Space weather forecast

Takashi Kikuchi
Solar-Terrestrial Environment Laboratory, Nagoya University
Nagoya, Aichi 464-8601, Japan

Satellite communication, broadcast, and positioning applications have become an essential part of our social and economic activities. Furthermore, opportunities for manned space activities are increasing, such as through the utilization of the International Space Station, and in the future, space tourism may become a reality. The spacecrafts are orbiting in the space ranging from 400km to 100000km. The near-Earth space called geospace is filled with electromagnetic fields, plasma and energetic particles, which occasionally cause serious damages in the onboard computer and the power system of the satellite, and becomes a hazard for astronauts (see Figure 1). Actually, there occurred many troubles on the satellites in recent years; the X-ray astronomy satellite, ASUKA, lost its attitude control during the enormous geomagnetic storm in July, 2000. The Earth observation satellite, MIDORI, also suffered serious damage at the solar power system during the auroral storm in October, 2003. Broadcast satellites have often suffered errors in computer that stopped continuous broadcasting. Geomagnetic field disturbances may damage power systems as actually occurred in Canada in March, 1989, and disrupt communications, degrade high-tech navigation systems, and create the spectacular aurora even at mid and low latitude.

One of the major causes of the space weather disturbances is the solar flare. The solar flare is a sudden, rapid, and intense variation in brightness, which occurs when magnetic energy is suddenly released. The amount of energy released is the equivalent of millions of 100-megaton hydrogen bombs exploding at the same time. As the magnetic energy is being released, particles, including electrons, protons, and heavy nuclei, are heated and accelerated in the solar atmosphere. These energetic particles hit the satellites and cause errors in the onboard computer. To predict the solar flare, observation of the magnetic field of the sunspot is important. When the magnetic configuration becomes complex, occurrence probability of the solar flare becomes high.

Another cause of the space weather disturbances is the coronal mass ejection (CME) that is accompanied by the major solar flare. The CME propagates toward the Earth at the speed of 1000-2000 km/s, and provides the geospace with electromagnetic energy and particles. As a result, a huge geomagnetic storm occurred 19 hours after the solar flare in October, 2003, which caused aurora in Hokkaido, northernmost part of Japan. To predict the geospace storms, we need to understand how the electromagnetic energy and particles are transported from the CME to the geospace, and cause electric currents in the ionosphere and heating of the neutral particle in the upper atmosphere. The number of the radiation-belt particles increases significantly due to the high speed solar wind, which often caused malfunction of the broadcasting satellites. The space weather disturbances are observed with satellites, radars, magnetometers, auroral TV camera and so on. The SOHO satellite continuously monitors the sunspot, solar flare and coronal holes, and the ACE satellite measures the solar wind and CME continuously at a stable point between the Sun and the Earth. Many satellites are orbiting inside the geospace, measuring electromagnetic fields, plasma and radiation-belt particles.

Online data acquisition and realtime data analysis enable us to nowcast the current space weather, and issue warning to the satellite control center, communication center at the airport,

power company, and so on. Space weather forecast activities are carried out by more than ten organizations over the globe under the ISES (International Space Environment Service). At present, we predict the occurrence of geospace storms with empirical models, but in the near future, the computer simulation will enable us to predict the geospace storms automatically and more precisely with an input of the online data.

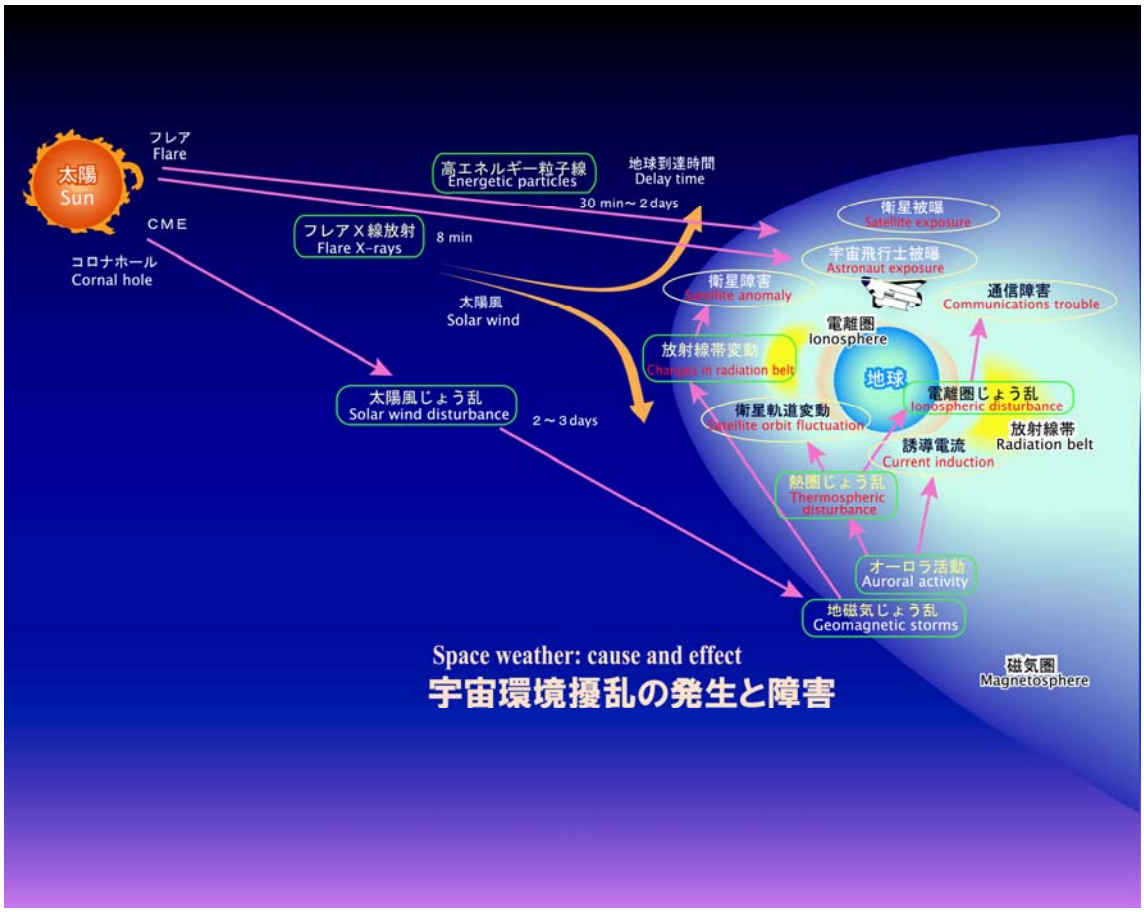

Figure 1
Space weather and its cause and effects (from Brochure of NICT space weather forecast center)