Application system and data description of the China Seismo-Electromagnetic Satellite

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Abstract: The China Seismo-Electromagnetic Satellite, launched into orbit from Jiuquan Satellite Launch Centre on February 2nd, 2018, is China’s first space satellite dedicated to geophysical exploration. The satellite carries eight scientific payloads including high-precision magnetometers to detect electromagnetic changes in space, in particular changes associated with global earthquake disasters. In order to encourage and facilitate use by geophysical scientists of data from the satellite’s payloads, this paper introduces the application systems developed for the China Seismo-Electromagnetic Satellite by the Institute of Crustal Dynamics, China Earthquake Administration; these include platform construction, data classification, data storage, data format, and data access and acquisition. 

Keywords: China Seismo-Electromagnetic Satellite; application system; geophysical field; data classification

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1. Introduction

The China Seismo-Electromagnetic Satellite (CSES, also called ZH-1) is China’s first satellite dedicated to geophysics; it is also the first component of the space-based Chinese earthquake stereoscopic monitoring system (Shen XH et al., 2018). Its scientific goal is to preliminarily explore the characteristics and mechanisms of changes in ionospheric response before and after earthquakes, based on real-time monitoring of changes in the state of the space electromagnetic environment. In addition, it helps to study the earth system, especially the interaction and effects of the ionosphere with other related earth’s spheres. There are 8 payloads on the satellite (Figure 1), which are divided into 3 categories, including electromagnetic type of high-precision magnetometers (Cheng BJ et al., 2018), search-coil magnetometers (Cao JB et al., 2018), and electric field detector (Huang JP et al., 2018), in-situ detection type as plasma analyzer and Langmuir probe (Liu C et al., 2018), and high energy particle detection package, structural type of GNSS occultation receivers (Cheng Y et al., 2018; Lin J et al., 2018) and tri-band beacon transmitters (Chen L et al., 2018). The satellite is also equipped with another high-energy particle detector (Ambrosi et al., 2018) from the Italian Space Agency. The satellite has a flying height of 507 km, inclination angle of 97.4\(^\circ\), a descending local time node of 14:00, and a revisiting period of 5 days.

In accordance with the engineering requirements and construction design of the ZH-1 satellite, the project is divided into six parts: a satellite system, a launch vehicle system, a launch site system, a measurement and control system, a ground system, and an application system. The satellite system is responsible for the development of the satellite platform and payloads; the launch vehicle system is responsible for the development of the rocket; the launch site system is responsible for launching the satellite into the target orbit; the measurement and control system is responsible for monitoring and controlling satellite operations, receiving the telemetry data transmitted by the satellite and transmitting it to the ground system; the ground system is responsible for coding the satellite work instructions, with the ground station receiving scientific data and conducting primary processing; and the application system is responsible for satellite mission planning, data processing, data service, and scientific applications. The satellite transmits the scientific data through the X-band at the downlink rate of 120 Mbps; the telemetry data is transmitted through the S-band (Yuan SG et al., 2018). Data links among the measurement and control systems and the ground system, and the ground system and application systems, are transmitted through the fiber-optic line.

The structure of this paper is as follows: Chapter 2 explains the overall construction of the application system. Chapters 3 and 4 respectively introduce data classification criteria and data processing procedures. Chapters 5 and 6 introduce data storage solutions and data service solutions. Chapter 7 suggests desirable future optimizations.
2. The Overall Construction of the Application System
The main task of the application system is to develop a work plan for the satellite and payloads, and receive scientific data and telemetry data transmitted from the ground system. Based on the above work products, it then produces standardized advanced products and scientific application products in order to provide data in formats suited to the needs of users. Therefore, the construction design of the entire application system is divided into an operation management subsystem, a data management subsystem, a data processing subsystem, a product quality evaluation subsystem, and a data service subsystem. For the block diagram of the structure, see Figure 2.

The operation management subsystem is further divided into two principal subsystems, dedicated to (1) mission planning and (2) task operation and control. The mission planning subsystem is responsible for formulating and pushing the work plan of areas with the burst mode and satellite (and payloads) to the ground system (Figure 3). The satellite and load operations are monitored according to telemetry data pushed by the ground system. In addition, satellite orbit calculation, simulation, and prediction are carried out instantaneously through the orbit, pushed by the ground system. The task operation and control subsystem is responsible for sending tasks of data processing, archiving, and management of the entire system, and for monitoring the operating state between task flow, the subsystems, the application system, and the external interface.

The data management subsystem is further subdivided into a data access subsystem and a data archiving and query subsystem. The data access subsystem is responsible for receiving scientific data and telemetry data at 0-2 levels, pushed by the ground system, and auxiliary data (including earthquake catalogue, space weather index, etc.) required by scientific applications. The data archiving and query subsystem is responsible for archiving received data and products at all levels in the form of a file directory, and querying, displaying, and downloading data in various forms according to daily needs.

The data processing and analysis subsystem is divided into eight payload processing subsystems and one integrated processing subsystem in order to realize single processing and comprehensive product display of each level for all data from each payload. At present, the format and procedure for the Italian high-energy particle payload have not been fully confirmed; these specifications will be provided to China for integration into the overall plan.

Through a web interface, the data service subsystem provides users, based on user levels and rights, with these functions: data registration, browsing, query and download.

3. Data Description
3.1 The Classification of Scientific Data
ZH-1 satellite data are divided into scientific data, telemetry data, and auxiliary data. Principal telemetry data include satellite position and speed, payload telemetry parameters, and other information. Examples of auxiliary data are calibration parameters for data processing, seismic catalogs, and space weather indices.

The scientific data and products are divided into the following categories and levels according to their content and processing actions.

**Raw data**: Raw data are data received by the ground receiving station, including the data from the satellite, and data from each station received by the tri-band beacon-receiving station of a particular application system.

**Level 0 data product**: Level 0 data include time-aligned scientific data and engineering parameters from each payload after frame synchronization, descrambling, error correction, and de-duplication, and observation data received by the tri-band beacon ground station.

**Level 1 product**: Time-aligned physical quantity data obtained after format conversion and calibration processing of Level 0 data are termed Level 1.

**Level 2 product**: Physical quantity data with information of geographic and geomagnetic coordinate system, time, position and attitude, generated after coordinate transformation and inversion of Level 1 data, are termed Level 2.
Figure 2. Construction of the application system.
**Level 2A product:** Level 2A data include (1) electric field observation data generated after removing the influence of the $V \times B$ electric field based on the electric field waveform data of the Level 2 payload coordinate system; (2) GNSS Radio occultation observation data obtained after precise orbit determination and inversion of Level 1 data.

**Level 3 product:** Time series data of the revisited orbits generated by resampling based on Level 2 and 2A data, or the ionospheric and atmospheric 2D structure data generated by inversion based on 2 and 2A level data, are termed Level 3.

**Level 4 product:** Spatial evolution data associated with a particular region generated after spatial interpolation processing, based on Level 2 and 2A data.

### 3.2 Data Storage Solution

The designed work scope of ZH-1 is the area between 65° north latitude and 65° south latitude, and the designed working modes of the payloads are burst and survey. According to the timeliness of data downlink, the data are divided into real-time data and revisit data. Therefore, in order to facilitate data storage, reading, and effective identification, ZH-1 data files are stored according to the orbit number, payload, and sub-probe. The stored content include the data file and relevant image product, the processing report, and the configuration file.

#### 3.2.1 File naming

The data file naming rules are as follows in Figure 4.

Among them:

1. **Satellite name (4 characters):** represented by CSES.
2. **Satellite number (2 digits):** starting from 01 and increasing in order; 01 for ZH-1.
3. **Payload code (3 characters):** HPM, SCM, EFD, LAP, PAP, GRO, TBB, HEP, respectively, represent the eight payloads of High-Precision Magnetometer, Search Coil Magnetometer, Electric Field Detector, Langmuir Probe, Plasma Analyzer Package, GNSS Radio Occultation, Tri-Band Beacon, and High-Energy Particle package.
4. **Payload serial number (1 digit):** used to distinguish multiple similar detector data generated by one payload, starting from 1 and increasing in sequence. If there is no necessity to distinguish the probe, it is represented by 0. If necessary, the digital correspondence is shown in the table.
5. **Data hierarchical coding (1-bit symbol, 2 digits):** from left to right, the first digit is "L", and the right two digits represent the data level. 0–4 levels are represented by 00, 01, 02/2A, 03 and 04, respectively.
6. **Observation object code (2 digits):** the observing object code, set according to the "Seismo-Electromagnetic Satellite Survey..."

![Figure 3](image1.png)

**Figure 3.** The schematic diagram of satellite working area. Yellow line refers to 65° north latitude and 65° south latitude; the green square refers to the working area in burst mode; within the yellow line and outside the green square is the working area in survey mode.

![Figure 4](image2.png)

**Figure 4.** The data file naming rules for Level 0 (a) and Level 1–4 (b).
Classification and Code” (draft for review). For Level 0 data, the observation object is coded as 00; for Level 1-4 of data, A1 represents satellite electric field observation, A2 represents satellite magnetic field observation, A3 represents satellite plasma in situ observation, A4 represents satellite high-energy particle observation, and A5 represents satellite ionospheric observation. The details are shown in Appendix Table 1A.

(7) Orbit number (5 digits): used to organize data files by track, starting from 00001, accumulating in turn. The data products that cannot be marked with a track number are represented by "00000".

(8) Descending/Ascending mark (1 digit): the descending is 1 (satellite flying from north to south) and the ascending is 0 (south to north).

(9) Data starting time, expressed by 14 digits: year (4 digits), month (2 digits), day (2 digits), hour (2 digits), minute (2 digits), and second (2 digits). For the TBB receiving station, this is the starting time received by each station. For the station chain data, it is the starting time of the chain combined by several stations along the same orbit.

(10) The data ending time: format is the same as (9). For the TBB receiving station, it is the ending time received by each station; for the station chain data, it is the ending time of the chain.

(11) Receiving station code (3 digits): refers to the information of earth station or GNSS satellite or TBB receiving station. The high 0 represents the data from the earth receiving station, and the code is recurred from 001. When the high bit stays at least 1, it indicates that the data is received from the TBB station. The highest bit refers to the link number, starting from 1, and the lower two bits refer to the station number, starting from 01. For example, the station code in chain 1 is 101-199 and the station code in chain 2 is 201-299. When the lower two bits are 00, it represents all the station data of a certain link. For example, 100 represents all the station data of the first link. For the GNSS occultation receiver, it represents the satellite signal of the received signal source, with the first digit representing GPS or BeiDou (G or B); the last two digits represent the satellite number.

(12) File extension name: if dat, it represents a data file stored in binary format. If the file name extension is h5, it means that the data is stored in hdf format.

The naming of scientific data product images and processing report files is similar, formed by modifying some of the files and adding the relevant suffix of ".XX.png" based on the naming of scientific data. Figure 5 is an example.

Table 1. Correspondence between load number and load data

| Load name                        | Load number | Data content                                      |
|----------------------------------|-------------|---------------------------------------------------|
| High precision magnetometer      | 1           | Vector magnetic field data of fluxgate probe 1    |
|                                  | 2           | Vector magnetic field data of fluxgate probe 2    |
|                                  | 3           | Scalar magnetic field data                        |
| Electric field instrument        | 1           | ULF electric field waveform/power spectrum       |
|                                  | 2           | ELF electric field waveform/power spectrum       |
|                                  | 3           | VLF electric field waveform/power spectrum       |
|                                  | 4           | HF electric field waveform/power spectrum        |
| Search coil magnetometer         | 1           | ULF induced magnetic field waveform/power spectrum|
|                                  | 2           | ELF induced magnetic field waveform/power spectrum|
|                                  | 3           | VLF induced magnetic field waveform/power spectrum|
| GNSS Radio Occultation           | 1           | Positioning data                                 |
|                                  | 2           | Ionospheric occultation event                     |
|                                  | 3           | Atmospheric occultation event                     |
| High-energy particle package     | 1           | Low-energy segment particle flux spectrum        |
|                                  | 2           | High-energy segment particle flux spectrum       |
|                                  | 3           | Italian load particle flux spectrum              |
|                                  | 4           | X-ray flux spectrum                              |
| Langmuir probe                   | 1           | Electronic temperature and density detected by 50 mm balls|
|                                  | 2           | Electronic temperature and density detected by 10 mm balls|

Figure 5. File extension naming rules.
The expansion code of the observation object consists of two characters. The first digit is used to distinguish different regions: 1 for China, 2 for the global area, and 0 for no distinction of area; the second digit is used to distinguish among multiple images of the same payload, starting from 1 and increasing sequentially.

Because the Level 4 image is a spatial image, independent of the orbit, (7) (in Figure 5) is set at zero. (9) represents the year, month and day of the first day of the last 5 days; the hour, minute, and second are set at 0. (11) represents the year, month and day of the fifth day, that is, the current day; the hour, minute, and second are set at 0.

### 3.2.2 File content

Standard scientific products are in hdf format, and the contents include interpretation of file attribute and data. Taking the ULF frequency band of the electric field as an example, the content of the second-level product is listed in Table 2 and Table 3.

The number of A111 in Table 3 is the data item code, which is

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**Table 2.** Description of the data file attribute of ULF Level-2 data of the electric field detector

| Number | Attribute name | Attribute content | Remarks |
|--------|----------------|-------------------|---------|
| 1      | PAYLOADID      | Instrument code   |         |
| 2      | ORBITNUM       | Track number      |         |
| 3      | ORBITTYPE      | Symbols of ascending and descending orbits, | Ascending orbits, descending orbits |
| 4      | SAMPLERATE     | Sampling rate     | ULF: 125 Hz |
| 5      | SOFTWARE       | Program version number |         |
| 6      | FREQUENCY      | Frequency band range | ULF: DC–16 Hz |

**Table 3.** Description of ULF Level-2 data of the electric field detector in tableau format

| Number | Table name   | Table content | Table type               | Table size | Table attribute | Remarks |
|--------|--------------|---------------|--------------------------|------------|-----------------|---------|
| 1      | VERSE TIME   | Relative time | 64-bit integer long      | N×1        |                 |         |
| 2      | UTC TIME     | Correction time | 64-bit integer long     | N×1        |                 |         |
| 3      | WORKMODE     | Operating mode | 32-bit integer int      | N×1        | 1: Burst 2; Survey -1: Invalid |         |
| 4      | A111_W       | X             | 64-bit floating-point double | N×256     | Unit: mV/m | Electric field X component |
| 5      | A112_W       | Y             | 64-bit floating-point double | N×256     | Unit: mV/m | Electric field Y component |
| 6      | A113_W       | Z             | 64-bit floating-point double | N×256     | Unit: mV/m | Electric field Z component |
| 7      | A111_P       | CH1           | 64-bit floating-point double | N×128     | Unit: mV/m | Electric field power spectrum of probe a-b combination |
| 8      | A112_P       | CH2           | 64-bit floating-point double | N×128     | Unit: mV/m | Electric field power spectrum of probe a-b combination |
| 9      | A113_P       | CH3           | 64-bit floating-point double | N×128     | Unit: mV/m | Electric field power spectrum of probe a-b combination |
| 10     | MAG_LON      | Geomagnetic longitude | 32-bit floating-point float | N×1        | The range of geomagnetic longitude | |
| 11     | MAG_LAT      | Geomagnetic latitude | 32-bit floating-point float | N×1        | The range of geomagnetic latitude | |
| 12     | GEO_LON      | Geomagnetic longitude | 32-bit floating-point float | N×1        | The range of geomagnetic longitude | |
| 13     | GEO_LAT      | Geomagnetic latitude | 64-bit floating-point double | N×1        | The range of geomagnetic longitude | |
| 14     | FLAG         | 32-bit integer int | N×1        | Data quality label | |
| 15     | FREQ         | Power spectrum frequency value | 32-bit floating-point float | N×1        | |

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based on the “Classification and Code of Seismic Satellite Electromagnetic Observation Items” issued by the China Earthquake Administration in 2017 (DB/T 67-2017). The corresponding meanings are shown in the Appendix Table A1.

### 4. Data Service

According to the requirements of the “China National Space Administration and China Earthquake Administration’s Notice on Strengthening Electromagnetic Monitoring and Test Satellite Data Management” issued by China National Space Administration and the China Earthquake Administration in 2018, the application system will be responsible for the updating, service, release and maintenance of ZH-1 satellite data. At present, the primary data service webpage has been built (www.leos.ac.cn) to provide related functions such as user registration and data download.

#### 4.1 User Registration

On the website of the Center for Satellite Application in Earthquake Science of the China Earthquake Administration, there are the column of “Data Service” and the function of user login/user registration. New users must click the user registration and fill in relevant information online. After the platform confirming relevant information, users can click the data download in the data service section to select the required data based on the data selection method provided on the page.

#### 4.2 Sharing Products

Data products of the ZH-1 Satellite will be shared for scientific application objectives; data products to be shared are shown in Table 4.

#### 4.3 Share Permissions

After registering, users will gain corresponding levels of ZH-1 satellite data according to the rights agreement. The corresponding relationship is as presented in Table 5.

According to the “China National Space Administration and China Earthquake Administration’s Notice on Strengthening Electromagnetic Monitoring and Test Satellite Data Management”, payload R&D users refer to companies or individuals involved in specific research and development of satellite engineering, especially in payload research and development. The project cooperation users refer to users who signed the agreement on the ZH-1 satellite data with data management administrations of the ZH-1 satellite, such as China National Space Administration, China Earthquake Administration, and Institute of Crustal Dynamics, China Earthquake Administration; such users can obtain relevant data according to the agreement. General professional users refer to scientific and technological personnel with professional tech-

### Table 4. Catalogue of ZH-1 shared products

| Load name | Physical quantity | Sampling rate | Region* |
|-----------|-------------------|---------------|---------|
| HPM       | \(B, B_x, B_y, B_z\) | 1 Hz          | All     |
| SCM       | \(B_x, B_y, B_z\)  | Waveform      | 50 kHz  |
|           |                   | Spectrum      | 50 kHz  |
| EFD       | \(E_x, E_y, E_z\) | Waveform      | 255 Hz  |
|           |                   | ELF           | 5 kHz   |
|           |                   | VLF           | 50 kHz  |
|           |                   | HF            | 10 MHz  |
|           |                   | Spectrum      | 255 Hz  |
|           |                   | ELF           | 5 kHz   |
|           |                   | VLF           | 50 kHz  |
|           |                   | HF            | 10 MHz  |
| LAP       | \(N_e, T_e\)      | 3 s           | All     |
| PAP       | \(\Delta N_i\)    | 3 s           | All     |
| HEP (Chinese) | Flux, counts, Pitch Angle | Electron | 100 keV–50 MeV | All |
|           |                   | Proton        | 2 MeV–200 MeV |
| HEPD (Italy) | Flux, counts, Pitch Angle | Electron | 3 MeV–50 MeV | All |
|           |                   | Proton        | 20 MeV–200 MeV |
| GRO       | \(N_e, TEC\)      | Ionosphere    | 20 Hz   |
|           | \(Ta, Pa\)        | Atmosphere    | 100 Hz  |
| TBB       | \(N_e, TEC\)      | 50 Hz         | China   |

*Note: Burst: area covers the all of China and the two global seismic belts. Survey: area within the geo-latitude of 65° except for the burst region. All: area within the geo-latitude of 65°.
nical backgrounds, such as seismic science and space physics science investigators, who plan to conduct public welfare scientific research based on ZH-1 satellite data.

5. Conclusion

The ZH-1 Satellite has been operating for more than 8 months to complete commissioning tests. The sub-systems of the application system are in regular operation, and preliminary scientific data products are ready to be officially released. The current working status shows that the operational control, data processing, data management, and data service of the application system of ZH-1 satellite have achieved designed functions and performance metrics. Since the satellite was launched into orbit, the commissioning tests have shown that the payload records contain not only information in the field of the space geophysics but also other information, including from the satellite platform itself. Future tasks include additional optimization of data processing algorithms. Dynamic and timely updating of the data content and data processing plan are needed for the application system to ensure the data quality of the ZH-1 satellite, improve the application efficiency of the data, and to exert greater scientific and social value.

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Table 5. User catalogue and their rights to ZH-1 products

| User level data permission | Payload development user (payload R&D) | Project cooperation user | General professional user |
|---------------------------|----------------------------------------|--------------------------|--------------------------|
| 0-level                   | √                                      |                          |                          |
| 1-level                   | √                                      | √                        |                          |
| 2-level                   | √                                      | √                        | √                        |

Table A1. Classification and code for electromagnetic observation of earthquake satellites

| Code | Name                                             | Description                                                                 |
|------|--------------------------------------------------|----------------------------------------------------------------------------|
| A    | Satellite electromagnetic observation            |                                                                           |
| A1   | Satellite electromagnetic observation            |                                                                           |
| A11  | Frequency band 1 of satellite electromagnetic observation | 3 Hz–30 Hz frequency band (DC–16 Hz)                                      |
| A111 | Frequency band 1 of satellite electromagnetic observation X-component | The northward component of the geographic coordinate system               |
| A112 | Frequency band 1 of satellite electromagnetic observation Y-component | The eastward component of the geographic coordinate system               |
| A113 | Frequency band 1 of satellite electromagnetic observation Z-component | The vertical component of the geographic coordinate system               |
| A12  | Frequency band 2 of satellite electromagnetic observation | 300 Hz–3 kHz frequency band (6 Hz–2.2 kHz)                               |
| A121 | Frequency band 2 of satellite electromagnetic observation X-component | The northward component of the geographic coordinate system               |
| A122 | Frequency band 2 of satellite electromagnetic observation Y-component | The eastward component of the geographic coordinate system               |
| A123 | Frequency band 2 of satellite electromagnetic observation Z-component | The vertical component of the geographic coordinate system               |
| A13  | Frequency band 3 of satellite electromagnetic observation | 3 kHz–30 kHz frequency band (1.8 kHz–20 kHz)                             |
| A131 | Frequency band 3 of satellite electromagnetic observation X-component | The northward component of the geographic coordinate system               |
| A132 | Frequency band 3 of satellite electromagnetic observation Y-component | The eastward component of the geographic coordinate system               |
| A133 | Frequency band 3 of satellite electromagnetic observation Z-component | The vertical component of the geographic coordinate system               |
| A14  | Frequency band 4 of satellite electromagnetic observation | 3 MHz–30 MHz frequency band (18 kHz–3.5 MHz)                             |
| A141 | Frequency band 4 of satellite electromagnetic observation X-component | The northward component of the geographic coordinate system               |
Continued from Table A1

| Code  | Name                                                                 | Description                                                                 |
|-------|----------------------------------------------------------------------|-----------------------------------------------------------------------------|
| A142  | Frequency band 4 of satellite electromagnetic observation Y-component | The eastward component of the geographic coordinate system                   |
| A143  | Frequency band 4 of satellite electromagnetic observation Z-component | The vertical component of the geographic coordinate system                   |
| A2    | Satellite magnetic observation                                        |                                                                             |
| A21   | Total intensity of satellite magnetic field observations              |                                                                             |
| A211  | Total intensity of satellite magnetic field observations              | DC-0.3 Hz                                                                   |
| A22   | Satellite magnetic vector observation                                 | DC-15 Hz                                                                    |
| A221  | Satellite magnetic vector observation X-component                    | The northward component of the geographic coordinate system                 |
| A222  | Satellite magnetic vector observation Y-component                    | The eastward component of the geographic coordinate system                  |
| A223  | Satellite magnetic vector observation Z-component                    | The vertical component of the geographic coordinate system                  |
| A23   | Frequency band 1 of satellite magnetic disturbance observation        | 10 Hz–200 Hz                                                                |
| A231  | Frequency band 1 of satellite magnetic disturbance observation X-component | The northward component of the geographic coordinate system                 |
| A232  | Frequency band 1 of satellite magnetic disturbance observation Y-component | The eastward component of the geographic coordinate system                  |
| A233  | Frequency band 1 of satellite magnetic disturbance observation Z-component | The vertical component of the geographic coordinate system                  |
| A24   | Frequency band 2 of satellite magnetic disturbance observation        | 200 Hz–2.2 kHz                                                              |
| A241  | Frequency band 2 of satellite magnetic disturbance observation X-component | The northward component of the geographic coordinate system                 |
| A242  | Frequency band 2 of satellite magnetic disturbance observation Y-component | The eastward component of the geographic coordinate system                  |
| A243  | Frequency band 2 of satellite magnetic disturbance observation Z-component | The vertical component of the geographic coordinate system                  |
| A25   | Frequency band 3 of satellite magnetic disturbance observation        | 1.8 kHz–20 kHz                                                              |
| A251  | Frequency band 3 of satellite magnetic disturbance observation X-component | The northward component of the geographic coordinate system                 |
| A252  | Frequency band 3 of satellite magnetic disturbance observation Y-component | The eastward component of the geographic coordinate system                  |
| A253  | Frequency band 3 of satellite magnetic disturbance observation Z-component | The vertical component of the geographic coordinate system                  |
| A3    | Satellite plasma in situ observation                                  |                                                                             |
| A31   | Plasma density                                                        | Total number of major components in a unit volume                           |
| A311  | Electron density                                                     | Total number of free electrons per unit volume                              |
| A312  | Ion density                                                          | Total number of all kinds of ions per unit volume                           |
| A313  | Hydrogen ion density                                                 | Total number of hydrogen ions per unit volume                               |
| A314  | Helium ion density                                                   | Total number of helium ions per unit volume                                 |
| A315  | Oxygen ion density                                                   | Total number of oxygen ions per unit volume                                 |
| A316  | Nitric oxide ion density                                             | Total number of nitric oxide ions per unit volume                           |
| A317  | The ion density fluctuates                                           | Small changes in ion density near its statistical average                   |
| A32   | plasma temperature                                                   | Average kinetic energy of a plasma at thermodynamic equilibrium             |
| A321  | Electronic temperature                                               | Average kinetic energy of electrons in a plasma                            |
| A322  | Ion temperature                                                      | Average kinetic energy of ions in a plasma                                  |
Continued from Table A1

| Code  | Name                                           | Description                                                                                       |
|-------|------------------------------------------------|--------------------------------------------------------------------------------------------------|
| A33   | Ion drift velocity                             | Average moving speed of ions in a plasma under the action of an electric field                    |
| A331  | $X$-component of Ion drift velocity            | The northward component of the geographic coordinate system                                       |
| A332  | $Y$-component of Ion drift velocity            | The eastward component of the geographic coordinate system                                       |
| A333  | $Z$-component of Ion drift velocity            | The vertical component of the geographic coordinate system                                       |
| A4    | Observations of satellite high energy particle |                                                                                                 |
| A41   | Energy spectrum of high energy particle        | Total number of high-energy particles in the solid angle per unit area and per unit time within a certain energy range |
| A411  | Electron spectroscopy                          | Total number of electrons in the solid angle per unit area and per unit time within a certain energy range |
| A412  | Proton spectroscopy                            | Total number of protons in the solid angle per unit area and per unit time within a certain energy range |
| A413  | X-ray energy spectrum                          | Total number of X-ray photons in the solid angle per unit area and per unit time within a certain energy range |
| A42   | Direction spectrum of high energy particle    | High-energy particle fluxes in the energy range of each direction within a certain direction       |
| A421  | Direction spectrum of electrons                | Electron flux of the energy region in the respective direction range within a certain direction |
| A422  | Direction spectrum of protons                  | Proton flux in the energy range of each direction within a certain direction                      |
| A43   | High energy particle flux                      | Total number of high energy particles per unit area and per unit time per solid angle             |
| A431  | Electron flux                                  | Total number of electrons per unit area, per unit time and per solid angle                        |
| A432  | Proton flux                                    | Total number of protons in the solid angle per unit area and per unit time                        |
| A433  | X-ray flux                                     | Total number of x-rays per unit area, per unit time and per solid angle                           |
| A5    | Satellite ionospheric observation             |                                                                                                 |
| A51   | Ionospheric observation                        | Multi-dimensional observation of the distribution of ionospheric electron density in time and space |
| A511  | Electron density profile                       | Electron density changes with height                                                            |
| A512  | Three-dimensional structure of electron density| Structural changes in electron density with height, latitude, and height                         |
| A513  | Four-dimensional structure of electron density | Structural changes in electron density with height, latitude, height, and local time             |
| A514  | Ionospheric scintillation index S4             | Ionospheric scintillation refers to the rapid and random fluctuation of signal intensity and phase caused by the irregular structure of the ionosphere when radio waves cross the ionosphere. The S4 index is a standard deviation of mean normalization that represents the intensity of the ionospheric scintillation information and indicates signal strength. |
| A52   | Total electron concentration (TEC)             | The integral of the electron density per unit area along the transmit-receive path               |
| A521  | Absolute TEC                                   | Total concentration of ionospheric electron concentration (TEC), also known as the ionospheric electron concentration column content, integral content, etc. It is the integral of the electron concentration per unit area with the height. |
| A522  | Relative TEC                                   | Relative change in the total content of integrated electrons                                     |
| A53   | Neutral atmospheric observation                |                                                                                                 |
| A531  | Atmospheric density profile                    |                                                                                                 |
| A532  | Atmospheric aerosol density profile            |                                                                                                 |
| A533  | Atmospheric temperature profile                |                                                                                                 |
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