Thermospheric Density Analyses

Project HASDM

Bruce R Bowman
W. Kent Tobiska
Outline

• 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 Tc and 1 global coefficient in Tx

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

## HASDM 2012 Calibration Satellites

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<th>Height Km:</th>
<th>190</th>
<th>250</th>
<th>300</th>
<th>400</th>
<th>500</th>
<th>550</th>
<th>600</th>
<th>700</th>
<th>Total</th>
<th>Deep</th>
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<td>9</td>
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<td>12</td>
<td>9</td>
<td>6</td>
<td>3</td>
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Global Density During Quiet Time

HASDM DENSITY FOR 450.0 KM ALT

DENSITY (KG/M**3)

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)

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
HASDM Density Accuracy

Density % Error (1 Sigma) HASDM DCA Values

Perigee Ht (km)

dRho %

Solar Max - 2001
Solar Mid - 2004
Solar Min - 2008
• 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
**Dst Values During 2004 Storm**

### 2004 Storm Geomagnetic Index Dst

- **1st Storm Start**
- **1st Storm End**
- **2nd Storm Start**
- **2nd Storm End**
- **Recovery Slope Change**
- **Main Phase**
- **Recovery Phase**
- **2nd Storm Dst Min**
- **1st Storm Dst Min**
- **1st Storm Main Phase End**
- **1st Storm Main Phase**
- **1st Storm Recovery**
- **2nd Storm Recovery Phase**

**Day of Year**

- 312
- 313
- 314
- 315
- 316
- 317

**Dst**

- -450
- -400
- -350
- -300
- -250
- -200
- -150
- -100
- -50
- 0
- 50
- 100

**Legend**

- Presentation Title
- Presentation Date
2003 Dst with Density Ratios: (CHAMP / Acc Ave) and (Model / Acc Ave)
2003 Dst with Density Ratios: (CHAMP / Acc Ave) and (Model / Acc Ave)

-50 -40 -30 -20 -10 0 10 20 30 40 50 60 70

Day of Year

-Dst

0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0

Rho Ratio

Dst

ap

CHAMP

MSIS

HASDM

JB2008
2004 Dst with Density Ratios: (GRACE / Acc Ave) and (Model / Acc Ave)
2004 Dst with Density Ratios: (GRACE / Acc Ave) and (Model / Acc Ave)
HASDM Data Applications

- 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
Conclusions

• 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
2001 Solar Storm Indices

Year Day

 DST

 ap