UNITED NATIONS
Office for Outer Space Affairs

Promoting Space Sustainability

PRESTO: Predictability of variable solar-terrestrial coupling

SCOSTEP

June 11, 2021

Implementation of the Guidelines for the Long-term Sustainability (LTS) of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space

Operational Case Studies

I. Short description of the outer space activity

The Scientific Committee on Solar-Terrestrial Physics (SCOSTEP) is a thematic organization of the International Science Council (ISC) and a permanent observer at the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS). SCOSTEP runs international interdisciplinary scientific programs that last 4-5 years and promotes solar-terrestrial physics research by providing the necessary scientific framework for international collaboration and dissemination of the derived scientific knowledge in collaboration with other ISC bodies.

The international program of SCOSTEP in 2020-2024 is PRESTO: Predictability of the variable Solar-Terrestrial Coupling. The mission of PRESTO is to identify predictability of the variable solar-terrestrial coupling performance metrics. As shown in **Figure 1**, there are various phenomena in the solar-terrestrial coupling, and their mechanisms are not well understood. The Sun emits both optical emissions and plasma particles (ions and electrons), and sometimes has big eruptions, i.e., flare and Coronal Mass Ejections (CMEs). The plasma particles coming from the Sun are called the solar wind which hits the Earth. The Earth is protected by its magnetic field, forming the magnetosphere. When the magnetospheric tail is teared off, high energy plasma is injected to the Earth's atmosphere, causing aurora and affecting the Earth's atmospheric environment. The atmospheric waves from the troposphere propagate upward into the near-Earth space and cause various ionospheric disturbances. These Sun-Earth connections cause plasma damage to space vehicles and astronauts, power-line damage due to geomagnetically induced currents, interference on radio communication and GNSS positioning, anomaly of satellite orbit, and long-term climate change on the Earth.

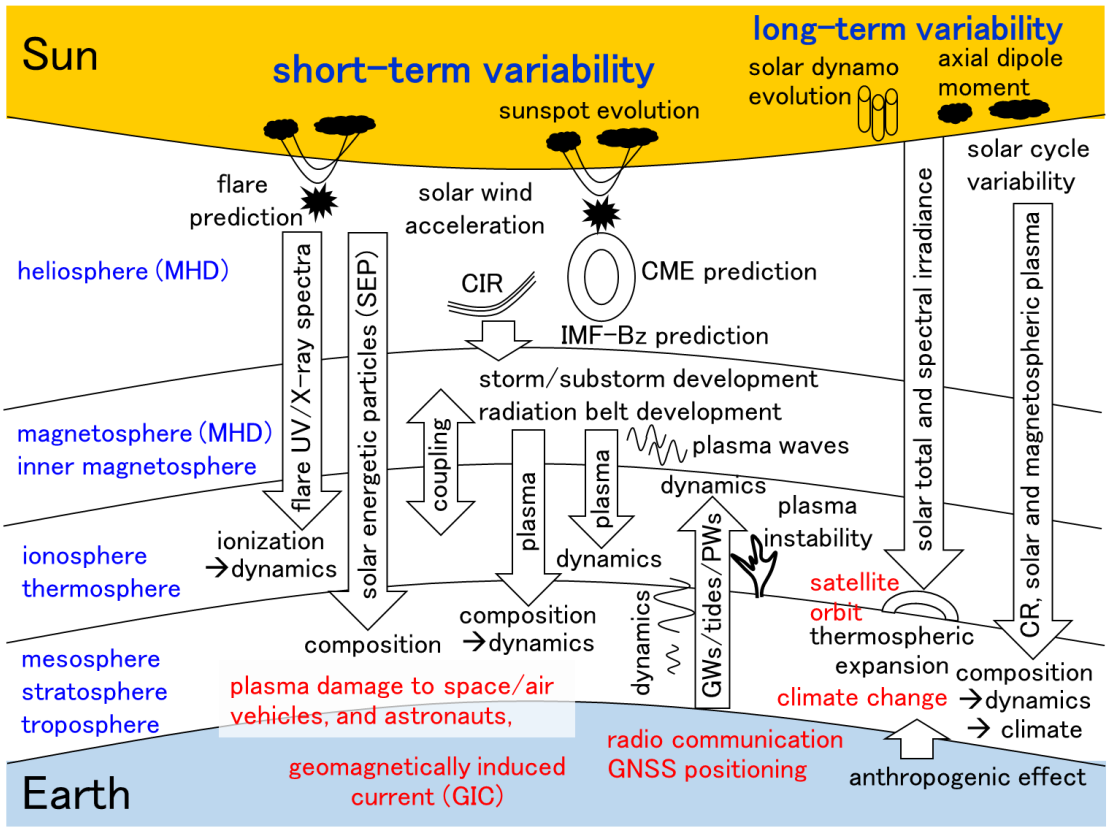

Figure 1. Black: challenging scientific topics in the solar-terrestrial coupling. Red: their consequences on human life. Short and long-term variabilities are shown in the left and right side of the figure, respectively. CIR corotating interaction region, CME coronal mass ejection, CR cosmic ray, IMF interplanetary magnetic field, GNSS global navigation satellite system, GW gravity wave, MHD magnetohydrodynamics, PW planetary wave, UV ultraviolet (from Shiokawa and Georgieva, 2021).

Mission: The mission of PRESTO is to identify predictability of these variable solar-terrestrial coupling performance metrics through modeling, measurements, and data analysis and to strengthen the communication between scientists and users. PRESTO has three Pillars. The topic of the three Pillars and their major scientific questions are as follows.

Pillar 1: The Sun, interplanetary space and geospace.

Question 1.1: Under what conditions are solar eruptions, CMEs, and SEPs produced, and which indicators of pre-CME and pre-flare activity are reliable?

Question 1.2: What are the required/critical model input parameters for most successfully forecasting the arrival of SEPs and the geoeffectiveness of CMEs, SIRs/CIRs and the consequences of the interactions between SIRs/CIRs and CMEs?

Question 1.3: How are different magnetospheric disturbances and waves (which are critical for the ring current and radiation belt dynamics) driven by variable solar wind structures, and/or internal magnetospheric processes?

Pillar 2: Space weather and Earth s atmosphere

Question 2.1: How does the thermosphere and ionosphere respond to various forcings from above and from below?

Question 2.2: How do atmospheric waves and composition changes impact the middle and upper atmosphere?

Question 2.3: What is the magnitude and spectral characteristics of solar and magnetospheric forcing, needed for accurate predictions of the atmospheric response?

Question 2.4: What is the chemical and dynamical response of the middle atmosphere to solar and magnetospheric forcing?

Pillar 3: Solar activity and its influence on climate

Question 3.1: How will future solar activity vary over different timescales and what are the physical reasons for the variations?

Question 3.2: How will the solar forcing on the Earth s system evolve in the future?

Question 3.3: What is the role of the coupling between atmospheric regions in the realization of the long- and short-term solar influence on the Earth system and how are those responses affected by increasing green-house gases?

Funding: Under the three Pillars, several working groups have been in operation to understand these scientific questions. The PRESTO has small funding resources to support meetings, campaign observations, and database constructions related to the PRESTO activity. The announcement of opportunity of these supports is done around the end of every year.

Online Seminar: Because of the COVID-19, however, it has been difficult to have face-to-face scientific meetings to promote these scientific activities. Under this situation, PRESTO has operated an online seminar series since 2020. The topics of the seminars so far were as follows.

1. “A challenge to Physics-based Prediction of Giant Solar Flares” by Kanya Kusano (Japan) on May 26, 2020,
2. “Extreme solar events: A new paradigm” by Ilya Usoskin (Finland) on July 20, 2020,
3. “Developing a Highliy Predictable Geomagnetic Index to Gauge Magnetospheric Activity and Space Weather” by Joe Borovsky (USA) on September 10, 2020,
4. “The Ionospheric Connection Explorer - Results from the first year on orbit” by Thomas Immel (USA) on November 17, 2020,

5. “Magnetospheric Response to Interplanetary Shocks: ULF Wave-Particle Interaction Perspective” by Q.-G. Zong (China) on Jan 14, 2021
6. “Utilizing galactic cosmic rays as signatures of interplanetary transients” by Mateja Dumbović (Croatia) on Jan 19, 2021,
7. “Physics at the edge between Earth's atmosphere and space” by Franz-Josef Lübken (Germany) on May 21, 2021, and
8. “The Sun making history. The mechanism behind the varying amplitude of the solar cycle” by Kristof Petrovay (Hungary) on June 8, 2021.

Figure 2. SCOSTEP/PRESTO Newsletter vol27 published in April 2021.

Newsletter: For communications among scientists in different regions, SCOSTEP/PRESTO distributes newsletters every three months, as shown in **Figure 2**. So far 7 issues have been distributed through the scostep-all mailing list which contains ~1800 scientists in the world.

The PRESTO program was defined by the SCOSTEP’s Next Scientific Program (NSP) committee in 2017-2019 through two face-to-face meetings in Beijing, China in 2018 and in Bern, Switzerland in 2019 with a support of the International Space Science Institute. The report of the NSP committee is available at http://www.issibj.ac.cn/Publications/Forum_Reports/201404/W020190620592906717714.pdf. The introductory description of the PRESTO program is also provided by the committee in Daglis et al. (2021). The latest status of the PRESTO program is available at the SCOSTEP website at https://scostep.org/presto/.

References:

Daglis, I. A., Chang, L. C., Dasso, S., Gopalswamy, N., Khabarova, O. V., Kilpua, E., Lopez, R., Marsh, D., Matthes, K., Nandi, D., Seppälä, A., Shiokawa, K., Thiéblemont, R., and Zong, Q.: Predictability of the variable solar-terrestrial coupling, Ann. Geophys. Discuss. [preprint], https://doi.org/10.5194/angeo-2020-94, in review, 2021.

Shiokawa, K. and K. Georgieva, A review of the SCOSTEP's 5-year scientific program VarSITI—Variability of the Sun and Its Terrestrial Impact, Progress in Earth and Planetary Science (2021) 8:21, https://doi.org/10.1186/s40645-021-00410-1

II. Connection with the LTS Guidelines

The PRESTO is a scientific program operated by the international interdisciplinary organization SCOSTEP. This program fairly fit the direction of LTS Guidelines, particularly for the Guideline D.1: Promote and support research into and the development of ways to support sustainable exploration and use of outer space. The mission of the PRESTO program, i.e., to identify predictability of the variable solar-terrestrial coupling performance metrics. The Sun is a variable star and its variability influences the Earth s space environment. Furthermore, changing solar magnetic fields, radiative and energetic particle fluxes force the Earth s atmosphere and climate. Transient energetic events such as flares, coronal mass ejections (CMEs), interplanetary shocks, stream interaction regions (SIRs), corotating interaction regions (CIRs) and energetic particles adversely impact critical technologies based in space and on Earth that our society is increasingly dependent upon. At the same time, the middle and upper atmosphere/ionosphere are impacted by processes originating at lower altitudes, e.g., by atmospheric gravity waves, tides and planetary waves and changes in radiatively active gases. With the enhanced understanding of causal connections in the Sun-Earth system over the last several decades, fueled by both observations and theoretical modelling, we are in a position to transform this understanding to improved predictions of the Sun-Earth coupled system, which is of relevance to the society and the focus of the current PRESTO program. The research promoted by the PRESTO program will contribute improving predictability of possible damage to space vehicles and astronauts, power-line damage due to geomagnetically induced currents, interference on radio communication and GNSS positioning, anomaly of satellite orbit, and long-term climate change on the Earth.

III. Lessons learned

The PRESTO program has been started since 2020. Thus, at the current stage in June 2021, it is difficult t~~o summarize t~~he lessons learned from the operation of the program. However, considering the various physical processes shown in Figure 1, it is clear that the 5-year program will not be sufficient to clarify the predictability of these processes from the sun to the earth and their consequences on sustainable activity in outer space. Continuous measurements and modelling efforts on solar-terrestrial physics should be made to understand the phenomena occurring in the sun-earth connection system. International collaboration of these measurements and modelling is essential, because the phenomena are occurring on global scale.