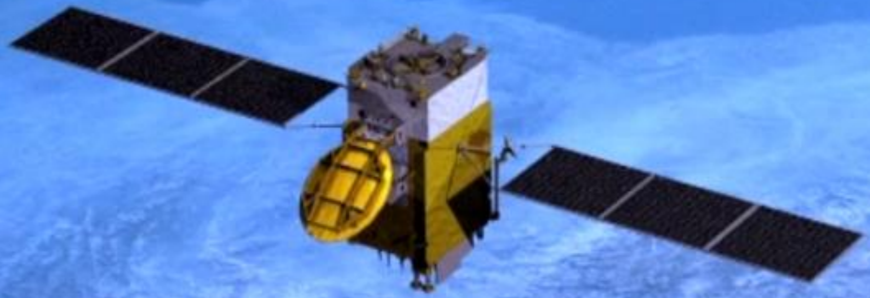
17th Meeting of the International Committee on Global Navigation Satellite Systems

Data and Applications of Space Weather Payloads onboard of BDS Satellites



Liu Kai

University of Science and Technology of China

2023-10-17 Madrid, Spain

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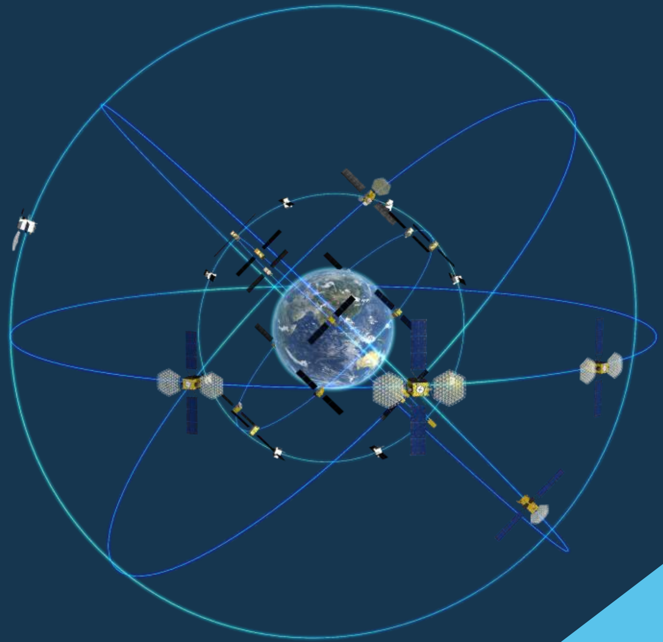
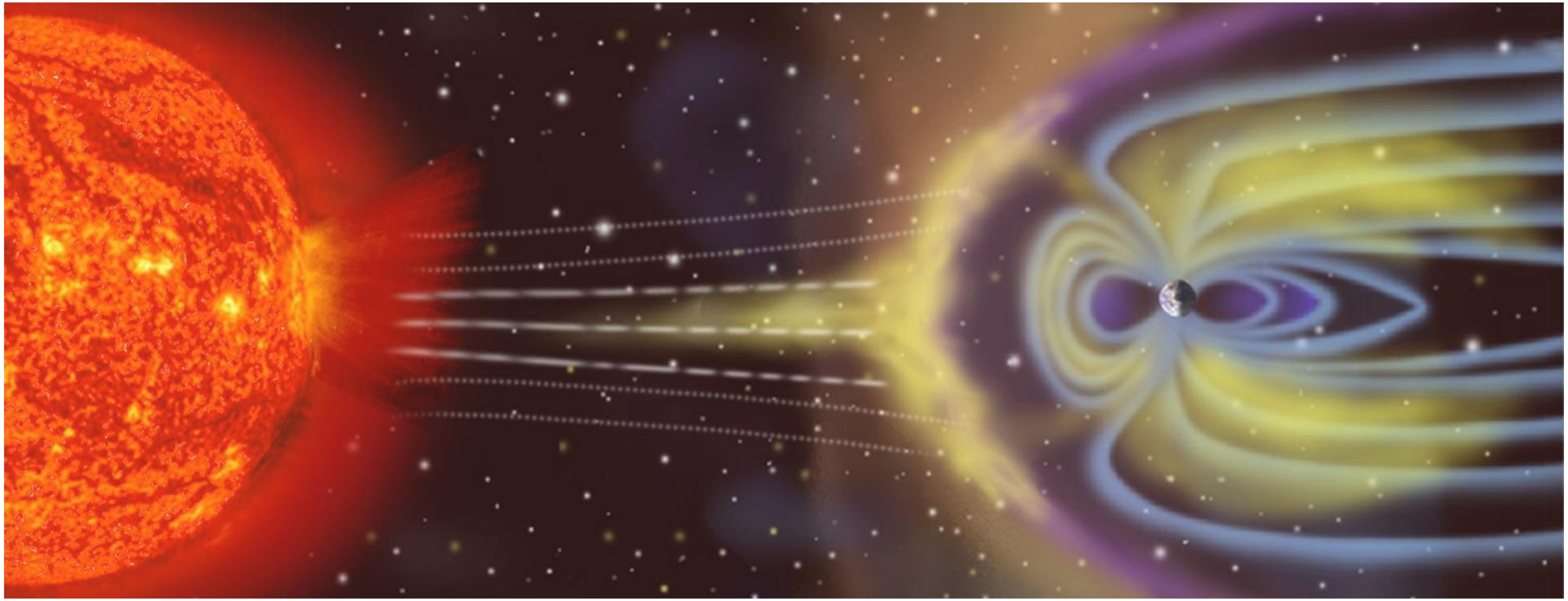


Space Weather and GNSS

01

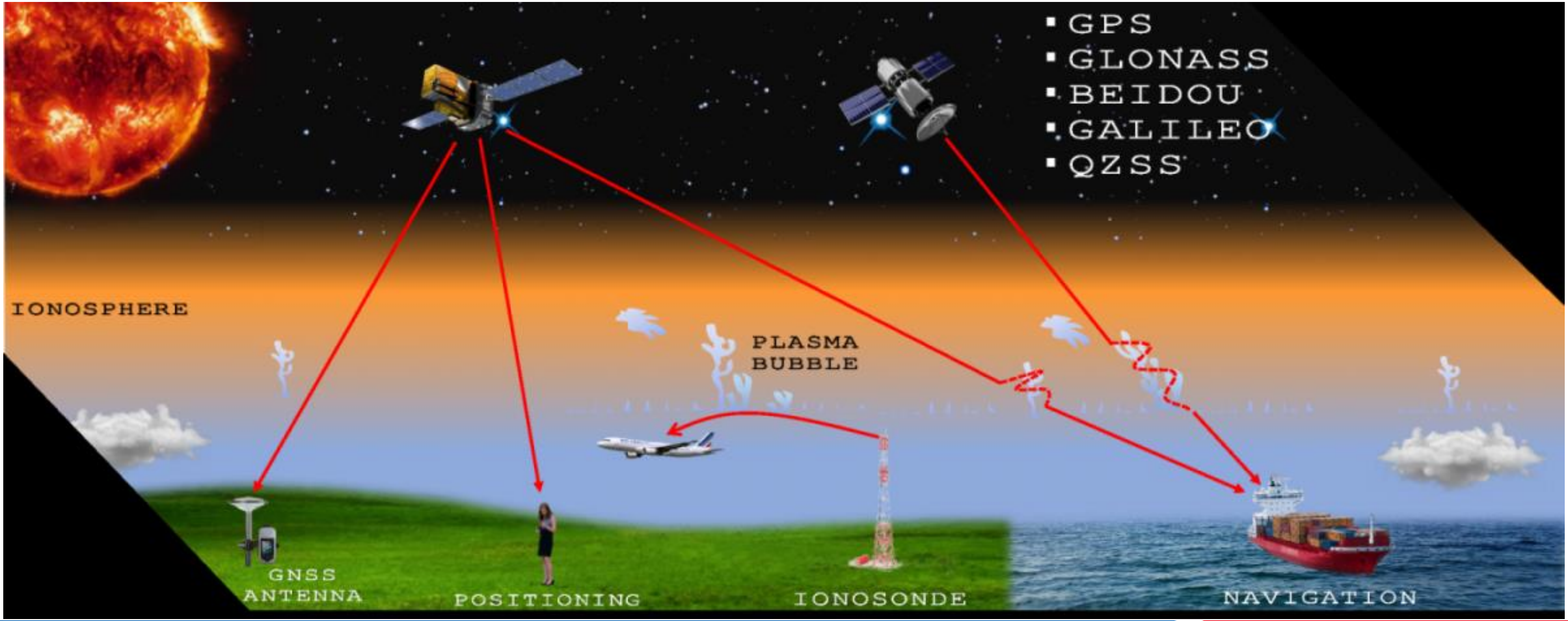
Space Weather and GNSS

1. Space environment disruptions near Earth, caused by solar activities



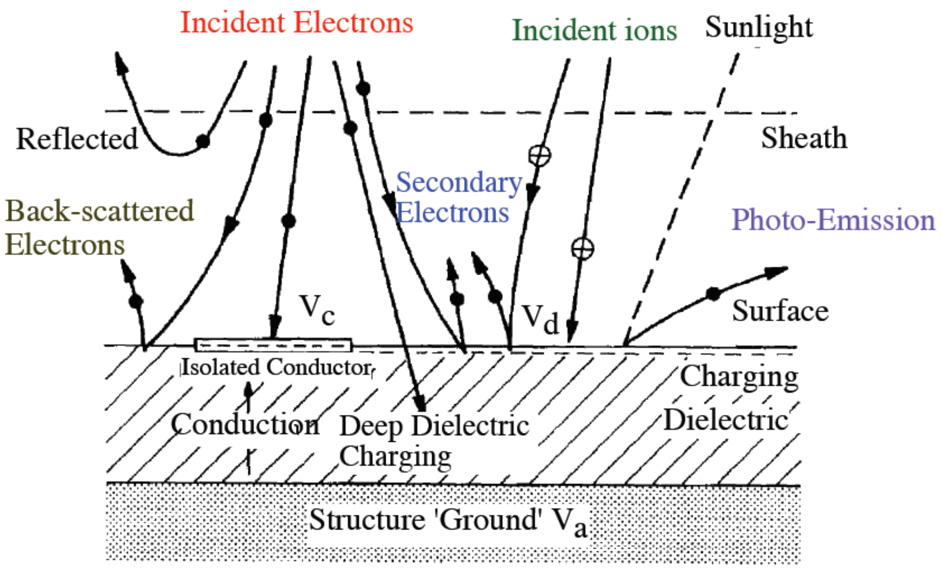
Space Weather and GNSS

2. Possible consequences of space weather events to GNSS

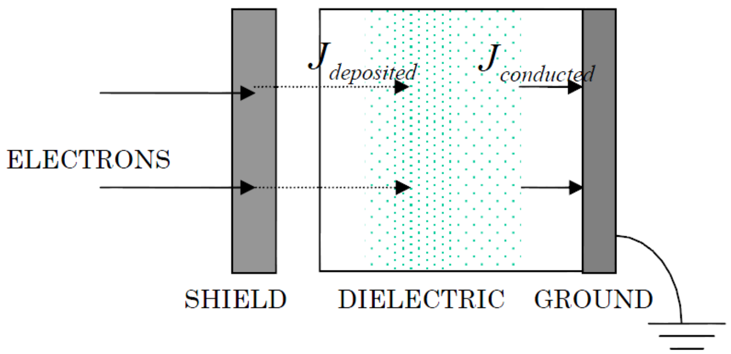


Space Weather and GNSS

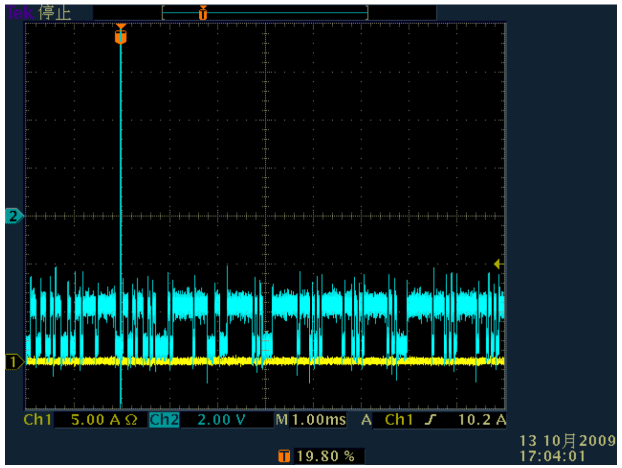
3. Incident Electrons and Charging Events



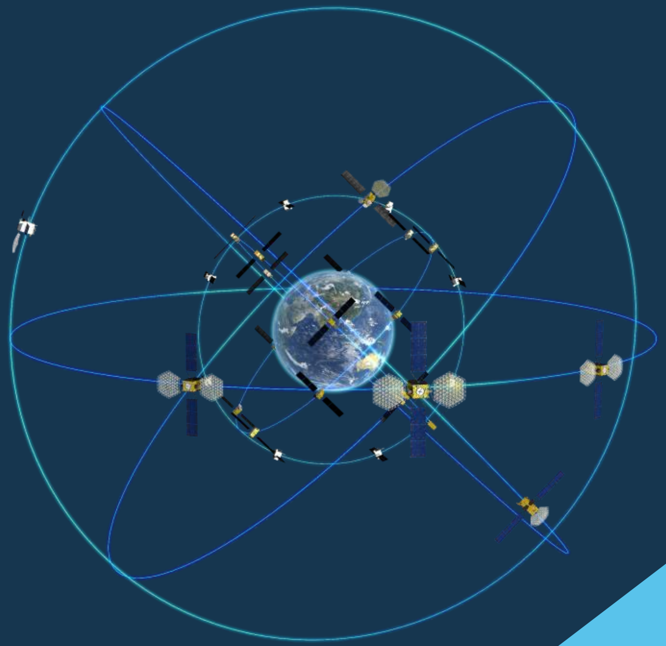
Surface Charging



Inner Charging



Interference

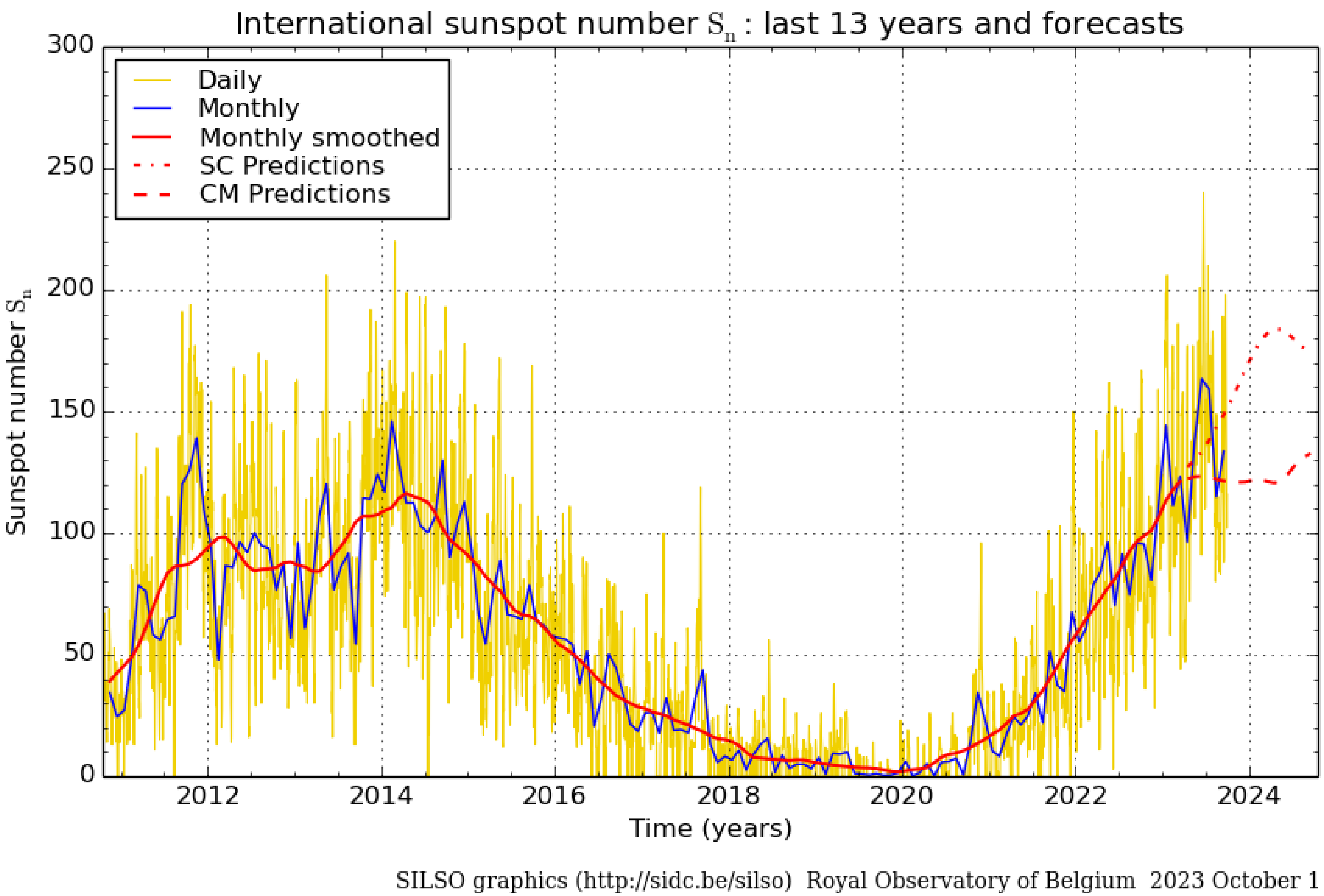


The Solar Cycle 25 is HERE

02

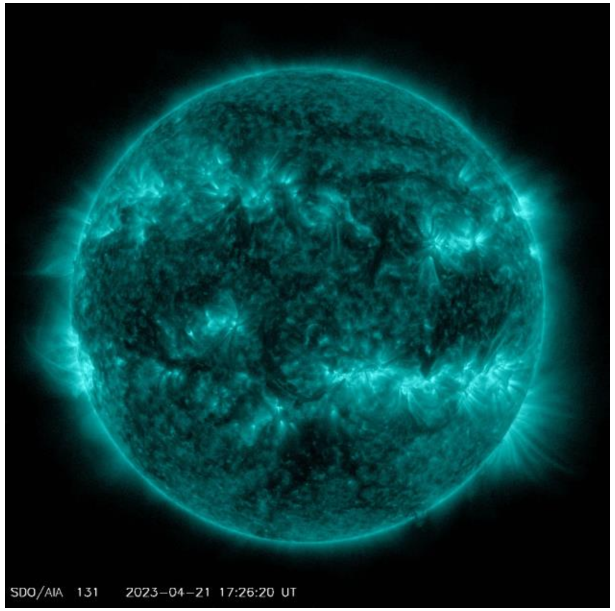
The Solar Cycle 25 is Here

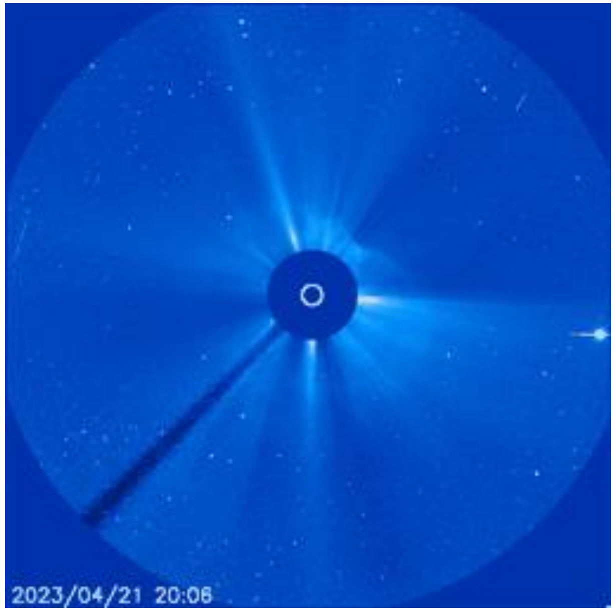
1. Sun's activity is higher than expected

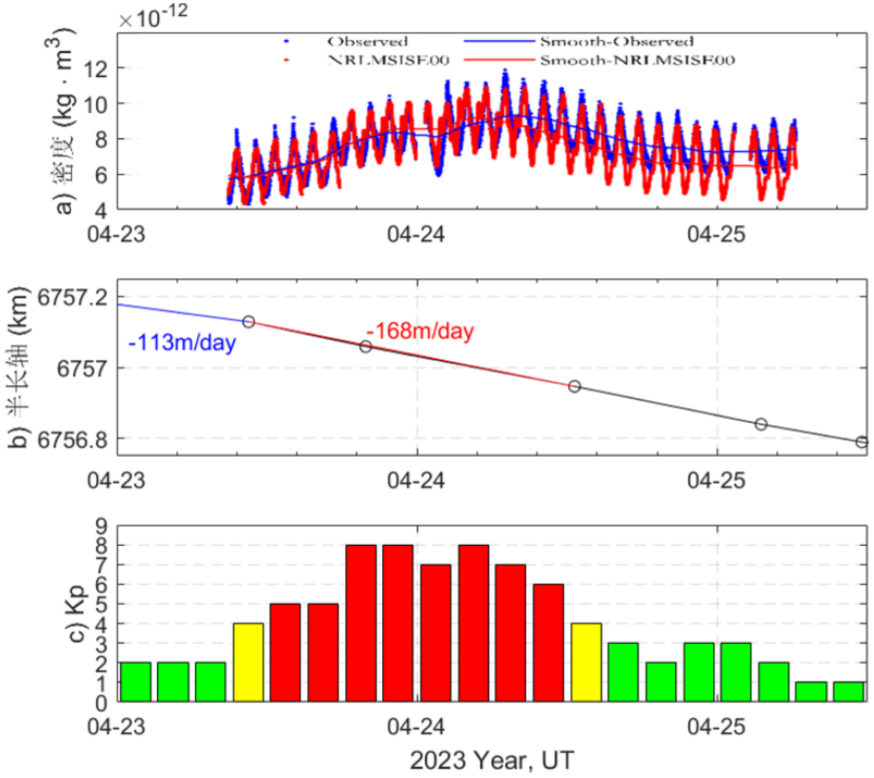


The Solar Cycle 25 is Here

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

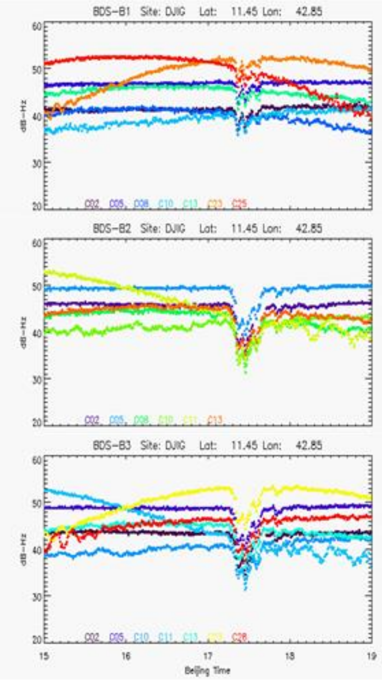


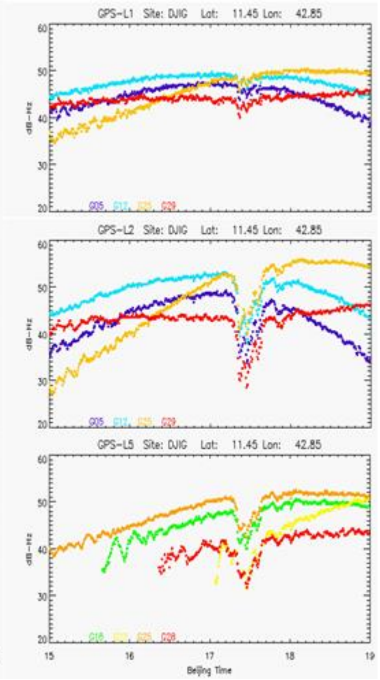


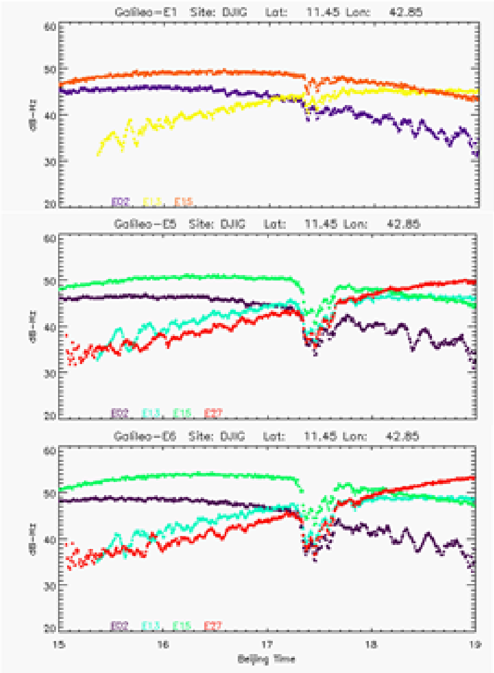


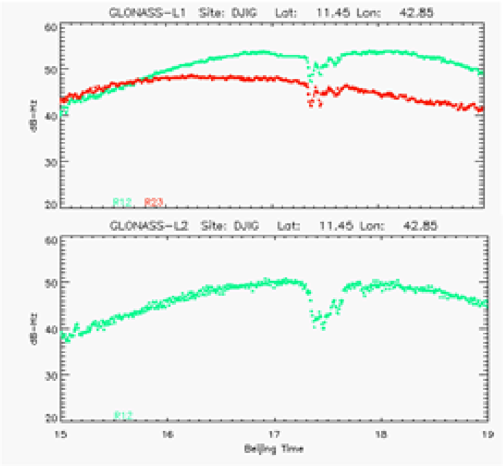
The Solar Cycle 25 is Here

3. Extensive interference and interruption of GNSS navigation signals on the dayside caused by L-band solar radio burst on May 4th, 2023





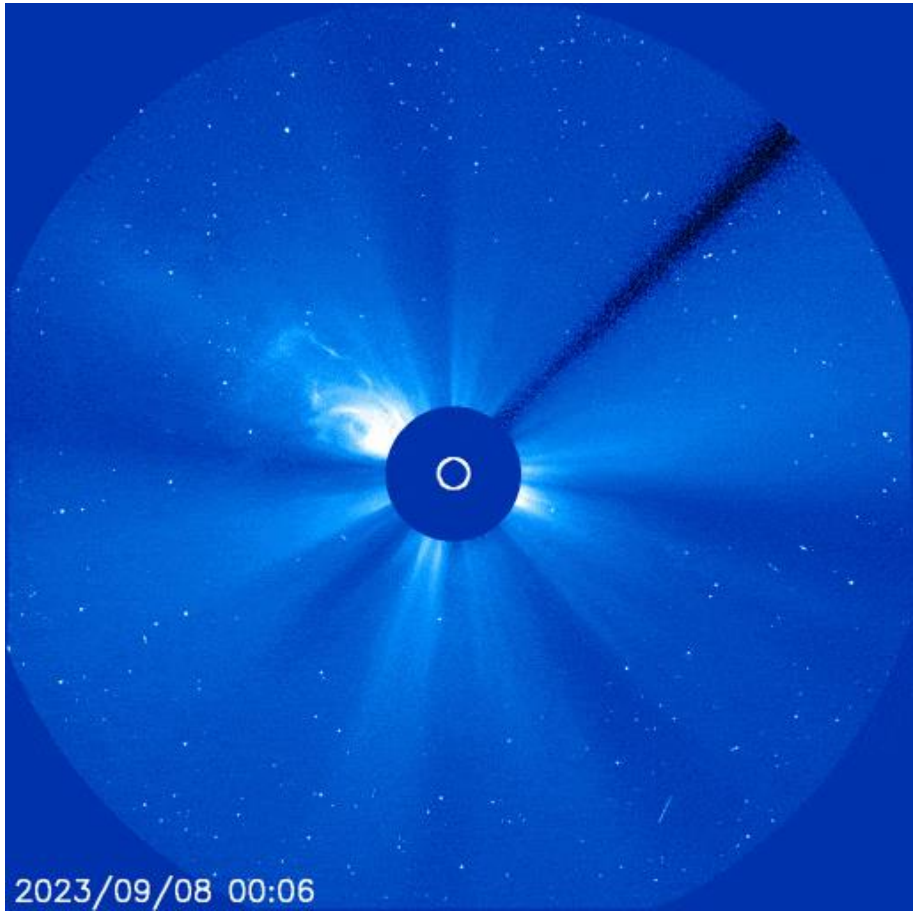


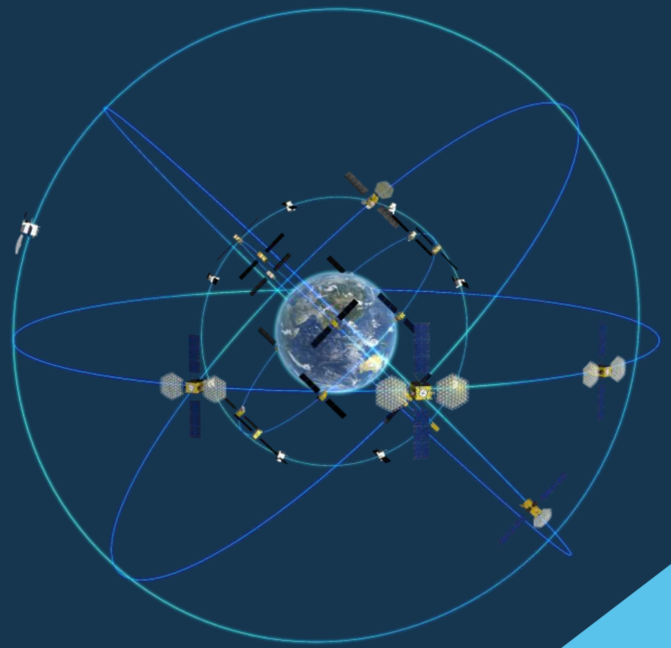


BDS GPS GALILEO GLONASS

The Solar Cycle is Here

4. Increasingly active solar activity





Space Weather Payloads on BDS

03

Space Weather Payloads on BDS

1. Energetic Electron Detection Packages

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

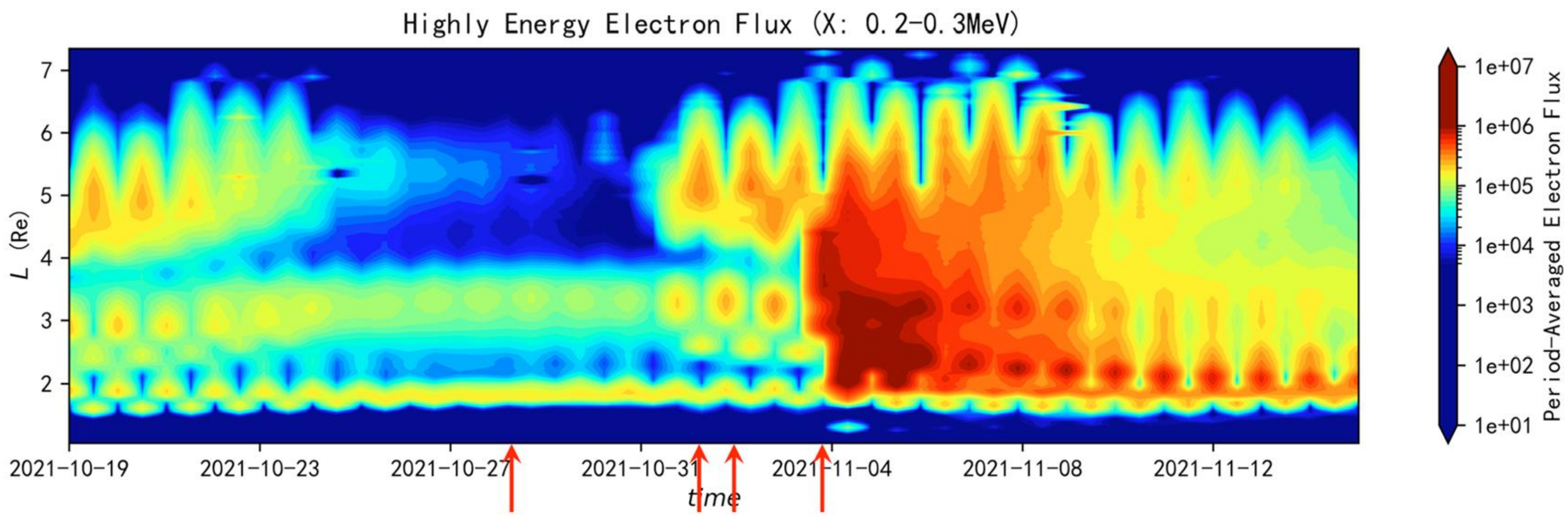
Space Weather Payloads on BDS

2. Space Plasma and Satellite Surface Charging Monitor

Payload	Characteristic Parameter	Function
Low Energy Electron/Ion Spectrometer	Energy: 0.1~15 keV FOV: 2π Resolution: ＜15%±2%	Detect parameters of in-situ electrons and ions, such as energy, flux, density and velocity.
Magnetometer	Range: -65000 nT ～ +65000 nT Noise: 10 nT	Measure the environmental magnetic field around the satellites.
Radiation dosimeter	Radiation dosage：0～10^7rad	Measure total radiation dose to evaluate the lifetime of satellite.
Surface potential detector	Surface potential ：0.1 ～10 kV	Monitor the satellite' s surface potential.

Space Weather Payloads on BDS

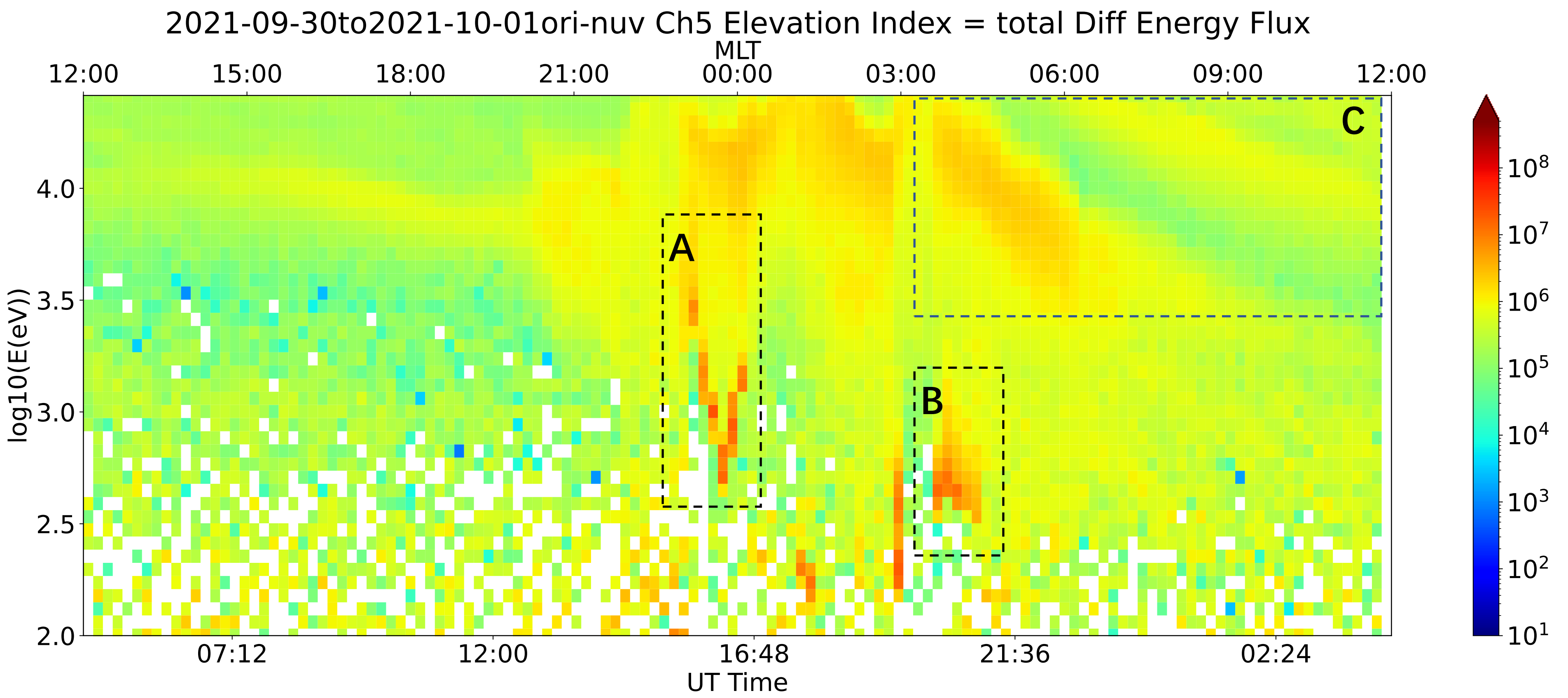
3. Data of HED (High-energy Electron Detector)



The red arrows indicate times of four CME (Coronal Mass Ejection) events

Space Weather Payloads on BDS

4. Data of LEIS (Low Energy Ion Spectrometer)

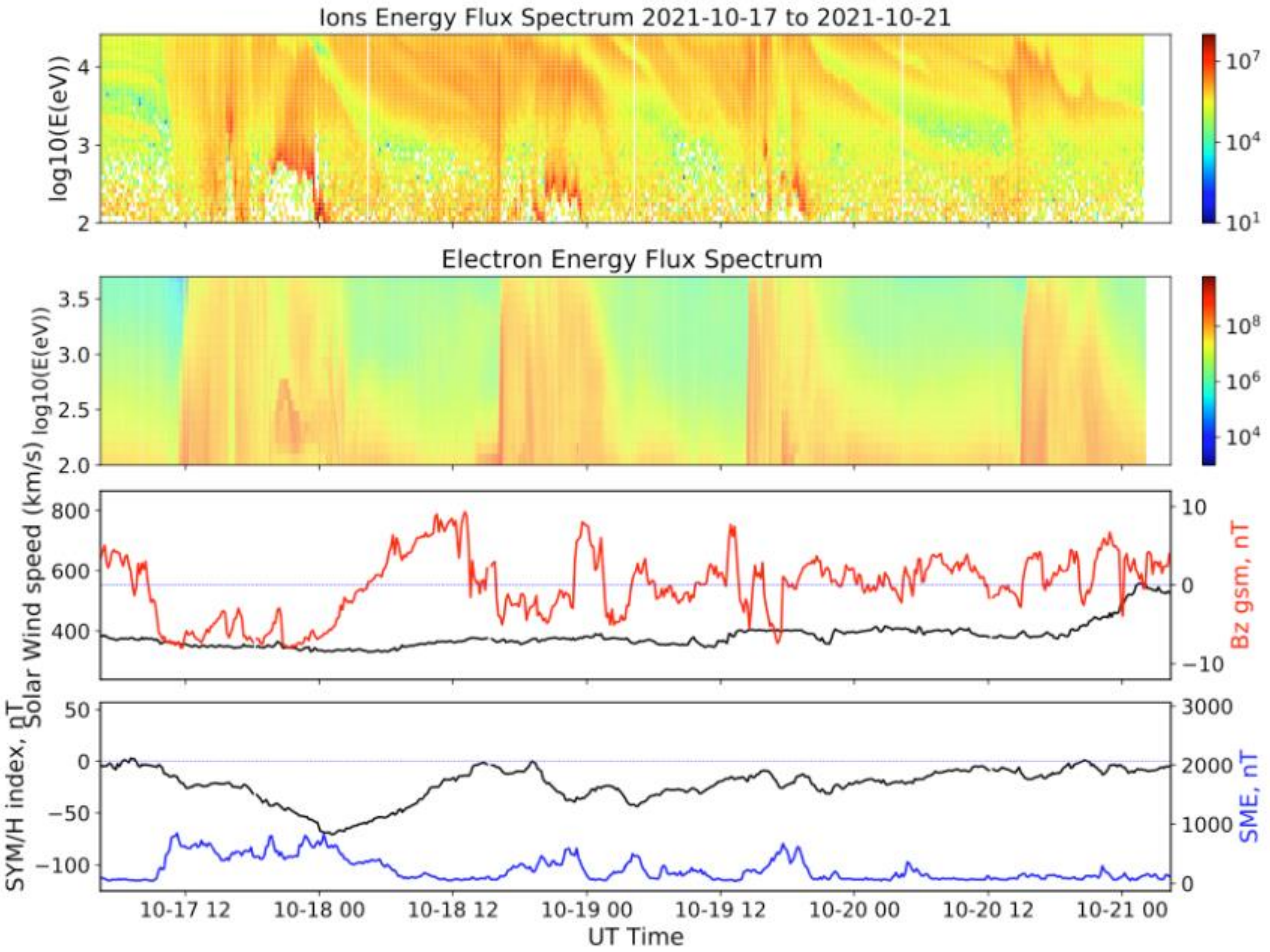


A and B: Surface charging events
C: Characteristic for injection of charged particles

Space Weather Payloads on BDS

4. Analysis of the Surface Charging Events

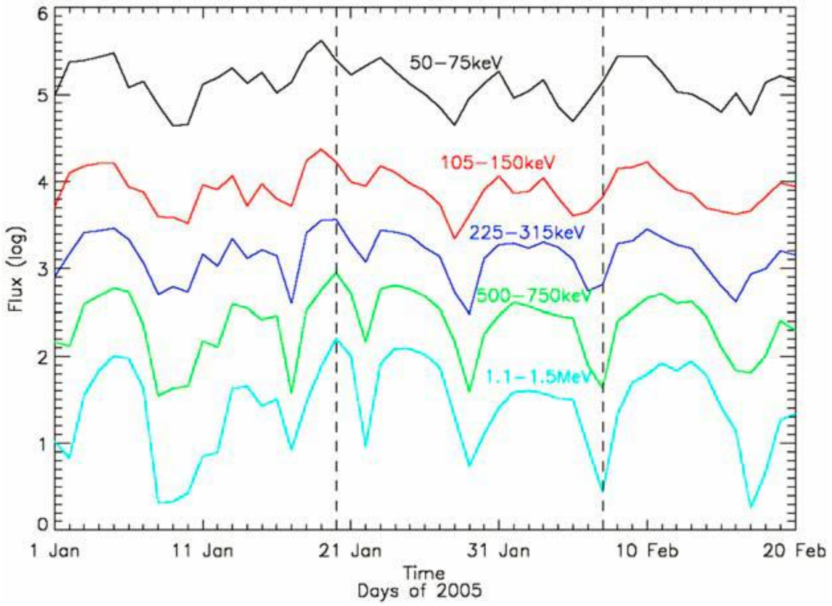
- Spectrum data of both Ions and Electrons are from the same satellite
- The higher electron fluxes appear from the midnight to the dawn side, which may indicate that the electron injection from the magnetotail mainly occurs at the dawn side
- The weakening of the substorm and the weakening of the electron flux observed by the electron detector on the dawn side may indicate a correlation in-betweens



Space Weather Payloads on BDS

5. A prediction model for high-energy electrons in radiation belt

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



- **Model Equations**

$$\frac{dj}{dt} = S + L$$

$$j(t+\Delta t)_{\text{high}} = j(t)_{\text{high}} + \Delta t(S+L)$$

$$S = C_1 C_2^{\left(\frac{j(t-t_0)_{\text{low}}}{j_0}\right)^b} + C_3 j(t-\Delta t)_{\text{high}}$$

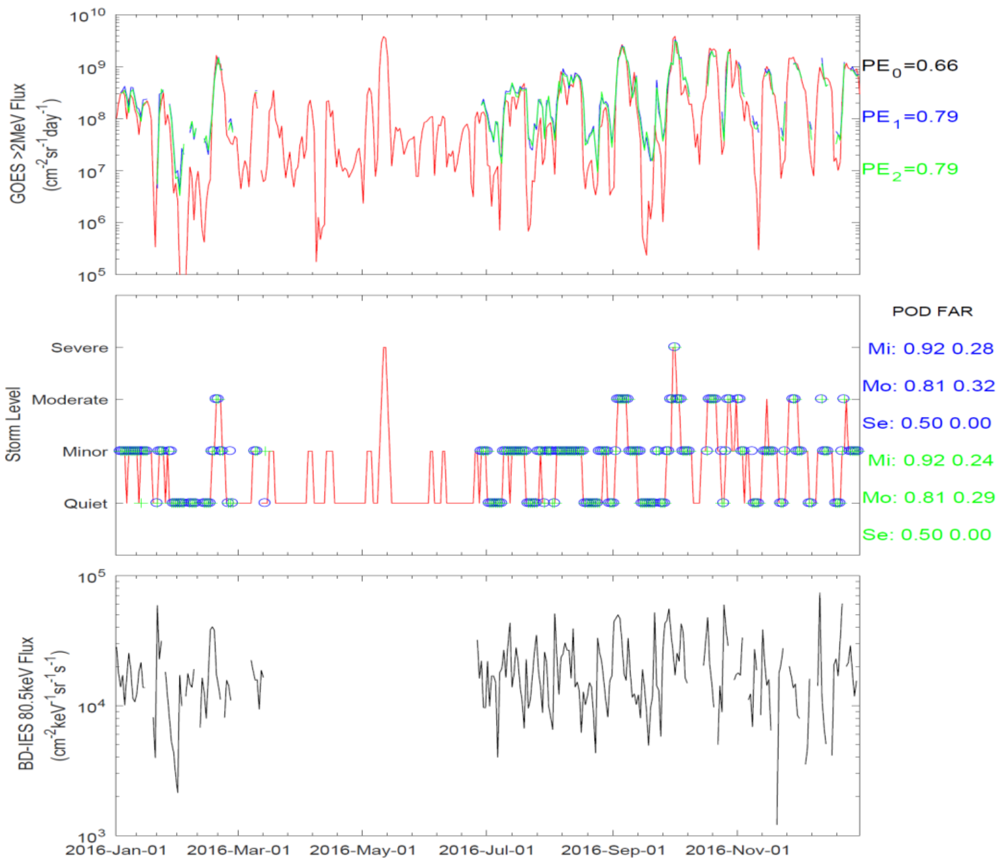
$$L = -C_4 j(t)_{\text{high}}$$

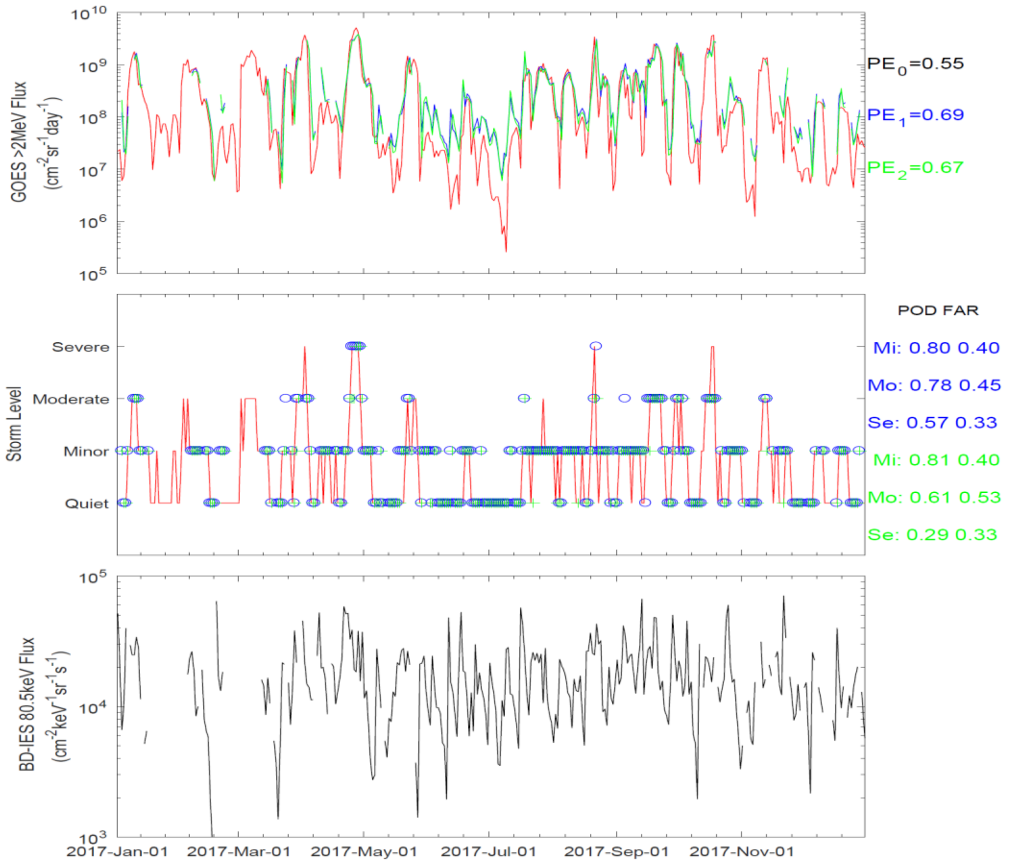
$$g = \log_{10}\left[j(t)_{\text{high}}\right] - \log_{10}\left[j(t-\Delta t)_{\text{high}}\right]$$

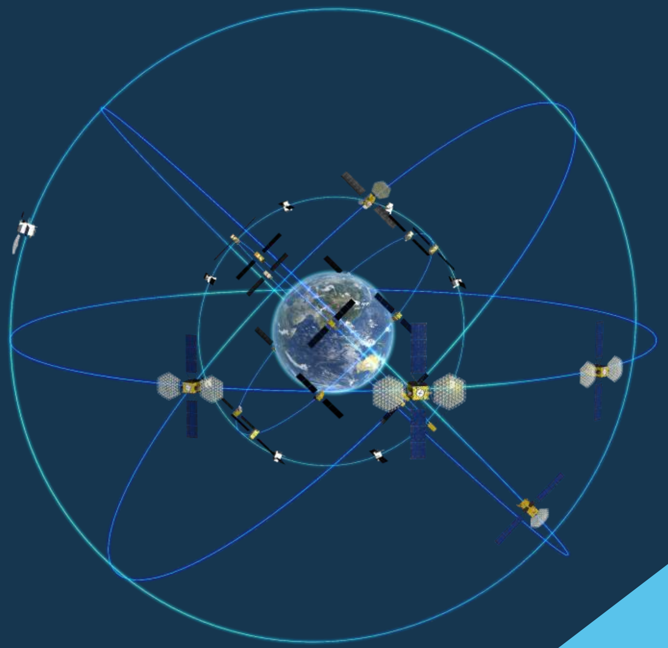
$$\log_{10}\left[j(t+\Delta t)_{\text{high corrected}}\right] = \log_{10}\left[j(t+\Delta t)_{\text{high}}\right](1+fg)$$

Space Weather Payloads on BDS

➢ **Model Results :**
The prediction efficiency and accuracy are both very good





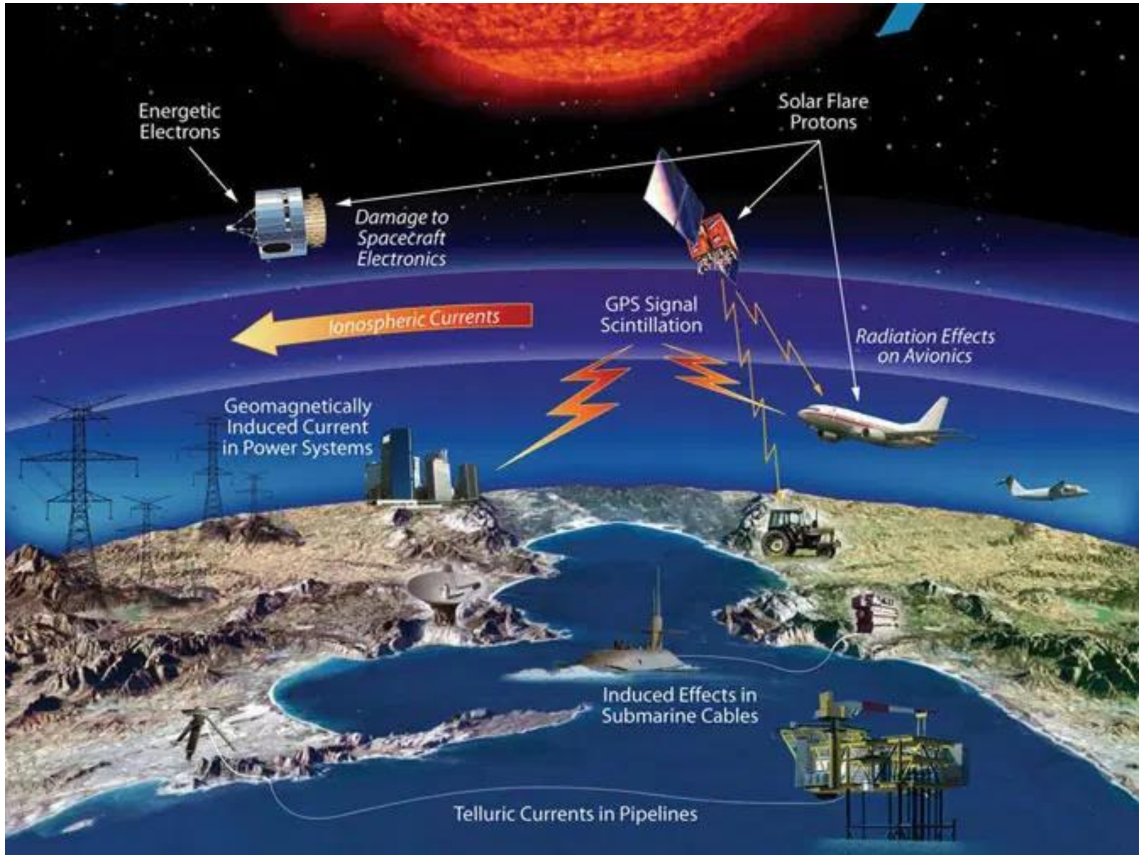


04 Proposal and Discussions

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

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