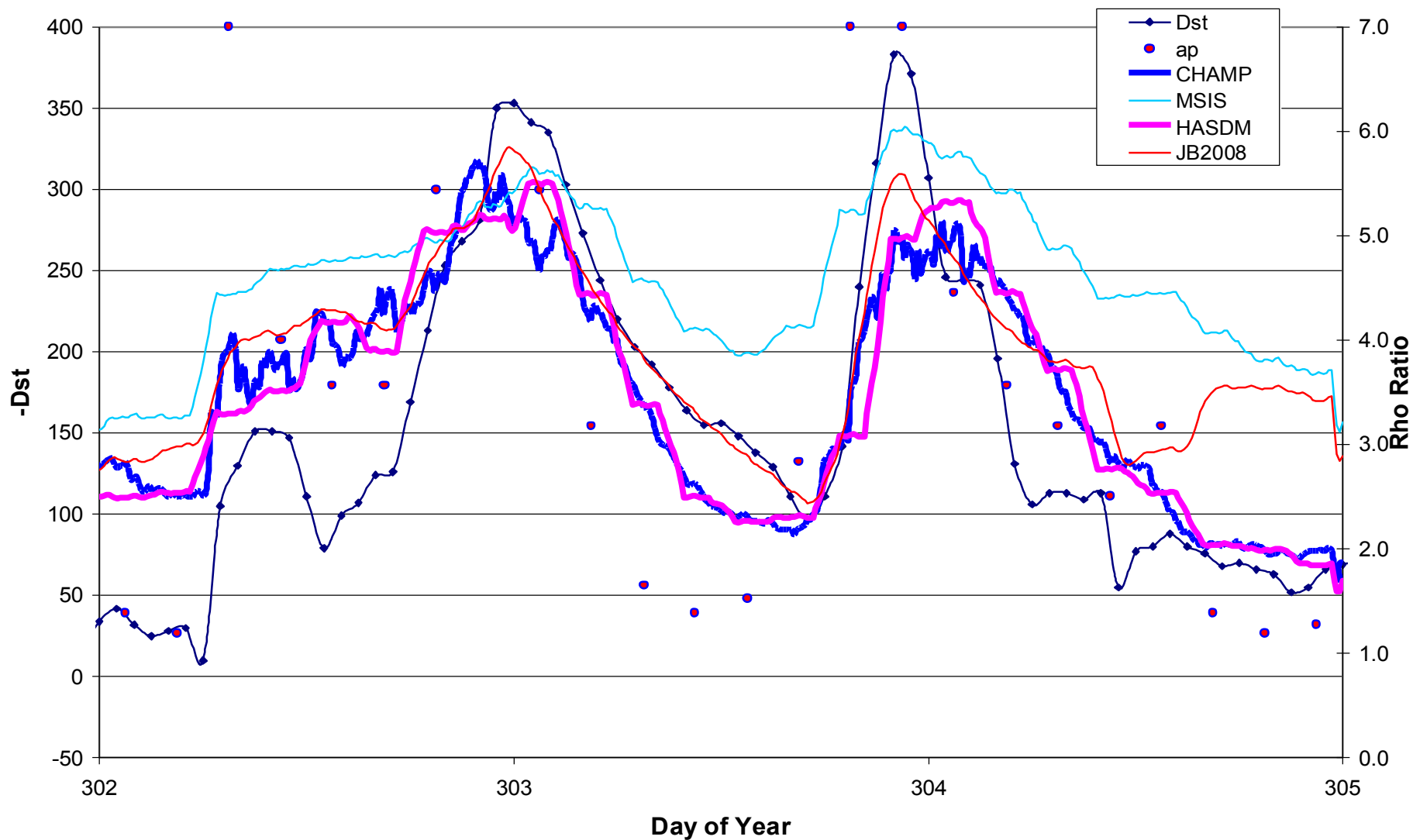
2004 Storm Geomagnetic Index Dst

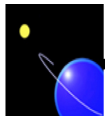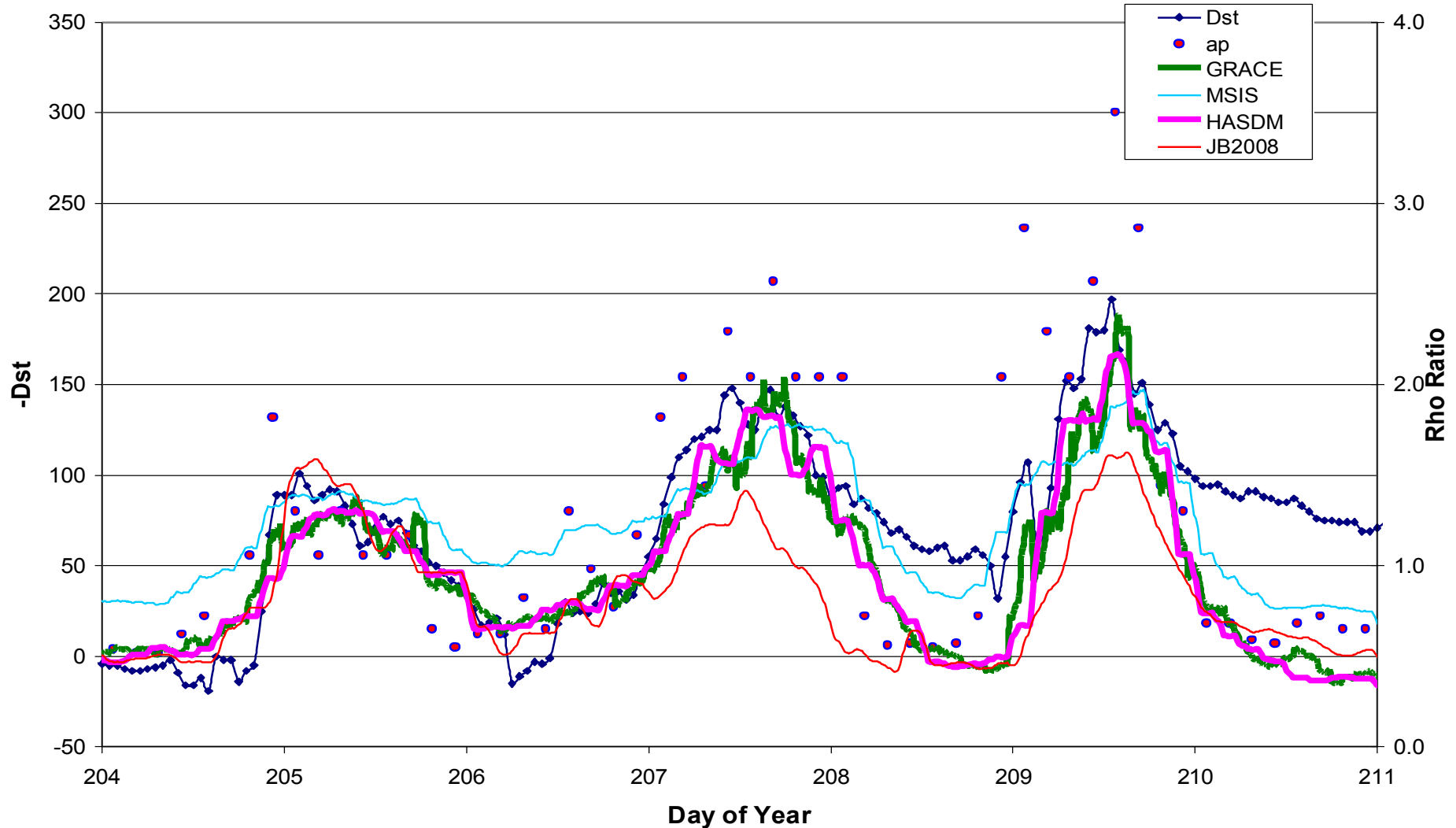2003 Dst with Density Ratios: (CHAMP / Acc Ave) and (Model / Acc Ave)

2003 Day 325 Storm

SPACE ENVIRONMENT TECHNOLOGIES

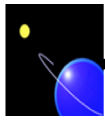Space Research   Space Operations   Space Standards

2003 Dst with Density Ratios: (CHAMP / Acc Ave) and (Model / Acc Ave)

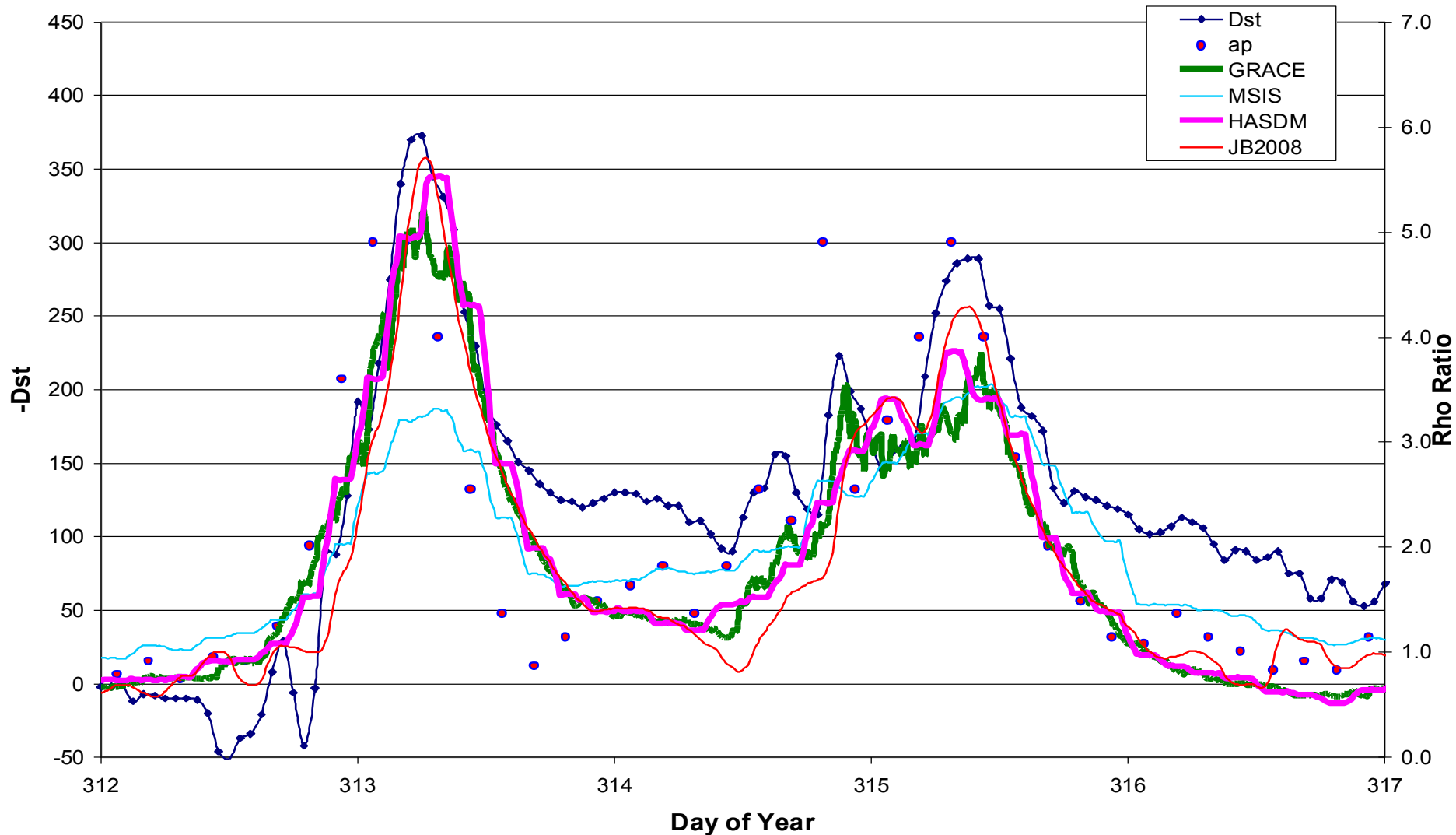## 2004 Dst with Density Ratios: (GRACE / Acc Ave) and (Model / Acc Ave)

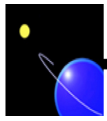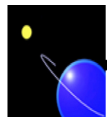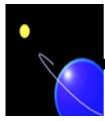2004 Dst with Density Ratios: (GRACE / Acc Ave) and (Model / Acc Ave)

- Calibration of on-orbit accelerometer density data
  - CHAMP 2001 – 2010
  - GRACE 2002 – Current
  - GOCE 2009 – 2013
  - DANDE 2013 – Current
  - SWARM 2014 –

- Atmospheric Model Research
  - Development of new empirical models
  - Validation of thermospheric density variations
  - Accurate geomagnetic storm modeling
  - Physics-based global density assimilation

- Satellite Drag Coefficient Modeling

- Air Force is maintaining an accurate real-time operational thermospheric density monitoring program

- The High Accuracy Satellite Drag Model (HASDM) is used to maintain the entire low earth orbit satellite drag catalog including all potential satellite conjunction analyses for DOD, NASA, and NOAA

- Real-time satellite observed solar and geomagnetic indices from SET are used as operational HASDM input for historical through 6 day predictions

- HASDM thermospheric density values are extremely valuable in thermospheric density research and for physics-based density modeling assimilations

- HASDM accurate 3-hour thermospheric density values from 200-800 km can be obtained from SET for years 2000 to current time

SPACE ENVIRONMENT TECHNOLOGIES
Space Research   Space Operations   Space Standards

2001 Solar Storm Indices