Brief introduction on the Importance of Space Weather Research with CubeSats

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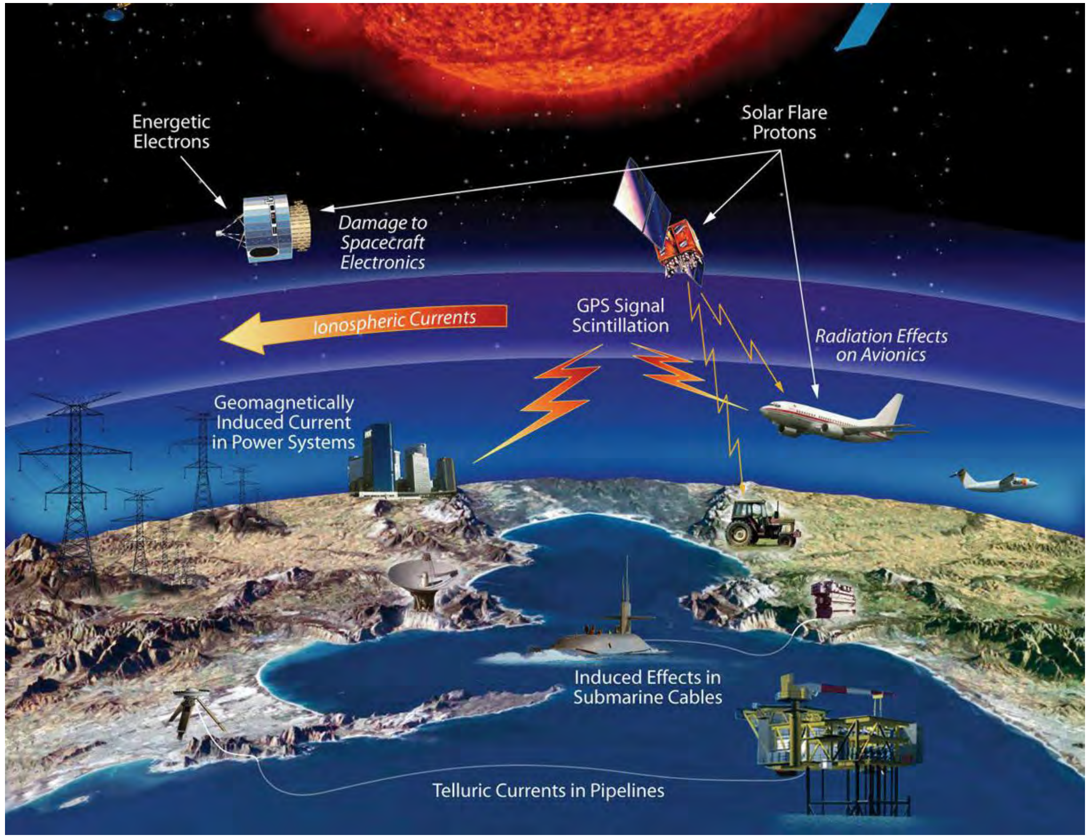
Space Weather （As practical science）



https://www.nasa.gov/mission_pages/sunearth/spaceweather/index.html

(1)Satellite Charging

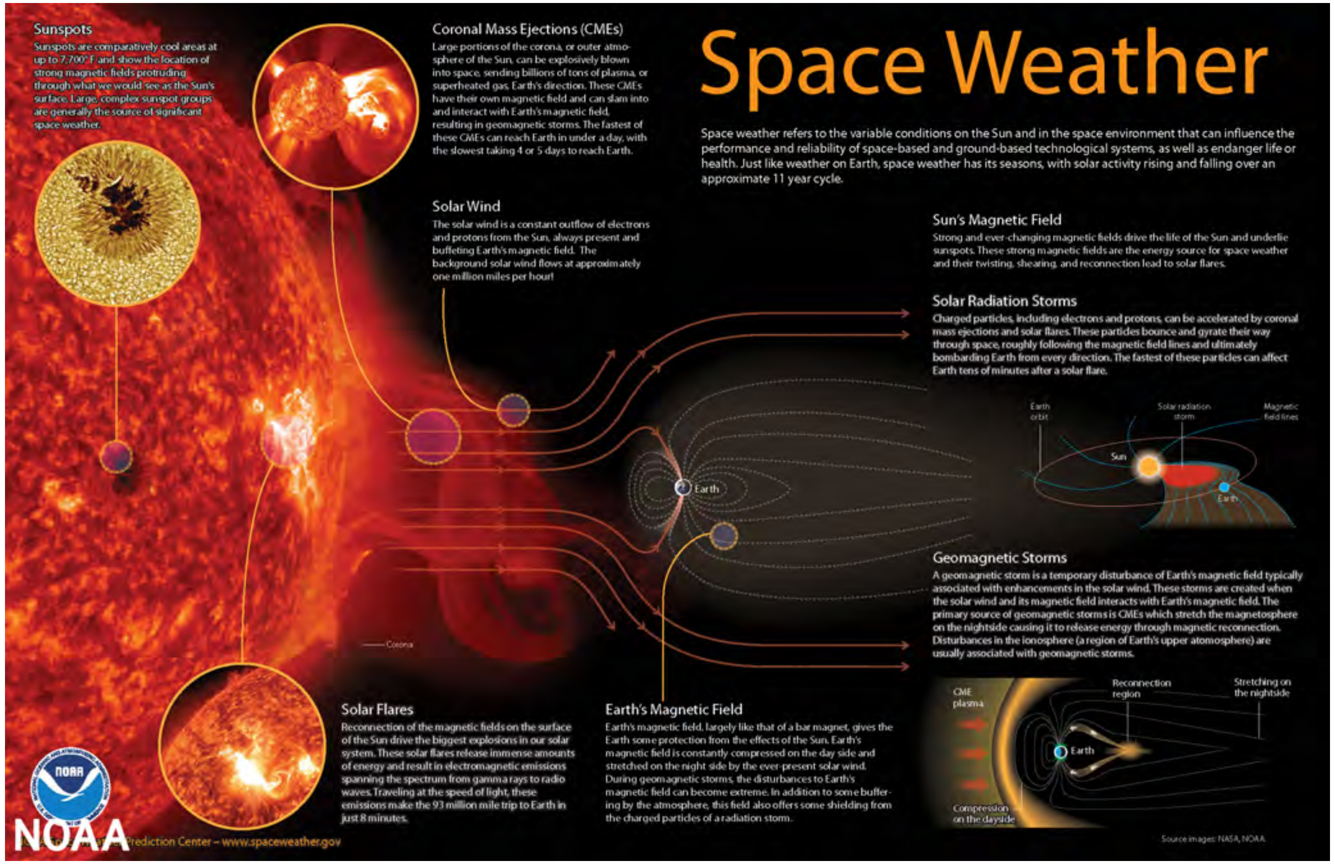
(2)Single Event Upset (Latch Up)

(3)Ionospheric Disturbance (GNSS error expansion and/or black out)

(4)Geomagnetically Induced Currents (Power grid black out)

(5)Aircraft exposure

Space Weather (as fundamental science)



https://www.noaa.gov/explainers/space-weather-storms-from-sun

Solar Terrestrial Physics (STP)

To understand:

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

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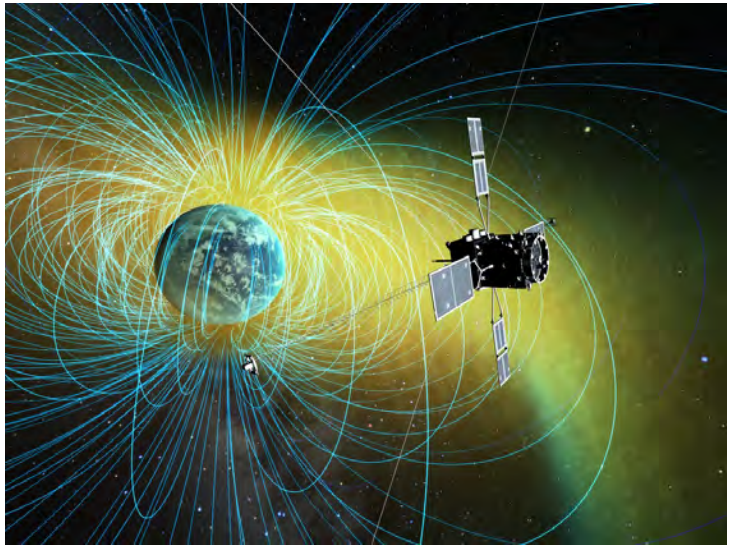
Improve the Space Weather forecast

ARASE (ERG) satellite

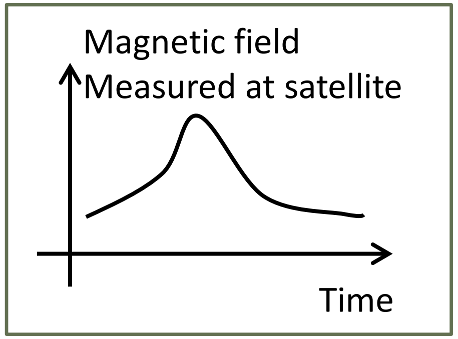


- Plasma particles and electrons at various energy ranges
- Electric field
- Magnetic field

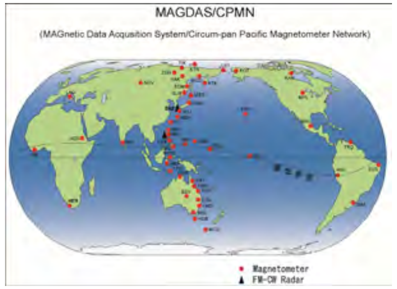
9 kinds of instruments are onboard the ARASE satellite

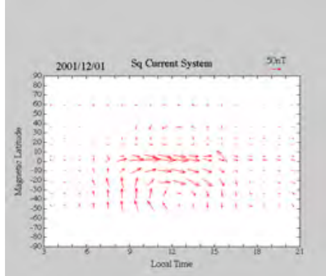
Name	Exploration of energization and Radiation in Geospace "ARASE" (ERG)
International Designation code	2016-080A
Launch Date	20:00, December 20, 2016 (JST)
Launch Location	Uchinoura Space Center (USC)
Launch Vehicle	Epsilon-2
Weight	about 350kg
Orbital Altitude	Perigee: about 440 km, Apogee: about 32,000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

Complementarity between satellite and ground-based observations



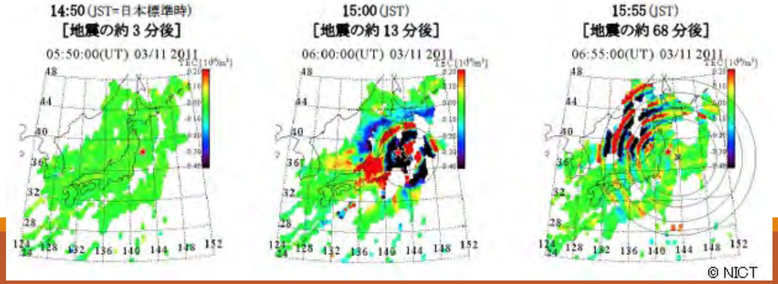
Equivalent Ionospheric Current Pattern derived from multi-ground geomagnetic observation





(Kyushu University)

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



https://www.nict.go.jp/press/2011/11/111104-02.html

□ 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

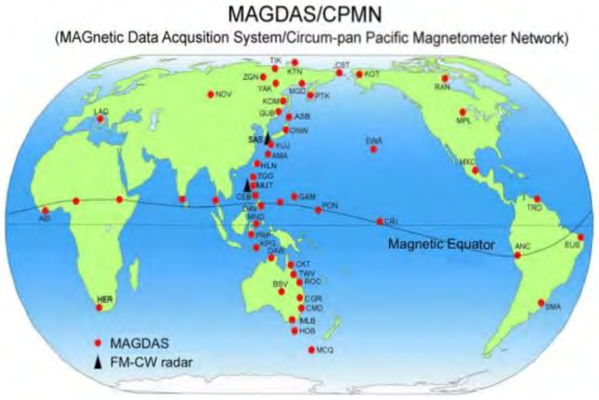
- Cons

  Measurement of indirect physical quantities requires inference through assumptions and models

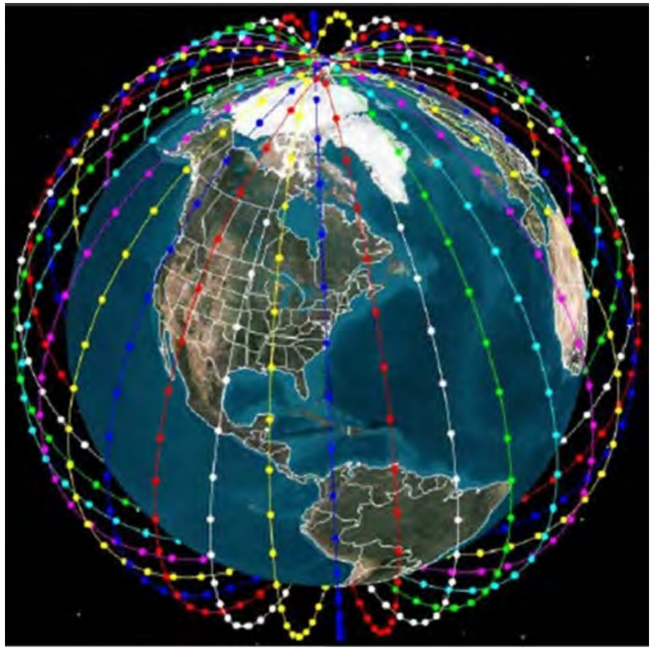
CubeSat Constellation observation could be a breakthrough on these issues.

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

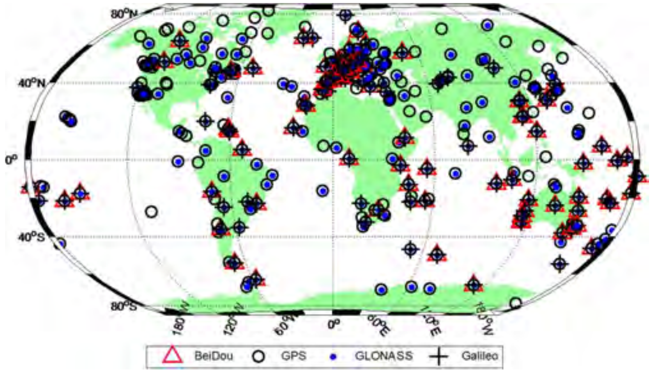


can be changed to CubeSat constellations ?



https://www.esa.int/ESA_Multimedia/Images/2018/07/A_satellite_mega-constellation

Global distribution of GNSS stations for TEC observations



Ren et al, 2016 (Nature)

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