Data and Applications of Space Weather Payloads onboard of BDS Satellites

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Space Weather and GNSS
1. Space environment disruptions near Earth, caused by solar activities
2. Possible consequences of space weather events to GNSS
3. Incident Electrons and Charging Events

- Incident Electrons
- Incident ions
- Sunlight
- Sheath
- Back-scattered Electrons
- Secondary Electrons
- Photo-Emission
- Isolated Conductor
- Conduction
- Deep Dielectric
- Charging
- Structure ‘Ground’ $V_a$

Surface Charging

Inner Charging

Interference
The Solar Cycle 25 is HERE
The Solar Cycle 25 is Here

1. Sun's activity is higher than expected

International sunspot number $S_{\text{sun}}$: last 13 years and forecasts

SILSO graphics (http://sidc.be/silso) Royal Observatory of Belgium 2023 October 1
The Solar Cycle 25 is Here

2. Solar activity-Geomagnetic storm-Increasing atmospheric density-Satellites Decay

![Solar image]

![Geomagnetic storm image]

![Graph showing atmospheric density and satellite decay]

2023/04/21 20:36

-113m/day
-168m/day

2023 Year, UT
3. Extensive interference and interruption of GNSS navigation signals on the dayside caused by L-band solar radio burst on May 4th, 2023
The Solar Cycle is Here

4. Increasingly active solar activity
Space Weather Payloads on BDS
## 1. Energetic Electron Detection Packages

<table>
<thead>
<tr>
<th>Payload</th>
<th>Characteristic Parameter</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium-energy Electron Spectrometer (MES)</td>
<td>Energy: 50~600keV, FOV: 30°×180°, Geometric factor: &lt;~2.0×10^{-3}</td>
<td>Measure the energy spectra and flux changes of medium electrons in the outer radiation belt.</td>
</tr>
<tr>
<td>High-energy Electron Detector (HED)</td>
<td>Energy: 0.5~3.0MeV, FOV: 30° cone-angle, Geometric factor: &lt;~1.0×10^{-2}</td>
<td>Measure the energy spectra and flux changes of high electrons in the outer radiation belt.</td>
</tr>
<tr>
<td>Deep Dielectric Charging Monitor (DDCM)</td>
<td>Charging Voltage: -2.5 kV to 0 V, Charging Current: 0.01-50 pA</td>
<td>Measure the deep dielectric charging current and voltage.</td>
</tr>
</tbody>
</table>
## 2. Space Plasma and Satellite Surface Charging Monitor

<table>
<thead>
<tr>
<th>Payload</th>
<th>Characteristic Parameter</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Energy Electron/Ion Spectrometer</td>
<td>Energy: 0.1~15 keV&lt;br&gt;FOV: 2π&lt;br&gt;Resolution: &lt;15%±2%</td>
<td>Detect parameters of in-situ electrons and ions, such as energy, flux, density and velocity.</td>
</tr>
<tr>
<td>Magnetometer</td>
<td>Range: -65000 nT ~ +65000 nT&lt;br&gt;Noise: 10 nT</td>
<td>Measure the environmental magnetic field around the satellites.</td>
</tr>
<tr>
<td>Radiation dosimeter</td>
<td>Radiation dosage: 0~$10^7$rad</td>
<td>Measure total radiation dose to evaluate the lifetime of satellite.</td>
</tr>
<tr>
<td>Surface potential detector</td>
<td>Surface potential: 0.1 ~10 kV</td>
<td>Monitor the satellite’s surface potential.</td>
</tr>
</tbody>
</table>
Space Weather Payloads on BDS

3. Data of HED (High-energy Electron Detector)

Highly Energy Electron Flux (X: 0.2–0.3MeV)

The red arrows indicate times of four CME (Coronal Mass Ejection) events
4. Data of LEIS (Low Energy Ion Spectrometer)

2021-09-30 to 2021-10-01
ori-nuv Ch5 Elevation Index = total Diff Energy Flux

A and B: Surface charging events
C: Characteristic for injection of charged particles
4. Analysis of the Surface Charging Events

- Spectrum data of both Ions and Electrons are from the same satellite

- The higher electron fluxes appear from the midnight to the dawn side, which may indicate that the electron injection from the magnetotail mainly occurs at the dawn side

- The weakening of the substorm and the weakening of the electron flux observed by the electron detector on the dawn side may indicate a correlation in-between.
5. A prediction model for high-energy electrons in radiation belt

- **Model Principle:** Delayed correlation between intermediate and high-energy electrons

- **Model Equations**

  \[
  \frac{dj}{dt} = S + L \\
  j(t + \Delta t)_{\text{high}} = j(t)_{\text{high}} + \Delta t(S + L) \\
  S = C_1 C_2 \left(\frac{j(t)_{\text{low}}}{j(t)_{\text{low}} + \Delta t}\right)^b + C_3 j(t - \Delta t)_{\text{high}} \\
  L = -C_4 j(t)_{\text{high}} \\
  g = \log_{10} \left[ j(t)_{\text{high}} \right] - \log_{10} \left[ j(t - \Delta t)_{\text{high}} \right] \\
  \log_{10} \left[ j(t + \Delta t)_{\text{high corrected}} \right] = \log_{10} \left[ j(t + \Delta t)_{\text{high}} \right] (1 + \bar{g})
  \]
Model Results:
The prediction efficiency and accuracy are both very good.
Proposal and Discussions
Proposal and Discussions

- **Joint response to catastrophic space weather events**

- We should work together to prevent possible damages from severe space weather events to our GNSS satellites

- The workshops for space weather events could be conducted in ICG

- Data products, models and forecast outputs could be shared and discussed in ICG.

- A platform, such as a website, could be built for public to study the impact for space weather events to GNSS
Thank you

http://en.beidou.gov.cn