

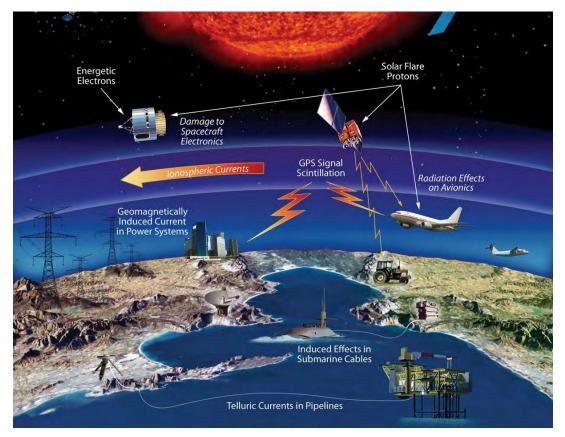
# Brief introduction on the Importance of Space Weather Research with CubeSats

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## Space Weather (As practical science)



https://www.nasa.gov/mission\_pages/sunearth/sp aceweather/index.html

(1)Satellite Charging (2) Single Event Upset (Latch Up) (3) Ionospheric Disturbance (GNSS error expansion and/or black out) (4)Geomagnetically Induced Currents (Power grid black out) (5) Aircraft exposure



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## Space Weather (as fundamental science)

Space Weather

Space weather refers to the variable conditions on the Sun and in the space environment that can influence the performance and reliability of space-based and ground-based technological systems, as well as endanger life or

health. Just like weather on Earth, space weather has its seasons, with solar activity rising and falling over an

Coronal Mass Ejections (CMEs) Large portions of the corona, or outer atmosphere of the Suri, can be explosively blown into space, sending billions of toris of plasma, or superhosted gas. Earth's direction. These CMEs have their own magnetic field, resulting in geomagnetic storms. The fastest of these CME's can reach farth in under a day, with the slowest taking 4 or 5 days to reach Earth.

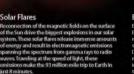
#### Solar Wind The solar wind is a constant outflow of electro and protons from the Sun, always present and buffeting Earth's magnetic field. The

and protons from the Sun, always present and buffeting Earth's magnetic field. The background solar wind flows at approximately one million miles per hour! Sun's Magnetic Field Strong and ever changing magnetic fields drive the life of the Sun and underlie surgeds. These strong magnetic fields are the energy source for space weather and their twisting, shearing and reconnection lead to solar Hares.

#### Solar Radiation Storms

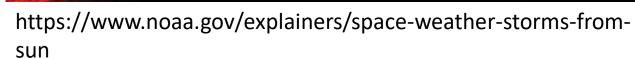
magnetic Storms

Charged particles, including electrons and protons, can be accelerated by coron mass ejections and solar flares. These particles bounce and gyrate their way through space, coughly following the magnetic field lines and utilized bombarding Earth from every direction. The fastest of these particles can affect Earth tens of mixtures after a solar flare.



Earth's Magnetic Field Earth's magnetic field, Jargely like that of a bar magnet, gives th Earth some protection in how he effects of the Sun. Earth's magnetic field is constantly compressed on the day side and stretched on the night ide by the ever present solar wind. During geomagnetic storms, the disturbances to Earth's magnetic field can become exterme. In addition to some buller ing by the atmosphere, this field also offers some shielding from the charged particles of anabiations storm.

approximate 11 year cycle.



#### Solar Terrestrial Physics (STP)

#### To understand:

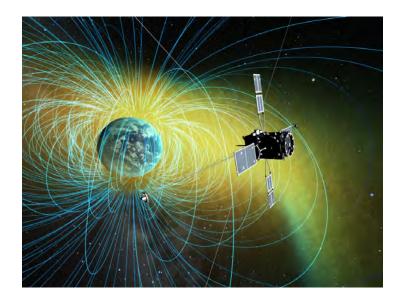
- (1) Energy transportation from the sun to the earth's atmosphere.
- (2) Electromagnetic coupling amoung sunsolarwind-magnetosphere –ionosphere.
- (3) Behaver of plasma particles coupled with many waves.



Improve the Space Weather forecast



## ARASE (ERG) satellite



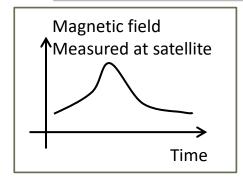
- Plasma particles and electrons at various energy ranges
- Electric field
- Magnetic field

9 kinds of instruments are onboard the ARASE satellite

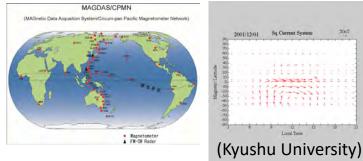
Name	Exploration of energization and Radiation in Geospace "ARASE" (ERG)
International Designation code	2016-080A
Launch Date	20:00, December 20, 2016 (JST)
Launch Location	Uchinoura Space Center (USC)
Launch Vehicle	Epsilon-2
Weight	about 350kg
Orbital Altitude	Perigee: about 440 km, Apogee: about 32,000 km
Orbital Inclinarion	about 32°
Type of Orbit	Elliptical orbit
Orbit Period	about 570 min.
Satellite bus	SPRINT bus
Major Scientific Instruments	<ul> <li>Low-energy particle experiments - electron analyzer (LEP-e)</li> <li>Low-energy particle experiments - ion mass analyzer (LEP-i)</li> <li>Medium-energy particle experiments - electron analyzer (MEP-e)</li> <li>Medium-energy particle experiments - ion mass analyzer (MEP-i)</li> <li>High-energy electron experiments (HEP)</li> <li>Extremely high-energy electron experiments (XEP)</li> <li>Magnetic field experiment (MGF)</li> <li>Plasma Wave Experiment (PWE)</li> <li>Software-type wave particle interaction analyzer (S-WPIA)</li> </ul>



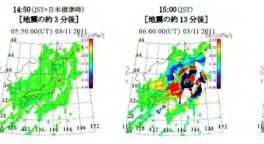
#### Complementarity between satellite and ground-based observations

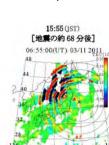


Equivalent Ionospheric Current Pattern derived from multiground geomagnetic observation



Spatial and temporal variation of TEC in the ionosphere derived from multi-ground GPS stations (NICT)





□Satellite (in situ) observation

• Pros

Capable of directly measuring physical quantities in situ

• Cons

Difficult to decompose Spatial and temporal variations from single point observation

- **Ground (multi-station)** Observation
  - Pros

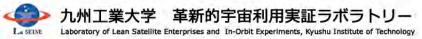
Multi-point observations enable us to understand the temporal and spatial distribution of phenomena

• Cons

Measurement of indirect physical quantities requires inference through assumptions and models



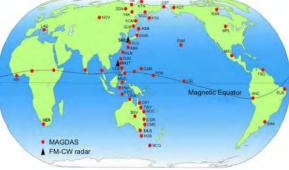
CubeSat Constellation observation could be a breakthrough on these issues.



# CubeSat Constellations is expected to change the Space Weather science

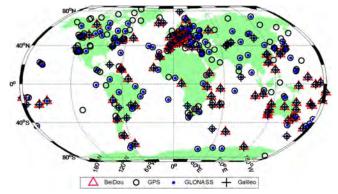
Ground Network Observation for Geomagnetic Field Conducted by Kyushu University, Japan https://www.i-spes.kyushu-u.ac.jp/magdas/MAGDAS Project.htm

MAGDAS/CPMN (MAGnetic Data Acquisition System/Circum-pan Pacific Magnetometer Network)

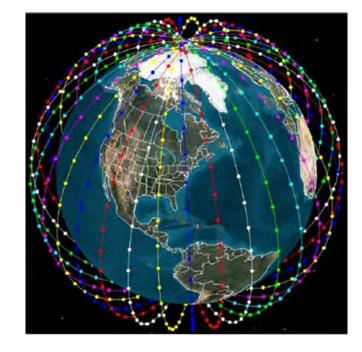


can be changed to CubeSat constellations ?

Global distribution of GNSS stations for TEC observations



Ren et al, 2016 (Nature)



https://www.esa.int/ESA\_Multimedia/Images /2018/07/A\_satellite\_mega-constellation



## Recent Space Weather mission by CubeSat in Japan

#### Yotsuba-KUlover

Use of COTS magnetometer for geomagnetic observation

### Birds-5/PINO

Miniaturization of high-energy electron measuring instruments used in conventional satellite observations

### KITSUNE/SPASIUM

A New Approach to Ionospheric TEC Observation Using the Characteristics of CubeSat